Virtual water trade in the SADC region

A grid-based approach

Enschede, January 2010

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Summary

In many areas in the world water is (becoming) a scarce resource. Therefore much research has been carried out on the alleviation of water stress or water quality. Most of these studies however focus only on water efficiency of production thereby neglecting the effects of consumption of commodities and virtual water flows related to trade. The water footprint concept considers these aspects and makes it possible to analyze the effects of (virtual) water allocation, trade and consumption on water scarcity more thoroughly. Also the concept makes a distinction between the types of water used: surface & ground waters (blue water), soil moisture and evaporated precipitation (green water), and polluted water (grey water). Virtual water refers to the actual volume of water that has been used to produce a commodity and that is virtually embedded in it: the so called water footprint.

Most studies on water scarcity are conducted at the local, national or global level. Regional studies however are often lacking. The goal of this study is to extend the knowledge base for national and regional water management by applying the water footprint computation method of crops in a spatially-explicit way and by analyzing the impacts of water consumption and international virtual water trade on water scarcity. The approach is carried out on the Southern African Development Community (SADC) region, because it is one of the most water insecure regions of the world.

The method to compute the water footprint of commodities is based on the approach of Hoekstra and Chapagain (2008). New in the approach, as used in this study, is that spatially explicit data (taking climatic variation in time and space into account) are used to compute the water footprint of crops. On top of that the actual crop evapotranspiration is used (instead of the maximum crop evapotranspiration) to determine the water footprint of crops, based on the water stress coefficient and a vertical soil water balance as described by Allen et al. (1998). Another improvement of this study is that grey water is taken into account. Seasonal variations in the water footprint of crops are still neglected. In this study water consumption of the SADC related to production and national consumption and virtual water trade of 22 crops (roughly 90% of total water consumption by crops), the 8 most reared animal categories and industry are taken into account. The time period analyzed is the period 1996-2005.

The water footprints related to production of crops and livestock (products) are very high for most SADC countries compared with the global average water footprints. When the water footprints of crops in this study are compared with the study of Chapagain & Hoekstra (2004), this study gives much lower water footprint due to the improved approach. The water footprint related to industrial production of the SADC countries is very low except for Madagascar, Malawi, Zambia and Zimbabwe compared to the global average water footprints.

Virtual water flows related to trade are very important for the SADC. The WF of consumption exists for 11.04% of virtual water imports related to imports of crops, livestock and industrial products. SADC’s water footprint related to production exists for 8.69% of water consumed for producing export products. Especially agricultural products are traded between global regions and the SADC and vice versa; especially crop products. The SADC is a net water saver due to international virtual water flows related to trade and saves 7 Gm^3/yr.The SADC is a net exporter of agricultural products

to Western Europe, Eastern Europe, North Africa, Middle East and Central America, mainly coffee, sugar, cloves, cotton and cereals, bovine meat and bovine leather. SADC is net importing from South America, South East Asia, Central & South Asia, North America, Oceania and the Former Soviet Union, mainly cereals, sugar, cotton and oil crop products, bovine animals, bovine meat and live poultry. The SADC is a net importer of industrial products, imported mainly from Western Europe, North America, and Central & South Asia. The SADC is a net exporter of industrial products to North and Central Africa.Virtual water flows related to intra SADC trade in crops, livestock and industrial products makes up 23.82%, 43.51% and 16.22% of total virtual water flows related to trade in these products respectively. Intra SADC trade is dominated by South Africa and Zimbabwe.

SADC's water footprints per capita per year related to consumption (772 m^3/capita/yr) are in general very low compared with the global average water footprint (1243 m^3/capita/yr). Only Swaziland has a quite large water footprint related to consumption per capita (1753 m^3/capita/yr). For the SADC the water footprint of consumption exists for almost 99% of agricultural products, 1% of industrial products and 0.39% of domestic water consumed.

In general water scarcity of the SADC region is low: blue water scarcity is only 1.33% based on the blue and grey water footprints. In South Africa, Zimbabwe and Namibia blue water scarcity is higher (15%-30%). Green water scarcity does not occur. Thus, the SADC region is water self-sufficient; 89% of the water comes from the region. For the other 11% the SADC region depends on virtual water imports. Exceptions are Seychelles, Mauritius and Swaziland, because these countries depend for 60% to 98% on foreign water resources.

For the SADC region the remaining blue water resources after water consumption are determined. Especially parts of South Africa, Namibia, Mozambique, Zimbabwe, Tanzania, Angola and Madagascar are water scarce; in total 27 areas. In these areas more water is used than naturally available, so these areas depend on water from other areas or groundwater. Of the 27 water scarce areas is determined which type of water use is causing the water scarcity. The grey water footprint of these regions is mainly caused by domestic and industrial water use, while the blue water footprint consists mainly of agricultural and domestic water use. Agricultural policies of the SADC nations have clearly influenced which crops are cultivated. When environmental flow requirements, uncaptured flood water, and remote flow are taken into account, more areas are likely to be water scarce. In the SADC region water scarcity is expected to increase due to increased water consumption caused by growth of the population, agricultural and industrial production.

First it is recommended to do an uncertainty analysis on the water footprint of crops to determine the uncertainty range in the water footprint values. Second it is advised to determine for which parameter the water footprint values are most sensitive. Third, also more research into the effect of temporal variations in water availability and the water footprint is important, especially in the case of the SADC. Fourth, the method used to compute the water footprint of livestock is recommended to improve by basing it on national data about the feeding system. Fifth, the water footprint of industry is recommended to improve by giving the water footprint per industrial sector. Sixth, research into scenarios and strategies is needed in order to determine which policy is best to decrease water scarcity (taken aspects like revenues and employment into account). Seventh it is advised to make a policy choice model in which the water footprint and virtual water trade concept are incorporated so that water managers can explore there options.

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Preface

"We never know the worth of water till the well is dry."
(French saying)

Profit and economic growth seem to be often the main goals of national governments, businesses and many individual people. Nowadays people all over the world however are becoming more conscious of the setbacks of this approach and its effects on resource use and the environment. Due to the globalization process environmental problems in one region of the world could be caused by the demand for products of the former in another region of the world. So far, not much attention is there on the effect of globalization on water scarcity and water related problems. Many regions are water scarce already and many regions are expected to face it soon. Managing the water needs in these regions is complicated and complex. Choices in water allocation should therefore be made with care.

This research gives a spatially-explicit approach to get more insight in water availability and allocation in relation to water scarcity; knowledge which is a prerequisite for making sound water (scarcity) policies. The usefulness of the approach is showed for the Southern African Development Community (SADC) region in southern Africa. I hope this study increases our appreciation of the value of water "before the well has dried up".

Special thanks are for my supervisors Arjen Hoekstra and Mesfin Mekonnen who helped me with their insights, improvements, and comments to finalize my report. Arjen, I learned a lot from you about structuring and writing more precisely. Your way of reasoning helped me to structure my own thoughts as well and to structure the report. Mesfin, I learned a lot from your computer skills with ArcGIS and Excel, your patience, and knowledge. I liked the way we cooperated. You gave me very useful insights, data and help.

Erwin Sterrenburg, I would like to thank you for reading and commenting my research proposal and parts of the report. Also I would like to thank Olav van Duin for his tips and tricks in using Excel and Pieter van Oel, Daniel Tollenaar and Wiebe de Boer for our discussions about this subject. Further I would like to thank all graduation students and employees of the WEM department for the social activities and lunches which were a welcome break from all the hard work.

I would like to thank my family, especially my parents, Piet and Anna Kort, for their love, support and giving me all these chances in learning and in life. Mum and dad, your wisdom and support helped me to learn and understand things better and to focus on the things in life that are truly important.

Finally I would like to thank you Petra, my precious and special friend, for all your patience, understanding, support, and never ending love. You are a real soul mate for me and without your support and love life would not have been so bright!

Bert Kort
Enschede, January 2010

1 Introduction

Water is becoming a scarce resource in many areas in the world. Especially in Southern Africa water is scarce due to overexploitation of water resources or economical and infrastructural constraints that make it difficult to get water on the place where it is needed (IWMI, 2006). Much research has been carried out on water stress of regions or improving water quality. However, in most of these studies the focus was only on water efficiency of production. The water footprint concept, as introduced by Hoeksta in 2002, stresses the importance of taking into account a consumption-based indicator of water use related to commodity use when determining the availability of water resources in an area (Hoekstra, 2003). Hoekstra & Chapagain (2008) add that trade in commodities could be helpful in alleviating the stress on domestic water resources or decrease the demand for domestic water because in these products virtual water is embedded. Virtual water refers to the actual volume of water that has been used to produce a commodity and that is virtually embedded in it (Hoekstra & Chapagain, 2008). The virtual water embedded in a product is the so called water footprint (WF) of that specific product.

So far, not much is known about virtual water trade and its importance for water management (Hoekstra & Hung, 2005; Hoekstra & Chapagain, 2008). According to Hoekstra and Chapagain (2008) the focus of research on water use has always been on production and allocation efficiency, but research on the merits of international trade, which can result in global water saving has been neglected, partly due to political sensitivities. Only a few studies on virtual water trade at the global scale or nation scale level have been carried out, e.g. Hoekstra & Hung (2002 & 2005), Chapagain et al. (2005) and Chapagain & Hoekstra (2008 a). Also a few more comprehensive studies on virtual trade of some nations and areas have been carried out, like China (Hoekstra & Chapagain, 2008), India (Kampman et al., 2008), the Nile basin (London Water Research Group, 2007), and Southern Africa (Earle, 2001).

Quite some research on the total water footprint related to the production of commodities has been carried out already. Especially research is carried out on the water footprints of crop, livestock and industrial products by for example Chapagain & Hoekstra (2004; 2008), Hoekstra & Hung (2005) and Chapagain & Hoekstra (2003) for almost all countries on the world. Also specific case studies were carried out for cotton production (Chapagain et al., 2006), Spanish tomato production (Chapagain & Orr, 2008) and tea and coffee consumption by the Dutch (Chapagain & Hoekstra, 2007) for example. Most existing studies compute the WF values only at the national scale level ignoring the possible spatial differences in local production circumstances over a country. Especially spatial differences are important to consider for crop production. Therefore, the method for the computation of the water footprint of commodities needs to be improved. This study tries to improve the methodology by investigating the WF of crops at a small grid level and by taking the spatial differences in crop production circumstances into account.

1.1 The water footprint and the virtual water trade concept

Water footprint concept

The water footprint concept focuses attention on the problems related to water use worldwide and consumption patterns of people, nations and whole regions on the world (Chapagain & Hoekstra, 2004). The water footprint adds new perspectives on "issues such as water scarcity, water dependency, sustainable water use, and the implications of global trade for water management" (Hoekstra & Chapagain, 2008: p.127-128). The national water footprint is a consumption-based indicator of water use that connects the area of consumption of virtual water due to consumption of commodities to the area of production. Nowadays many commodities are imported from other parts of the world, hence causing virtual water imports, so that the water footprint exists of two parts: use of national water resources and use of water outside the borders of a country (Chapagain & Hoekstra, 2004).

The water footprint concept considers also the type and amount of water used for producing a commodity. The type of water defines the source of which the water is obtained from and the impact of the usage on the environment and socio-economic conditions. In the past the focus was only on the use of surface and ground water. A more comprehensive distinction of water types however is considering three types of water (Hoekstra & Chapagain, 2008):

- green water which consists of evapotranspiration of rainwater and soil moisture;
- blue water which contains ground and surface waters;
- and grey water which exists of polluted (ground and surface) water.

The reason for this approach is that the opportunity costs of blue water are larger than of green and grey water, because blue water can be used easier and for more types of production (for industrial, agricultural as well as domestic use) than green water which can be used by crops or vegetation only or grey water which can not be used for many purposes without treatment. Blue water is most of the times also scarcer than green water, so that loss of blue water is more pressing than loss of green water (Hoekstra & Chapagain, 2008).

The concept makes also decisions in water allocation and water use efficiency of this water allocation visible, because it analyzes the production of commodities in a country in detail. The inclusion of green water use is an important improvement, because green water is very important for food production. Earl (2001) and Rost et al. (2008) both state that rain fed agriculture accounts for 60 to 70 percent of the world food supply. So the water footprints of many crops exist for a large part of green water besides blue water. For some regions changes in the type of crop cultivated can result therefore in a more efficient use of green and blue water when looked at the country, region or global scale level with possible benefits related to food security and water availability for nature or other uses as well.

Virtual water trade: countries depend on water used in other parts of the world

The virtual water concept has become more and more important in water research and policy-making, because it gives insight in the quantity of water used for production of commodities consumed in a nation. Virtual water flows form also a basis for comparison of water efficiency of commodity production between countries and net water savings due to the trade flows. A country consumes products made of its own water resources and exports products made of its own water resources. But the same country also imports products from other countries that are made with the water resources of those countries. Virtual water trade has therefore impact on the water systems and food security of a country. Hence the consumption based water footprint of a nation is influenced through trade in commodities by the virtual water export and import flows. Countries with scarce water resources for example could use trade to import products that need a lot of water (water-intensive products) to decrease the pressure on their own water resources. The concept can help water scarce countries to secure their water resources more adequately by importing virtual water (Allan, 2003).

Global virtual water trade between nations is very large; estimates of international virtual water flows exceed 1000 billion cubic metres per annum (Hoekstra & Hung, 2005; Chapagain & Hoekstra, 2003; Hoekstra & Chapagain, 2008). Trade between economic blocks and countries is growing still. Nowadays already 16% of global water use is used for export commodities (Hoekstra & Chapagain, 2008). It can be concluded that virtual water trade has a substantial impact on the water resources of a country.

Using a more comprehensive approach to the WF and virtual water concept

Despite the advantages of the WF and virtual water concept, Chapagain & Orr (2008: p.2) state that most of the current available studies on the WF and virtual water trade concept have several shortcomings:

1. In most studies it is still difficult to determine the effects of the relation between specific growing sites, crop production and water related problems.
2. In previous studies average climate data have been used to compute the water footprint of commodities, thereby neglecting climatic variations over a country in time and space.
3. The assumption is made that crops have abundant water and that potential crop evapotranspiration is always met, resulting in an overestimation of the water footprint of crop and livestock products.
4. Most of the previous studies do not take polluted water (grey water) into account.
5. Most studies do not consider the seasonal water footprint variability of crops; the crop water use is computed for one dominant season only.

In this study the first four shortcomings mentioned by Chapagain & Orr (2008) are improved. Point 5 is not yet improved due to lack of data and complexity of cropping patterns possible.

The first and second shortcomings as mentioned by Chapagain & Orr (2008) can be improved by taking geospatial explicit grid-data on cultivation circumstances (both climatic and production circumstances) of crops into account. In this way the consumption of crop products in a country can be linked to the production areas and climatic variability is taken into account.

Research on crop models for the computation of the water footprint of crops integrated with geospatial explicit data however is scarce. The most comprehensive studies currently available are of Siebert & Döll (2008) and Rost et al. (2008). The study of Siebert and Döll (2008) however presents results for irrigated crops only and the study of Rost et al. (2008) used a quite coarse grid size and no individual crops. This report gives a more comprehensive study on the water footprint of crops and crop water use by taking irrigated and rain fed cultivation of crops into account and covering 90% of the total water used for crop production.

For livestock and industrial production, differences in local production circumstances are not so important for the WF because the WF of animals depends mostly on the feed crops and the WF of industry depends more or less on the technologic abilities of a country. However geospatially explicit grid-data on domestic and industrial water use is used as well to link production of commodities to consumption.

The third shortcoming mentioned by Chapagain & Orr (2008) is improved in this study by using the actual crop evapotranspiration instead of the crop water requirement, i.e. the evapotranspiration under ideal growth conditions.

The fourth shortcoming mentioned by Chapagain & Orr (2008) is improved by considering the grey water footprint of crops, livestock and industry. In this way more insight is obtained in the effects of pollution related to production of commodities on the available water resources.

Other shortcomings in previous studies besides the ones mentioned by Chapagain & Orr (2008) are often related to the comprehensiveness of the studies. In this study therefore most of the water use related to the production of crop, livestock and industrial products is covered. In this study, the water footprint of crop and crop products covers 90% of crop water use as already said. The virtual water trade in livestock and livestock products is based on the 8 most reared animals. For industry total water use is considered.

Most studies also do not take agricultural, livestock and industrial products into account combined with virtual water trade of these products. Therefore the combined effects of water use for production and virtual water flows related to trade of these products are not known. In this study these combined effects are considered.

Further water use efficiency research has been carried out mostly on local and watershed level, but not on the global or regional level (Allan, 1999; Hoekstra & Hung, 2005; Hoekstra & Chapagain, 2008). The most comprehensive studies on global and national level are of Hoekstra and Chapagain (2007; 2008 (a)), who have made global studies on virtual water trade in agricultural and livestock products and made an assessment of the water footprints of nations. More knowledge on water use at different scale levels has to be acquired to get more understanding of the processes playing at different scales and their interactions with water use and consumption. Multilevel research is therefore advised by several authors (Hay, 2005; Gontier, 2007; Zurek & Henrichs, 2007). Research at the regional level is therefore very valuable. The new and more comprehensive approach used in this study is applied on the Southern African Development Community (SADC), because this is one of the most water insecure regions of the world (London Water Research Group, 2007).

1.2 The region of the Southern African Development Community (SADC)

The SADC is an economic and political community of fifteen states[1] (see figure 1). The SADC region lies roughly between longitude 12° 30' E and 55° 40' E and latitude 6° N and 33° S. The surface area of the 15 countries is approximately 9,883,414 km^2. In July 2008 the total population has been estimated at 255 million people (BBC, 2008). The total GDP of the SADC region is 431.78 billion US$ in 2007 (CIA, 2008). Among the SADC member states are several very poor nations and their share in the global economic product is declining (Cilliers, 1996).

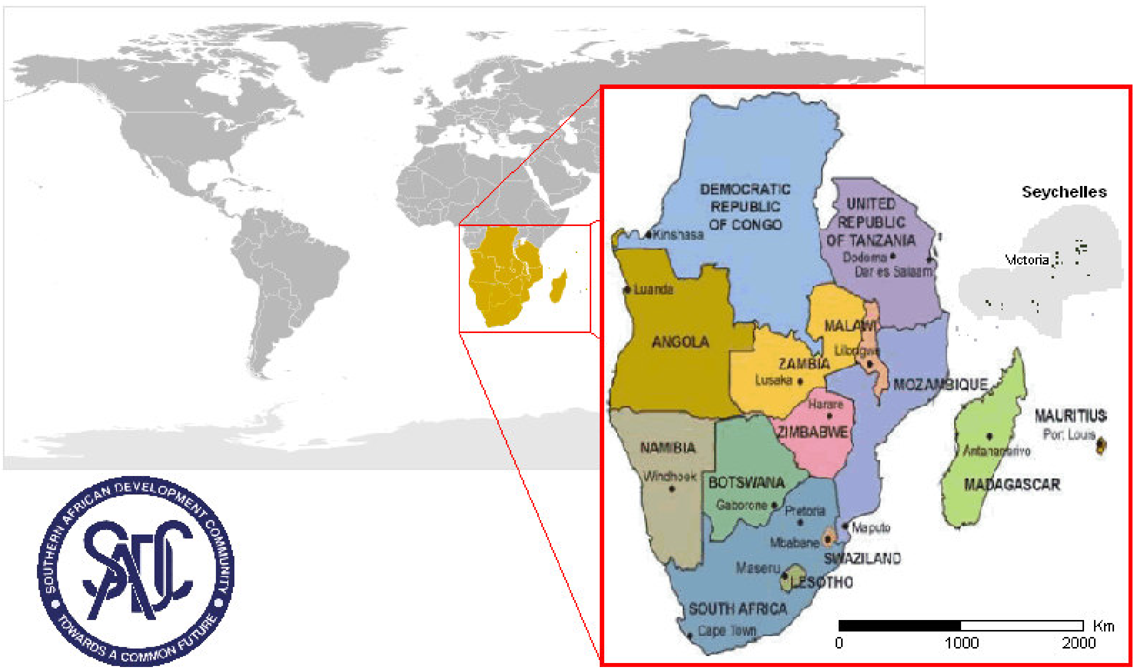


Figure 1. The SADC region in southern Africa; an economic and political community of fifteen states, i.e. Angola, Botswana, the Democratic Republic of Congo (DRC), Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, Swaziland, United Republic of Tanzania, Zambia and Zimbabwe (SADC, 2008). Map modified from Agro-Industry (2008).

The SADC region experiences often droughts which devastate harvests and decrease the availability of drinking water (Maasdorp, 1998; Allan, 2003; Magadzire, 2005; CIA, 2008; Bates et al., 2008) (figure 1). According to Abalu & Hassan (1998) water insecurity increases due to overpopulation as well. Due to overpopulation the demand for agricultural land and firewood is too high, causing unsustainable exploitation of the (marginal) plots, resulting in erosion, decreasing yields and an increased demand for water resources. As stated by the London Water Research Group (Allan, 2003)

[1] The position of the Seychelles as a member of SADC is somewhat unclear, because according to EUROSTAT (n.d.) and Madakufamba (n.d.) this country is not a member of SADC. According to Madakufamba (n.d.), deputy director of the Southern African Research and Documentation Centre (SARDC), the Seychelles are not a member of SADC anymore since July 2004 due to "financial constraints to attend SADC meetings and fulfill membership contributions." However according to the official SADC site (2008) the Seychelles are still a member of SADC. In this report the Seychelles are therefore taken as a part of SADC.

international virtual water trade is important to study for the SADC region, because water security in this region is very low. Virtual water trade could improve water security of the region.

In future water scarcity is expected to increase even more due to an increase in water use caused by growth of the industrial and agricultural sectors and population growth (SADC Review, 2008; CIA, 2008; UNFPA, 1999). On top of that, droughts will probably occur more often (Arnell, 2004; Maasdorp, 1998; Meigh, McKenzie & Sene (1999) and runoff may decrease due to climatic changes (Arnell, 2004). Therefore ways need to be found by which the governments and water users are able to decrease water stress in the area while food and water security are increased.

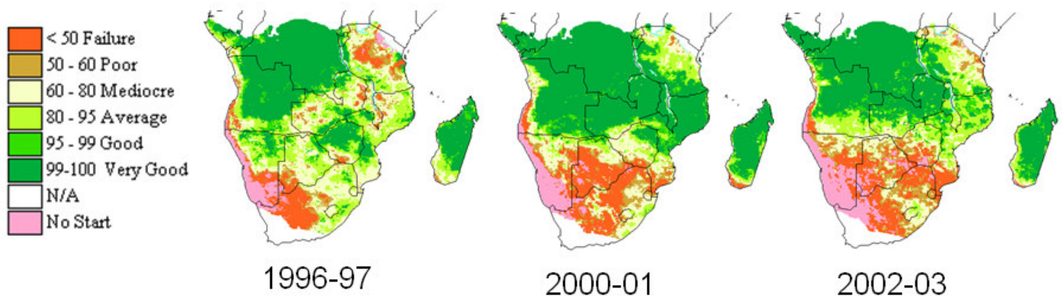


Figure 2. Expected yields as percentage of normal yields over the SADC region for the years 1996/1997, 2000/2001 and 2002/2003 with droughts on different places in the region (Magadzire, 2005).

1.3 Research objective

The objective of this study is to extend the knowledge base for national and regional water management by applying the water footprint computation method for crops in a spatially-explicit way. In addition the impacts of water consumption by crop, livestock and industrial production and of international virtual water trade on the available water resources of the SADC region are analyzed.

1.4 Research questions

The main research question is:
Does a more comprehensive view on the spatially-explicit water footprints and international virtual water trade flows of SADC countries result in improved insights for national and regional water management?

The resulting sub-questions are:

- What are the spatially-explicit water footprints of crop, livestock and industrial products?
- What are the sizes and directions of the international virtual water trade flows between the SADC region and the rest of the world and within the SADC itself?
- How large are the water footprints related to consumption?
- What are the effects of the international virtual water flows and water footprint related to production and consumption on water availability in the SADC region?
- How much does the spatially-explicit approach for computing the water footprint of crops and crop products improve the water footprint of crops as reported in the earlier study of Chapagain & Hoekstra (2004) for countries in the SADC region?

1.5 Outline of the report

Figure 3 describes the outline of the report schematically. Chapter 2 discusses the approach used to compute the geospatially-explicit WF of crops. It also discusses the method applied to compute the WF of livestock and industrial products, virtual water trade and the impact of water use and trade on available water resources. Chapter 3 shows the water use for producing crop, livestock and industrial products, the virtual water trade within the SADC and between world regions and the SADC, the remaining water resources after water use and the resulting water footprints of the SADC and its member states. Also the consequences of water use and virtual water trade on the available water resources are discussed. Chapter 4 contains a discussion of the results, especially of the uncertainties and limitations of this study. Chapter 5 presents the conclusions on the impacts of water use and virtual water trade on the local (remaining) available water resources. Finally chapter 6 gives recommendations for further research.

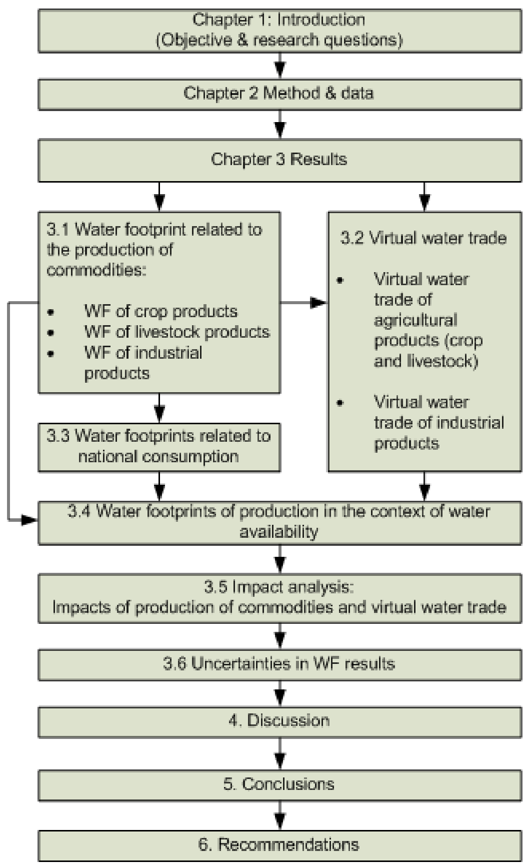


Figure 3. Outline of the report.

2 Method & data

2.1 Method

The approach for computing the water footprint and international virtual water trade is based on Hoekstra & Chapagain (2008) and Chapagain & Hoekstra (2004), as shown in figure 4. The first part of the method concerns the computation of the water footprints of crop, livestock and industrial products. The second part of the method is to compute the virtual water flows related to trade in these products. The third part of the method is to analyze the impacts of water use and virtual water trade on the water resources in the SADC region.

The first part of the method, about the computation of the water footprint of crops, is improved by using a spatially-explicit approach. The computation of the water footprint of crops is based on the method of Hoekstra & Chapagain (2008) and from Chapagain & Hoekstra (2004) and is adjusted to make grid-based computations possible. Also the actual evapotranspiration is incorporated into the method. Therefore more and new input parameters are required to compute the water footprint of crops better.

The computation of the water footprint of livestock products is based on the method of Chapagain & Hoekstra (2004) (figure 4). In this study, for the SADC region the water footprint of livestock products is improved by splitting the water footprint into the green, blue and grey water footprints. The water footprint of livestock is difficult to improve with geospatially explicit data because data on fodder, hay and pasture is lacking, so that it is not precisely known what the water footprint of these feed types ate by animals in a grazing system is. Also data on where livestock is reared exactly is lacking. Therefore the average water footprint values of livestock products in the SADC region, as computed by Chapagain & Hoekstra (2004), will be improved with the improved water footprint of feed crops that comes available in this study. This approach is best, because the water footprint of livestock is assumed to be equal to the aggregated water footprints of the feed and the amount of process water used to produce the livestock.

The water footprint of industrial products is computed based on the method used by Chapagain & Hoekstra (2004) (figure 4).

The second part of the methodology exists of the formulas needed to compute the virtual water flows. The method on computing virtual water flows is obtained from Hoekstra & Chapagain (2008) and Chapagain & Hoekstra (2004) (figure 4). The water footprints of the imported products by the SADC region are based on the values given by Chapagain & Hoekstra (2004). They have computed the average water footprint of crop, livestock and industrial products for almost all the countries in the world. These average values will be used to determine the size of the virtual water flows related to trade in these products. A disadvantage of this is that they took blue and green water combined, making an analysis of the type of water imported impossible. The water footprints of the exported products are based on the (green, blue and grey) water footprints computed in this study.

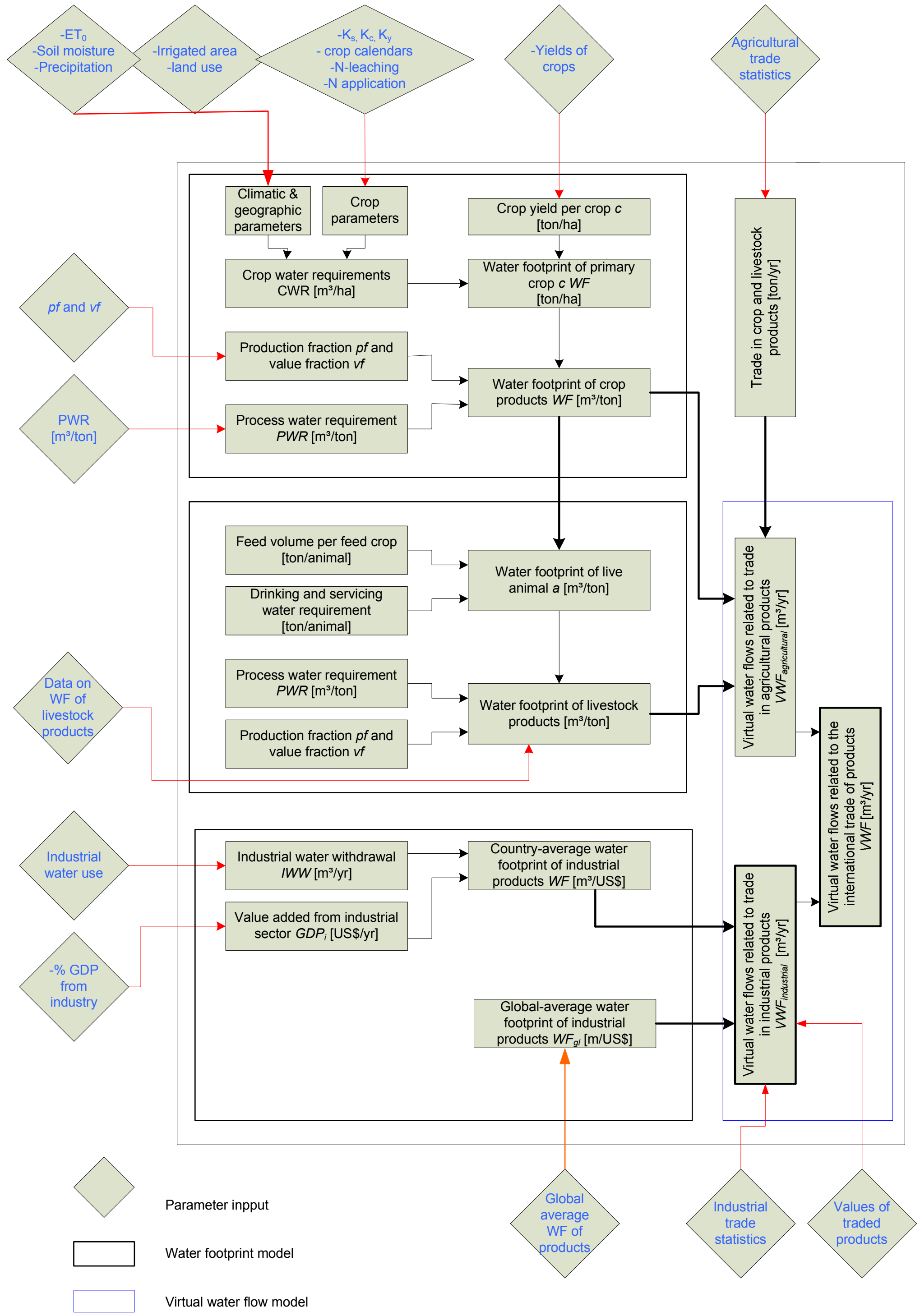


Figure 4. Steps in the computation of virtual water flows of a country related to international trade of agricultural and industrial products (adapted from Chapagain & Hoekstra (2004: p. 31). In the diamonds model parameters are standing as input for the model so that the different steps to compute the water footprint of products and the virtual water flows can be computed. WF=water footprint; WF_{gl}=global-average water footprint; CWR=Crop water requirement; K_s=water stress coefficient; K_c=crop coefficient; K_y=yield response factor; pf=product fraction; vf=value fraction; PWR=process water requirement; IWW=industrial water withdrawal; GDP_i=Gross Domestic Product by industry; VWF=virtual water flow.

The third part of the method describes tools for analyzing the impacts of the water footprint of products and virtual water trade on the water resources of a country. The method for the indicators used is derived from Hoekstra & Chapagain (2008). These data combined can give useful insights for water policy makers of the SADC countries about the effects of domestic water use for production and virtual water trade on the available water resources.

2.1.1 Water footprint computation

Geospatially explicit water footprint of crops

For the SADC region the WF computation of crops is done at a 5 by 5 arc minutes grid cell size (about 9.25 km by 9.25 km around the Equator and about 8.40 km by 8.40 km in South Africa). The computation is based on a daily soil water balance model and computes the crop water requirement (*CWR*), the actual crop evapotranspiration (ET_a), the actual yield (Y_a) and the water footprint of a crop (*c*) in each grid cell (*x,y*). The computation of *CWR*, ET_a and Y_a for each crop are based on Allen et al. (1998).

For the grid-based computation grid data is needed on the areas equipped for irrigation (AEI), land use, precipitation, reference evapotranspiration and soil moisture. Further, crop data on the amount of irrigated and cultivated hectares, application rates of nitrogenous fertilizer, duration of the growth stages, maximum and minimum root length, the depletion fraction, the yield response factor, the climatic region, the planting date and the crop coefficient per growth stage are needed for the water footprint computation of crop and crop products.

Computation of the actual crop evapotranspiration and actual crop yield

First the maximum crop evapotranspiration (ET_c) or crop water requirement (*CWR*) needed for an optimal growth is computed for each grid cell (equation 1). The *CWR* is the evapotranspiration of a healthy, well watered crop; it is the daily maximum evapotranspiration based on crop type and crop development stage, which is expressed in the crop coefficient, the K_c-factor (see figure 5) multiplied with the reference evapotranspiration (ET_0). According to Allen et al. (1998) soil water is bonded more strongly by absorptive and capillary forces when the soil is drier. In the case of dry soils, the roots of plants have more difficulty extracting soil water. This is reflected in the water stress coefficient K_s:

$$ET_a[t] = ET_0[t] \times K_c[t] \times K_s[t] = CWR[t] \times K_s[t] \quad (1)$$

with ET_a the actual crop evapotranspiration in (mm/d) for crop (*c*) in grid cell (*x,y*) at time step (*t*), ET_0 the reference evapotranspiration in (mm/d), K_c the crop coefficient (-), K_s the water stress coefficient of the crop (-), and *CWR* the maximum crop water requirement in (mm/d) for grid cell (*x,y*) at time step (*t*). Equation (1) has as assumption that evaporation of the ground is not a large component of total evaporation; this is also the restriction of the use of a single crop coefficient. Equation (1) makes computations under both water abundant and water stressed circumstances possible.

The crop coefficient (K_c) changes over the growing period of the crop, just as the root zone of the crop (equation 7). The changes in the crop coefficient and root zone are depending on the growth stage of the crop (figure 5). The computation of the crop coefficient at each time step is done as follows:

$$K_c(t)=\begin{cases} K_{c\,ini} & if \quad J \le J_{ini\,end} \\ K_{c\,prev}+\left(\dfrac{J-\sum L_{prev}}{L_{stage}}\right)*\left(K_{c\,next}-K_{c\,prev}\right) & if \quad J_{ini\,end} < J < J_{mid\,start} \\ K_{c\,mid} & if \quad J_{mid\,start} < J < J_{mid\,end} \\ K_{c\,prev}+\left(\dfrac{J-\sum L_{prev}}{L_{stage}}\right)*\left(K_{c\,next}-K_{c\,prev}\right) & if \quad J_{mid\,end} < J < J_{end} \end{cases} \tag{2}$$

with *J* the Julian day number within the growing season of the crop (the crop water use of the crop is computed over the period 1997-2003 with the average for the year 2000; so in this case the Julian year has 366 days);

K_c the crop coefficient at a certain day in the growing period (-);

$K_{c\,ini}$ the crop coefficient for the initial stage (-);

$K_{c\,prev}$ the crop coefficient of the previous crop development stage (-);

$K_{c\,mid}$ the crop coefficient of the mid-season stage (-);

K_{next} the crop coefficient of the next crop development stage (-);

L_{prev} sum of the lengths of all previous crop development stages (d);

L_{stage} length of the stage under consideration (d).

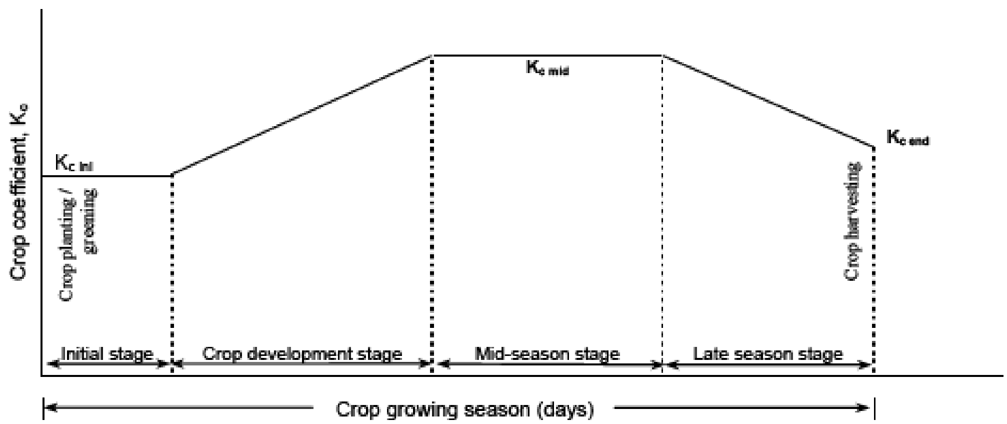


Figure 5. The development of the crop and the related crop coefficient during the crop growing season (Chapagain & Hoekstra, 2004: p.19).

The water stress coefficient of a crop is depending on the soil water available for the roots. The water stress of the crop can be large or small, depending on the water stored in the soil and the soil water depletion by the roots of the crop. In figure 6 an overview of the soil water balance is given. The water stress coefficient is equal to 1 if there is no water stress, else K_s is computed with equation (3) (Allen et al., 1998: p.169):

$$K_s[t]=\begin{cases} \dfrac{S_t[t]}{(1-p[t])\times S_{\max}[t]} & if \;\; S_t[t]<(1-p[t])S_{\max}[t] \\ 1 & otherwise \end{cases} \tag{3}$$

with S_{max} the maximum available soil water in the root zone per grid cell (mm) (equal to *TAW* in Allen et al. (1998);

S_t the actual soil water content per grid cell (mm);

p the fraction of S_{max} a crop can extract from the root zone per grid cell without suffering water stress (-) (Allen et al., 1998).

The maximum available soil water (S_{max}) in the root zone of a crop gives an indication of the capacity of the soil to retain water available for plants. Normally a well drained soil fills up to field capacity after heavy rainfall. Field capacity is the amount of water a soil is able to retain against gravitational forces (Allen et al., 1998). Crops extract water (and minerals) from the soil in their root zone for growth and in order to meet the atmospheric water demand. In the absence of additional rain or irrigation water added to the soil, the water extraction by the crop lowers the water content of the soil. For the crops it will become more difficult to extract water when the soil gets drier, because the water is attached more to the soil particles. At last the crops are not able to extract water from the soil anymore and will start to wilt; this point is referred to as the wilting point. Water content above field capacity will drain, because this can not be held against gravitational forces in. Therefore the maximum available soil water in the root zone is the difference between the water content at field capacity and at wilting point multiplied by the root depth. The difference between water content at field capacity and wilting point (in meters) can be called total available soil water capacity (*TAWC*) as well, resulting in the following formula:

$$S_{\max}[t] = 1000(\theta_{FC} - \theta_{WP}) \times z_r[t] = TAWC \times z_r[t] \qquad (4)$$

with θ_{FC} the water content at field capacity (m^3/m^3);

θ_{WP} the water content at wilting point (m^3/m^3);

TAWC the total available water capacity per grid cell (*x,y*) (mm/m) (obtained from grid-data of Batjes (2006));

z_r the root depth of crop *c* at moment (*t*) in time (m).

The ability of the crop to extract water from the soil is reduced already from a certain treshold, because the water is bonded more strongly to soil particles. Up to this threshold the crop is able to extract water from the soil equal to the atmospheric transpiration demand. The water content of the soil is high enough to make extraction of water possible without suffering of water stress. This amount of water is called the readily available water (*RAW*). Below the threshold the crop starts to experience water stress, because it can not meet the transpiration demands of the atmosphere with water extractions from the soil. The *RAW* can be computed by multiplying the maximum available soil water with the average soil water depletion factor before a crop experience water stress:

$$RAW[t] = p[t] \times S_{\max}[t] \qquad (5)$$

with *RAW* the readily available soil water in the root zone (mm);

p the average fraction of the maximum available soil water that can be depleted from the root zone before reduction in evapotranspiration occurs (-).

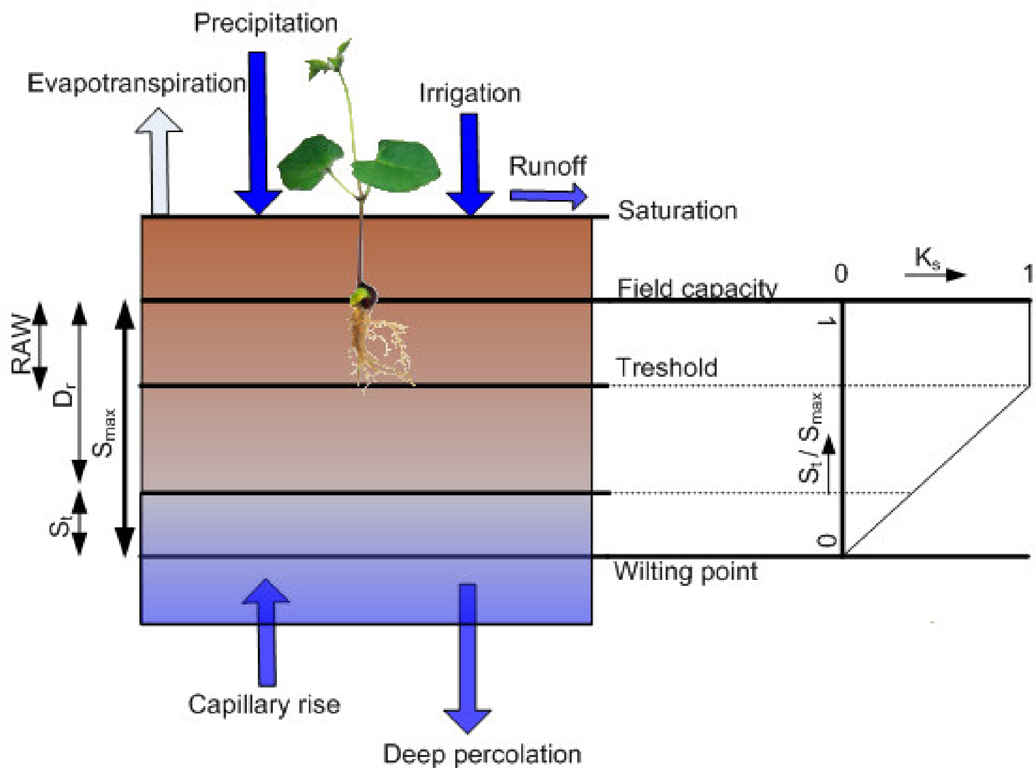


Figure 6. Overview of the soil water balance of the root zone (based on Allen et al., 1998). RAW = the readily available water in the root zone (mm); S_{max} = the maximum available soil water in the root zone (mm); S_t = the actual soil water content in the root zone (mm); D_r = the root zone depletion factor (mm) by the roots of the crop; K_s = the water stress coefficient (-).

The fraction that a crop can extract from the root zone is computed as follows:

$$p[t] = p_{std} + 0.04(5 - CWR[t]) \quad (6)$$

with p_{std} the crop specific depletion fraction valid for an evaporation level of about 5 mm per day and *CWR* the maximum crop evapotranspiration in mm/d. Because p is dimensionless 0.04 is in d/mm. For a lot of crops values for p_{std} can be found in Allen et al. (1998).

The root zone depth of a crop is varying over its growing period and can be computed with the method described by Allen et al. (1998) (figure 7):

$$Z_r(t) = \begin{cases} Z_{r\,min} + (Z_{r\,max} - Z_{r\,min}) * \dfrac{(K_{c\,J} - K_{c\;ini})}{(K_{c\;mid} - K_{c\;ini})} & if \quad J < J_{mid} \\ Z_{r\,max} & if \quad J \geq J_{mid} \end{cases} \quad (7)$$

with $K_{c\,ini}$ the initial crop coefficient (-);
$K_{c\,mid}$ the midseason's crop coefficient (-);
$K_{c\,J}$ the crop coefficient at Julian date J at a certain moment in the growing period (-);

J	the day of the Julian year (d) (the crop water use of the crop is computed over the period 1997-2003 with the average for the year 2000; so in this case the Julian year has 366 days);
J_{mid}	the first day of the mid-seasons growth stage at Julian date J (d);
Z_r	the effective depth of the root zone on a specific day in the growing period (m);
$Z_{r\ min}$	the initial effective depth of the root zone at the beginning of the initial period (at planting and is assumed to be 0.15 to 0.20 m).
$Z_{r\ max}$	the maximum effective depth of the root zone during the midseason period (m) (values per crop are standing in table 22 in the report of Allen et al., 1998)

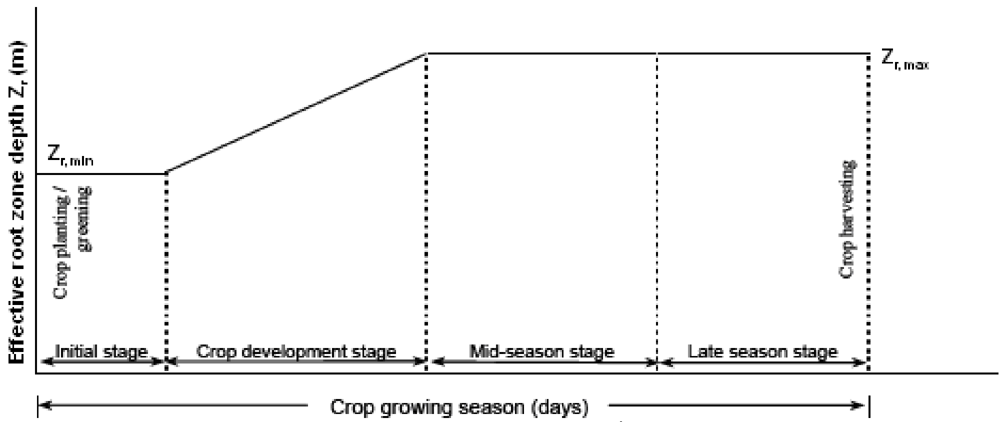


Figure 7. The development of the root zone depth during the growth stages of the crop (Allen et al., 1998).

Equation (3) implies that crops even with high levels of soil moisture can experience water stress if the evapotranspiration of the crop is very high due to the atmospheric water demand at a certain moment in time. With equation (4), (6) and (7) it is possible to compute *p*, S_{max} and *RAW* in equation (3). To compute S_t in equation (3), it is necessary to define the daily soil water balance. The soil water balance is presented in equation (8) and in figure 6:

$$S_t[t] = S_t[t-1] + (Prec[t] - R[t]) + I[t] + CR[t] - ET_a[t] - DP[t] \quad (8)$$

with

$S_t(t)$	the soil water storage at the end of day *t* (mm);
$S_t(t\text{-}1)$	the soil water storage at the end of the previous day, *t-1* (mm);
Prec (t)	the water added by precipitation to soil moisture on day *t* (mm);
R (t)	the amount of water flowing away from soil moisture as runoff on day *t* (mm);
I (t)	the actual amount of water added to soil moisture by irrigation on day *t* (mm);
CR (t)	the capillary rise from the groundwater table on day *t* (mm);
$ET_a(t)$	the actual crop evapotranspiration on day *t* (mm);
DP (t)	the water lost from the root zone by deep percolation on day *t* (mm).

According to Allen et al. (1998: p.153/171) the part of soil moisture going into runoff can be neglected, as well as capillary rise. In this research *R* and *CR* have been set equal to zero therefore. Another assumption in the model is that at the start of the model run the available soil moisture content (S_t) is assumed to be at field capacity. So it could be said that the model is started at the beginning of the rainy season. This assumption is necessary to get a correct crop water use, because a crop can only grow when enough water is available. It is also most likely that farmers plant their crops when growth conditions are optimal; hence when the soil moisture content is sufficient.

For irrigated areas the assumption is made that the water stress coefficient is always equal to 1 (Siebert & Döll, 2008). This means that root depletion of the soil moisture is equal to the irrigated amount so that the plant does not experience water stress. In this way the estimation of blue water use by the crop is too high because crops will not always receive irrigation on time. Another assumption behind the irrigation modeling is that blue water is always available. This is of course not true for some regions, because in these regions irrigation is not always possible during the dry season because rivers and boreholes dry up. Despite these points of consideration, this approach gives still the most reliable estimation of blue water use for crop cultivation.

The amount of irrigation water required, taking the available soil moisture into account, is computed as follows:

$$IR[t] = \begin{cases} S_{\max}[t] - S_t[t] & if \quad S_{\max}[t-1] - S_t[t-1] \geq p[t] \times S_{\max}[t] \\ 0 & otherwise \end{cases} \tag{9}$$

The required irrigated amount however is not applied to each crop in reality, because not all plots are irrigated. Therefore the actual irrigated amount is differing from the required irrigated amount that is needed to minimize water stress of the crop:

$$I[t] = \alpha_a \times IR[t] \tag{10}$$

with *I* the actual irrigated amount (mm);
α_a percentage of the area cultivated by the crop that is actual irrigated (%);
IR irrigation requirement for each crop based on the soil moisture stress experienced by the crop (mm).

After heavy rain or excessive irrigation, the soil water content in the root zone may exceed field capacity, which results in deep percolation of soil water what brings the water out of reach for the roots of the crops. It is assumed that after one day the soil is at field capacity again, so that the root zone depletion may be assumed to be zero (Allen et al., 1998). In that case deep percolation is equal to:

$$DP[t] = (\Pr ec[t] - R[t]) - I[t] - CR[t] + ET_a[t] \quad \geq 0 \tag{11}$$

Water stress affects crop development and yield. The yield of an irrigated crop is therefore often higher than the yield of a not irrigated crop, just as its water use. A linear relationship between yield and crop evapotranspiration has been defined by Doorenbos & Kassam (1979) (in Reynolds et al., 2000) which is used to compute the spatially differences in the actual yield of a crop:

$$Y_a = Y_m \times K_y \left(\frac{\sum_{d=1}^{d=\lg p} ET_a[t]}{\sum_{d=1}^{d=\lg p} CWR[t]} - 1 \right) + Y_m \quad (12)$$

with Y_a the actual harvested yield of the crop (kg/ha);
Y_m the maximum yield of the crop [kg/ha];
K_y the yield response factor of the crop (-);
ET_a the actual crop evapotranspiration (mm/d)
CWR the crop water requirement of crop evapotranspiration for the standard condition (no water stress) (mm/d);
d day in growing period of crop (d);
lgp length growing period crop (d).

The K_y factor describes for a crop the reduction in yield due to shortage of water. Allen et al. (1998) give K_y values for many crops in table 24 of their report. The maximum yield of a crop has been estimated to be 1.2 times higher than the national average yield of a crop in a country as has been done by Reynolds et al. (2000) as well. The computed actual yield per grid cell is rescaled to match with yield data provided by FAO (2009 c). Therefore the actual yield per grid cell is averaged over the nation and compared with the national average yield over the period (1996-2005) as reported by FAO (2009 c). For rescaling, the computed actual yield per grid cell is multiplied with the ratio of the national average computed actual yield divided by the national average yield as reported by FAO (2009 c).

In the approach of computing the WF of crops, multi cropping is not considered. The assumption is made that each crop is cropped separately on a plot. Of course this assumption is not totally true for Africa, where often crops are cropped together, for example cassava and legumes, maize and legumes, or banana and yams. Also one crop season per crop is considered only. In the SADC region rice is the only crop that is officially reported to be cultivated more than once a year (FAO, 2005 a). FAO (2005 a) reports how many hectares are cropped twice or even three times, so it is easy to correct for this fact by enlarging the growing area. So for the SADC region double cropping is not really an issue.

Crop water use and water footprint computation

The green and blue crop water use (*CWU*, m^3/ha) of crop *c* in grid cell (*x*,*y*) at time-step *t* (per day) are computed with the values per grid cell for the actual crop evapotranspiration and the crop yield. It is necessary to divide the *CWU* into a blue and green component, because the opportunity costs of blue water (existing of ground and surface water) are much higher than of green water (containing soil moisture and rainwater). Blue water is more valuable, because it is easier to extract and can be used for more purposes like industrial, agricultural and domestic water use (Hoekstra & Chapagain, 2008; Dabrowksi, Masekoameng & Ashton, 2008).

The green water use of crops is computed by running the model without irrigation water supply (α=0). The blue water use is computed by running the model a second time taking irrigation into account (α=1). The second simulation gives a combined value of the blue and green water consumed by the crop. It is assumed that the green water consumption in the second simulation is equal to the green water use in the first simulation without irrigation water supply. So the blue water use of crops is the difference in water use between simulation 2 (α=1) and simulation 1 (α=0).

Simulation 1: Rain fed scenario (α=0); green WF of crops

The green crop water use (CWU_g) is computed by taking the sum of the actual evapotranspiration of crop c (ET_a, mm/d) over the growing period of the crop (*d*=1 till *d=lgp* (length of growing period), with *d* time in days) multiplied by 10 to convert to m³/ha (equation 13). The water footprint of the rain fed crops per grid cell is computed by dividing the green crop water use per grid cell by the yield for each grid cell:

$$CWU_g[\alpha=0]=10\times\sum_{d=1}^{d=\mathrm{lgp}}ET_a[t][\alpha=0] \quad (13)$$

$$CWU_b[\alpha=0]=0 \quad (14)$$

$$CWU[\alpha=0]=CWU_g[\alpha=0]+CWU_b[\alpha=0]=CWU_g[\alpha=0] \quad (15)$$

$$WF[\alpha=0]=WF_g[\alpha=0]=\frac{CWU[\alpha=0]}{Y_a[\alpha=0]} \quad (16)$$

Simulation 2: Irrigated scenario (α=1); blue WF of crops

The computation of the blue crop water use (CWU_b) per grid cell is analogue to the computation of the green crop water use, except that simulation 1 (α=0) is subtracted from simulation 2 (α=1):

$$CWU_g[\alpha=1]=CWU_g[\alpha=0] \quad (17)$$

$$CWU_b[\alpha=1]=CWU[\alpha=1]-CWU_g[\alpha=1] \quad (18)$$

$$CWU[\alpha=1]=10\times\sum_{d=1}^{d=\mathrm{lgp}}ET_a[t]\,[\alpha=1] \quad (19)$$

$$WF_b[\alpha=1]=\frac{CWU_b[\alpha=1]}{Y_a[\alpha=1]} \quad (20)$$

$$WF[\alpha=1]=\frac{CWU[\alpha=1]}{Y_a[\alpha=1]} \quad (21)$$

Grey WF of crops

For crop production grey water is the volume of water needed to dilute pollution caused by herbicides, pesticides, fungicides and fertilizers, which are applied to crops to improve crop growth. In this study nitrogenous fertilizer application is taken representative for water pollution by crops, because it is the major source of water pollution, especially of eutrophication (Carpenter et al. 1998). Of the main fertilizers types nitrogen (N), phosphor (P), and potassium (K), nitrogen is the most polluting substance because it is highly mobile in the environment (Augustijn, 2006). On top of that N is also most of the times the growth limiting factor for biomass (Verhoeven, Koerselman &

Meuleman, 1996). Also data on application of other types of chemicals is lacking. Therefore nitrogen is considered to give a good impression of the grey water footprint of crop production. The grey WF is used to increase the awareness of the relation between crop production and pollution. It is important to note that the grey water use of crop production is underestimated in this study, because only pollution caused by nitrogen is included (see for more information A1.1.3).

The grey water footprint of crop production per grid cell can be computed with:

$$WF_{grey} = \frac{\frac{N_{applied} \times f_{leach}}{c_{max}}}{Y_a} = \frac{\frac{N_{leached}}{c_{max}}}{Y_a} \tag{22}$$

with WF_{grey} Grey water footprint (m^3/ton);
$N_{applied}$ the amount of fertilizer applied to a crop (kg/ha);
f_{leach} the N-leaching factor of the crop (-);
$N_{leached}$ the amount of fertilizer leached to the ground and surface waters (kg/ha);
c_{max} maximum acceptable concentration for the pollutant (kg/m^3);
Y_a Actual harvested yield (ton/ha).

Total water footprint of crops

The total water footprint for each crop per grid cell exists of the blue (equations 20 and 21), green (equation 16) and grey (equation 22) water footprints, accounted for the actual irrigated area:

$$\begin{aligned} WF &= \alpha_a \times WF[\alpha = 1] + (1 - \alpha_a) \times WF[\alpha = 0] + WF_{grey} \\ &= \alpha_a \times \left(WF_g[\alpha = 1] + WF_b[\alpha = 1]\right) + (1 - \alpha_a) \times WF_g[\alpha = 0] + WF_{grey} \end{aligned} \tag{23}$$

The average (green, blue or grey) *WF* of crop (*c*) in m^3/ton at the nation level can be computed as follows:

$$\overline{WF}[c] = \frac{\overline{CWU}[c]}{\overline{Y}[c]} = \frac{\sum_{j=1}^{n}\left(CWU[x,y,c] \times \frac{\text{area grid cell cultivated }[c]}{\text{total size grid cell}}\right)}{\sum_{j=1}^{n}\left(Y_a[x,y,c] \times \frac{\text{area grid cell cultivated }[c]}{\text{total size grid cell}}\right)} \tag{24}$$

with *j* the number of grid cells, ranging from 1 to *n*, which are laying within the boundaries of the country over which the average water footprint is computed. The computation of the water footprint of primary crop products (*WF[pp]*, m^3/ton) will be done by using the product fractions (f_p, ton/ton), value fractions (f_v, US$/US$), the average water footprint of the root crop in the specific nation ($\overline{WF}[r]$, m^3/ton), and process water use (*PWU*, m^3/ton) needed for processing the root product (*r*) as given by Chapagain & Hoekstra (2008). This result in equation (25) (Chapagain & Hoekstra, 2008):

$$WF[p] = \left(\overline{WF}[r] + PWU[r]\right) \times \frac{f_v[p]}{f_p[p]} \tag{25}$$

In equation (25) the average water footprint of the root crop ($WF[r]$, m³/ton) is used, because it is not precisely known in general of which area the crops used for production of the primary are coming from.

Which crops are taken into account?

For the SADC region the major water consuming crops have been determined so that 90% of the total water consumption by crops is included in this study. Data on the cultivated crops are obtained from FAO (2009 c), which contains yearly information on the area, yield and total production of each crop for each SADC country. The average production data (period 1996-2005) are multiplied with the WF data (obtained from Hoekstra & Chapagain (2008)) to get an idea of the major water consuming crops per country. The water consumption by each crop is added over the whole SADC region. Next the share of water consumption by each crop of total water consumption by crops has been determined. The crops with the highest shares of water consumption are added until at least 90% of the water footprint of crops grown in the area is obtained. This approach results in 22 crops, belonging to 8 different crop groups that consume 90% of the water consumed by crops in the SADC region over the period 1996-2005 (table 1 & figure 8). In the SADC the largest water consuming crops are maize, cassava and rice and the largest water consuming crop groups are cereals, roots & tubers and oil crops.

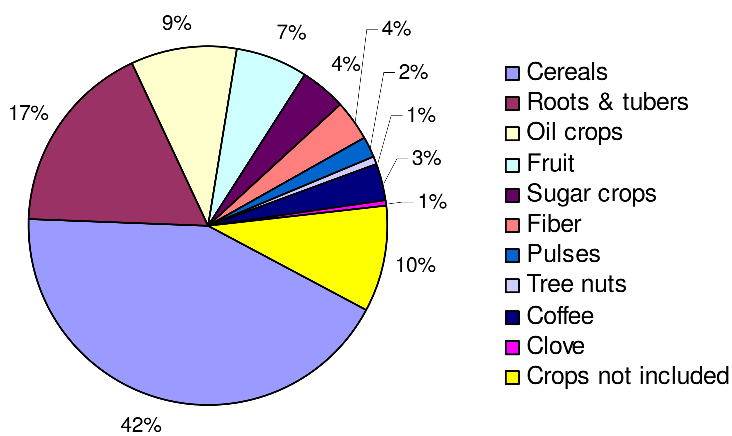


Figure 8. Average water consumption of crop groups as percentage of total water consumption by crops in the SADC region over the period 1996-2005. The crop groups are based on Ramankutty (n.d.). The water consumption of each group is based on the addition of the average production of each specific crop in a group over the period 1996-2005 (FAO, 2009 c) multiplied with the WF of the specific crop (Hoekstra & Chapagain, 2008).

Table 1. Overview of the selected crops responsible for 90% of the water consumption in the SADC region. Of these crops total water use, share of total crop water consumption and crop group (based on Ramankutty (n.d.)) are given as well.

Selected major water consuming crops, contributing to 90% water use by crops in SADC region	FAO-code	Total water use* (10^9 m^3/yr)	% of total crop water consumption SADC	Group
Maize	56	54.0	25.38	Cereals
Cassava	125	32.4	15.49	Roots & tubers
Rice	27	24.5	11.68	Cereals
Sugarcane	156	8.36	4.02	Sugar crops
Plantain	489	7.78	3.76	Fruit
Cotton seed	328	8.31	3.76	Fiber
Coffee, green	656	6.33	3.14	Other
Groundnut	242	5.75	2.85	Oil crops
Coconut	249	5.58	2.74	Oil crops
Sorghum	83	5.40	2.45	Cereals
Banana	486	4.69	2.27	Fruit
Sunflower seed	267	3.94	1.94	Oil crops
Bean	176	3.77	1.84	Pulses
Wheat	15	3.49	1.72	Cereals
Millet	79	3.34	1.59	Cereals
Oil palm	254	3.12	1.53	Oil crops
Sweet potato	122	2.86	1.35	Roots & tubers
Potato	116	1.52	0.74	Roots & tubers
Cashew	217	1.48	0.73	Tree nuts
Clove	698	1.06	0.51	Other
Orange	490	0.98	0.48	Fruit
Soybean	236	0.94	0.46	Oil crops
Subtotal		**182.34**	**90.43**	
Total crop water use SADC region (100 %)		**214**		

*Computed by multiplying the average crop production (ton/yr) over the period 1996-2005 (FAO, 2009 c) with the crop WF's (m^3/ton) (Hoekstra & Chapagain, 2008) for the SADC region.

Water footprint of livestock and livestock products

The method used for computing the improved water footprint of livestock is the same as used by Chapagain & Hoekstra (2004). In this study the WF of livestock and livestock products is based on the eight most reared animal types for farming and one rest group: (1) horses, asses, mules & hinnies, (2) laying hens, (3) dairy cattle, (4) bovine animals, (5) poultry, (6) goats, (7) sheep, (8) swine, and (9) other live animals.

The WF of livestock products is mainly based on the WFs of the feed eaten by the animals and for a smaller part by the service water used. The diet per animal category is obtained from Hoekstra & Hung (2005) and contains seven feed crops. For the SADC region the WF of livestock is improved by using the new computed WFs of feed crops. Of the seven feed types, five (wheat, maize, other cereals, soybean and potato) are improved by this study and two (dry peas and other rolled flaked grains) are not. For fodder crops, like alfalfa, hay and grass, geospatially explicit data and FAO (2009 c) production data are not available; so it is not possible to compute the WFs of these crops and take them into account.

Water footprint of industrial products

The computation of the average water footprint of industrial products is based on Hoekstra & Chapagain (2004; 2008). The average water footprint of industrial products is computed as follows:

$$\overline{WF_i}[n] = \frac{IWW[n]}{GDP_i[n]} \tag{26}$$

with $\overline{WF_i}[n]$ the industrial water footprint of a country (n) (m^3/US$);
IWW the industrial water withdrawals (m^3/yr);
GDP_i the added value of industry to GDP (US$/yr).

It is assumed that the industrial water footprint consists of a blue and grey water footprint only. It is assumed that of the industrial water withdrawals a certain (δ) percentage of blue water is consumed and that 100 percent minus that certain (δ) percentage for the blue water footprint is discharged again as grey water.

2.1.2 International virtual water flows

In figure 9 the relation between the water footprint and international virtual water trade is described. The total water footprint of a country related to consumption (WF_c) exists of the internal and external water footprints related to consumption. The internal water footprint (WF_i) is defined as the use of domestic water resources to produce goods and services consumed by the inhabitants of the country (Hoekstra & Chapagain, 2008). The external water footprint (WF_e) is defined as the virtual water consumption by the inhabitants of a country due to the consumption of imported goods. The part of the domestic water resources used to produce commodities for export is called the WF related to export ($V_{e,d}$). The water footprint related to production (WF_p) exists of the domestic water resources used, hence the internal WF and the WF related to export. The total of the domestic water used in a country (WF_p) and the virtual water imported (V_i) by a country due to import of commodities are together called the virtual water budget B_v (m^3/ton). The virtual water budget is also equal to the sum of the water footprint of a nation and the virtual water exported by the country.

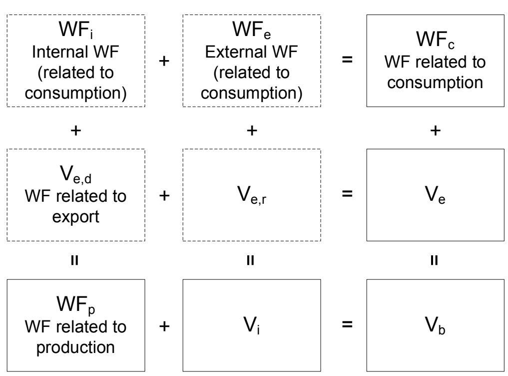


Figure 9. The water footprint and virtual water accounting framework (modified from Van Oel et al., 2009). It describes the relation between virtual water import (V_i), re-export of virtual water imported ($V_{e,r}$), virtual water export (V_e), the WF related to production (WF_p), the internal water footprint related to consumption of commodities (WF_i), the external water footprint related to consumption of commodities (WF_e), the national water footprint (*WF*) related to consumption and the virtual water budget (V_b).

International virtual water flows of agricultural products

The formula for calculating the virtual water flows (V) (m^3/yr) related to trade in livestock and crop products from exporting country (n_e) to importing country (n_i) of livestock or crop product (c) is given by:

$$V[n_e, n_i, c] = T[n_e, n_i, c] \times WF[n_e, c] \quad (27)$$

with T product trade in (ton/yr) of commodity c from exporting n_e to importing country n_i and WF the water footprint of primary product c of exporting country n_e.

International virtual water flows of industrial products

In equation (28) the formula for computing the virtual water flows related to the import and export of industrial commodities is given. The computations for import are mostly done by using the global average water footprint (WF_g) of a product, because it is often not known where the products are coming from due to re-export of products.

$$V[n_e, n_i, c] = \overline{WF_i[n_e]} \times \text{value of industrial products traded } [\mathrm{n_e}, c] \quad (28)$$

2.1.3 Water resources

Internal and external water footprint of a nation

With the aggregated water footprint and virtual water flows data, it is possible to compute the internal and external water footprints of a nation. Van Oel et al. (2009) states that it is necessary to use the following assumption, so that all the terms as presented in figure 9 can be computed:

$$WF_e = \frac{WF_n}{V_i + WU_n} \times V_i \quad (29)$$

With equation (29) it is possible to compute all the other terms of figure 9.

$$V_{e,r} = V_i - WF_e \quad (30)$$

$$V_{e,d} = V_e - V_{e,r} \quad (31)$$

The internal footprint of a nation (WF_i, m^3/ton) exists of agricultural (WU_a), domestic (WU_d), and industrial water use (WU_i), minus the virtual water export related to export of domestically produced products ($V_{e,d}$) (Hoekstra & Chapagain, 2008):

$$WF_i = WF_p - V_{e,d} = WU_a + WU_i + WU_d - V_{e.d} \quad (32)$$

In the internal water footprint the blue, green and grey water components are taken into account. The size of the blue footprints can be compared with the size of the total blue water resources available to get an idea of the impacts of water use by a country.

Remaining water resources after water consumption

The impact of domestic, agricultural and industrial water consumption on the green and blue water resources of an area are analyzed on a grid-based level. The preparations of the grid-based maps of blue and green water consumption of agriculture are described in 2.1.1 and appendix A1. Industrial and domestic water consumption exist both of blue water only. The grid-based maps of blue water consumption by industry and domestic users are based on grid-based blue water withdrawal maps from GWSP (2008 e,d) multiplied by the percentage of blue water consumed by industry respectively domestic water users (based on Shiklomanov (1997)). According to Shiklomanov (1997) roughly 17% of the blue water withdrawn by industry in Africa is consumed and approximately 12% of the domestic blue water withdrawals are consumed. It is assumed that the return flows of domestic and industrial blue water withdrawals are polluted; thus are grey water. It is assumed that the dilution factor is equal to 1.

The remaining green water resources (RWA_g) per grid cell (*x,y*) are obtained by subtracting the amount of green water consumed by agriculture ($WU_{a,g}$) from the total available green water resources (WA_g) (equation 33). The total available green water resources per grid cell are equal to the actual evapotranspiration (ET_a) in the grid cell.

$$RWA_g = WA_g - WU_{a,g} \tag{33}$$

The remaining blue water resources (RWA_b), which is based on blue water consumption only and excluding the grey water footprint, are obtained by subtracting the amounts of blue water consumed by agriculture ($WU_{a,b}$), domestic users ($WU_{i,b}$) and industry ($WU_{d,b}$) from the total available blue water resources (WA_b) (equal to FAO's (2009 a) total renewable water resources) (equation 34). Note that the RWA_b computation does not account for environmental flow requirements (EFR)! Currently the uncertainties in the method to apply for EFR are too large to incorporate it already in this study. Nevertheless it is important to consider the environmental consequences of water use. Also groundwater use and availability are neglected because maps on groundwater use and availability are not yet available.

$$RWA_b = WA_b - WU_{a,b} - WU_{i,b} - WU_{d,b} \tag{34}$$

If grey water use is taken into account as well, the remaining blue water resources (RWA_b^*) are computed by subtracting the grey and blue WFs of agriculture, industry and domestic users from the total available blue water resources:

$$RWA_b^* = WA_b - \left(WU_{a,b} + WU_{a,grey}\right) - \left(WU_{i,b} + WU_{i,grey}\right) - \left(WU_{d,b} + WU_{d,grey}\right) \tag{35}$$

Indicators related to the state of the water resources

It is important to know what the claims on the national water resources are and what the dependency of a country is on the import of water resources in combination with data about the water footprint of a country. This increases insight in the use of water by a country and its water related problems. Note that it is possible to do these computations on grid level as well.

Water scarcity

Green water scarcity (WS_g) is defined as the ratio of the green water footprint to the nation's green water availability (actual evapotranspiration) (WA_g):

$$WS_g = \frac{WF_g}{WA_g} \times 100 \qquad (36)$$

Blue water scarcity (WS_b) is defined as the ratio of the blue water footprint to the nation's blue water availability (WA_b):

$$WS_b = \frac{WF_b}{WA_b} \times 100 \qquad (37)$$

If the national blue water scarcity is more than 100%, this means that a country needs more blue water for its consumption than that is available in the country. This causes depletion of ground and surface waters and/or water pollution.

Water dependency and water self-sufficiency

Another indicator is water import dependency (*WD*), which express the percentage of a country's total water footprint (WF_n) depending on imports of virtual water (external water footprint WF_e):

$$WD = \frac{WF_e}{WF_n} \times 100 \qquad (38)$$

The water self-sufficiency indicator (*WSS*) is the opposite of the water dependency indicator. Here the internal water footprint (WF_i) is taken as a percentage of the total water footprint of nation (WF_n):

$$WSS = \frac{WF_i}{WF_n} \times 100 \qquad (39)$$

2.2 Data

The input data needed for the computation of the water footprints and virtual water trade flows are:

- Allen et al. (1998): data on maximum root length of crops for irrigated and non-irrigated growth conditions, data on the depletion fraction of crops, and data on the yield response factor of crops.
- Chapagain & Hoekstra (2004), Appendices, Vol. 2 with data on: climatic regions per country, crop calendars, K_c-values for crops in each growth stage, duration of growth stages for each crop. Also product fractions and value fractions are obtained from Chapagain & Hoekstra (2004).
- FAO (2009 a): AQUASTAT database with information on blue water resources available in a country and on water use per country for the sectors agriculture, domestic and industry and information on irrigation and cropping calendars per country. (http://www.fao.org/nr/water/aquastat/main/index.stm)
- FAO (2009 c): FAOSTAT database on trade statistics, prices of crops, land resources, agricultural production data, cultivated area data of crops and yield data of crops. (http://faostat.fao.org/default.aspx)
- FAO (2009 d): FAOSTAT ResourceSTAT database with data on the total nitrogenous fertilizer consumption per country.
(http://faostat.fao.org/site/422/default.aspx#ancor; data for 1996-2005)
(http://faostat.fao.org/site/575/default.aspx#ancor; data for 2002-2006)

- FAO (2009 e): FERTISTAT database on fertilizer application rates for (some) crops for several SADC countries.
  (http://www.fao.org/ag/agl/fertistat/)
- Hoekstra & Chapagain (2008), Chapagain & Hoekstra (2004) and Earle (2001): the WF and virtual water flow results of this study are compared with these studies.
- Portmann et al. (2008): data on the amount of hectares irrigated for each crop per country.
- Trade statistics database SITA (Statistics for International Trade Analysis) of the International Trade Centre (ITC) in Geneva, Switzerland: contains trade data and prices of products for 230 countries and territories on the world, direct and indirect (on DVD) (ITC, 2007).
  (http://www.intracen.org/mas/sita.htm; data for 1996-2005)
- UN Statistics Division (2009): data on the value added by the industrial sectors mining, utilities, manufacturing and construction that are aggregated to give the value added by industry per country.
  (http://unstats.un.org/unsd/snaama/selbasicFast.asp; data for 1996-2005)
- Water quality norm for nitrogen: EPA (2005) List of drinking water contaminants: Ground and drinking water.
  (http://www.epa.gov/safewater/contaminants/index.html#listmcl)

- GIS maps of:
  - Average monthly reference evapotranspiration (ET_0) based on data from 1961-1990 at 10 arc minutes:
    http://www.fao.org/geonetwork/srv/en/ (FAO, 2004)
    (download Global map of monthly reference evapotranspiration – 10 Arc minutes)
  - Soil moisture capacity (*TAWC*) available at 5 arc minutes:
    http://www.isric.org/UK/About+Soils/Soil+data/Geographic+data/Global/WISE5by5minutes.htm
    (ISRIC-WISE; Batjes, 2006)
  - Average monthly precipitation based on data from 1961-1990 at 30 arc minutes:
    http://cru.csi.cgiar.org/continent_selection.asp (CRU 2.1 data; Mitchell et al. (2005))
  - Cultivated crop area and yields, land use and yield data of crops data of 175 crops for the year 2000 available at 5 arc minutes:
    http://www.geog.mcgill.ca/landuse/pub/Data/175crops2000/ (Monfreda et al., 2008)
  - Cultivated area of crops, land use data on 18 major crops available at 5 arc minutes from:
    http://www.sage.wisc.edu/download/get_info?dl_file_name=majorcrops/NetCDF_5min.zip
    (Leff et al., 2004)
  - Areas equipped for irrigation at 5 arc minutes from Siebert et al. (2007):
    ftp://ftp.fao.org/agl/aglw/aquastat/ (FAO, 2009 b)
  - Available green water resources based on mean annual actual evapotranspiration data over the period 1950-2000 at 30 arc minutes (GWSP, 2008 b):
    http://atlas.gwsp.org/index.php?option=com_content&task=view&id=143&Itemid=52
  - Available blue water resources per sub catchment based on data from 1961-1990 at 30 arc minutes (GWSP, 2008 a):
    http://atlas.gwsp.org/index.php?option=com_content&task=view&id=40&Itemid=52
    Industrial water withdrawals at 30 arc minutes (GWSP, 2008 d):
    http://atlas.gwsp.org/index.php?option=com_content&task=view&id=151&Itemid=52
    Domestic water withdrawals at 30 arc minutes (GWSP, 2008 e):
    http://atlas.gwsp.org/index.php?option=com_content&task=view&id=152&Itemid=52

- Literature on N-leaching of crops, planting time of crops, fertilizer use in southern Africa, comparative advantages of SADC countries in cereal cultivation et cetera.

Time period analyzed 1996-2005

In this study the time period 1996-2005 is analyzed. This period is chosen, because recently trade data over this period has been released by the ITC (2007). This choice has some consequences for data analysis because not all data is always available over the same time periods or with the same accuracy. Therefore choices are made about the time periods used and the aggregation level of grid based data.

The data of the different datasets is available of the years as follows:

- trade statistics data available from 1996-2005;
- national average yields of crop statistics (fertilizer consumption, cultivated area, yield and production data per crop) available from 1996-2005 in FAO (2009 c);
- irrigated area data mostly based on data for the year 2000 (Portmann et al., 2008) and 2002 FAO (2005 a);
- Grid-data of precipitation and reference evapotranspiration based on climate average data from 1961 till 1990;
- Grid-data on yield and cultivated area for 175 crops based on data over the period 1997-2003, with the average taken for the year 2000.

Data on trade statistics, national average yield and crop statistics are available for the period 1996-2005. In this study average climate data is used, because the yield and cultivated area grid-data are only available as average data over the period 1997-2003. A disadvantage of this choice is that some years suffered from drought in this period (Magadzire, 2005). These droughts will not be reflected in the crop water model therefore. Another consequence of this choice is that the crop water use is not differing over the years. Therefore the water footprint of crops is only depending on yield variations over the period 1996-2005 (the water footprint (in m^3/ton) of a crop is the crop water use (in m^3/ha) divided by the yield (in ton/ha).

Data constraints, data transformations and errors in input data

Before it is possible to compute the WFs and the virtual water trade flows, it is necessary to transform the data to the needed input conditions. Also solving data errors and data constraints was necessary. Here a short description of the transformations, errors and constraints of the input data is given. A more detailed description of all data aspects is given in appendix A1.

Collecting data on the application rate of nitrogenous fertilizer to crops

Data on nitrogenous fertilizer application is scarcely available. FERTISTAT (2009) reports only for a few countries and crops of the SADC region how much fertilizer is applied per crop. Hence for many crops and countries it is not known how much fertilizer per crop by farmers is applied. Therefore assumptions are made in the nitrogen application per crop for each country. These assumptions are based on a combination of the study of Morris, Kelly & Kopicki (2007), who determined which share each crop has in the total fertilizer consumption in sub-Saharan Africa, and data on the total nitrogenous fertilizer application in a country obtained from FAO (2009 d). For some countries however this method was not applicable since it resulted in extreme fertilizer application rates for some crops. For those countries, optimal fertilizer application rates are used for the crops which got too large nitrogenous fertilizer application rates based on research studies on the optimal nitrogenous fertilizer application rates for that crop in the specific country. The nitrogenous fertilizer undistributed at the end of this approach is logically distributed to crops that received very low application rates compared to application rates in neighboring countries and the mentioned optimal application rates in the literature. For more details see A1.1.3.

Determination of nitrogen leaching value of crops

The exact nitrogen leaching of crops is very difficult to determine, because nitrogen leaching of crops depends on many factors like soil type, crop type, climate, rainfall events and intensiveness, irrigation events and intensiveness, cropping calendars, cropping pattern, N-application rate, and the cropping season. According to Chapagain et al. (2006) N-leaching can be assumed to be around 10% for each crop. This assumption, however very crude, lies well in the reported range of N-leaching of crops to the aquatic system which varies between 2 and 17% for crops (table 10). In this report N-leaching is taken as 10% for each crop as well, because the case studies mentioned can not be applied straightforward on other regions as well because N-leaching depends on too many factors. In this study the water quality standard as set by the EPA (2009) is used, which is 10 mg N per litre.

Grid size

Small constraints of the input data are related to the spatial data available. The grid-based data is available at 5, 10 and 30 arc minutes. All data can be converted easily to 5, 10 or 30 arc minutes for example, by simply dividing one 10 arc minute grid cell into four 5 arc minute grid cells or by aggregating four 5 arc minutes cells into one 10 arc minute grid cell. In this study a grid size of 5 arc minutes is chosen, so that more details on the crop growing area and of the yield distribution are taken into account.

Conversion of climate data to daily input data

The climatic grid-data on precipitation and reference evapotranspiration are only available as average monthly data, while the water footprint computations are per day. So the monthly data are converted to daily data. For ET_0, this can be done by following the CROPWAT-approach of the polynomial curve fitting method. For precipitation, daily data is generated using the weather generator model dGen-CRU (Schuol & Abbaspour, 2007).

Rescaling cultivated area geo-data to FAO figures

FAO (2009 c) data are taken as reference, because it is official data and it has information on cultivated area, yield and production figures per country for each year. The latter is important because the FAO (2009 c) data can be taken as a reference level, while the geo-data maps on cultivated area, the irrigated area maps of Siebert & Döll (2007) and the yield estimation are all based on other sources. Therefore using one reference dataset makes the research more coherent.

Hence the cultivated area maps are rescaled to the FAO (2009 c) data by multiplying the maps with a correction ratio which is based on the cultivated area reported by FAO (2009 c) divided by the cultivated area reported in the geo-data. Before rescaling, the maps on cultivated area of Monfreda et al. (2008) are improved with the cultivated area maps of Leff et al. (2004) when possible. This has been done if cultivation data for a crop in a country is missing or if data for that crop in that country is of poor quality (i.e. too few grid cells resulting in very high adjustment ratios). For more details on the rescaling and making of the cultivated area maps for each crop see A1.2.2.

Distribution of irrigated area

The irrigated area as reported per crop per nation by Portmann et al. (2008) is spatially distributed while it is not exactly known of each crop where the irrigated areas are located. Only general spatial information on areas equipped for irrigation (AEI) as reported by Siebert & Döll (2007) is available, i.e. non-crop specific spatially explicit data is available. The approach used to distribute the irrigated hectares of each crop is therefore as follows:

The irrigated hectares per crop per country are obtained from Portmann et al. (2008). The reported irrigated hectares by Portmann et al. (2008) are distributed homogenously over those grid cells which are reported to be equipped for irrigation (by Siebert & Döll (2007)) and that are reported to be cultivated by the crop considered (by Monfreda et al. (2008)). When this is done, the total intersection of AEI and cultivated area is added at the country level. The total amount of hectares should be equal to the amount reported by Portmann et al. (2008).

If the amount of irrigated hectares (derived from the intersection of cultivated area and AEI) is lower than the total amount of irrigated hectares as reported by Portmann et al. (2008), than 100% of the intersection of the cultivated area and the AEI is taken as irrigated. Further the remaining irrigated hectares as reported by Portmann et al. (2008) are distributed homogenously over the areas cultivated in that country without AEI. In this case for this specific crop it is not known where the remaining irrigated areas are, because they are not reported by Siebert & Döll (2007). Also it could be possible that the cultivated area as reported by Monfreda et al. (2008) is not totally correct.

Rescaling yield and production data of crops to FAO figures

The yield and production data of each crop are rescaled with a rescaling factor: FAO (2009 c) production figures divided by production figures based on the crop water use model (the yield computed in equation 12 times the cropped area in a nation as reported by FAO (2009 c)). The water footprint of each crop is computed based on the rescaled actual yields (Y_a) per grid cell and the crop water consumption (green, blue and grey) (see equations 16, 20 and 22).

Checking model output

The computed WFs of crops are checked on errors to determine if the model computation of the WF of crops is right. If the computation is correct, then the crop water requirement (*CWR*) (same as maximum crop evapotranspiration) of the crop will be larger than or at least equal to the maximum actual evapotranspiration of the crop ($CWR \geq ET_g + ET_b$). Normally a crop experiences periods of water stress during growth, so that the actual evapotranspiration of a crop will always be lower than the *CWR*. If the actual evapotranspiration of a crop is larger than the *CWR*, this means that the crop is not able to live while the evaporative demand of the atmosphere is higher than the crop is able to evaporate; hence the crop has permanently wilted.

Data quality

An important issue is the quality of the input data. As described in more detail in appendix A1, many errors, shortcomings and mismatches in the data are present. For example FAO (2009 c) reports sometimes only production figures of a crop and not how much area was cultivated per crop and the yield of the crop. Also Chapagain & Hoekstra (2004) reported sometimes the WF of a crop while FAO (2009 c) did not report cultivation of that crop for a specific country or the other way around. Especially data quality on nitrogenous fertilizer application is of poor quality, because for many crops and countries it is not known how much fertilizer per crop by farmers is applied. Therefore assumptions are made in nitrogen application per crop for each country. However the real fertilizer application rates are not known. Data on the yield reduction factor for crops was also not available for each crop. Crops without data received the same yield reduction factor as crops belonging to the same crop group or crop type. Precise data on the leaching of nitrogen by crops is even not available; the leaching values are only available for case studies that can not be used in general.

As becomes clear of all these statements, data quality is not very well. Improvements in the availability and quality of the data are not superfluous, however the assumptions made are reasonable and logic which will overcome most data quality problems. However for such a detailed study into the WF of crops based on geo-date, it is important that data quality is good.

3 Results

In this chapter the results are shown with regard to water efficiency and total water consumption of the SADC region. Both, water consumption and efficiency are important to present because it has influence on regional water management affairs. First the water footprint related to production of crops, livestock, industry will be discussed. Second international virtual water flows are analyzed. Third, the water footprint related to production is compared with the water availability in the region. Fourth, the water footprint of the SADC region and the SADC countries is discussed. Fifth the impacts of the water footprint related to production and of virtual water trade and the water footprint of a country are discussed.

Population density and climatic characteristics

To understand spatial distribution of agricultural, domestic and industrial water use in the SADC, it is important to know where the users are living (figure 10). Especially domestic and industrial water uses are strongly related to population density. It is important to know the climatic conditions (figure 10) to understand the distribution of precipitation and evapotranspiration in the SADC region. Maps of precipitation and actual evapotranspiration are given in figure 11. The maps of precipitation and actual evaporation together give an idea of the water availability over the SADC region.

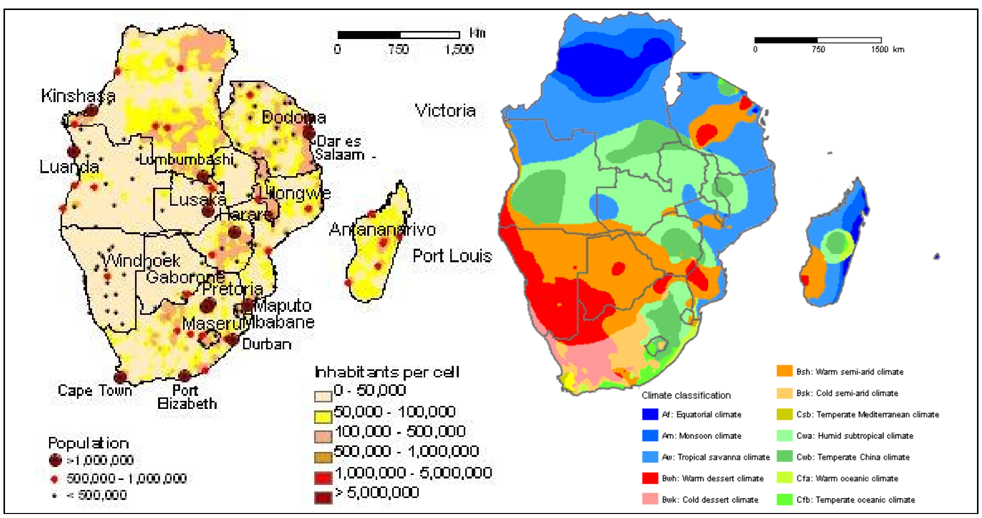


Figure 10. Overview of the population density (GWSP, 2008 c) and climatic regions (Peel et al., 2007) for the SADC region.

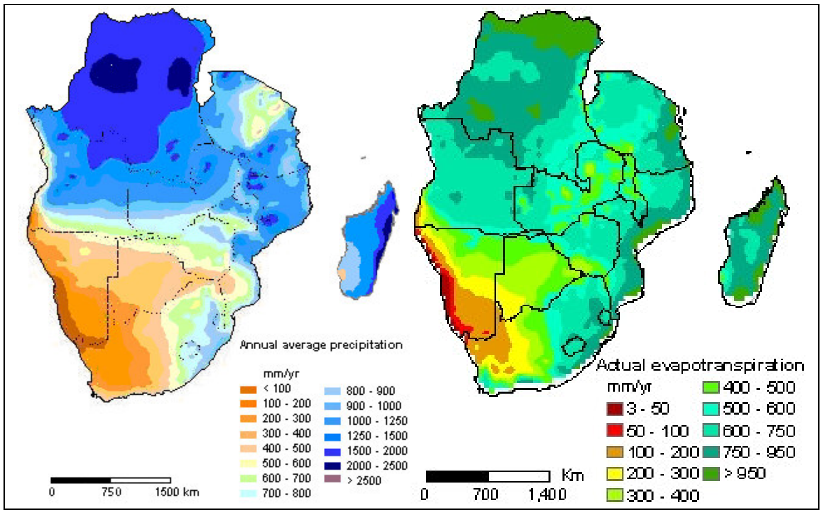


Figure 11. Overview of the annual average precipitation (FAO (2000); Ashton et al. (2001)) and actual evapotranspiration (GWSP, 2008 b) for the SADC region.

3.1 Water footprint related to production

The water footprint of production is the total volume of freshwater that is used to produce goods and services (Hoekstra & Chapagain, 2008). Because this study uses a grid-based approach, water used for the production of commodities per grid cell can be coupled to water availability in each grid cell. The water footprint of a product therefore says something about the total impact of the production of the commodity on the water resources (used) and about the water efficiency of production of the commodity for each grid cell. In this section the water footprint of crop, livestock and industrial products will be discussed.

3.1.1 Water footprint of crops

In this report, for the SADC region the maps on the water footprint of crops are provided for the four major water consuming crops maize, cassava, rice and sugarcane in more detail. The cultivation of these crops is responsible for almost 57% of the total water consumption by agriculture in the region. Maize, cassava and rice are the most important stable foods of the SADC region. Sugarcane is an important energy and food crop. "Seventy percent of the region's average per capita calorie supply comes from cereals, starchy roots and sugar" (Earl, 2001). Therefore these crops are discussed in more detail because of their impact on water use and importance for food supply in the SADC region. The water consumption of the other 18 crops is discussed in general by discussing the total water footprint of crop production of all 22 major water consuming crops of the SADC region. Also national average values are given for all 22 crops in this report in appendix A2.

Water footprint of major water consuming crops

Maize

In the SADC region maize is the most important food crop. Also the cultivation and processing of maize provides many people jobs. In the SADC region the total maize production is roughly 20 million tons per year and on average almost 14 million hectares are cropped with maize each year for the period 1996-2005 (FAO, 2009 c). It is also one of the few crops that is cropped in all the SADC member states.

In figure 12 the yield variation per country can be seen for rain fed and irrigated maize. The highest rain fed productive areas are located in South Africa and Zambia. Many parts of the SADC region however have poor yields for the rain fed crop, especially in Angola, the DRC and Tanzania. On average the irrigated maize crop shows higher yields than the rain fed crop with average yields of 2.46 ton/ha versus 1.42 ton/ha respectively for the SADC region. Namibia and South Africa are the countries with highest irrigated yields. Compared to the world average yield of 3.41 ton/ha (for 2003), it may be concluded that the yields are quite low in the SADC (Oklahoma State University, n.d.). The most productive countries, per hectare seen only, are South Africa, Namibia and Zambia. The rain fed yield of Botswana is so low, since the country is quite dry and uses less fertilizer per hectare than Namibia for example, which is also a semi-arid country. In many parts of the SADC the general low yields can be explained by low fertilizer use. For more details on cropped area, yields, and production please see appendix A2. For more information about fertilizer use see A1.

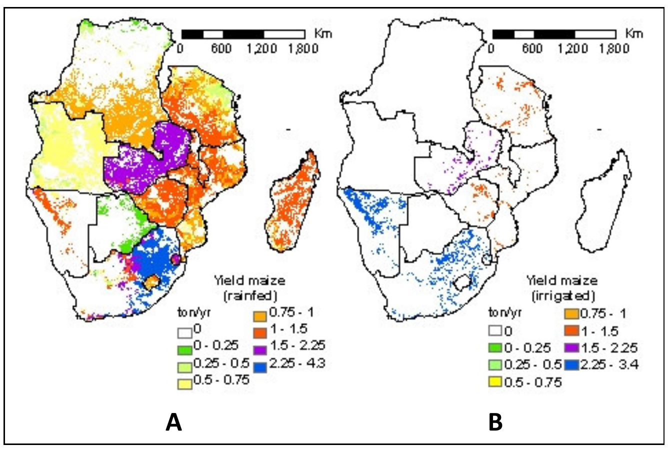


Figure 12. Overview of the yield variation per country for rain fed (A) and irrigated maize (B) for the period 1996-2005.

In figure 14 the green, blue, grey and total water footprint of maize can be seen. For the SADC the green water footprint of maize is largest in Botswana with an average WF_g of approximately 27000 m^3/ton. In this country the water footprint is so high due to the low maize yields and the high evaporative demand of the atmosphere (figure 11). For Angola and parts of Tanzania, DRC, Mozambique, Madagascar, the south of Zimbabwe and some plots near the Kalahari dessert in South Africa the green water footprints are also quite large due to the high evaporative demands in these areas. When looked at the green water footprint only, maize production is most efficient in South Africa and Namibia. Zambia is rather efficient as well. The average green WF of maize is 2972 m^3/ton in the SADC region (figure 13). Looked at the blue water footprint of maize (figure 14), it can be seen that maize is irrigated in only a few areas. Blue water demand is especially high in Namibia and Tanzania. The grey water footprint of maize is especially high in the most intensive cropped and developed areas of the SADC (Botswana, Lesotho, Namibia, South Africa and Zimbabwe). The grey WF is very low in Angola, the DRC and Madagascar since nitrogenous fertilizer application is low. In this study the grey WF is only used to give an idea of water pollution by farming as a result of nitrogenous fertilizer use. For the SADC region the average blue WF of maize is 8.78 m^3/ton and the average grey WF is 165.11 m^3/ton.

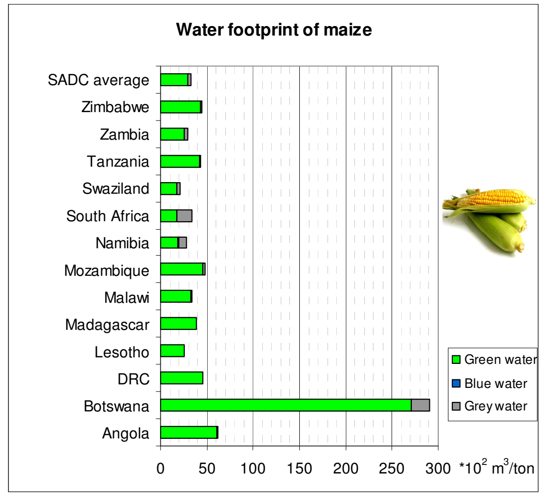


Figure 13. Average water footprint of maize per country split out in green, blue and grey water for the period 1996-2005.

The total WF of maize shows the areas that are best suited for maize production when looked at water efficiency per ton crop produced. Especially Lesotho, South Africa, Swaziland and Zambia are efficient maize producers compared to the other SADC members (figures 13 and 14). In the SADC the average water footprint of maize produced is 3146 m^3/ton. The SADC region is a less water efficient maize producer than other parts on the world when the average combined green-blue WF of maize of both are compared: 2981 m^3/ton compared to 909 m^3/ton (Chapagain & Hoekstra, 2004) respectively.

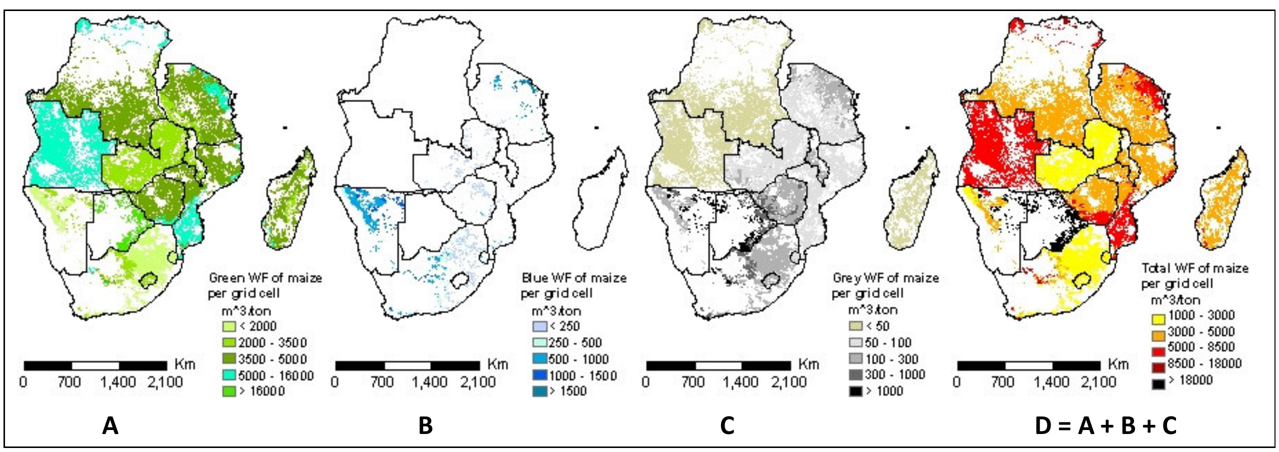


Figure 14. Green (A), blue (B), grey (C) and total water footprint (D) of maize per grid cell for the period 1996-2005.

In figure 15 the yearly average water consumption related to maize production per gird cell is given for the period 1996-2005. For maize the yearly water footprint of production is especially high in Malawi, South Africa and Zimbabwe. Total green water consumption related to maize production is $5.9*10^{10}$ m^3/yr and total blue water consumption is $1.7*10^8$ m^3/yr. The total amount of water needed to meet water quality standards is $3.3*10^9$ m^3/yr for nitrogenous pollution. For more details on the average water footprint and total water use of maize production per country please see appendix A2.

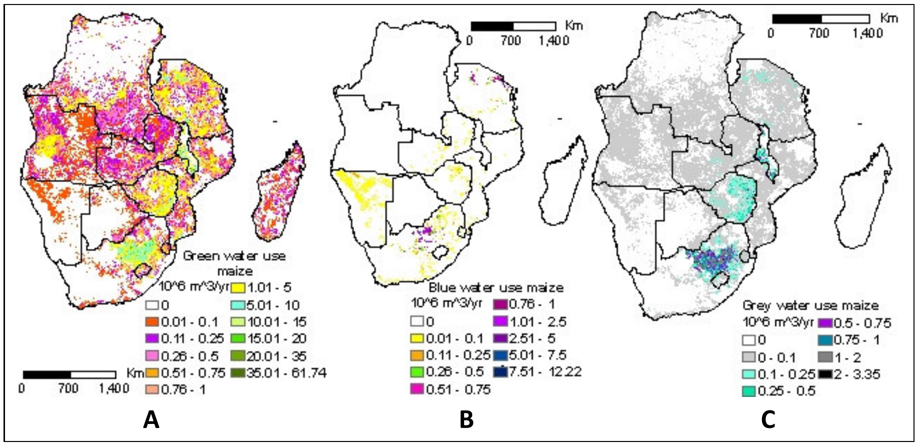


Figure 15. Green (A), blue (B) and grey (C) water use per grid cell per year for maize production for the period 1996-2005.

Cassava

Looked at the share of total water consumption and the area cultivated, cassava is the second most important food crop of the SADC region. In production figures it is even the most important stable food crop with an overall production larger than 38 million tons per annum which is almost twice the total production of maize. Another important aspect of cassava cultivation is that it is entirely rain fed.

The cultivation of cassava is concentrated in the humid and sub-humid areas of the SADC, i.e. the DRC, Angola, Zambia, Zimbabwe, Malawi, Tanzania and Madagascar. The most productive areas are located in Tanzania and Malawi (with yields above 15 ton/ha) and further in Angola and the DRC (10-15 ton/ha) (figure 17). The SADC average cassava yield is 7.82 ton/ha which is less than the average global yield of approximately 10 ton/ha (FAO, 2003). Only Malawi has a higher average yield than the global average yield of 12 ton/ha respectively.

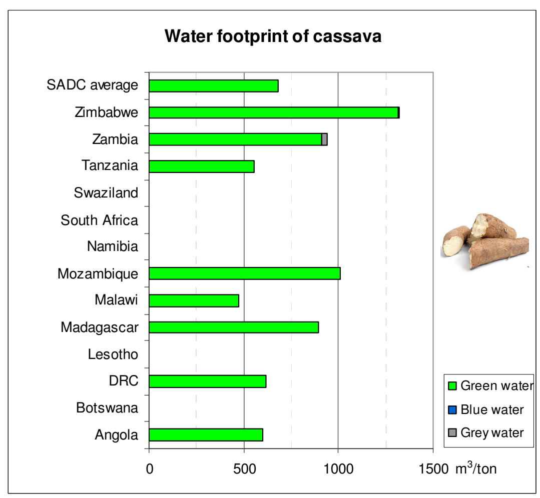


Figure 16. The average water footprint of cassava split out in green, blue and grey for the period 1996-2005.

Green water demand is highest in the southeastern part of the DRC reaching more than 16000 m^3/ton. In parts of Angola, Malawi, Mozambique, Madagascar and Tanzania the water footprint of cassava is also quite large (figures 17). The yearly green water footprint of cassava production is highest in parts of Mozambique, the DRC and Madagascar. For the SADC, the nitrogenous fertilizer application to cassava is highest in Zambia (16.41 kg N/ha) and Tanzania (4.11 kg N/ha) resulting in the highest grey WF prints for these countries as well. In general, the nitrogenous fertilizer application rate for cassava is very low in the SADC region (see A2). The SADC average green WF of cassava is 682 m^3/ton (figure 16), which is slightly higher than the global average WF of cassava of 605 m^3/ton (Chapagain & Hoekstra, 2004). Note that the average WF of maize is much larger than the average WF of cassava, for both the global and the SADC average. The SADC average grey WF of cassava is only 2 m^3/ton for the period 1996-2005. So in general cassava production is less water polluting and demanding than maize production.

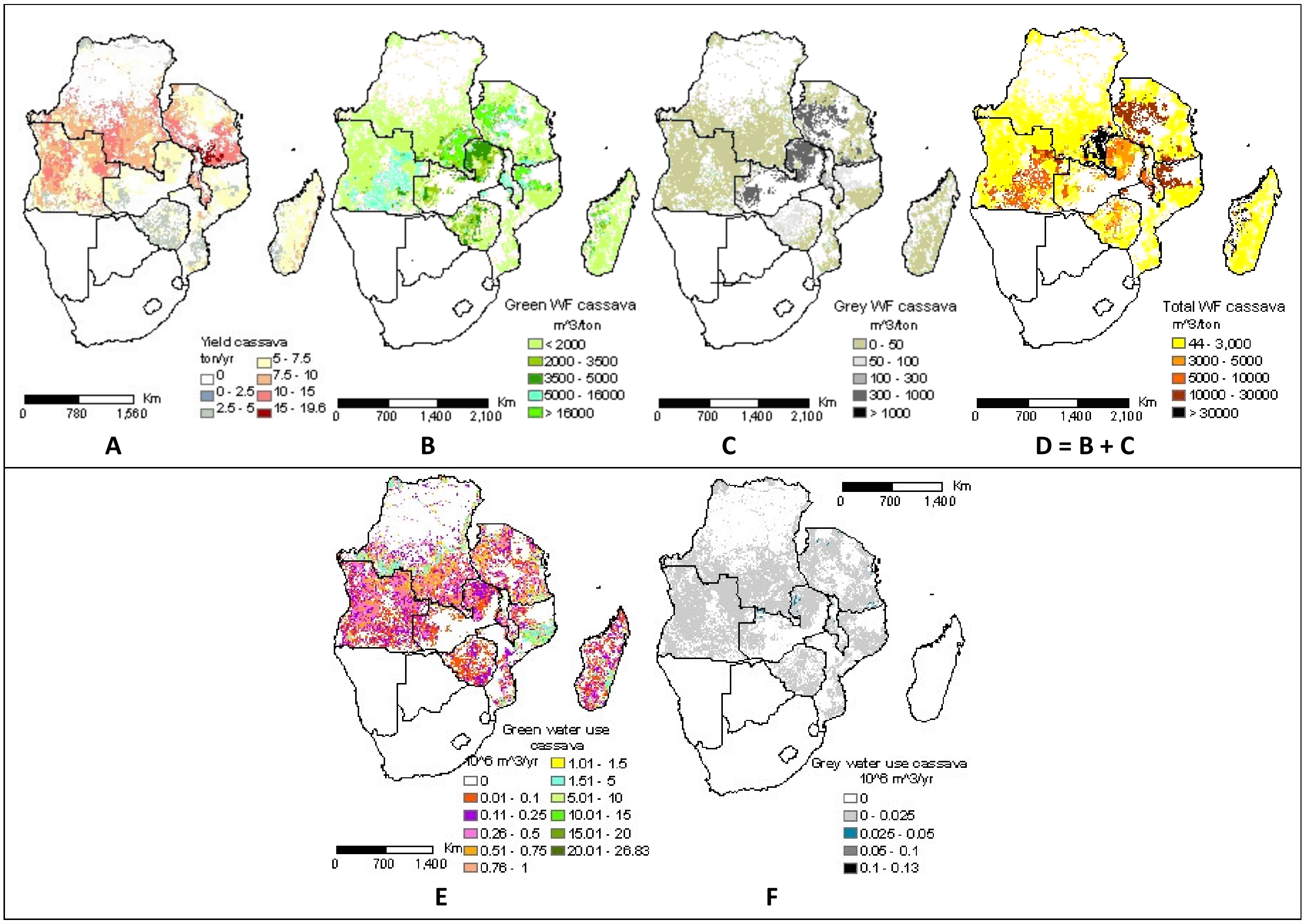


Figure 17. Average yield (A), water footprint (B,C,D) and water use maps (E,F) for cassava for the period 1996-2005.

Over the time span 1996-2005 the areas which are suited best for cassava production are the very high productive areas in Tanzania, because these areas have also a low WF per ton. Other rather well production areas are the western part and utmost east of Angola, the eastern part of Tanzania and the mid-south of the DRC because the yields are quite well and water use per ton and in total is low. For more details on cassava production per country please see appendix A2.

Rice

In the SADC region the production of rice is especially very large in Madagascar, Tanzania, DRC, Mozambique and Malawi (figure 19). In Malawi, Tanzania and Zimbabwe irrigated and non-irrigated rice plots show a patched pattern. In Angola and Swaziland rice is 100% irrigated and in South Africa and Zimbabwe it is almost totally irrigated. Important to notice is that rice is cropped at least twice a year in Angola, DRC and Malawi.

Rain fed yields are quite high in Madagascar (figure 19). Irrigated yields are high in Tanzania, Malawi, Madagascar, Swaziland and Mozambique with yields above 5 ton/ha up to even 12 ton/ha. SADC average rain fed yield is 1.08 ton/ha and the average irrigated yield is 3.52 ton/ha. Compared with the global average rice yield of roughly 3.9 ton/ha (period 1996-2005), the SADC region's irrigated yield is reasonable, but the rain fed yield of rice is very poor in the SADC. The SADC average yield (rain fed and irrigated combined) of 1.74 ton/ha is even low, even compared to the African average rice yield of roughly 2.3 ton/ha (IRRI, 2009). For more details on rice production and average yields per country please see appendix A2.

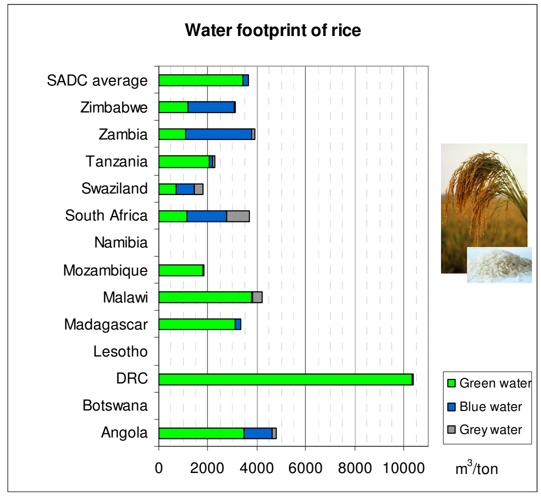


Figure 18. The average water footprint of rice split out in green, blue and grey water for the period 1996-2005.

Especially in the DRC the green water demand of rice is very high due to the high evaporative demands and low yields (figures 11, 19 and 20). In Tanzania the green WF is quite low due to moderate water use and high yields. The blue water demand is high in some areas of Angola, Zambia and South Africa. The production circumstances in South Africa, Swaziland and Madagascar look quite favorable for rice production compared to other SADC countries due to the quite high yields and low green and blue water footprints. But the grey water footprint of South Africa, Swaziland and Malawi is larger due to the higher application rates of fertilizer. The SADC average combined green-blue water footprint of rice is 3632 m^3/ton which is larger than the global average WF of 2291 m^3/ton. The average green, blue and grey water footprints of rice production are respectively 3441 m^3/ton, 191 m^3/ton and 37 m^3/ton (figure 18). Rice production needs quite a lot of green and blue water compared with the production of maize and cassava.

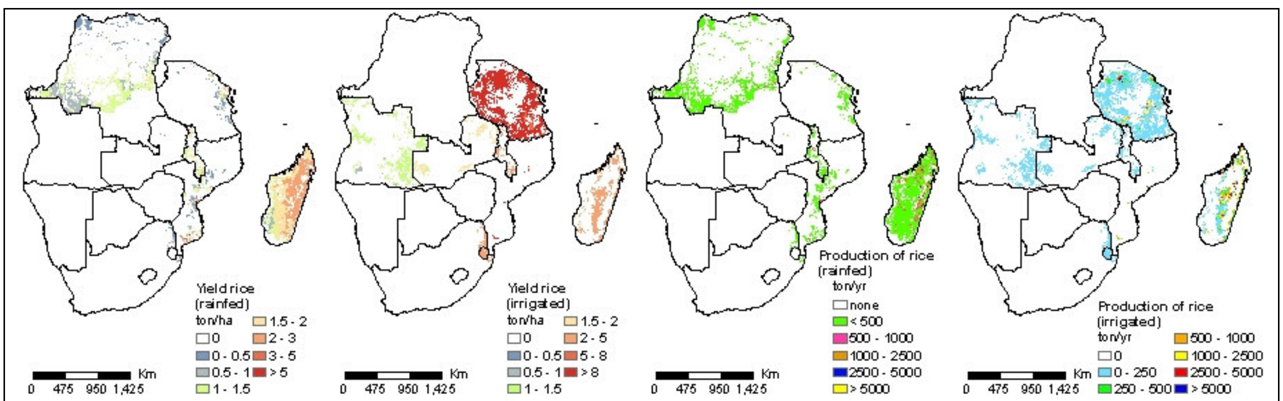


Figure 19. Yield (rain fed (A); irrigated (B)) and production (rain fed (C); irrigated (D)) areas of rice in the SADC region for the period 1996-2005.

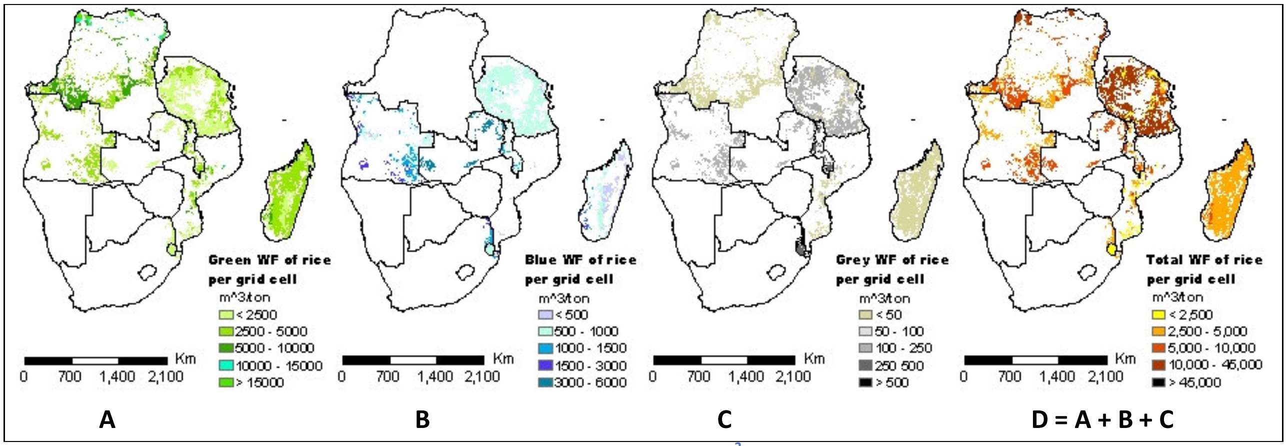


Figure 20. The green (A), blue (B), grey (C) and total WF (D) of rice in m^3/ton for the SADC region for the period 1996-2005.

Green water use per year per cell is especially large in Madagascar; the largest producer of rice in the SADC (figure 21). Blue water use per year per cell is especially large in Tanzania due to intensive irrigated rice production in the western part of the country. The grey water footprint of rice is low. Highest grey water use demands per cell are located in the intensive rice production regions of Malawi and Tanzania.

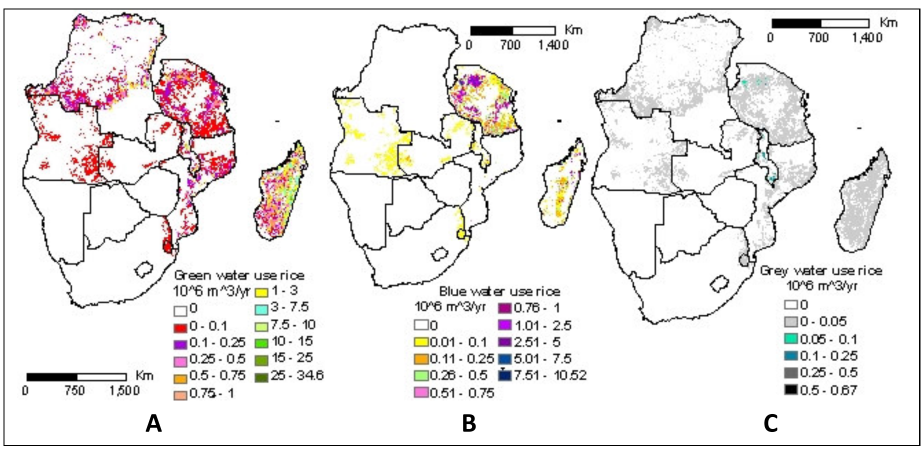


Figure 21. Green (A), blue (B) and grey (C) water used for rice production per year per grid cell for the period 1996-2005.

Sugarcane

In the SADC region sugarcane is cultivated in eleven countries (figure 22 and A3). The total average sugarcane production is 41 million ton/yr (1996-2005). In the SADC the three largest sugarcane producing countries are South Africa, Swaziland and Zimbabwe. For many SADC countries the sugar industry is very important for the national economy, especially for Mauritius and Swaziland (Maasdorp, 1998; SADC Review, 2008).

Normally sugarcane is harvested more than once a year. Average national yields are varying much between different SADC member states. The highest national average yields are around 100 tons per hectare (Tanzania and Malawi), while the lowest is only 14.2 tons per hectare (Mozambique). Zimbabwe, Zambia, Malawi and Swaziland have the highest irrigated yields while Tanzania has the

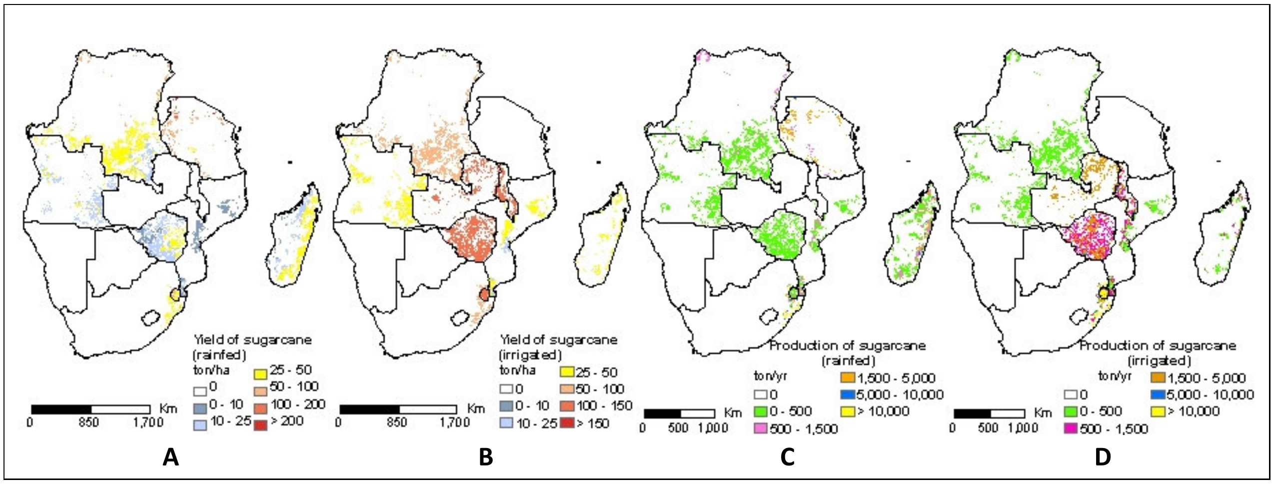


Figure 22. The yield (rain fed (A); irrigated (B)) and production (rain fed (C); irrigated (D)) of sugarcane per grid cell for the period 1996-2005.

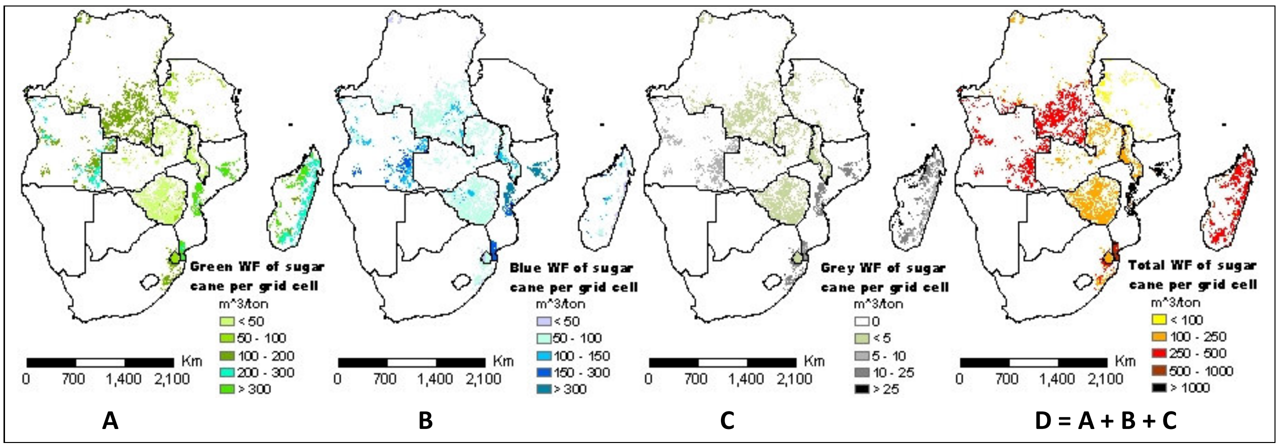


Figure 24. The green (A), blue (B) grey (C) and total water footprint (D) of sugarcane per grid cell for the period 1996-2005.

highest rain fed yields (figure 22 and A3). The SADC average sugarcane yield is 41 ton/ha for a rain fed crop and 87 ton/ha for an irrigated crop. The combined (rain fed and irrigated crop included) average SADC yield of 58 ton/ha is slightly lower than the world average yield of approximately 64 ton/ha (FAO, 2003).

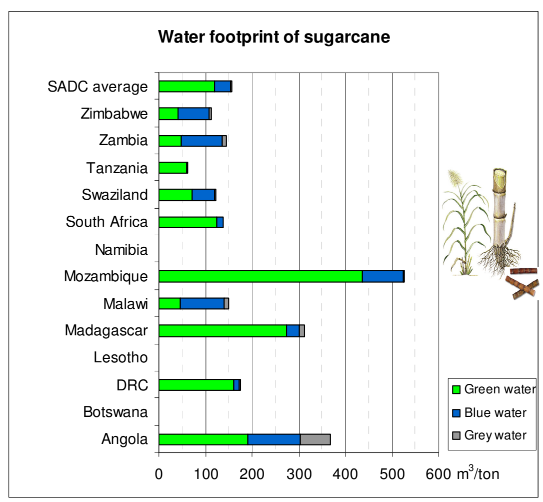


Figure 23. The average water footprint of sugarcane per country split in green, blue and grey water for the period 1996-2005.

The strong variations in yield are reflected in the WF of sugarcane as well: some countries have quite low green and blue WFs for sugarcane like Tanzania, Zimbabwe, Zambia, Swaziland and South Africa, while other countries like Angola, Madagascar and Mozambique have rather high WFs (figures 23 and 24). Sugarcane cultivation is most water efficient and productive in Tanzania with only 60 m^3/ton and an average yield of 104 ton/ha. Other water efficient producers are Zimbabwe, Zambia, Swaziland and South Africa (figures 23 and 24). However the most water efficient and highest sugarcane producing countries apply also the most nitrogenous fertilizer to their crops, the grey WF for these regions is very low. The SADC region is a water efficient producer of sugarcane based on the comparison of the SADC average combined green-blue water footprint of sugarcane with the global average, i.e. 154 m^3/ton against 175 m^3/ton respectively. The SADC average green, blue and grey water footprints of sugarcane are 121 m^3/ton, 33 m^3/ton and 3 m^3/ton respectively.

Average yearly green and blue water use for sugarcane production per cell is highest in Swaziland and South Africa due to the intensive cropping of sugarcane in quite small regions. In Mozambique green and blue water use for sugarcane production per grid cell is very high compared to water use in other SADC countries. Of the SADC region, Mozambique has also the largest WF of sugarcane due to the very low yields (figures 24 and 25).

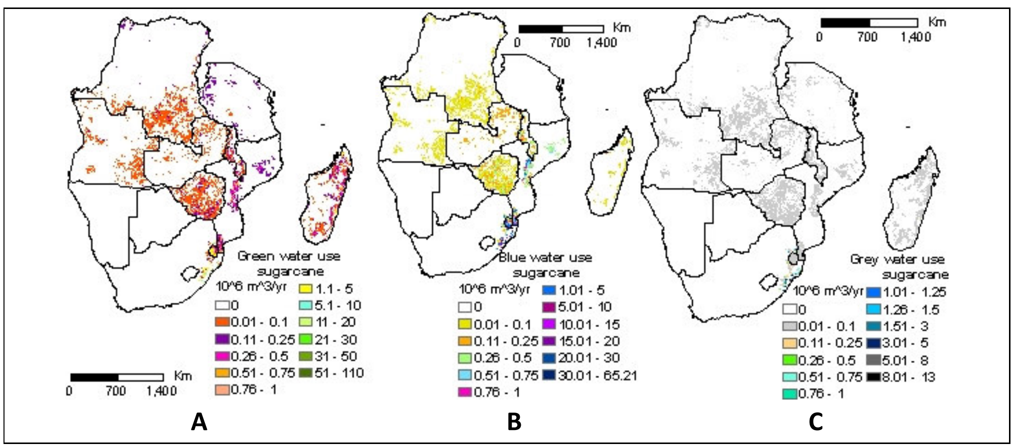


Figure 25. Green (A), blue (B) and grey (C) water use per year per cell related to sugar production for the period 1996-2005.

Total water use of the 22 major water consuming crops

It is possible to make an in-depth analysis of each crop just as has been done for maize, cassava, rice and sugarcane. Because these crops are less important to discuss in detail, only the total water use related to agricultural production is discussed further (figure 26). These maps give more insight in the effects of agriculture on water use and pollution and which areas consume most of the green and blue water. These maps are also input for the impact analysis in section 3.5.

In figure 26 can be seen clearly that the green water consumption is especially large in the central part of South Africa, parts of Zimbabwe, DRC, Mozambique, Malawi, Tanzania and Madagascar. Most of the irrigated areas are also matching largely with the highest green water consuming areas. The highest blue water consuming areas (water consumption above 25 mm/yr) are located in South Africa, Swaziland, Zimbabwe and Tanzania. Grey water use reflects nicely the most intensified cultivated areas of the SADC region which are stretching from South Africa over Zimbabwe, Malawi up to Tanzania.

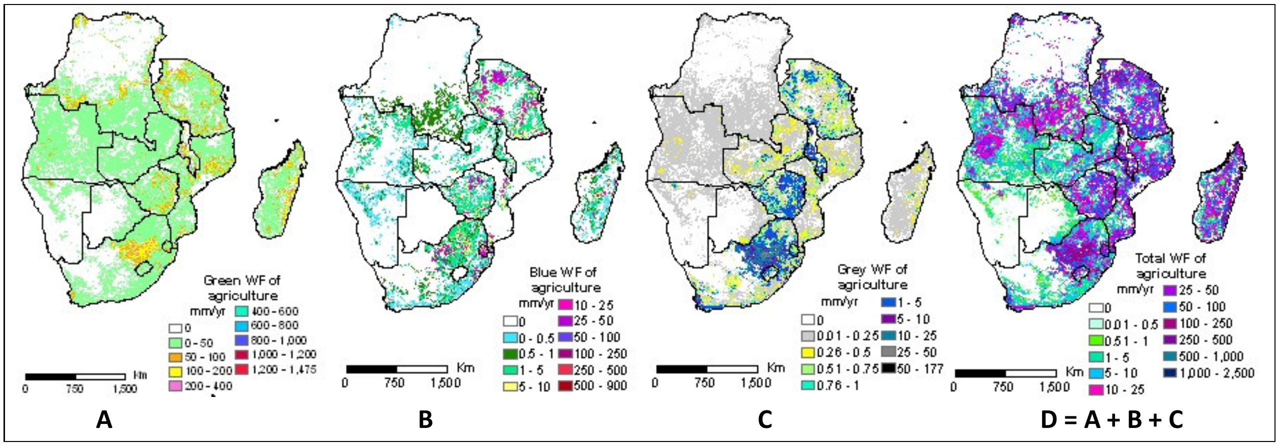


Figure 26. The average green (A), blue (B), grey (C) and total water use (D) related to crop production of the 22 major water consuming crops in the SADC region for the period 1996-2005.

3.1.2 Water footprint of livestock

The method for computing the WF of livestock and livestock products is based on the study of Chapagain & Hoekstra (2004). In the current study the WFs of livestock commodities are improved using new data on the green, blue and grey WF of feed crops for each SADC country. In the SADC region livestock is fed seven main types of crops besides pasture, silage and hay. Of these seven feed types, five could be improved with new data, i.e. wheat, maize, other cereals, soybean and potato. The other two feed types, dry peas and other rolled flaked grains, could not be improved. Of these feed types it is assumed that only green water is used for their growth. Currently silage, hay and pasture are not considered in the WF of livestock due to data shortage on these feed crops.

The water footprint of livestock is mainly based on the water footprint of crops. For the SADC region drinking and servicing water use by livestock are assumed to be very small and partially covered by domestic or industrial water use figures.

It is important to know the production system for computing the water footprint of livestock, because it determines the diet for each animal category. The three systems for livestock rearing are: the grazing system, the mixed system, and the industrial system (Chapagain & Hoekstra, 2003). In the SADC region only the grazing system (i.e. in Angola, DRC, Lesotho, Madagascar, Malawi, Mozambique, Tanzania, Zambia and Zimbabwe) and mixed system are used (i.e. in Botswana, Mauritius, Namibia, Seychelles, South Africa, and Swaziland). The diet data for these systems are obtained from Chapagain & Hoekstra (2003). For the SADC region, the diet data are not totally suited, because the data for the industrial system are based on the Canadian industrial system and the data for the grazing system are based on data for the USA, eastern and southern Africa, Asia and global averages. The diet data are not improved because they are scarcely or not available for the SADC.

For the SADC an overview of the average WF of live animals and main animal products is given in figure 27 and 28. For most countries the WF of (live) livestock per animal category is not differing much, except for the Democratic Republic of Congo and Botswana where livestock production is very water intensive due to the high WFs of the feed crops. In the SADC region, especially swine, bovine and poultry meat and leather from swine and bovine are very water intensive. The WF of livestock

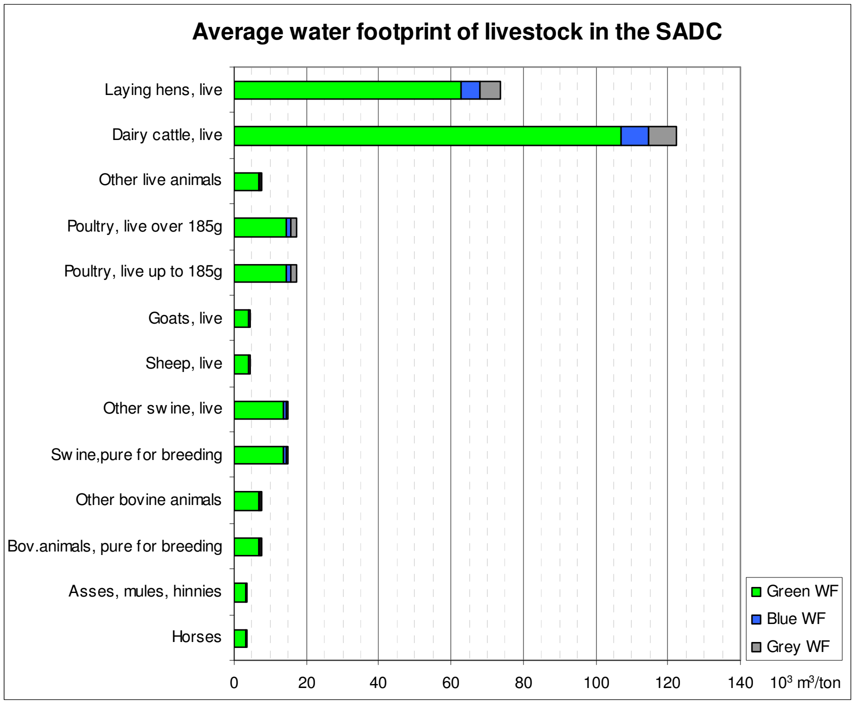


Figure 27. Overview of the average WF of live livestock in the SADC region for the period 1996-2005.

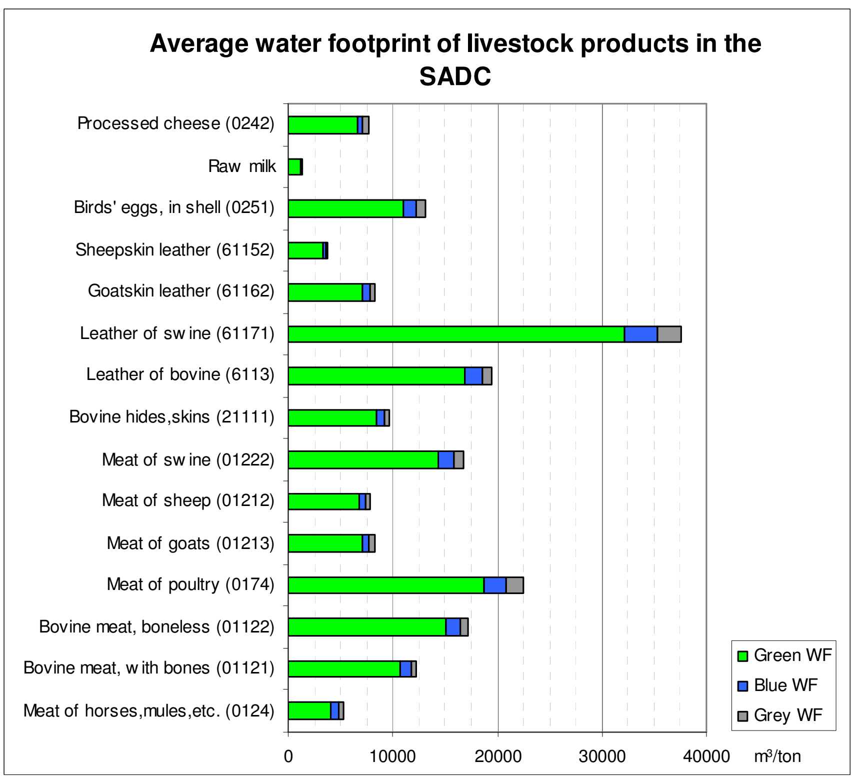


Figure 28. Overview of the average WF of livestock products in the SADC region for the period 1996-2005. Values in brackets behind product category are the SITC codes (ITC, 2007).

and livestock products exists largely of green water. Blue water use for livestock rearing is especially large in Angola, South Africa, Zambia and Zimbabwe compared with other SADC countries. For the SADC the grey WF for livestock production is highest in Angola, Botswana and South Africa. In the SADC livestock rearing is very water intensive compared to the world average WFs of livestock and its products (Chapagain & Hoekstra, 2004). For more information on the WF of livestock and the most important livestock products per country please see appendix A4.

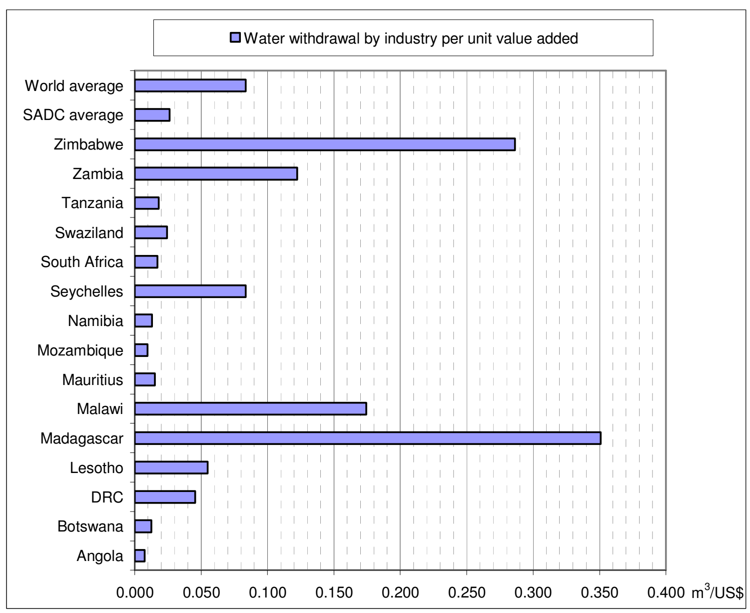
3.1.3 Water footprint of industry

In table 2 the average water use by industry and the average water withdrawal per unit value added by industry over the period 1996-2005 is given. Industrial (blue) water use is quite low compared with agricultural or domestic water use (appendix A7): the latter are using roughly 66.04% and 27.82% respectively compared to 6.13% of the former of total blue water use in the SADC. The water footprint of industry is not split into green, blue or grey water, because it is assumed that industry is only using blue and grey water. So a part of the withdrawal is consumed (blue water) and the rest is discharged into surface waters again as grey water.

On average the industrial of the SADC region is more water efficient than the global average water efficiency of industry; the SADC needs only 0.026 m^3 to get one dollar added value compared to the global average of 0.084 m^3 per US$ added value. Zimbabwe, Zambia, Malawi and Madagascar however are rather water inefficient with industrial water footprints ranging from 0.123 m^3/US$ up to even 0.351 m^3/US$. The industrial production is quite water efficient in the other SADC countries.

Table 2. Overview of water use by industry and of the industrial water footprint for each SADC member state. Average industrial water withdrawal obtained from FAO (2009 a). Statistics on value added by industry per country obtained from UN Statistics Division (2009).

Country	Average industrial water withdrawal 1996-2005 (10^6 m^3/yr)	Average water withdrawal per unit value 1996-2005 (10^6 m^3/yr)
Angola	60	0.007
Botswana	35	0.013
DRC	60	0.046
Lesotho	20	0.055
Madagascar	230	0.351
Malawi	50	0.174
Mauritius	20	0.015
Mozambique	10	0.010
Namibia	14	0.013
Seychelles	0	0.084
South Africa	756	0.017
Swaziland	12	0.024
Tanzania	25	0.018
Zambia	130	0.123
Zimbabwe	298	0.286
SADC total	1720	0.026
World total	775117	0.084



3.2 International virtual water flows in the SADC region

In this section international virtual water trade is discussed. The virtual water flows exist of green and blue water, because only combined green-blue values are available for the imports by SADC countries from countries outside the region since Chapagain & Hoekstra (2004) did not divide the WFs into green, blue and grey yet. In this section first the virtual water trade between the SADC and other world regions is discussed. Therefore the world has been divided into thirteen world regions (based on Chapagain & Hoekstra, 2003). Second the intra SADC virtual water trade is discussed.

International virtual water trade between the SADC region and other world regions

For the period 1996-2005 the major share of products traded between the SADC and other world regions are agricultural products. The share of crop products is 73% of virtual water exports and 74% of virtual water imports against 18% and 13% for livestock and 9% and 12% for industry respectively (table 3). The SADC region imports agricultural products from South America, South East Asia, Central & South Asia, North America, Oceania and the Former Soviet Union (FSU) (in order of importance) (figure 30). The SADC exports agricultural products to Western Europe, Central Africa, Eastern Europe, North Africa, the Middle East and Central America (in order of importance) (figure 30).

The SADC exports mainly coffee, sugarcane, maize, cotton, clove and orange products (90% of total exports). Imports exist mainly of rice, wheat, maize, cotton seed, soybean, oil palm, sunflower and sugarcane products (95% of total imports). The largest exporting countries of crop products are South Africa, Madagascar, Tanzania, Zimbabwe and Mauritius (80% of total export). The largest importers of crop products are South Africa, Tanzania, Mozambique, Mauritius and Angola (74% of total import).

Livestock and livestock products are mainly exported to Western Europe, Eastern Europe, the Middle East, Central Africa, South East Asia, and the FSU. The main exported products are bovine leather, bovine meat (boneless and with bone), bovine animals, live poultry, bovine skins and hides, swine meat, milk products, live swine, bird's eggs in shell and goat leather (86.6% of total exports). The largest exporting countries are South Africa, Zimbabwe, Botswana, Swaziland, and Namibia (95.26% of total exports). The imports of livestock and livestock products are mainly from Central & South Asia, Western Europe, South America, Oceania and North America. The imported virtual water flows are mainly related to bovine animals, bovine meat, swine meat, live poultry, bird's eggs in shell, milk products and bovine leather (84.49 % of total imports). The largest importers of livestock products are Swaziland, Angola, South Africa, Malawi and Namibia (89.5% of total imports). Gross export in livestock and livestock products was especially large from 1999-2002. Causes of this increase in exports could be droughts and/or the worldwide economical growth and increased demand for livestock products. The sudden export decrease after 2002 could be a result of the economical downturn in 2001-2002 after the World Trade Center attacks in the USA and/or animal diseases and continuing drought. For now, the exact reasons behind the trends in the virtual water trade of livestock and livestock products are not known however.

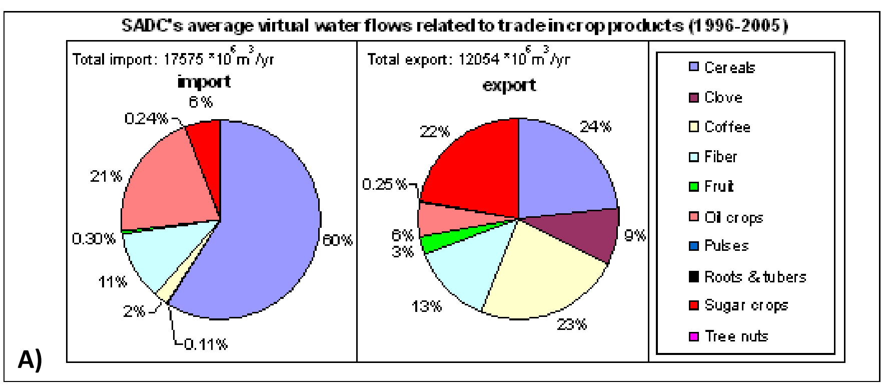
Industrial products are imported mainly from Central & South Asia, Western Europe, North America and the FSU (figure 31). The SADC net virtual water exports of industrial products are to Central

Africa, Oceania and North Africa. The average net virtual water exports related to industrial products (of $8*10^6 m^3/yr$) are very small compared to the net virtual water imports (of $1427*10^6$ m^3/yr). South Africa, Mauritius, Angola, Tanzania and Madagascar are importing almost 86% of all the virtual water related to import of industrial products. In the SADC almost ninety percent of total industrial virtual water is exported by South Africa, Zimbabwe, Zambia, Madagascar and Angola. The main imported products fall in the product classes of machines & transport equipment, manufactured goods, miscellaneous manufactured articles, and chemical products. For the SADC exports are mainly made up of manufactured goods, miscellaneous manufactured articles, non-ferrous metals, fuels, lubricants etc., and machines & transport equipment.

Table 3. Overview of virtual water flows and net virtual water import related to trade in crop, livestock and industrial products for each SADC country and the SADC region as whole.

Country	Average gross virtual-water flows over the period 1996-2005 (10^6 m^3/yr)								Net virtual-water import (10^6 m^3/yr)			
	Related to trade in crop products		Related to trade in livestock products		Related to trade in industrial products		Total		Related to trade in crop products	Related to trade in livestock products	Related to trade in industrial products	Total
	Export	Import	Export	Import	Export	Import	Export	Import				
Angola	418	1180	4	665	63	147	485	1992	762	661	84	1508
Botswana	10	277	351	64	22	38	383	380	267	-287	17	-3
DRC	528	507	0	0	58	41	586	548	-21	0	-18	-39
Lesotho	97	177	0	0	20	31	117	208	80	0	12	91
Madagascar	2011	859	30	10	157	101	2198	970	-1152	-20	-57	-1228
Malawi	255	584	3	306	11	42	270	932	328	303	31	662
Mauritius	755	1188	18	167	20	197	792	1553	434	150	177	760
Mozambique	590	1489	5	155	7	40	602	1684	899	150	33	1082
Namibia	47	255	215	182	9	32	271	469	207	-33	24	198
Seychelles	8	82	1	10	3	15	12	107	73	9	12	95
South Africa	4490	7864	1734	636	585	1949	6809	10450	3374	-1098	1365	3641
Swaziland	365	582	145	876	8	21	517	1479	218	732	13	962
Tanzania	1463	1748	61	18	5	103	1529	1869	285	-44	98	340
Zambia	348	489	19	11	170	73	538	573	141	-8	-97	35
Zimbabwe	876	863	478	29	342	78	1696	970	-13	-449	-264	-726
Total	12262	18145	3064	3131	1478	2908	16805	24184	5883	66	1430	7379

Based on figures 29, 31, 32 and 33, table 3 and appendix A6, it can be concluded that the SADC region is a net virtual water importer of agricultural and industrial products. More information about the exported goods, main trade partners and trade between the SADC region and other world regions is given in appendix A6.



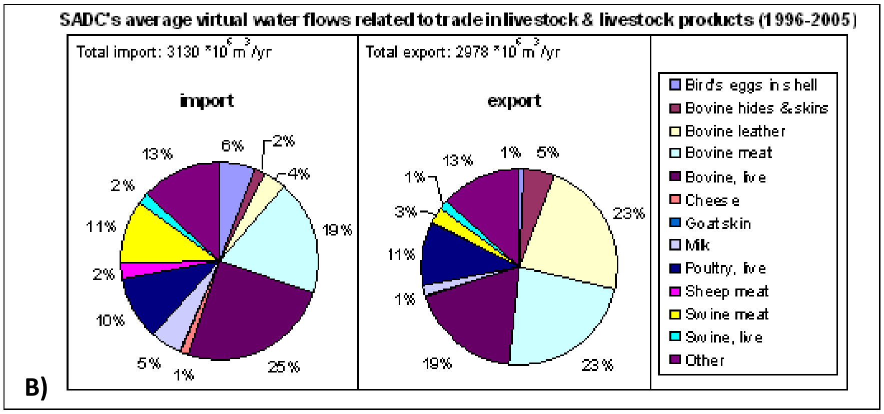


Figure 29. Overview of the import and export of virtual water flows related to trade in crop (A) and livestock (B) products in the SADC region for the period 1996-2005.

International virtual water trade within the SADC region

On average intra SADC virtual water trade is making up 23.82% of crop trade, 43.51% of livestock trade, and 16.22% of industrial trade (figure 30). Over the period 1996-2005 intra virtual water trade related to crop products increased steadily from roughly 6% to 28%. For livestock, figures are different. Between 1999-2002 intra SADC trade in livestock and livestock products was quite large (roughly 70% of total livestock trade), but in 2003 it dropped to the levels of before 1998 (roughly 17%). The reason for this sudden increase and drop in livestock trade is not known (see also the explanation in the section before). Intra trade in industrial products is quite constant around 16% and increasing slowly.

Intra SADC virtual water trade related to import of crop products is dominated mainly by South Africa, Zimbabwe, Zambia, Mozambique and Malawi (67.54% of intra crop imports) (appendix A6). Export of these products comes mainly from South Africa, Zimbabwe, and Mozambique (80% of intra crop exports). Especially cotton products, cereals, coffee, sugarcane, soybean and fruit are traded within the SADC.

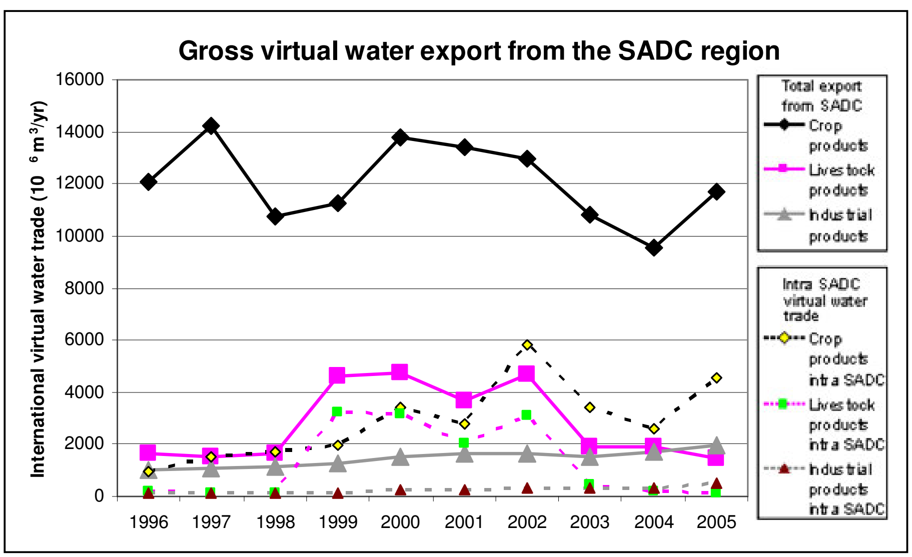


Figure 30. Gross virtual water export from the SADC from 1996-2005. Figures of total virtual water export by SADC countries and of internal SADC virtual water trade are given for crop, livestock and industrial products.

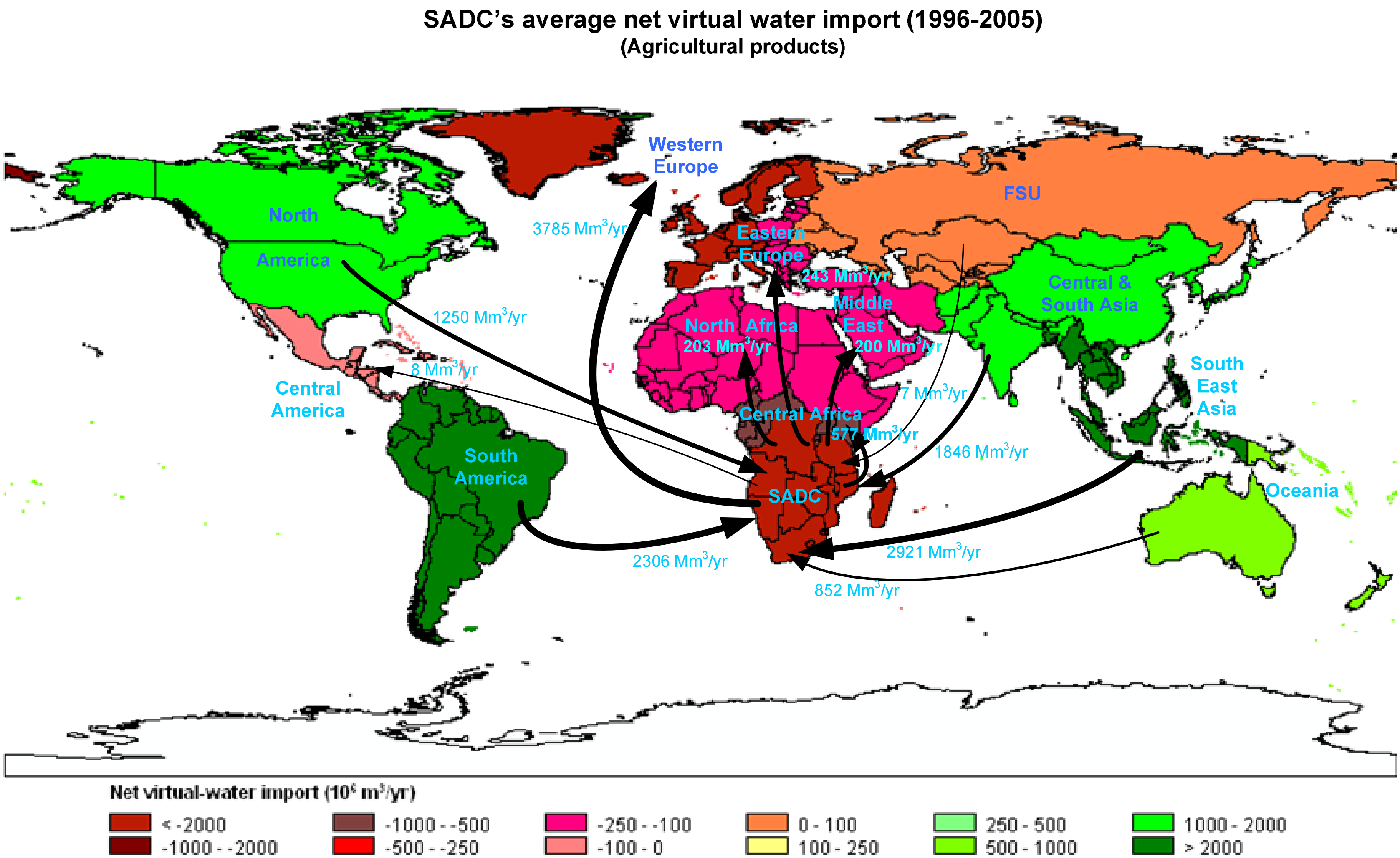


Figure 31. The average international virtual water flows related to trade in agricultural (crop and livestock) products between the SADC region and other world regions for the period 1996-2005.

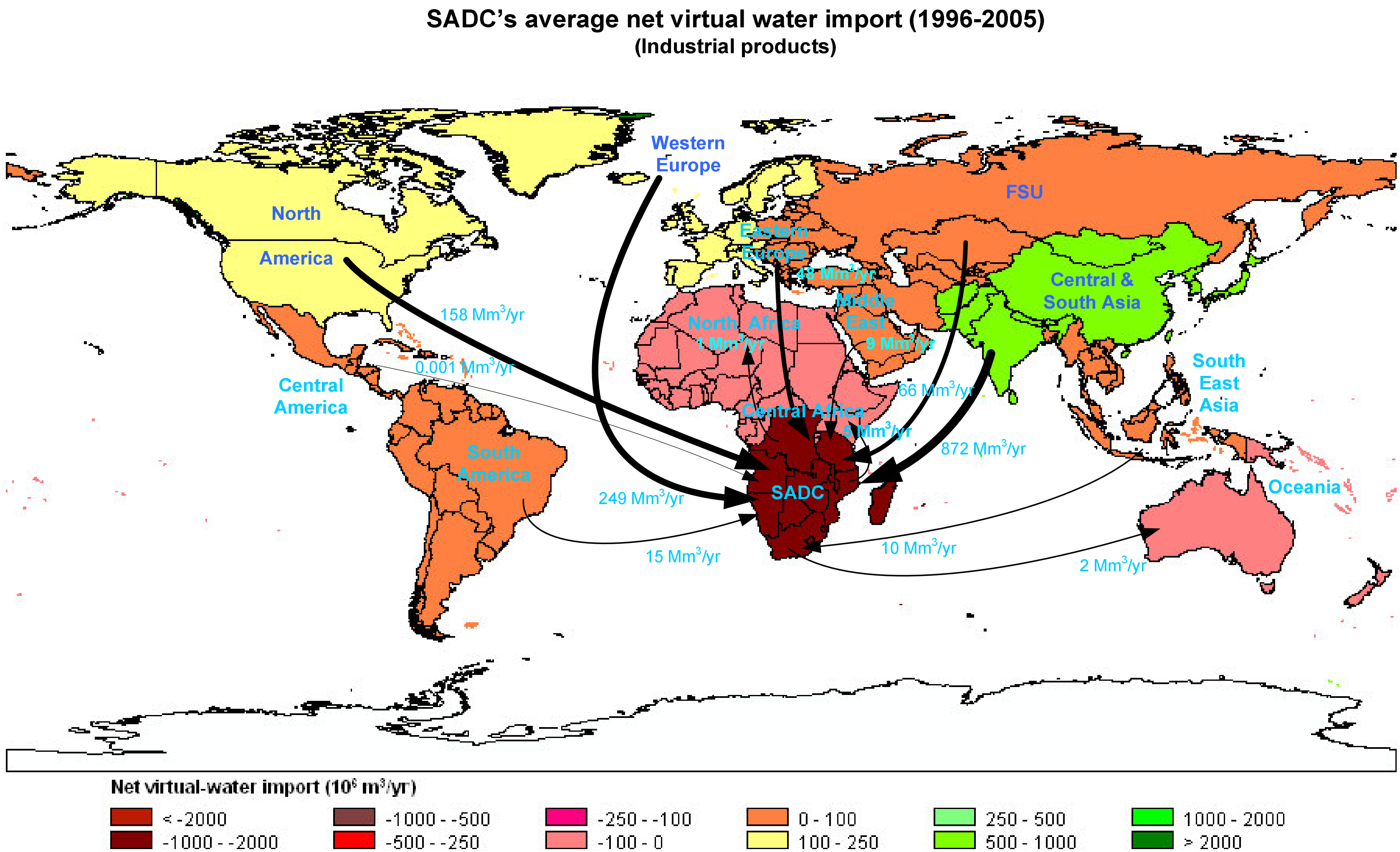


Figure 32. The average international virtual water flows related to trade in industrial products between the SADC region and other world regions for the period 1996-2005.

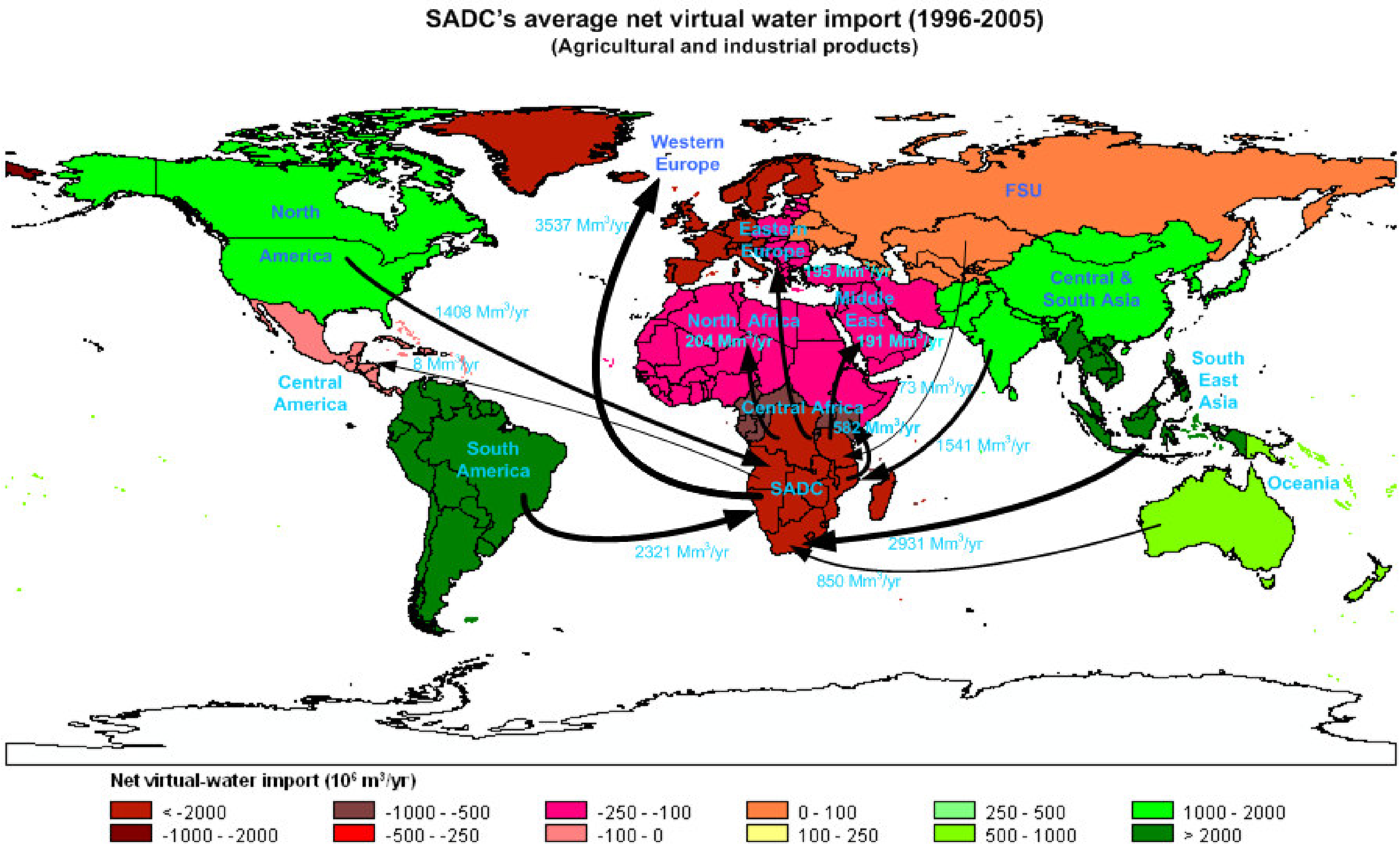


Figure 33. The average international virtual water flows related to trade in agricultural and industrial products between the SADC region and other world regions for the period 1996-2005.

Swaziland, Malawi and Mozambique imported most virtual water related to livestock from other SADC countries (76.7% of total intra livestock imports). South Africa, Zimbabwe, and Swaziland dominated the export of virtual water related to livestock & livestock products with 97.8 % of intra livestock trade. Bovine meat, bovine animals, swine, poultry and milk products are trade mostly between the SADC countries.

Within the SADC, industrial products are mainly imported by South Africa, Zambia, Malawi and Zimbabwe (72.1% of total intra industrial imports). South Africa and Zimbabwe are exporting most industrial products traded within the SADC (83.31 % of total intra industrial exports). Especially machines & transport equipment and manufactured goods are trade within the SADC.

In table 3 the net virtual water imports are given for each SADC country. Only Botswana, DRC, Lesotho, Madagascar and Zimbabwe are net virtual water exporters. All the other SADC countries are net virtual water importers. For each nation, more information is given in appendix A6. It is important to mention that trade is influenced by trade barriers in the SADC. The cereal sector for example is so important that trade barriers are used to protect national markets and grain millers in most SADC countries (Maasdorp, 1998). Potentially sensitive products are grain milling products, edible fruit and nuts, coffee, spices, meat, dairy products, sugar and cereals (Maasdorp, 1998).

3.3 Water footprints related to national consumption

The national water footprint related to consumption depends on the virtual water embedded in the consumed products that are produced in the country itself and products that are consumed in the country and are imported from other nations. In this study the water footprint is based on the green and blue WFs only, because the virtual water flows imported from outside the SADC are given as green-blue WF only (based on Chapagain & Hoekstra, 2004).

Table 4. The average virtual-water budget, green-blue water footprint related to consumption, and the virtual water flows exported for each country and the SADC region for the period 1996-2005.

Virtual-water budget, water footprint related to consumption and virtual water flows exported

Country	Total B_v (10^6 m^3/yr)	WF[#] (10^6 m^3/yr)	WFe[#] (10^6 m^3/yr)	WFi[#] (10^6 m^3/yr)	Ve,r (10^6 m^3/yr)	Ve,d (10^6 m^3/yr)	WF[#] per capita (m^3/cap/yr)
Angola	11177	10692	1906	8786	86	398	855
Botswana	901	518	218	299	162	222	288
DRC	30451	29865	537	29328	11	576	449
Lesotho	730	613	175	438	33	84	292
Madagascar	21069	18871	868	18002	101	2097	942
Malawi	12268	11998	911	11087	20	249	863
Mauritius*	1622	830	794	36	758	34	638
Mozambique	21996	21394	1638	19756	46	556	1004
Namibia	1183	912	362	550	108	164	434
Seychelles*	112	100	96	5	11	1	1224
South Africa	47130	40321	8940	31381	1510	5299	826
Swaziland	2446	1929	1167	762	313	204	1753
Tanzania	40920	39391	1799	37592	70	1459	980
Zambia	5499	4961	517	4444	56	482	424
Zimbabwe	13121	11425	845	10580	125	1571	1002
SADC total	213556	196751	22281	174470	1903	14902	772

*Only blue water included. Total available blue water resources based on FAO AQUASTAT (2009)

[#]The water footprint contains in this computation only the green and blue WF, because this water is actually consumed

In table 4 the WF related to consumption are given per capita, nation and of the SADC. The average water footprint of consumers in the SADC is 776 m^3 per capita per year, which is comparable with

23.5 truckloads of 33.000 liter. The SADC countries consume mostly agricultural products (96 %). Industrial products are responsible for only 3 % of the footprint and domestic water consumption accounts for 1 % of the total water footprint of consumption (figure 38). The Comparison of the WF of the SADC with the WF of a Western industrialized country like the Netherlands shows clearly that the WF of a Western country contains a much larger share of industrial products consumed. For the Netherlands this is roughly 30% (Van Oel et al., 2009). This is also reflected in the water footprints of Mauritius and the Seychelles, which are one of the most industrialized and rich countries of the SADC (World Bank, 2009). The global average WF per capita has been estimated on 1243 m^3/capita/yr (Hoekstra & Chapagain, 2008). So the WFs of the SADC countries are quite low compared with this figure. Only Swaziland has a high WF related to consumption. Botswana, DRC, Lesotho, Namibia and Zambia have really low water footprints. Per capita consumption is very low in these countries. On top of that these countries export so much products compared to their imports that their water footprint per capita stays very low. Probably the WFs of the latter five countries are also low because not all crops are included and due to errors in the input data.

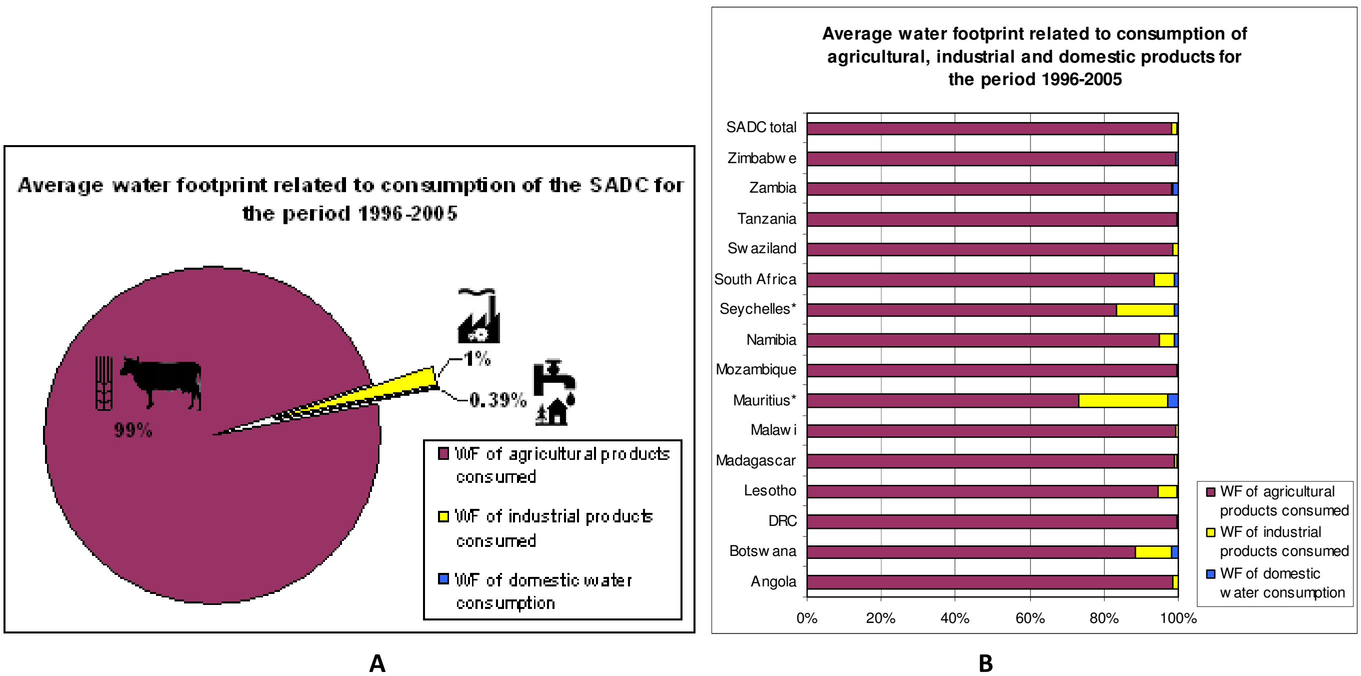


Figure 34. The average shares of the water footprint of agricultural, industrial and domestic products consumed of the total water footprint of consumption for the SADC region (A) and SADC countries (B) for the period 1996-2005.

3.4 Water footprints of production in the context of water availability

Green water footprint of production vs. green water availability

The green water footprint of production is compared with the available green water resources using the actual evapotranspiration in the SADC. The green water footprint exists only of the actual evaporation by crops, since industry and households are not using green water. In figure 34 the actual evapotranspiration and green water footprint by agriculture can be seen. The actual evapotranspiration by natural vegetation is obtained by the subtracting the latter of the former (figure 34). It can be seen that the green water footprint is often not higher than 10% of the available green water in the grid cell for most parts of the SADC. Only in South Africa, Tanzania, Madagascar, Zimbabwe and Malawi the green water footprint is reaching in some parts 50% of the total available green water.

For a few cells in the DRC, Malawi, Tanzania and South Africa the green water footprint related to agricultural production is higher than the actual evaporation according to the model, which is not possible of course. This error is caused by the fact that in these cells more hectares are considered to be cropped taken all crops together than possible regarding the cell size. This minor error is caused by grid cells overlapping the border of two countries. ArcGIS 9.3 considers a grid cell to belong to a country when more than half of it is lying in the country. An example is Malawi, which is quite small and has a long border so that quite many grid cells are considered to belong to the neighboring country. Despite of this minor error for a few cells, it can be concluded that the model is working properly.

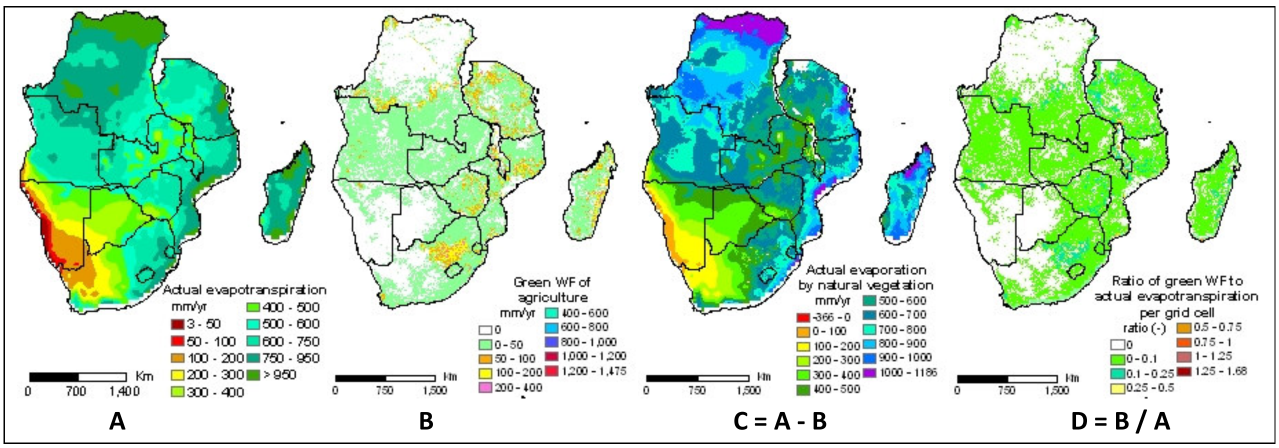


Figure 35. A) Actual evapotranspiration map (obtained from GWSP Digital Water Atlas, 2008 b). B) The average green water footprint per cell for the period 1996-2005. Note that agriculture is using green water only. C) The actual evapotranspiration by natural vegetation (obtained by subtracting map B from map A). D) The ratio of the green water footprint to the actual evapotranspiration per grid cell (map B divided by map A).

Blue water footprint of production vs. blue water availability

According to this study the agricultural, industrial and domestic blue water footprints are 93%, 2% and 5% in the total blue water footprint of the SADC respectively (appendix A7). The blue-grey water footprints of agriculture, industry and households are 70%, 5% and 25% in the total blue-grey WF of the SADC respectively. The share of SADC's total agricultural blue-grey WF in the total blue-grey WF differs quite substantial from the share of agricultural water withdrawal in total water withdrawal as reported by FAO (2009 a): 70% against 81% respectively. The shares are differing, because this study considers the actual blue water consumption and blue water pollution related to agricultural production and not the water withdrawals by agriculture, which contain both water consumption and water losses, as FAO (2009 a) does. The amounts of blue water use by industry and households are based on FAO (2009 a). It is assumed that the water withdrawals for these sectors are the combination of the blue and grey WF since the dilution factor is assumed to be one. Hence the blue-grey WFs of these sectors are equal to the water withdrawal values as reported by FAO (2009 a). The GIS maps on blue water use by households and industry from GWSP (2008 e,d) have been rescaled to the FAO (2009 a) figures. For Madagascar spatially explicit data on industrial water use is lacking. In the tables the blue and grey WF of Madagascar's industry is taken into account. In appendix A7 more information on the average blue and grey WF and water use is given for each sector per country for the period 1996-2005.

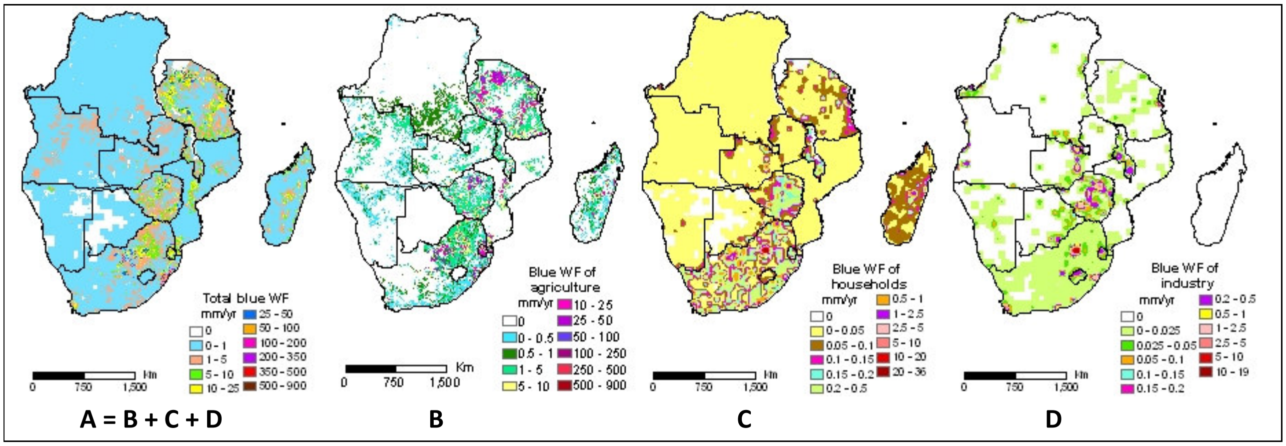


Figure 36. Total blue WF and blue WF per sub category: agriculture (this study), households (GWSP Digital Water Atlas, 2008 e; rescaled to FAO (2009 a) figures) and industry (GWSP Digital Water Atlas, 2008 d; rescaled to FAO (2009 a) figures) per cell for the period 1996-2005. Water consumption by industry and households is based on Shiklomanov (1997). He argues that water consumption of industry is approximately 17% of total water withdrawal and that domestic water consumption is around 12%.

Figure 35 gives the blue WFs of agriculture, households, industry and the total blue WF. The spatially explicit map on the blue WF of agriculture is based on the 22 crops analyzed. The total blue WF is especially large in parts of Madagascar, Mozambique, South Africa, Swaziland, Tanzania and Zimbabwe. For these countries the agricultural, domestic and industrial WFs are also largest. Industrial and domestic water use is large in the big towns, especially in the large towns of Malawi, South Africa, Zambia and Zimbabwe.

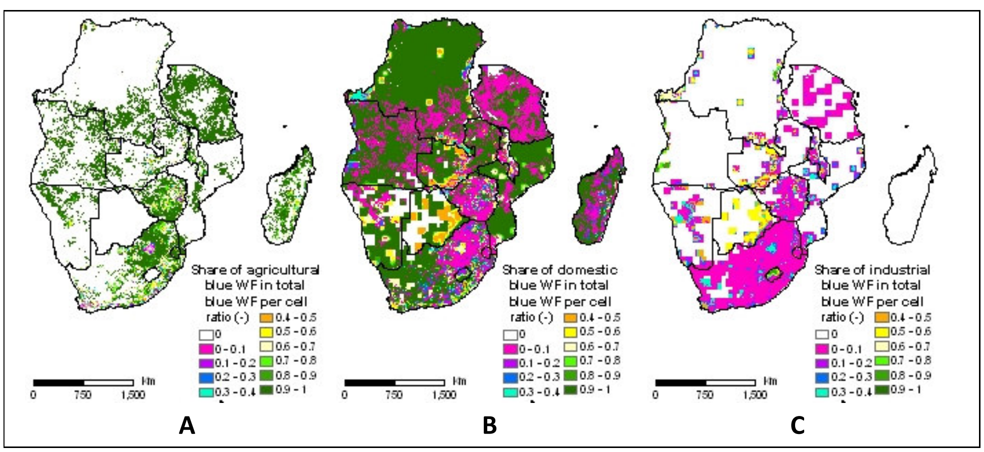


Figure 37. The shares of the agricultural (A), domestic (B) and industrial (C) blue water footprints in the total blue water footprint per grid cell for the period 1996-2005.

In figure 36 the water used in every grid cell has been split out into the type of use. In many grid cells, domestic water use is 90-100%, because irrigation and industrial water use does not take place in these cells. However rain fed agriculture could be practiced in these regions still, since it is depending on green water only (see section 3.1 and figure 34).

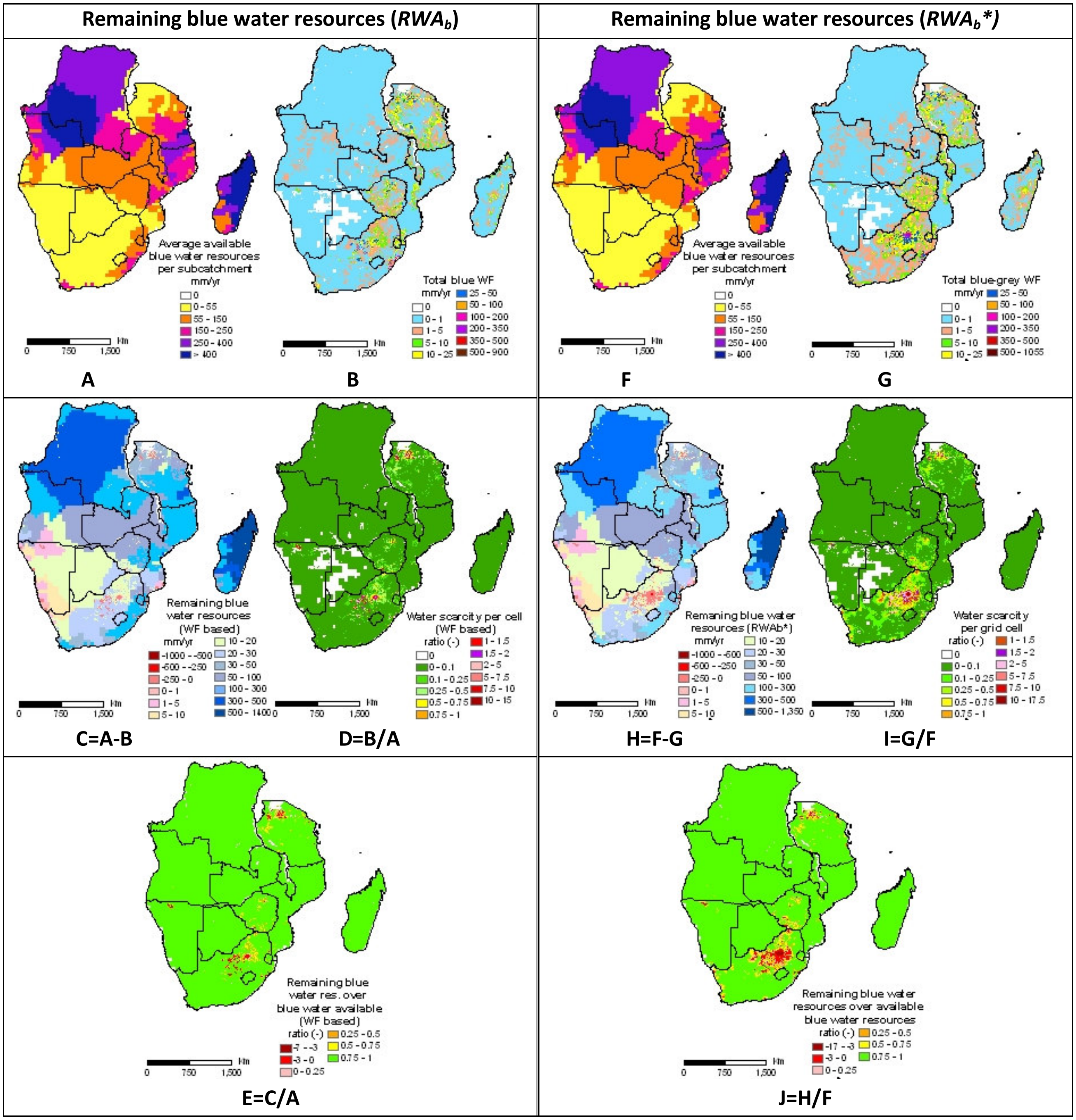


Figure 38. The average blue WF and blue-grey WF compared with the total available blue water resources per grid cell for the period 1996-2005. A & F) The average available water resources per sub catchment (obtained from GWSP Digital Water Atlas, 2008 a). B) The total blue WF of agriculture, households and industry. C) The remaining blue water resources (map A minus map B). D) Water scarcity per grid cell (map B divided by map A). E) Remaining blue water resources over blue water available (map C divided by map A). G) The total blue-grey WF of agriculture, households and industry. H) The remaining blue water resources (map F minus map G). I) Water scarcity per grid cell (map G divided by map F). J) Remaining blue water resources over blue water available (map H divided by map F).

In this study, blue water availability is based on the average annual available blue water resources (i.e. runoff or FAO's (2009 a) total renewable water resources) per sub catchment (GWSP, 2008 a). The idea behind this map (figures 37,A and 37,F) is that water is often made available off-stream by transport of water through gullies, rivers, channels and pipelines. Except for some large water transfers like the Limpopo water transfers, Orange water transfers, water transfers from Lesotho to South Africa, and water transfers from Lake Kariba on the Zambezi river (FAO, 2009 b), water is normally not transported over large distances because this is too expensive or technically complex. Therefore the map divides the available water resources only over the sub catchment. Of course one should take in mind that in reality this assumption should not necessarily be true for the every place in a sub catchment; it could be possible that some areas do not receive water diverted from the river. In general this assumption however gives a good idea of the availability of blue water over the total catchment area. Another point of attention is that water is more available near the source instead of far away from the river. A discharge based map is not used because water is not only available at the source, as already mentioned, and due to large uncertainties in the discharge-runoff models. For example annual world runoff has been estimated between 33,500 km^3 up to even 47,000 km^3 (Postel et al., 1996). Therefore it is believed that using the average annual blue water available at the sub catchment gives the best insights in water availability. In this study groundwater use and availability are neglected because good spatial explicit maps on ground water use and availability are lacking.

Figures 37,C and 37,H give comparisons of blue water availability (the same as total renewable water resources as reported by the FAO (2009 a)) and blue water consumption (RWA_b) and of blue water availability and blue water consumption & pollution (RWA_b*). Also water scarcity and the remaining blue water resources for nature are shown based on both RWA_b and RWA_b*.

Based on RWA_b* the areas where more water is used than naturally available are larger and more severe than based on the consumption of blue water RWA_b only of course. Based on both maps for RWA_b and RWA_b*, several areas use more water than naturally available:

- the Pretoria-Johannesburg urban area in South Africa;
- the intensively cropped and irrigated region to the west of Johannesburg (between Kagisano Rural and Lichtenburg, South Africa);
- parts of the coastal urban areas of Namibia (Elizabeth Bay area, Walvisbaai area, Otjiwarongo area);
- the irrigated area in the mid-north of Namibia (Ehosta pan region);
- the urban and irrigated areas in the Maputo-region at the mouth of the Limpopo river in Mozambique;
- the urban area of Bulawayo in Zimbabwe;
- the urban and irrigated areas near Harare in Zimbabwe;
- and the irrigated areas near Lake Victoria in Tanzania.

In figure 37,D and 37,I, water scarcity is given for both datasets as a ratio of water footprints divided by water availability. In some regions more than 10 times the amount of water available is used. Especially water withdrawals are very large in the Johannesburg-Pretoria area and the irrigated areas between Kagisano Rural and Lichtenburg of South Africa. Figure 37,E and 37,J show the percentage of water left for other water users like vegetation and animals.

Environmental flow requirements

According to Postel et al. (1996) not all water discharged by rivers is accessible for human purposes. Postel et al. (1996) argue that shares of river runoff are too remote to withdraw because of the high technical or economic constraints. Also floodwater is often not possible to capture. Smakhtin et al. (2004) state that environmental flow requirements (EFR) need to be taken into account as well, which are the amounts of water needed to sustain ecosystems. However progress is made to establish a method to determine the exact shares of remote flow, uncaptured floodwater, and EFR; a well established methodology is still lacking. In this study values for these aspects are therefore not shown yet. But when environmental flow requirements, remote flow and uncaptured flood water are taken into account, the SADC region will be much more water stressed. For example, the first estimation on remote flow for the Congo basin is 50% of total runoff (Postel et al., 1996) and Smakhtin et al. (2004) estimated the average environment flow requirement for the SADC region on approximately 29%.

3.5 Impacts of water use and virtual water trade on water resources

Water consumption due to production is so high in some areas that more water is consumed than naturally available (section 3.4). The discussion about international virtual water flows related to trade of the SADC region showed that in the SADC region a part of the water used for the production of agricultural and industrial products is actually used for export products (section 3.2). In section 3.1 the water footprint of crop, livestock and industrial products is discussed. Based on these figures it can be concluded that in general the SADC region is not a water-efficient producer of most agricultural products compared with the global average WF of these products. Industrial production however is quite efficient compared with the global average WF. This section discusses the effects of production and international virtual water flows on the water resources of the SADC in more detail. In 3.5.1 the influence of trade on SADC's WFs related to consumption and production is discussed; it results both in water savings due to import of commodities as well as in water losses for producing export products. In 3.5.2 the impact of production on the water scarce areas are elaborated further. Sub-section 3.5.3 discussed blue and green water scarcity at both the national and grid level. In 3.5.4 conclusions are drawn about the water footprints of production, consumption and water scarcity in the SADC.

3.5.1 Importance of trade for SADC's water footprints related to production and consumption

Of all water used for the production of agricultural and industrial products in the SADC, 8.69% is used for producing export products. The share of the water footprint for producing agricultural export products in the total agricultural water footprint for production is 8.46%; for industry this export share in the total industrial WF related to production is 33.68%.

The share of imported virtual water related to the import of agricultural and industrial products in the total water footprint related to consumption of the SADC is 11.04%; the share of imports in the total WF related to the consumption of agricultural products is 10.21%. For industry the share of imports in the total WF of consumed industrial products is 66.31%.

Based on these figures, it can be concluded that water flows related to trade of commodities are making-up quite large parts of both the water footprint related to production as well as of the water footprint related to consumption of the SADC. In table 5 this point is even further emphasized. Due to trade in crop products (that are making-up the largest shares of both the WFs of production and consumption; both > 97%), the SADC region is saving 11028.5 million m^3/yr of green water, 2026.8 million m^3/yr of blue water and 1366.6m^3/yr of grey water. These SADC water savings are mainly due to imports of rice, maize, wheat, and cotton. The SADC is losing water due to exports of sugarcane, oranges, coffee, beans and bananas. So it can be concluded that the SADC region is improving its water availability by importing crop products. In this way the SADC countries are decreasing the pressure on their own (scarce) water resources, because they do not have to grow the crops themselves. In the SADC many areas are already water stressed as shown in section 3.4 and figure 39. More information about national water savings due to trade in crop products is given in appendix A10.

Table 5. Net water saving of the SADC region due to international virtual water flows related to trade in agricultural products.

Region	FAO crop code	Crop name	Net green water saving (10^6 m^3/yr)	Net blue water saving (10^6 m^3/yr)	Net grey water saving (10^6 m^3/yr)	Net total water saving (10^6 m^3/yr)
SADC	27	Rice	3200.8	1714.1	817.1	5732.0
	56	Maize	3198.1	14.7	90.4	3303.2
	15	Wheat	2539.8	233.6	357.6	3130.9
	328	Cotton seed	2521.1	178.9	43.8	2743.9
	242	Groundnut	331.6	7.6	6.9	346.1
	79	Millet	293.2	-26.0	-6.8	260.4
	254	Oil palm	246.3	6.8	0.0	253.2
	267	Sunflower seed	176.1	10.8	4.4	191.3
	236	Soybean	159.4	61.3	-27.7	193.0
	83	Sorghum	140.9	-0.2	8.2	148.9
	249	Coconut	60.8	-0.4	0.0	60.4
	116	Potato	28.1	1.6	0.4	30.1
	125	Cassava	6.1	0.1	0.2	6.5
	122	Sweet potato	1.2	0.1	0.1	1.4
	698	Clove	1.1	0.0	0.0	1.2
	217	Cashew	0.0	0.0	0.0	0.0
	489	Plantain	0.0	0.0	0.0	0.0
	486	Banana	-36.9	3.3	-5.8	-39.4
	176	Bean	-47.7	-5.8	-0.1	-53.7
	656	Coffee, green	-379.8	-7.0	-1.4	-388.2
	490	Orange	-494.2	-12.6	-0.3	-507.1
	156	Sugarcane	-917.6	-118.1	79.4	-956.3
SADC total water saving			11028.5	2062.8	1366.6	14457.9

The agricultural products are mainly produced in the countries themselves (at least 89% is produced domestically), except for Botswana, Mauritius, Namibia, the Seychelles and Swaziland (table 6 & appendix A8). The latter countries depend on trade for food security. Most SADC countries depend for more than 50% on other nations for the industrial products they consume, except for the DRC, Madagascar, Malawi, Zambia and Zimbabwe. So trade helps also to meet the industrial consumptive needs of the SADC countries. The water dependency of Mauritius and the Seychelles on foreign water resources is even almost 100%. Countries like the DRC, Madagascar, Malawi, Mozambique, Tanzania and Zimbabwe are depending less on foreign water resources and are even very water self-sufficient. On average water dependency of the SADC is only 11%.

Table 6. Average green, blue and blue-grey water scarcity, water self-sufficiency and water dependency of the SADC region and SADC countries for the period 1996-2005.

Country	Green water scarcity (10^{-12} %)	Blue water scarcity (blue water only) (%)	Blue water scarcity (blue & grey water) (%)	Water self-sufficiency (%)	Water dependency (%)
Angola	1.05	0.22	0.33	82	18
Botswana	0.21	0.13	1.07	56	44
DRC	1.56	0.02	0.04	98	2
Lesotho	2.17	0.57	2.78	71	29
Madagascar	4.19	0.33	0.46	95	5
Malawi	20.18	2.02	5.94	92	8
Mauritius*	N/A	2	N/A but > 2	3	97
Mozambique	3.63	0.40	0.51	92	8
Namibia	0.28	18.15	32.56	61	39
Seychelles*	N/A	N/A	N/A	2	98
South Africa	5.78	11.62	28.42	78	22
Swaziland	5.78	5.89	6.98	40	60
Tanzania	5.69	5.73	6.69	95	5
Zambia	1.06	0.42	1.19	89	11
Zimbabwe	4.59	8.91	15.93	93	7
SADC total	2.88	0.74	1.33	89	11

*Only blue water included. Total available blue water resources based on FAO AQUASTAT (2009)

3.5.2 Impact assessment

In section 3.4 the areas that are using more water than naturally available are identified. For these areas it is determined more precisely how big the impact of water consumption by agriculture, industry and households is on the total water consumption in these areas. For agricultural water consumption also the most important (maximal 3 crops) water consuming crops in these areas are shown. In appendix A9 a more precise analysis is given, showing the water use of all crops cultivated in these areas.

In figure 39 an overview is given of the 27 areas in which less than 5 mm of blue water resources is left after subtracting the blue and grey water footprints related to production (of agriculture, industry and households) from the naturally available water resources (water scarce areas) (based on GWSP (2008 a). In table 7 the naming of the areas and the blue water WF and users per area are shown. In table 8 this is done for the grey WF. As already noticed in section 3.4, many of these areas are urban or irrigated agricultural areas (table 7 & 8).

The grey WF (table 8) is mainly caused by households and industry. For Mozambique, South Africa and Tanzania agriculture has a rather polluting effect in some areas as well. Also the crops responsible for the largest nitrogenous pollution (grey WF) in the water scarce areas are often differing from the most important blue water consuming crops. For the blue WF in these area mainly maize, sugarcane, cotton, rice, oranges and bananas are important. For the grey WF crops like groundnuts, soybean, sorghum, millet, bean, cassava and sunflower are important as well. The grey WF in the water scarce areas is in general larger than blue WF due to dilution requirements needed (dilution factor of 1 assumed).

Agriculture dominated areas

Surprisingly in most water scarce areas blue water is only used to cultivate certain crops. In the areas 2, 3, 4, 17, 19, 20, 21, and 23 (see figure 39) the cultivation of only one or two crops often in combination with water use by households are causing water stress.

Angola & Namibia

In area 2 (South Angola) in figure 39 irrigated banana plantations are causing water scarcity in the area (table 7). Just across the border in the North of Namibia (area 5 in figure 39) maize and cotton are causing water scarcity (table 7). This case shows the importance of taken regional differences into account. These differences in which crops are irrigated are probably caused by differences in national agricultural policies between Angola and Namibia.

Namibia is focusing on food security and improving the revenues of farmers (Ministry of Agriculture, Water and Rural Development, 2000). So the Namibian agricultural policy explains well why in Namibia especially food crops like maize, wheat and millet are cropped, just as the cultivation of cash crops like cotton. In the virtual water flows related to exports of crop products this is also reflected. The products grown in the water scarce areas (figure 39), cotton, maize and wheat, are all also exported by Namibia (appendix A6).

Angola's agricultural has been devastated by the years of civil war. The agricultural sector of Angola is therefore subsistence-oriented. The main cash crops nowadays are fruits, coffee, vegetables, palm oil and sunflower oil (Rush, 2009). This could give an explanation for the fact that in South Angola bananas are irrigated instead of maize or cotton as done in Namibia. These bananas however are mainly produced for the domestic market, because Angola exports especially coffee (appendix A6). An important note for the irrigation of bananas in Angola is that it is not known for sure where the irrigated areas in Angola are. On the other hand the total irrigated area reported by Portmann et al. (2008) is equal to the reported cultivated area for bananas reported by FAO (2009 c); so it can be assumed that 100% of the cultivated area of bananas is irrigated.

Madagascar

The government of Madagascar has nowadays, after years of neglecting national agricultural development, agricultural policies in place promoting food self-sufficiency and cash crop production for export (World Bank, 2001). Especially growth of rice and cotton are stimulated. This is also reflected in area 21 (figure 39) in the South of Madagascar: rice (food crop) and sugarcane (cash crop) are causing water scarcity in this area (table 7 and 8). In the 1960s Madagascar was still a large exporter of rice (World Bank, 2001). For the period 1997-2005 sugarcane is the most important export crop (appendix A6).

Mozambique

Agricultural production in Mozambique is mainly directed to food crops, because the poor rural population tries to meet their food requirements. Therefore the production of cash crops is still small. The government nowadays tries to increase agricultural production by improving the infrastructure and availability of inputs like fertilizers, but also by expanding the cultivated area (also reflected in cultivated area figures provided by FAO (2009 c), however large yearly variations in cultivated area are still possible). Government focus is both on increasing food crop production as well as cash crop production (World Bank, 2006). The crops that are most important for water scarcity caused by agriculture in the water scarce areas in Mozambique are also a mix of cash and food crops: rice, maize, cassava, sugarcane, oranges, and groundnuts (table 7 and 8). These crops are all except cassava also important export products (appendix A6). Especially sugarcane and maize have a large share in the virtual water exported by Mozambique. Groundnuts are the cash crop of small scale farmers, while sugarcane is mainly cultivated on plantations (World Bank, 2006). Due to the worse political and economical situation Zimbabwean farmers are investing in cash crop production in Mozambique. Also cash crops are often produced on contract in special cash crop zones. Further it is easily understood that area 16 (figure 39) in the south of Mozambique is facing water scarcity, because the South is much drier (400-1000 mm/yr) than the North (1000-1800 mm/yr). When taken in mind that sugarcane and rice need both a lot of water, water problems can be expected.

South Africa

During apartheid South Africa aimed at self-sufficiency and food security. Since the end of the 1990s, South Africa is reforming its agricultural sector towards an internationally competitive open market sector (Ministry for Agriculture and Land Affairs, 1998; OECD, 2006). The agricultural sector of South Africa is highly diversified. The main cash crops are sugarcane, fresh fruits and wine products (OECD, 2006). The major water consuming crops in the water scarce regions of South Africa are showing also

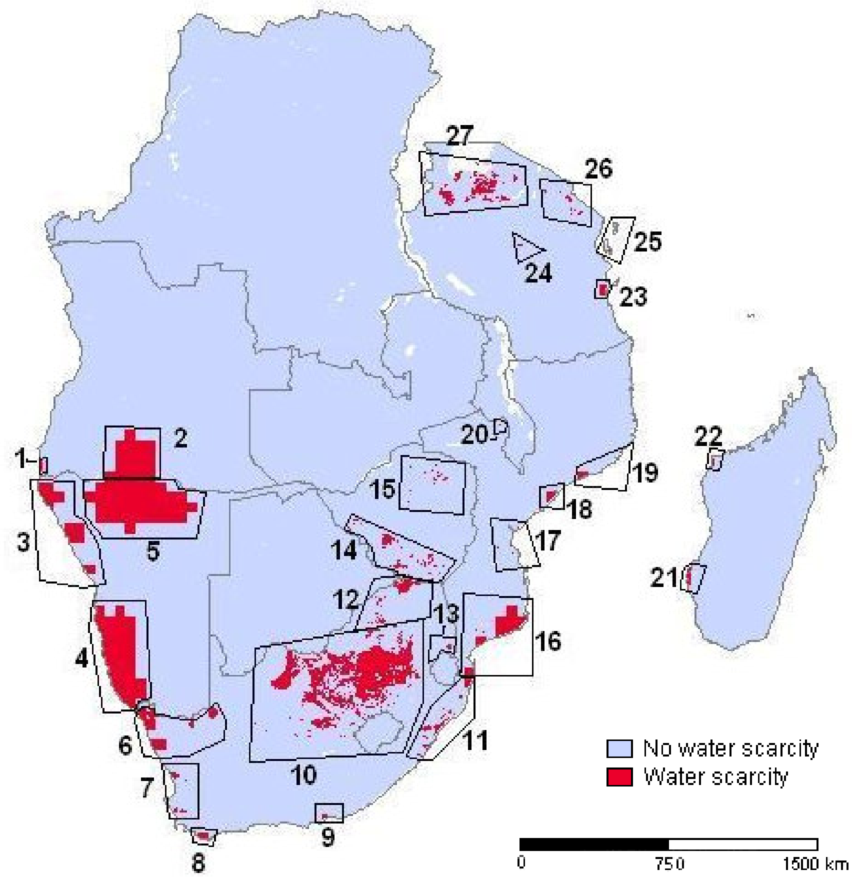


Figure 39. The red grid cells have less than 5 mm of blue water resources left after subtracting blue and grey water consumption from blue water availability (based on figure 38,H). The blue water availability in each grid cell is based on the average water resources available over a catchment through precipitation (figure 38,F). The blue-grey areas have more than 5 mm of blue water resources left. Naming of the areas, blue WF, and information on water consumption by agriculture, households, industry and the most important crop are given in table 6. The same information is given in table 7 for the grey WF.

Table 7. Blue water consumption in the areas as indicated in figure 39.

Areas in which more or almost more blue water is consumed than naturally available

(< 5 mm water of blue water resources left in area after subtracting blue water consumption from blue water availability)

Area No.	Country & area name	Blue WF (km^3/yr)	Share in total blue WF per area (%) Agriculture (by crops)	Households	Industry	Share in total blue WF per area of major water consuming crops (%)		
	Angola							
1	South-west Angola (Coast: Parque Nacional do Iona)	4	0.00	100.00	0.00			
2	South Angola (Cunene Province)	1369	81.49	17.75	0.75	Banana 81.49		
	Namibia							
3	North-west coast Namibia (Kunene Region)	402	39.88	47.93	12.19	Maize 39.88		
4	South-west coast Namibia (Area round Uubvlei - Elizabeth Bay - Walvisbaai)	1789	6.04	82.10	11.86	Maize 4.23	Wheat 1.81	
5	Central-north Namibia (Ohangwena, Omusati, Oshana & Oshikoto Regions)	45858	96.19	2.55	1.26	Maize 55.31	Cotton 40.45	Wheat 0.43
	Madagascar							
21	South-west coast Madagascar	1935	72.93	27.07	0.00	Rice 55.64	Sugarcane 17.29	
22	North-west coast Madagascar (Area between Ampanihira & Sarobakony)	146	0.00	100.00	0.00			
	Mozambique							
16	South Mozambique (Area around Maputo - Xai Xai - Inhamme)	31321	94.46	3.85	1.68	Sugarcane 79.03	Rice 8.02	Maize 7.41
17	Central Mozambique (near Beira)	5093	84.43	11.16	4.41	Sugarcane 84.43		
18	Mid-East coast Mozambique (near Quelimane)	149	0.00	73.22	26.78			
19	North-mid-east coast Mozambique (Area between Bauala & Lumbo)	245	59.37	34.94	5.69	Rice 43.34	Maize 16.03	
20	North Mozambique (Area between the border with Malawi and Vila Coutinho)	6650	97.30	2.20	0.49	Orange 92.25	Sugarcane 5.05	
	South Africa							
6	North-west South Africa (Namakwa & Siyanda Districts)	14400	3.32	95.65	1.03	Maize 1.16	Cotton 0.94	Potato 0.78
7	West Coast District, South Africa	37843	10.83	63.98	25.19	Wheat 8.53	Soybean 0.70	Groundnut 0.45
8	Overberg District, South Africa	1204	14.22	78.55	7.22	Maize 9.33	Wheat 2.70	Sweet potato 1.29
9	Port Elizabeth, South Africa (Nelson Mandela Bay Metropolitan Municipality)	10364	3.24	69.20	27.56	Orange 2.47	Potato 0.28	Maize 0.23
10	Free State, North West & Gauteng Provinces, South Africa (Area between Kagisano Rural & Johannesburg)	2043717	80.29	14.62	5.09	Maize 47.74	Wheat 10.89	Potato 3.34
11	South-east South Africa (Area between Amatole & Umkhanyakude Districts)	1187760	97.67	1.71	0.62	Sugarcane 97.34	Banana 0.13	Potato 0.07
12	North South Africa (Vhembe, Capricorn, Waterberg Districts)	131052	80.24	19.14	0.61	Orange 24.98	Cotton 23.25	Banana 7.91
13	East South Africa (Ehlanzeni District)	67457	98.34	1.14	0.52	Sugarcane 95.29	Banana 0.92	Rice 0.49
	Tanzania							
23	Area near Mohoro, Rufiji District, Pwani Region, Tanzania	827	9.81	90.19	0.00	Banana 9.81		
24	Dodoma, Dodoma Region, Tanzania	4488	71.51	25.13	3.36	Rice 38.86	Maize 12.53	Banana 12.49
25	Pemba & Zanzibar, Tanzania	176	0.00	74.97	25.03			
26	Arusha & Kilimanjaro Regions, Tanzania	152844	97.41	2.39	0.20	Maize 74.42	Rice 9.60	Cotton 9.13
27	Mara, Mwanza, Shinyanga & Arusha Regions, Tanzania	958209	99.20	0.77	0.03	Rice 85.60	Maize 6.56	Banana 4.75
	Zimbabwe							
14	South Zimbabwe (Masvingo Province, Matabeleland North & South Province)	123735	78.45	12.55	9.00	Sugarcane 31.64	Soybean 13.43	Coffee 9.92
15	North Zimbabwe (Mashonaland West & Central Provinces)	225966	76.73	11.54	11.73	Cotton 64.79	Groundnut 4.91	Sugarcane 1.92

Table 8. Grey water consumption in the areas as indicated in figure 39.

Grey water consumption in areas where more blue & grey water is consumed than naturally available
(< 5 mm water of blue water resources left in area after subtracting blue & grey water consumption from blue water availability)

Area No.	Country & area name	Grey WF (km^3/yr)	Share in total blue WF per area (%) Agriculture (by crops)	Households	Industry	Share in total blue WF per area of major water consuming crops (%)		
	Angola							
1	South-west Angola (Coast: Parque Nacional do Iona)	31	0.00	100.00	0.00			
2	South Angola (Cunene Province)	2339	10.81	76.22	2.15	Maize 4.79	Millet 1.92	Bean 1.84
	Namibia							
3	North-west coast Namibia (Kunene Region)	1714	1.74	82.54	13.98	Maize 1.74		
4	South-west coast Namibia (Area round Uubvlei - Elizabeth Bay - Walvisbaai)	11833	0.10	91.05	8.76	Maize 0.09	Wheat 0.01	
5	Central-north Namibia (Ohangwena, Omusati, Oshana & Oshikoto Regions)	30463	31.31	28.12	9.26	Millet 20.33	Maize 7.33	Cotton 1.68
	Madagascar							
21	South-west coast Madagascar	3874	0.42	99.15	0.00	Sugarcane 0.35	Rice 0.07	
22	North-west coast Madagascar (Area between Ampanihira & Sarobakony)	1074	0.25	99.49	0.00	Rice 0.25		
	Mozambique							
16	South Mozambique (Area around Maputo - Xai Xai - Inhamme)	24474	26.65	36.18	10.53	Maize 11.50	Sugarcane 6.61	Groundnuts 4.21
17	Central Mozambique (near Beira)	5999	6.11	69.49	18.29	Maize 2.86	Sugarcane 1.45	Rice 0.70
18	Mid-East coast Mozambique (near Quelimane)	1016	0.99	78.82	19.20	Maize 0.83	Cassava 0.06	Groundnuts 0.05
19	North-mid-east coast Mozambique (Area between Bauala & Lumbo)	904	11.49	69.50	7.53	Maize 5.87	Rice 2.85	Cassava 1.28
20	North Mozambique (Area between the border with Malawi and Vila Coutinho)	2265	22.73	47.46	7.08	Maize 12.02	Orange 8.34	Groundnuts 0.79
	South Africa							
6	North-west South Africa (Namakwa & Siyanda Districts)	102913	0.58	98.14	0.71	Groundnuts 0.25	Wheat 0.19	Maize 0.06
7	West Coast District, South Africa	240106	3.34	73.95	19.38	Wheat 2.79	Sunflower 0.16	Sweet potato 0.15
8	Overberg District, South Africa	10102	13.56	68.68	4.20	Wheat 8.84	Sunflower 1.81	Millet 1.19
9	Port Elizabeth, South Africa (Nelson Mandela Bay Metropolitan Municipality)	66865	3.34	73.95	19.38	Wheat 2.79	Sunflower 0.16	Sweet potato 0.15
10	Free State, North West & Gauteng Provinces, South Africa (Area between Kagisano Rural & Johannesburg)	6534006	29.35	33.54	7.77	Maize 19.77	Sorghum 3.43	Groundnuts 1.56
11	South-east South Africa (Area between Amatole & Umkhanyakude Districts)	656333	35.93	22.70	5.44	Sugarcane 34.92	Maize 0.28	Millet 0.14
12	North South Africa (Vhembe, Capricorn, Waterberg Districts)	261903	14.13	70.25	1.50	Sorghum 2.47	Maize 2.69	Orange 1.54
13	East South Africa (Ehlanzeni District)	30703	38.03	18.36	5.57	Sugarcane 32.34	Bean 1.94	Maize 1.25
	Tanzania							
23	Area near Mohoro, Rufiji District, Pwani Region, Tanzania	5552	0.76	98.48	0.00	Cotton 0.26	Maize 0.18	Coconut 0.11
24	Dodoma, Dodoma Region, Tanzania	9863	4.35	83.84	7.46	Maize 2.55	Sorghum 0.53	Millet 0.39
25	Pemba & Zanzibar, Tanzania	1184	0.05	81.73	18.17	Oilpalm 0.03	Soybean 0.02	
26	Arusha & Kilimanjaro Regions, Tanzania	36696	11.48	72.90	4.15	Maize 8.44	Cotton 0.82	Rice 0.56
27	Mara, Mwanza, Shinyanga & Arusha Regions, Tanzania	144718	30.79	37.56	0.86	Maize 17.50	Rice 6.06	Sorghum 1.90
	Zimbabwe							
14	South Zimbabwe (Masvingo Province, Matabeleland North & South Province)	227679	13.04	50.02	23.89	Maize 9.45	Soybean 1.38	Wheat 1.43
15	North Zimbabwe (Mashonaland West & Central Provinces)	352690	4.54	54.24	36.69	Maize 2.40	Cotton 1.87	Soybean 0.11

a high level of diversification existing of a combination of cash crops and food crops. In the areas 11 and 13 (figure 39) especially sugar production is causing water scarcity (table 7). Fifty percent of the sugar produced in South Africa is exported (OECD, 2006). South Africa is highly protecting the sugar market, just as maize production (OECD, 2006). Sugarcane exports make up roughly 31% of the virtual water flow related to export of crop products by South Africa (appendix A6). Maize is even making up 37% of the virtual water exported related to crop products. The other major water consuming crops grown in the water scarce areas of South Africa, oranges, sunflowers, rice, groundnuts, wheat, cotton and soybeans are also in the top ten of the most important export crops (appendix A6).

Tanzania

In the past Tanzania was a socialistic planning economy. Farmers were therefore not able to produce and sell crops as they liked. For many crops prices were even fixed. Nowadays government tries to increase agricultural output and profit and focus on strengthening the sector (Tanzania National Website, n.d.). Therefore farmers are now free to market crops in the way they like and motivated to invest. The agricultural sector is still dominated by peasant farming and staple food production. The Tanzanian government recognizes 10 specific farming systems. These farming systems are also reflected in table 7 and 8. In areas 26 and 27 (figure 39) the banana/coffee/horticulture system, maize/cotton system and rice/sugarcane systems are present, which are reflected also in the major water consuming crops cultivated: rice (food crop), maize (food crop), banana (food crop) and cotton (cash crop). In the Dodoma region (area 24 in figure 39) normally only pastoralists and sorghum/millet cultivation are present due to the low yearly precipitation amounts (Tanzania National Website, n.d.). According to this study water scarcity however is caused by more water intensive crops like banana, rice and maize, what could explain the occurring water scarcity in this area. In the areas 23 and 25 (figure 39) water scarcity is mainly due to domestic and/or industrial water use. The crops grown in the water scarce areas are also important export products (appendix A6).

Zimbabwe

Zimbabwe faces currently severe economic and social problems. Since 1979 the government started with land resettlement in an effort to more equitably distribute land between the native black (landless) people and the (white) big land owners. From 2000 onwards this approach was so aggressive and violent that many white landlords fled the country or were deprived of the ability to do business anymore. This resulted in a dramatic drop in agricultural output and wide spread food shortage and declined agricultural exports (Meldrum, 2005). In the past Zimbabwe produced both a tremendous amount of food crops and cash crops. According to this study based on table 7 and 8 cash crops like cotton, sugarcane, groundnuts, coffee and soybean and food crops as wheat and maize, which are also the important export crops (appendix A6), are causing water scarcity in the North and South of Zimbabwe. However it could be possible that the data provided by the FAO (2009 c) is not correct. According to Mugabe himself "only 44% of the land seized from whites was being cultivated and the remainder was lying fallow" in 2005 (Meldrum, 2005). If you take in mind that the seized land area has been estimated on 8.6 million hectares in 2003 by the BBC (Schleicher, 2004), this means that huge parts of the country are out of production!

Urban areas

In the areas 1, 6, 22 and 23 in figure 39 water scarcity is caused mainly by domestic water use (more than 90% of the total blue WF) (table 7). In the areas 4, 7, 8, 9, 18 and 25 in figure 39 water scarcity is caused especially by industrial and domestic water use. Hence these areas in which only households and/or industry use water are the urban areas, for example the urban areas of Uubvlei-Elizabeth Bay-Walvisbaai (area 4), Cape Town (area 8), Port Elizabeth (area 9), and Quelimane (area 18).

3.5.3 Water scarcity

Besides looking at absolute water scarcity of an area at grid level, as done in section 3.5.2, water scarcity can be determined as a ratio of the water footprint over water availability. In table 6 and in the figures 34,D, 37,E and 37,J water scarcity is given at the national and grid level for the green and blue water resources.

The blue water scarcity ratio at grid level shows of course the same pattern as discussed in section 3.5.2. Interesting to see is that especially the Kagisano Rural-Johannesburg area in South Africa and the area just south from Lake Victoria in Tanzania are using much more water than naturally available. The blue and grey WF around Johannesburg is 7.5 up to even 17.5 times larger (figure 37,J) than the natural available amount of blue water! This area is also depending severely on water transfers from Lesotho and the Orange River. The area south Lake Victoria uses at least 1.5 times more water than naturally available. At the national level Namibia (32.56%), South Africa (28.42%) and Zimbabwe (15.93%) are most blue water scarce when looked at the share of the blue and grey WF in total blue water available (table 6). At the national level water scarcity may not seem to be severe, but at the grid level for some regions it is, as shown in figures 37,E and 37,J. So when interpreting a national water scarcity value it is important to take the size of the country and the variability of water distribution over the country into consideration. It is therefore preferred to look at smaller scales than the national level. The SADC itself is not really water scarce based on this computation, however due to regional variability in WFs and water availability some regions are. Green water scarcity at both the grid cell level (figure 34,D) and national level (table 6) does not occur.

3.5.4 Conclusion

So it can be concluded based on the sections 3.1-3.5 that large parts of Mozambique, Namibia, South Africa, Tanzania, and Zimbabwe use more water than there is naturally available. So water is brought from more distance places to these areas or (fossil) groundwater is pumped up. Large parts of the SADC have or are likely to have water related problems, especially when environmental flow requirements, uncaptured flood water and remote flow are taken into account as well. Agricultural policies of the SADC nations have clearly influenced which crops are grown. So choices made on which crops are promoted to grow by the national governments influence the water footprint related to production in the areas much.

On the moment however it is difficult to say in which direction each country could develop their agricultural sector best taking water efficiency, labor costs, employment, farmer and national revenues, and food security into account (Wichelns, 2004; Abalu & Hassan, 1998). More research is therefore recommended on this topic. In this study the water scarce areas are already indicated, needed for further research. For now a preliminary conclusion could be, based on the indication of the water scarce areas and which crops are causing this scarcity, that in the water scarce regions crops should be grown that use less water but give more revenue or yield per hectare. Many cash crops like fruits are also labor intensive, so that it could benefit the peasant farmers as well. Cassava for example is a food crop that uses less water per ton and has high yields per hectare. Further industry has a much higher added value than agriculture. So industrialization is also a good strategy for the SADC to increase the living standard of people. Of course it is important to keep pollution as low as possible; thereby keeping the grey WF as low as possible.

The water needs of the SADC members are likely to increase in future due to the growth of the population, agricultural production and industrial output (UNFPA, 1999; SADC Review, 2008; IWMI, 2006). So pressure on the available water resources and national consumption are expected to increase. SADC countries could relief water shortages by improving water efficiency of agriculture. Therefore the yields need to be increased by using more fertilizer, animal dung, better seeds, improved farming techniques and so on (Maasdorp, 1998). These improvements require the improvement of the agricultural infrastructure.

Zimbabwe, Zambia, Malawi and Madagascar should try to improve the production water efficiency of their industries. On the moment the industries are very water inefficient in these countries with a value added per m^3 water two to four times less as the world average and even six to thirteen times less as the SADC average.

The efficiency improvements in production, however needed, are on the short term and long term not solving the water shortage related problems by itself. In future water use is even expected to increase so that most of the efficiency benefits are lost again. In water scarce regions imports of water-intensive bulk crops are needed to decrease water demand in these regions. So choices have to be made which crops are cultivated and which crops not. Cash crops for example could be planted in South Africa to finance the import of the low priced stable foods for example. Angola, the DRC, Zambia, Madagascar, and the North of Mozambique could produce the more water intensive crops that are needed in the SADC, if yields are improved dramatically. The other regions could cultivate cash crops so that they are able to import the more water intensive crops. In this way the water scarce regions are not depending on one country or single area for their water needs that are supplied by water transfers. Also it is important to notice that the high (water-inefficient) WFs of crops are caused by a general lack of investment in the agricultural infrastructure by most SADC countries, lack of capital available especially for peasant farmers and due to low fertilizer and dung utilization in crop cultivation (Maasdorp, 1998; World Bank 2001).

3.6 Comparison of the water footprints of this study with the study of Chapagain & Hoekstra (2004)

The WFs related to the production of crops and the national WFs related to consumption of the current study for the period 1996-2005 are compared with the study of Chapagain & Hoekstra (2004) for the period 1997-2001. This comparison shows the differences in the WF estimates resulting from the difference approached used in this study more clearly. In this section these differences in WF estimates are discussed.

The WF of the current study is often based on different average yields than the study of Chapagain & Hoekstra (2004) due to differences in the period analyzed. To make a comparison of both studies possible the absolute percentile difference and the relative percentile difference have been computed. The absolute percentile difference gives just the difference without considering yield differences. The relative difference corrects for the variation in yield between both studies. So it makes a comparison of both WFs based on the same average yield for each nation possible; in this case the yield over the period 1996-2005 has been taken as reference.

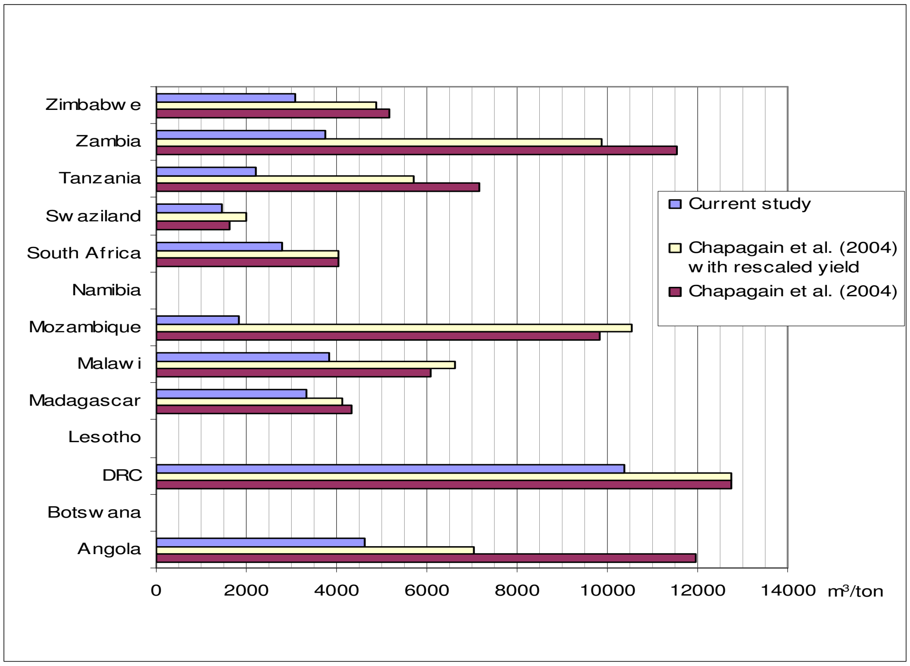


Figure 40. Comparison of the water footprints of rice between this study and the study of Chapagain & Hoekstra (2004).

Table 9. Comparison of the WF of rice with the study of Chapagain & Hoekstra (2004).

Rice

Country	Green-blue WF (this study) (1996-2005) (m³/ton)	(Green-blue) WF Chapagain et al. (2004) (1997-2001) (m³/ton)	Absolute difference (%)	A) Average yield Chapagain et al. (2004) (1997-2001) (ton/ha)	B) Average yield (this study) (1996-2005) (ton/ha)	Yield ratio (B/A) (-)	Reference WF (m³/ton)	Relative difference (%)
Angola	4640	11953	-61.19	0.83	1.42	1.70	7024	-33.95
Botswana	0	0	0	0	0	0	0	0
DRC	10367	12768	-18.81	0.76	0.75	1.00	12769	-18.81
Lesotho	0	0	0	0	0	0	0	0
Madagascar	3344	4347	-23.06	2.12	2.24	1.06	4112	-18.66
Malawi	3833	6080	-36.95	1.76	1.61	0.92	6636	-42.23
Mozambique	1825	9836	-81.45	1.01	0.95	0.93	10534	-82.68
Namibia	0	0	0	0	0	0	0	0
South Africa	2789	4035	-30.89	2.30	2.29	0.99	4059	-31.29
Swaziland	1461	1625	-10.07	5.12	4.12	0.81	2017	-27.57
Tanzania	2193	7171	-69.42	1.40	1.76	1.26	5689	-61.45
Zambia	3763	11532	-67.37	1.00	1.17	1.17	9870	-61.87
Zimbabwe	3098	5163	-40.00	2.08	2.20	1.06	4873	-36.42

In appendix A3 the differences in WFs of crops between this study and the study of Chapagain & Hoekstra (2004) are given. Here the differences are presented for rice. Spreading in the WF results of rice stay quite large when the results of this study are compared with the outcomes of Chapagain & Hoekstra (2004) (figure 40 and table 9). First of all these differences can be explained while Chapagain & Hoekstra (2004) used potential evapotranspiration to compute the WF of crops and this study uses the actual evapotranspiration of crops. Second this study uses more precise climate data for the specific growing sites instead of one country average climate. In the case of rice, especially for some countries like Angola, Mozambique, Tanzania and Zambia, this seems to have a quite substantial impact on the water footprint of rice as well. The current study gives therefore WFs that are 20% to 80% lower when both WFs are rescaled to comparable yields.

In table 10 the national WFs related to consumption of this study are compared with the study of Chapagain & Hoekstra (2004). The national WFs as computed in this study are in general much lower than compared to the study of Chapagain & Hoekstra (2004). This difference is mainly due to the lower estimation of the WF of crops (see appendix A3). Note that the WF of Botswana, DRC, Lesotho, Namibia and Zambia in this study are really low. The WFs per capita of the latter countries are so low due to (1) much lower WFs of crops and livestock (this study) compared with the study of Chapagain & Hoekstra (2004) and (2) high virtual water export flows (equaling almost the virtual water import flows) (this study) compared with Chapagain & Hoekstra (2004). For Botswana and Namibia and to a lesser extent also for Zambia, the low water footprints per capita are caused by the too low water footprint of livestock. Important feed crops as alfalfa, pasture, hay and silage are not taken into account, resulting in too low water footprints related to production and national consumption. Because not all crops cultivated and traded are included (besides pasture, silage and hay), it could be that this is for the latter countries is also causing differences. It is known for example for the DRC that tobacco, cacao, rubber and tea are also important crops and for Zambia tobacco and horticulture (FAO, 2009 c). Also it is likely that errors in the input data are causing lower estimations.

Table 10. Comparison between the WF per capita per year from the study of Chapagain & Hoekstra (2004) and this study.

Country	WF# per capita (this study) (m3/cap/yr)	WF# per capita (Hoekstra & Chapagain, 2008) (m3/cap/yr)	Difference (%)
	A	B	C=(A-B) / B*100
Angola	852	1004	-15.12
Botswana	272	623	-56.38
DRC	449	734	-38.89
Lesotho	284	N/A	N/A
Madagascar	921	1296	-28.96
Malawi	864	1277	-32.34
Mauritius*	626	1351	-53.69
Mozambique	1012	1113	-9.10
Namibia	437	683	-35.97
Seychelles*	1189	N/A	N/A
South Africa	836	931	-10.20
Swaziland	1758	1225	43.52
Tanzania	994	1127	-11.79
Zambia	418	754	-44.60
Zimbabwe	991	952	4.09

#The water footprint contains in this computation only the green and blue WF, because this water is actually consumed

*Only blue water included. Total available blue water resources based on FAO (2009 a)

In general it can be concluded that the WFs of the current study are much lower than in the study of Chapagain & Hoekstra (2004) for both the WFs related to crop production as well as national WFs of consumption. The WF estimates are lower because this study uses actual evapotranspiration and spatial climatic variation over a country. Also the blue water need of irrigated crops is computed more precisely in this study. The differences in WF estimates between both studies are very large. Therefore it is recommended to investigate the reason for these large differences more thoroughly by carrying out uncertainty and sensitivity analyses. An uncertainty analysis shows the uncertainty bands around the WF estimates and gives more insight into the WF estimates of this study compared with the study of Chapagain & Hoekstra (2004). A sensitivity analysis gives more insight into which parameters exert the largest influence on the WF estimates. Field experiments could be used to validate the WF estimates.

4 Uncertainties and limitations

4.1 Uncertainties due to the scope of the study

A limitation of this study is that it takes not 100% of the water footprint of crops and livestock into account. In this study approximately 90% of the total water footprint of crops is taken into account by analyzing 22 crops. For livestock the eight major reared animals are included. So in general this study gives a good overview of the WF related to production and consumption, but regional differences could be possible. Because 22 crops and eight livestock categories are considered, it could be possible that for some SADC countries important export products are excluded that are important for the analysis of the international trade flows. Also no difference is made in the value added by the different industrial sectors, making it impossible to analyze the water efficiency and water footprint of the different industrial sectors.

The water footprint of livestock is underestimated because the WF of hay, pasture, and silage could not be taken into account due to lack of data. These food crops however are very important for livestock rearing.

The grey WF should be interpreted with care. As already explained in chapter 2, the grey WF is presented to connect the water consumed related to the production of crops to water pollution by crop production. The grey WF related to crop production is difficult to determine, because each polluting substance has its own dilution factor required. In this study only nitrogenous pollution by agriculture is taken into account, because it is one of the most polluting substances emitted by agriculture (Carpenter et al., 1998). However the combination of all pollutants emitted by agriculture could result in much larger grey WFs of crops.

4.2 Sensitivity of model outcomes to input data and assumptions

The correct planting date is very crucial for the right estimation of the WF of a crop. In table 11 an overview is given of the WF of rice for each SADC member state based on two different planting dates. The WF values for Angola, DRC, Madagascar, Malawi and Mozambique are too large (table 11 A), because the planting dates obtained from Chapagain & Hoekstra (2004) proved to be less likely. The planting dates, as suggested, are around May-June for rice. For these countries this planting moment is during the dry season, so the crop is using too much water or will even wilt. This results in low yields and very large WFs. The International Rice Research Institute (IRRI) (2008) advises rice to plant at the start of the rainy season, which goes from October/November until March for most of the SADC region. Mozambique however is an exception where it is advised to plant the crop in June, because it has another rainy season. The WF of rice based on the planting dates of the IRRI give much better results as can be seen in table 11 B.

So it is very important to know the planting date, because else the WF estimation will be much too large. Farmers are most likely to plant the crop when growth circumstances are most optimal for the crop; resulting in the most optimal water footprint as well. Depending on crop type (if it needs a lot of water or not) the crop is most often planted at the start or the end of the rainy season when there is enough water. However exceptions are possible. Crops like cassava can be planted almost whole year round if soil moisture conditions are moderate, so also in somewhat drier seasons (Grace, 1977). In this study for all the crops with exceptional average WF results the planting date has been checked and when necessary improved based on other literature sources. In reality there could be still a small deviation, but it is believed that the national planting dates used for the crops in this study are quite correct. An overview of the changes is given in appendix A1.

Table 11. Overview of the WF of rice for each SADC member state. A) the WF of rice based on the wrong planting dates for rice for Angola, DRC, Madagascar, Malawi and Mozambique obtained from Chapagain & Hoekstra (2004). B) the WF of rice with improved planting dates for the latter countries obtained from IRRI (2008).

	A) WFs with wrong planting date				B) WFs with improved planting date			
Country	Green WF (m^3/ton)	Blue WF (m^3/ton)	Grey WF (m^3/ton)	Total WF (m^3/ton)	Green WF (m^3/ton)	Blue WF (m^3/ton)	Grey WF (m^3/ton)	Total WF (m^3/ton)
Angola	2631	16011	150	18792	3473	1166	151	4790
Botswana	0	0	0	0	0	0	0	0
DRC	42768	7	69	42844	10361	6	4	10371
Lesotho	0	0	0	0	0	0	0	0
Madagascar	69776	233	432	70441	3118	227	4	3348
Malawi	41542	14	19760	61316	3784	50	379	4213
Mozambique	35946	4	692	36643	1816	9	22	1847
Namibia	0	0	0	0	0	0	0	0
South Africa	1102	1609	892	3603	1166	1623	892	3680
Swaziland	700	754	321	1776	706	755	321	1783
Tanzania	2042	138	116	2296	2055	138	116	2309
Zambia	1053	2665	148	3866	1117	2646	147	3910
Zimbabwe	842	1939	13	2794	1188	1910	13	3111
SADC	102228	381	1347	103955	3441	191	37	3668

The trade data obtained from ITC (2007) have also their shortcomings. Countries are not always registering properly what they import and export. So is it for example often unclear of the imports of maize, rice, wheat and vegetable oil, as part of food aid, are included in the trade balances or neglected. Also the informal trading circuit is ignored in this study. So it can be said that international virtual water flows are even more important for the SADC countries to meet their needs than as shown in this study, because when the informal trading circuit and food aid need to be added the total virtual water flows related to SADC trade are much larger.

4.3 Uncertainties in the input data

Uncertainties in the input data for water footprint estimation

In the input data, obtained from several sources like the FAO (2009 a,c,d,e), Monfreda et al. (2008), Portmann et al. (2008), and Siebert et al. (2007) are many uncertainties and shortcomings as described in appendix A1. These uncertainties and shortcomings influence the output; the WFs. The national WF of Botswana for example is very low mainly due to a very low total water footprint related to the production of crops, which stands in sharp contrast with the high WF estimates for crops in Botswana. For Botswana this low total WF of total crop production is probably caused by shortcomings in data on the irrigated areas as reported by Siebert et al. (2007), the amount of irrigated hectares per crops as reported by Portmann et al. (2008) and the total amount of cultivated area per crop as reported by the FAO (2009 c), so that total agricultural production and water consumption are low, regardless of the large WFs. Also it is possible that crops that receive a lot of irrigation water in Botswana are not taken into account, causing the blue water estimation to be too low as well. For Botswana, Namibia, Swaziland, and Zambia the blue-grey water use estimations are lower than the estimations of FAO (2009 a). For the other countries the estimations seem to be quite well or even larger because grey water is taken into account, except for the Seychelles and Mauritius for which (spatial) data is lacking. For the latter countries SADC average or FAO (2009 a) data are used. The data on nitrogen application to crops are still uncertain because of lack of data (see appendix A1). Despite these uncertainties the general picture shown by the results about the water footprint of the SADC remains valid. Of course with better input data the study will give better results, but on basis of the current data it is already possible to draw conclusion on the water efficiency and water footprint of the SADC and the SADC nations.

Uncertainties in the input data for international virtual water flows

As already mentioned it is most likely that there are uncertainties in the trade data. At least the informal trade sector is not registered, which is for some African countries quite important. Also countries do not always properly register what type of goods are imported or exported. On the moment however better data is not available. The current data is giving at least the order of magnitude and the trade flow direction.

Uncertainties in the input data for water availability and water scarcity

An important uncertainty is in the estimation of how much (blue) water is available in the SADC region. In this study the dataset of GWSP (2008 a) is used because it shows water availability on a catchment level. However there is still much uncertainty in the estimations of how much (blue) water is available. For instance according to Postel et al. (1996) estimations of annual runoff worldwide vary between 33,500 km^3 to 47,000 km^3. This uncertainty influences the determination of the water scarce areas much (section 3.4). Also datasets on water use by households (GWSP, 2008 e) and industry (GWSP, 2008 d) are used to compute the total blue WF and grey WFs. These datasets contain also uncertainties, because in many African countries water consumers are not charged for using tap water or the amount of tap water used is poorly registered. To be consistent with the other data used, these datasets are rescaled to FAO (2009 a) figures on water used by industry and households. Despite these uncertainties more accurate data is on the moment not available.

4.4 Uncertainties in and limitations of the model used to compute the water footprint of crops

The WF results of this study are also influenced by the approach used to compute the WFs. This study uses a vertical soil water balance (based on many empirical formulas) for each grid cell to determine the WF of crops, neglecting runoff and ground water flow from grid cell to grid cell. Neglecting runoff may lead to an overestimation of the green water footprint and underestimation of the blue water footprint of irrigated crops. Neglecting capillary rise may lead to an underestimation of the green WF of crops. The same thing is valid for runoff which could recharge soil moisture of neighboring grid cells. This influences the WF of crops. On the other hand the vertical soil water model is less complex and already much more sophisticated than the earlier approach used by Chapagain & Hoekstra (2004). A recommendation could be to include also runoff and capillary rise in the model. By neglecting runoff and capillary rise in this study it is indirectly assumed than horizontal inflow is equal to horizontal outflow. Taken into consideration that much water is directed to rivers and is therefore not directly recharging the soil moisture of the fields on which the crops are grown, this approach is even quite accurate already. For irrigated areas including runoff is more important, because during the dry season the runoff in river could be very low so that blue water is not available for irrigation.

Another point is the spatial resolution level used for the determination of the green, blue and grey WFs per grid cell of small countries. In the computation method the grid cell on the border of two countries is included to the country with the largest share of that border grid cell. For Malawi, Lesotho and Swaziland this approach causes some problems. However this problem is for most problem areas overcome by the way the cultivated area, and irrigated areas are rescaled.

Another uncertainty in the WFs is related to temporal variations of the WF of crops throughout the year. Some crops have several cropping seasons in a year, which could results in significant differences in the seasonal WF of the crop. Related to this point is that it is difficult to determine which crops are cropped after each other. In this study the approach is used that a crop is planted at the recommended planting date for a specific country where the crop is reported to be cultivated in grid cells. In theory this could result in more hectares cropped per grid than the grid cell is large. In this study this however happened almost nowhere. Only in a few grid cells in Malawi and South Africa this problem occurred, mostly due to the way how ArcGIS handles the grid cells (section 3.4). So it can be concluded that this approach in general is working very well, at least when accurate maps on land use over a year are available.

5 Conclusions

5.1 The water footprints related to production

In general it can be concluded that the WFs of crop products in the SADC, compared to the global average WF of these products, are very high. So the SADC is in general a water-inefficient producer of crop products. The reason for the inefficiency of crop production is related to the high atmospheric water demand in many (semi-arid) regions of the SADC, the low yields due to the minor use of fertilizers, pesticides and poor quality seeds used, and poor agricultural infrastructure. The large WF of crops is mostly cost by the low yields. The largest share of the WF of crops exists of green water. Cashew, cassava, clove, coconut, oil palm, and plantain are even entirely rain fed. The blue WF is for most crops quite low. Only for rice, sugarcane, oranges, bananas, cotton and wheat the blue WF for most SADC nations is considerable. The grey WF of most crops is also quite low. Only for bananas, maize, millet, oranges, potatoes, rice, sorghum, sweet potatoes, sunflower seed and wheat the grey WF is making up a relative considerable share of the total WF of these crops. The latter crops receive also the largest share of the nitrogenous fertilizer applied in the SADC region; especially cereals and pulses receive comparatively much fertilizer in the SADC region. The spatial variation in the WF of the crops is varying much from country to country and crop by crop. In general it can be concluded that Botswana has high WFs, just as the DRC for most crops. For the other countries it depends on the crop and region. For example the spatial total WF of maize is large in Botswana, Angola, south Mozambique, south Zimbabwe and north-east Tanzania. On the other hand South Africa, Zambia and Namibia have comparative low WFs for maize and north Zimbabwe has moderate WFs.

For the SADC the WF of live poultry and swine are especially large. Also the WF of bovine animals is large due to the high WF of their feed crops. The WF of livestock exists mainly of green water. For the SADC blue WFs of livestock are largest in Angola, South Africa, Zambia and Zimbabwe. The grey WFs of livestock are largest in Angola, Botswana and South Africa. It should be noted that the WFs of livestock are not yet complete, because hay, pasture, and silage are not included in this study due to lack of data.

In contrast with the poor water efficiency of agricultural production, water efficiency of industrial production compared to global averages is in general very high. Only Zimbabwe, Zambia, Malawi and Madagascar are rather water inefficient industrial producers with industrial water footprints ranging from 0.123 m^3/US$ up to even 0.351 m^3/US$ compared to the SADC average of 0.026 m^3/US$ and the global average of 0.084 m^3/US$ (section 3.13).

5.2 International virtual water flows related to trade in commodities

International water flows related to trade in commodities are important for the SADC to meet their needs; the SADC depends for 11% on imported virtual water to meet their consumption needs. The largest share of the virtual water flows leaving and entering the SADC are related to trade in crop products (exports 73% and imports 74%), second livestock products (exports 18% and imports 13%), and third industrial products (exports 9% and imports 12%). The SADC region as a whole and the majority of the SADC countries are net importers of virtual water. The net virtual-water import by the SADC is 7379 million m^3/yr, which is equal to 0.11 times the annual runoff by the Rhine River at Lobith (Te Linde et al., 2008) or 0.09 times the annual runoff of the Zambezi below Luangwa (Edwards et al., 1983). Only Botswana, DRC, Madagascar and Zimbabwe are net exporters of virtual water.

Agricultural products are imported from South America, South East Asia, Central & South Asia, North America, Oceania and the Former Soviet Union (in order of importance). SADC exports agricultural products to Western Europe, Central Africa, Eastern Europe, North Africa, the Middle East and Central America (in order of importance).

Crop exports from the SADC exist mainly of coffee, sugarcane, maize, cotton, clove and orange products (90% of total exports) and South Africa, Madagascar, Tanzania, Zimbabwe, and Mauritius dominate 80% of SADC virtual water exports related to crop products. Ninety-five percent of imported virtual water related to crop products by the SADC exists of rice, wheat, maize, cotton seed, soybean, oil palm, sunflower seed, and sugarcane products. The largest importers are South Africa, Tanzania, Mozambique, Mauritius and Angola.

Livestock and its products that are mainly exported are bovine leather, bovine meat, bovine animals, live poultry, bovine skins and hides, swine meat, milk products live swine, bird's eggs in shell and goat leather (86.6% of total exports). More than 90% of these virtual water exports are coming from South Africa, Zimbabwe, Botswana, Swaziland and Namibia. Virtual water import of livestock products are mainly done by Swaziland, Angola, South Africa, Malawi, and Namibia. They import especially bovine animals, bovine meat, swine meat, live poultry, bird's eggs in shell, milk products and bovine leather (84.5% of total imports). From 1999-2002 there was a peak in the virtual water export related to trade in livestock products. The causes of this peak in export are not totally clear. The drop in exports could be caused by diseases, drought or due to economical downturn in 2001-2002.

Ninety percent of the virtual water exports related to industrial products are on the account of South Africa, Zimbabwe, Zambia, Madagascar and Angola. Especially manufactured goods and miscellaneous manufactures articles are exported. South Africa, Mauritius, Angola, Tanzania and Madagascar import 86% of total virtual water related to the import of industrial goods. They import machines & transport equipment and manufactured goods mostly.

South Africa and Zimbabwe dominate intra SADC trade. SADC intra trade of crop products is 23.82% of total crop trade, intra SADC livestock trade is 43.51% of total livestock trade and intra SADC industrial trade is 16.22% of total industrial trade.

5.3 National water footprints related to consumption

The SADC and most of the national water footprints related to consumption are much lower than the global average WF related to consumption. The SADC average WF related to consumption is only 776 m^3/capita/yr compared to the global average of 1243 m^3/capita/yr (Hoekstra & Chapagain, 2008). For the SADC, only the WF of Swaziland with 1753 m^3/capita/yr is larger than the global average. In the more developed countries the consumption of industrial goods is much larger. In the SADC this is only 1% of the total water footprint consumed. The SADC consumes especially agricultural products (99%). Domestic water consumption counts for only 0.39%. The share of imported virtual water related to the import of agricultural and industrial products in the total water footprint related to consumption of the SADC is 11.04%; the share of imports in the WF related to the consumption is for agricultural products 10.21% and for industry 66.31%.

5.4 Effects of international virtual water flows and the water footprints related to production and consumption on water scarcity

Over the period 1996-2005 the SADC used 8.69% of the total water footprint related to production to produce agricultural and industrial export products. The water footprint of consumption exists for 11% of virtual water related to the import of agricultural and industrial commodities. Due to international virtual water flows related to trade in crop products (which make up more than 97% of total virtual water flows related to trade), the SADC region saves 11028.5 million m^3/yr of green water, 2026.8 million m^3/yr of blue water and 1366.6m^3/yr of grey water. SADC's largest water savings are due to virtual water imports of rice, maize, wheat, and cotton. The region losses water due to exports of sugarcane, oranges, coffee, beans and bananas. Based on the net savings, it can be concluded that the SADC region improves its water availability by importing crop products and decreases the pressure on its water resources. On average SADC 's water dependency is 11%, varying from countries like the DRC, Madagascar, Malawi, Mozambique, Tanzania and Zimbabwe that have low water dependencies (< 10%) to countries like Mauritius and the Seychelles who depend for almost 100% on international virtual water imports. In general it can be said that the SADC itself is not directly water scarce and that the southern parts of the SADC have less water resources available than the northern parts.

In 27 areas located in Mozambique, Namibia, South Africa, Tanzania, and Zimbabwe more water or almost more water (only 5 mm/yr or less left) is used than naturally available in those areas. To the latter areas water is transferred from more distance places or (fossil) groundwater is pumped up. These water scarce areas are all urban or irrigated agricultural areas. In the irrigation dominated areas often only a few crops are causing the water scarcity, often crops which are stimulated by governments to grown. For most countries with water scarce areas, agricultural policies of the nations are clearly influencing which crops are grown and hence the WF of these nations. The grey WF in the water scarce areas is mainly caused by domestic and industrial water use. In Mozambique, South Africa and Tanzania agriculture has in the most intensive agricultural areas also a rather polluting effect. The crops causing the grey WF are often differing from the crops that cause the blue WF related to crop production in the water scarce areas. Also the grey WF of the water scarce areas is larger than the blue WF due to the dilution requirements. When environmental flow requirements, uncaptured flood water and remote flows are taken into account as well, water scarcity in the SADC region will be even larger, especially in the south of the SADC and Tanzania.

Water scarcity at the grid level is especially high in the area between Kagisano Rural and Johannesburg in South Africa and the area just south from Lake Victoria in Tanzania. The blue-grey WF in the former is 7.5 up to even 17.5 times larger than the natural available amount of blue water and for the latter it is at least 1.5 times larger. Water scarcity is of course also high in the other 25 water scarce areas. At the national level, Namibia (32.56%) , South Africa (28.42%) and Zimbabwe (15.93%) are most blue water scarce based on the ratio of the blue-grey WF over total blue water available (equal to FAO (2009 a) total renewable water resources). Green water scarcity at both the grid cell level and the national level does not occur.

The water needs of the SADC members are likely to increase in future due to the growth of the population, agricultural production and industrial output (UNFPA, 1999; SADC Review, 2008; IWMI, 2006). So pressure on the available water resources and national consumption are expected to increase. SADC countries could relief water shortages by improving water efficiency of agriculture. Therefore the yields need to be increased by using more fertilizer, animal dung, better seeds, improved farming techniques and so on (Maasdorp, 1998). However improving water efficiency is probably not enough due to the expected increase in water use and consumption. So the importance of virtual water imports will increase for SADC countries in the future to secure their consumptive demands. SADC countries have to make choices in which crops are cultivated. It could be a strategy to plant cash crops to finance the imports of (water-intensive) low priced staple foods. Further research on such strategies however is still needed.

5.5 Improvement in the water footprint of crops and crop products

In this study a new method is used that incorporates geospatial explicit data on climate and cultivation area into the computation of the water footprint. It improves the water footprint method on several points compared to the method used in earlier studies:

- a spatially explicit approach is used which takes local climatic conditions and other spatial variations as the growing area and yield of crops in time and space into account;
- the actual evapotranspiration is used instead of the refercence evapotranspiration (CWR) of each crop in each grid cell;
- the water need of the irrigated crop is computed on a daily basis instead of assuming that 100% of the evaporated water of irrigated crops is blue water;

These improvements result in much lower WFs of crops in this study compared to the water footprints computed by Chapagain & Hoekstra (2004). The improved WFs of crops could be up to 80% lower compared to the WFs of Chapagain & Hoekstra (2004). An uncertainty analysis is needed to compare the improvements in the WFs computed of this study with the study of Chapagain & Hoekstra (2004) better.

5.6 Improved insights for water management in the SADC

This study gives more insight in water scarce areas and causes of this water scarcity for the SADC. It gives a better understanding of water efficiency of industry and agriculture and the amounts of green, blue and grey water needed for the production and consumption in the SADC. A benefit of the spatial-explicit approach is that it takes spatial variations in the water footprint of production into account. Also it makes it possible to trace back which product or water user causes water scarcity. By taking international virtual water flows related to trade in commodities into account, it is possible to connect the national WF of consumption to the WF of production. The analysis of virtual water trade shows the importance of trade on securing consumptive demands of a nation. Also it shows the effect of trade on national water resources because it indicates how much water is needed for the production of export products. This knowledge can be used for policy making influencing the consumption of products or the water used for production.

The water scarce areas, or hotspots, are indicated for the SADC region; 27 areas in which more or almost more water is used than naturally available and where water pressure on the available water resources is highest. By pointing out the water scarce regions, it is possible to determine which areas need most attention by water managers and policy-makers. Also the spatial-explicit approach can be used as input for an evaluation of water policies or refocus of policies on a regional basis to tackle water related problems as a result of local production. With information of the WF of products produced in the area, it gives insights in the water efficiency of the production.

Further the importance of considering scale levels for making water policies is pointed out. In this study three scale levels are considered: the SADC, the SADC countries, and local areas in SADC countries. Analyzing the national water footprints of production and consumption at this level increases the knowledge base on which policies are made and indicates the direction of policies made at the different levels and how to integrate them.

This study can be used as input for making strategies to change water use and consumption. Based on this study it is however still difficult to say in which direction each country could develop their agricultural and industrial policies best so that the national water resources are used as optimal as possible. For example to develop a policy which focuses on improving the water-efficiency of the agricultural sector in such a way that national GDP is highest and total water consumption stays equal, it is needed to take labor costs, employment, farmer and national revenues, food security and so on into account (Wichelns, 2004; Abalu & Hassan, 1998). Therefore more research is recommended on this topic.

6 Future research

The first recommendation is to do further research on water footprint scenarios and strategies to give the consequences of policy directions chosen by water managers or to give them tools to determine which policy is best to use for the SADC. For example if cotton production is causing water scarcity in an area and the production is already water efficient, what are the options to have enough revenue, but improve water availability in the region. So it would be nice if different water policy strategies or scenario's are analyzed taking comparative advantages, employment, national revenue, revenue of the entrepreneurs, and water-efficiency and so on into account.

Second for the SADC region temporal variations in water availability and need are probably very important, especially for the water scarce and semi-arid areas. Therefore a study on the temporal availability of water and water needs is recommended. This gives further insights in the water scarcity of the SADC during the year. Based on this information it is possible to take action and direct policies. For such a study also the seasonal crop water footprint is important, which has been neglected in this study.

Third, for the further development of the water footprint and virtual water flow concept is a sensitivity analysis in order to determine for which parameters the WF of crops and livestock are most sensitive. Such a study gives more insight in the reliability of the study conducted and weaknesses and strengths of the method. In relation to the sensitivity analysis mentioned, this study already pointed out the influence of the correct planting date on the computation of the WF of crops. It is therefore recommended to check these planting dates in further research on the WF very well.

Fourth, it is important that in WF studies an uncertainty analysis is carried out to determine the uncertainty ranges of WFs computed and thus the certainty of the results presented. Hence it is recommended to do this for this study as well. Based on such an uncertainty analysis it is possible to compare the results of different studies and methods and to determine which method or study gives the most reliable results. For policy-makers it is really important to know how reliable the WF results are, if they want to base their policies on such studies. Therefore it could be necessary as well to combine such an uncertainty analysis with a validation of the model, at least for the WF of crops, by doing field experiments on how much water is consumed by crops.

Fifth, it is recommended to improve the vertical flow model, as used in this study, by including runoff and groundwater flow. This will improve the spatial-explicit estimation of the WF of crops, because recharge or lowering of the soil moisture content in the root zone of a crop by runoff or groundwater flow influences the daily transpiration by the crop and hence the WF. It improves especially the spatial variation in WFs, because the areas near rivers are expected to have more water available in the root zone of crops due to the replenishment of soil moisture by runoff and groundwater flow than areas further away from rivers.

Sixth, the WF of livestock could be improved by using a more country-wise approach to the input data used for the different livestock rearing systems (industrial, grazing and mixed system). In the current studies on the WF of livestock for each rearing system one feed diet is used per animal category, which is applied on all countries with such a system and animal category reared. This causes probably incorrect WFs for livestock, because each country has its own approach to livestock rearing and feeding of animals.

Seventh, it is recommended to distinguish between the different WFs of industy per industrial sector. In most of the current studies on the WF the WF of industry is taken as the cubic meters of water needed to add one US dollar value. However this approach is not totally fair, because some industries are very polluting and low value adding, while others are much more profitable. For policy makers it is therefore essential information to know which sector is "the cleanest".

Eight, incorporating the WF and virtual water trade concept in a water policy choice model would be very nice so that water managers have a tool to determine the directions for water management well. Such a model should point out the direction of water management policy based on water-efficiency of production, consumptive needs and water stress in an area. For example it could determine four types of areas: areas that are water scarce and water inefficient, areas that are water scare and water efficient, areas that are water abundant and water inefficient, and areas that are water abundant and water efficient. For example if an area faces water stress and is water inefficient, water strategies could be focused on improving water efficiency. In this way for each category recommendations could made.

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Glossary

Biodiversity water requirements: the sum of 'green' and 'blue water requirements for biodiversity' (Hoekstra, 2007).

Blue water: Fresh surface and groundwater, i.e. the water in freshwater lakes, river and aquifers (Hoekstra et al., 2009).

Blue water availability: the part of the runoff from land to oceans that is available for human use. It is the total runoff minus the environmental flow requirements. (Hoekstra, 2007)

Blue water footprint: the volume of surface and groundwater consumed to produce the goods and services consumed by an individual or community (Hoekstra, 2007). Consumption refers to the volume of freshwater used and then evaporated or incorporated into a product (Hoekstra et al., 2009).

Blue water scarcity: the ratio of blue water footprint to blue water availability, varying over the year and from year to year (Hoekstra et al., 2009).

Crop water requirement: the total water needed for evapotranspiration, from planting to harvest for a given crop in a specific climate regime, when adequate soil water is maintained by rainfall and/or irrigation so that it does not limit plant growth and crop yield (Hoekstra et al., 2009).

Crop yield: weight of harvested crop per unit of harvested area.

Environmental flow requirements: the quantity, quality, and timing of water flows reuired to sustain freshwater and estuarine ecosystems and biodiversity and the human livelihoods and well-being that depend on these ecosystems (Hoekstra et al., 2009).

External **renewable water resources of a country**: the inflows from upstream countries (groundwater and surface water) and part of the water of border lakes or rivers, i.e. the externally generated runoff available in a country (Hoekstra, 2007).

External water footprint of national consumption: the part of the water footprint of national consumption that falls outside the nation considered. It refers to the appropriation of water resources in other nations for the production of goods and services that are imported into and consumed within the nation considered (Hoekstra et al., 2009).

Green water: the evapotranspiration of rainwater or soil moisture (Hoekstra & Chapagain, 2008: p. 4).

Green water availability: the part of the actual evapotranspiration above land that is available for human use: total evapotranspiration minus green water requirements for biodiversity minus evapotranspiration from land that can not be made productive (Hoekstra, 2007).

Green water footprint: the volume of water evaporated from the global green water resources (rainwater stored in the soil as soil moisture) to produce the goods and services consumed by an individual or community (Hoekstra, 2007).

Green water scarcity: the ratio of green water footprint to green water availability, which varies within the year and from year to year (Hoekstra et al., 2009).

Grey water: estimation of the volume of water needed to dilute a certain amount of pollution such that it meets ambient water quality standards (Hoekstra & Chapagain, 2008: p. 4).

Grey water footprint: the volume of water needed to dilute polluted water to ambient water quality standards, which associates with the production of all goods and services for an individual or community (Hoekstra, 2007; Hoekstra & Chapagain, 2008).

Internal renewable water resources of a country: long-term average annual available water resources existing of annual flow of rivers, recharge of aquifers, and soil moisture and evapotranspiration generated from endogenous precipitation (FAO, 2009 a).

Internal water footprint of national consumption: the part of the water footprint of national consumption that falls inside the nation, i.e. the appropriation of domestic water resources for producing goods and services that are consumed domestically (Hoekstra et al., 2009).

Inter regional virtual water trade: virtual water flows as a result of trade between a specific nation/region and other countries on the world outside the nation/region.

Intra regional virtual water trade: virtual water flows as a result of mutual trade between nations within a specific region.

Irrigation requirement: the quantity of water exclusive of precipitation, i.e. quantity of irrigation water, required for normal crop production. It includes soil evapotranspiration and some unavoidable losses under given conditions (Hoekstra et al., 2009).

National scale: at the level of individual states, e.g. SADC member states.

National water footprint: is the same as what is more accurately called the 'water footprint of national consumption', which is defined as the total amount of freshwater that is used to produce the goods and services consumed by the inhabitants of the nation (Hoekstra et al., 2009).

National water saving through trade: a nation can preserve its domestic freshwater resources by importing a (water-intensive) product instead of producing it domestically (Hoekstra et al., 2009).

Regional scale: at the level of a part of a continent, e.g. the SADC region in Southern Africa.

Runoff: the discharge of surface and ground waters as a result of precipitation minus evaporation.

Total renewable water resources of a country: sum of the internal and external renewable water resources, i.e. the total runoff available in a country (Hoekstra, 2007).

Virtual water (content): the actual volume of water that has been used to produce a commodity and that is virtually embedded in it (Hoekstra & Chapagain, 2008: p. 2).

Virtual water export: the total volume of virtual water required to produce goods and services that are exported from a country or region to an importing country or region.

Virtual water flow: the virtual water flow between two geographically delineated areas (e.g. two nations or regions) is the volume of virtual water that is being transferred from the one to the other area as a result of product trade (Hoekstra et al., 2009).

Virtual water import: the total volume of virtual freshwater required to produce goods and services in the exporting country, which are imported later on by another country or region.

Water availability: a general term that refers to the availability of freshwater for human purposes; indicators of it are for example total renewable water resources, total precipitation, and runoff (Hoekstra, 2007).

Water abstraction: see 'water withdrawal'.

Water consumption: the volume of freshwater that is evaporated or incorporated into a product with water use.

Water dependency of a nation: the ratio of the external to the total water footprint of national consumption, denoting the degree to which the nation depends on virtual water resources from outside the country to meet the domestic demand for goods and services.

Water footprint: the total volume of freshwater that is used to produce the goods and services consumed by the individual, business or nation (Hoekstra & Chapagain, 2008: p. 52).

Water footprint of national consumption: the total amount of freshwater that is used to produce the goods and services consumed by the inhabitants of the nation (Hoekstra et al., 2009).

Water footprint of a product: the water footprint of a product (commodity, good or service) is the total volume or freshwater used to produce the product, summed over the various steps of the production chain (Hoekstra et al., 2009).

Water footprint of national production: the total freshwater volume consumed or polluted within the territory of the nation due to the production of commodities, goods and services.

Water scarcity: see 'blue water scarcity' and 'green water scarcity'.

Water self-sufficiency of a nation: the ratio of the internal to the total water footprint of national consumption, denoting the degree to which the nation supplies the water needed for the production of the domestic demand for goods and services.

Water use: the volume of freshwater withdrawn from surface or groundwater to serve a human purpose of which a part evaporates or gets incorporated in a product (both water consumption) or gets polluted (grey water footprint).

Water withdrawal: the volume of freshwater that is withdrawn from ground- or surface water in order to serve a human purpose (Hoekstra, 2007).

List of symbols

α	[-]	indicator if irrigation is considered (α =1) or not (α =0)
α_a	[%]	percentage of the cultivated area actual irrigated
θ_{FC}	[m^3/m^3]	the water content of a soil at field capacity
θ_{WP}	[m^3/m^3]	the water content of a soil at wilting point
B_v	[m^3/yr]	Virtual water budget of country
c	[-]	Crop/Commodity
c_{max}	[kg/m^3]	Maximum acceptable concentration for the pollutant
CR	[mm]	Capillary rise from the groundwater table
CWR	[mm/d]	Crop water requirement (equal to ET_c)
CWU	[m^3/ha]	Crop water use
CWU_b	[m^3/ha]	Blue water use by crop
CWU_g	[m^3/ha]	Green water use by crop
d	[d]	Time in days
D_r	[mm]	Root zone depletion [mm]
DP	[mm]	Water loss from the root zone by deep percolation
ET_0	[mm/d]	Reference evapotranspiration
ET_c	[mm/d]	Maximum crop evapotranspiration
ET_a	[mm/d]	Actual crop evapotranspiration
f_v[p]	[US$/US$]	Value fraction
f_{leach}	[-]	Nitrogen leaching factor
f_p[p]	[ton/ton]	Product fraction
GDP_i	[US$/yr]	Added value of industry to Gross Domestic Product of a nation
IR	[mm]	Irrigation requirement
I	[mm]	The actual irrigated amount of water
IWW	[m^3/yr]	Industrial water withdrawal
J	[d]	Day of the year (between 1 and 366 days for year 2000)
J_{mid}	[d]	the first day of the mid-seasons growth stage of a crop at Julian date J
K_c	[-]	Crop coefficient
$K_{c\ ini}$	[-]	Crop coefficient for the initial crop development stage
$K_{c\ prev}$	[-]	Crop coefficient of the previous crop development stage
$K_{c\ mid}$	[-]	Crop coefficient of the mid-season development stage
$K_{c\ next}$	[-]	Crop coefficient of the next crop development stage
K_s	[-]	Water stress coefficient
K_y	[-]	Yield response factor
L_{prev}	[d]	Sum of the lengths of all previous crop development stages
L_{stage}	[d]	Length of the crop development stage under consideration
lgp	[d]	Length growing period of crop
n	[-]	Nation

n_i	[-]	Importing nation
n_e	[-]	Exporting nation
$N_{applied}$	[kg/ha]	Amount of fertilizer applied
$N_{leached}$	[kg/ha]	Amount of fertilizer leached to ground and surface water
p	[-]	The fraction of the S_{max} a crop can extract from the root zone without suffering of water stress
p_{std}	[-]	Crop specific depletion factor
Prec	[mm]	Water added by precipitation to soil moisture
PWU	[m^3/ton]	Process water use
r	[-]	Root product
R	[mm]	Runoff
RAW	[mm]	Readily available soil water in the root zone
RWA_g	[m^3/yr]	Remaining green water resources (green WF subtracted)
RWA_b	[m^3/yr]	Remaining blue water resources (only blue WF subtracted, grey WF excluded)
RWA_b*	[m^3/yr]	Remaining blue water resources (blue and grey WF subtracted)
S_{max}	[mm]	the maximum available soil water in the root zone (equal to *TAW*)
S_t	[mm]	the actual soil water content in the root zone
t	[d]	Time step
T	[ton/yr]	Product trade of commodity
TAW	[mm]	Total available soil water in the root zone
TAWC	[mm/m]	Total available water capacity per grid cell
V	[m^3/yr]	Virtual water flow
$V_{e,r}$	[m^3/yr]	Virtual water flow related to the re-export of imported goods
$V_{e,d}$	[m^3/yr]	Virtual water flow related to the export of domestically produced goods
V_i	[m^3/yr]	Virtual water flow related to the import of goods
WA_b	[m^3/yr]	Blue water availability
WA_g	[m^3/yr]	Green water availability
WD	[%]	Water dependency (in this study combined blue-green water value used, because data on water footprints of imported products obtained from Chapagain & Hoekstra (2004)
WF	[m^3/ton]	Water footprint of a product
WF_g	[m^3/ton]	Green water footprint of a product
WF_b	[m^3/ton]	Blue water footprint of a product
WF_c	[m^3/ton]	Water footprint related to national consumption
WF_e	[m^3/ton]	External water footprint (related to national consumption)
WF_{grey}	[m^3/ton]	Grey water footprint of a product
$\overline{WF_i}$	[m^3/US$]	Industrial water footprint of a nation
WF_i	[m^3/ton]	Internal water footprint of a nation
WF_n	[m^3/ton]	Total water footprint of a nation (equal to WF_c)

WF_p	[m³/ton]	Water footprint related to production
WF[p]	[m³/ton]	Water footprint of a primary product
WF[r]	[m³/ton]	Water footprint of a root product
WS_g	[%]	Green water scarcity
WS_b	[%]	Blue water scarcity
WSS	[%]	Water self-sufficiency
WU	[m³/yr]	Water use
WU_a	[m³/yr]	Water use by agriculture
$WU_{a,b}$	[m³/yr]	Blue water use by agriculture (blue WF of agriculture)
$WU_{a,g}$	[m³/yr]	Green water use by agriculture (green WF of agriculture)
$WU_{a,grey}$	[m³/yr]	Grey water use caused by agriculture (grey WF of agriculture)
$WU_{d,b}$	[m³/yr]	Domestic blue water use (domestic blue WF)
$WU_{d,grey}$	[m³/yr]	Domestic grey water use (domestic grey WF)
WU_i	[m³/yr]	Water use by industry
$WU_{i,b}$	[m³/yr]	Blue water use by industry (blue WF of industry)
$WU_{i,grey}$	[m³/yr]	Grey water use caused by industry (grey WF of industry)
WU_d	[m³/yr]	Domestic water use
WU_n	[m³/yr]	Water use in a nation
x	[-]	x-coordinate grid cell
y	[-]	y-coordinate grid cell
Y_a	[kg/ha]	Actual harvested yield
Y_m	[kg/ha]	Maximum yield for a crop
z_r	[m]	The root depth of a crop
$z_{r\ min}$	[m]	The initial effective root depth of a crop at the beginning of the initial period
$z_{r\ max}$	[m]	The maximum effective root depth of the root zone during the midseason period

Virtual water trade in the SADC region

A grid-based approach

Appendices

Enschede, January 2010

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A1 Data

In this appendix some of the operations carried out on the data are described in more detail. Especially operations on input data are discussed which are used to overcome shortcomings and errors in the data. In this way it should be possible to reconstruct the data. This appendix gives also a better understanding of the shortcomings and prepositions in the current dataset due to the scarcity in data availability, especially with regard to the use of fertilizer (nitrogen), fertilized areas, irrigated crops and irrigated area.

Figure 41 gives a description of the different steps taken in the data preparation. In the first part of the diagram is described how the main input data file has been created. In the second part of the diagram the preparation of the GIS-maps has been described. The third part describes the combination of the GIS-data and main data file, which results in the final data, used as input for the crop water use model.

In section A1.1 the first part of the diagram (figure 41) is described in more detail. The sources of the data on cultivated area, yield and production, water footprint, nitrogen fertilizer application and irrigated area per crop for each country are described first. This is followed by an overview of uncertainties in the main dataset caused by the combination of the cultivated area, yield and production data of the FAO and the water footprint data. Than the choice for taking only nitrogenous fertilizer application per crop into consideration has been explained and the preparation and exceptions in the fertilizer data are discussed. Next the irrigation data preparation and the shortcomings in it are presented. At last the crop parameter data is given.

In section A1.2 the second part of the flow model in figure 41 is elaborated. The sources of the GIS-data are described first, followed by a description of the operations on the GIS data needed for data preparation.

In section A1.3 the combination of the main dataset and the GIS-data is described, what is the third part of figure 41.

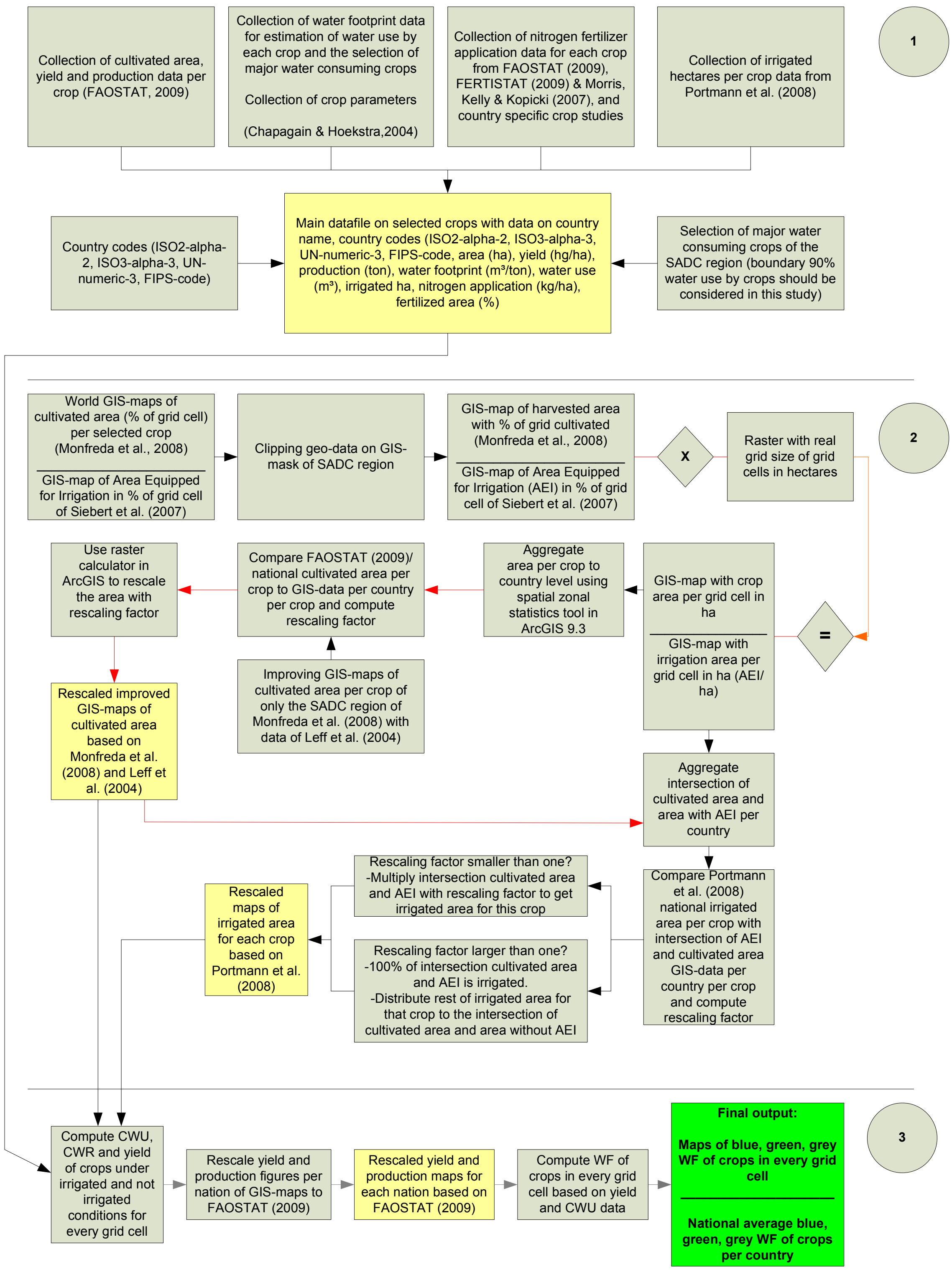


Figure 1. Overview of steps in the data preparation.

A1.1 Preparation of main dataset

- Of all the countries a list is made of which crops are cultivated in the country (combination of literature study of Kort (2009), the study of Chapagain & Hoekstra (2004) on the water footprint of nations and FAO (2009 c) country data).
- Data on area, yield, production, water footprint, irrigated area, nitrogen fertilizer use and crop parameters per crop for each country are collected. The data on area, yield and production per crop is obtained from FAO (2009 c). The data on the water footprint and crop parameters per crop for each country are obtained from Chapagain & Hoekstra (2004) and Allen et al. (1998). Irrigation data is obtained from Portmann et al. (2008). For nitrogen application data is obtained from various sources described in more detail in section A1.1.3). The N-leaching factor of crops as assumed by Chapagain et al. (2006) is compared with these data.

A1.1.1 Shortcomings and uncertainties in the main dataset

For all crops data on cultivated area (ha), yield (hg/ha), and production (ton) (from FAO, 2009 c), on the water footprint (m^3/ton) (from Chapagain & Hoekstra, 2004), water use (m^3), irrigation data (ha) (from Portmann et al., 2008), nitrogen application (kg/ha) and percentage of area fertilized is obtained. In the dataset however are a few shortcomings. The shortcomings in data available per country are:

- DRC: water footprint data is missing for pigeon peas (197) and beans (green) (414)
- Madagascar: chili & peppers (401) miss data on area, yield and water footprint
- Malawi: peas (green) (417) & broad beans (green) (420) have both no cultivated area data; Tung nuts (275) miss water footprint data.
- Mauritius: water footprint data of leak (407) is there, but no production data. Water footprint of green corn (maize) (446) is missing (does have cultivated area, yield and production data). Pistachios (223) production data only.
- Mozambique: water footprint of oilseed nes (339) is missing in the data of Chapagain & Hoekstra (2004).
- Namibia: water footprint data of tomatoes (388), grapes (560), water melons (567), cantaloupes & other Melons (568) and dates (577) are missing.
- Seychelles: avocados (572), fruit fresh nes (619), mangoes (571), and oranges (490) all do have production figures, but no cropped area and water footprint data.
- South Africa: citrus nes (512), chicory roots (459) and quinces (523) have production figures and a cropped area but the water footprints are missing. For chili & peppers (401), asparagus (367), mushrooms (449), there are production figures only. For alfalfa for forage (641) there is a water footprint given, but no production.
- Swaziland: citrus nes (512), roots (149), dates (577), plums (536), tangerines, manderines and clementines (495) have area and production figures; however the water footprint is not given. Lemon & limes (497) have production figures only
- Tanzania: orange (490), chili & peppers (401), pyrethrum (754), cabbages (358), oilseeds nes (339), lemon & limes (497), peas (green) (417), pears (521), broad

beans (420), watermelons (567), have area and production figures; however the water footprint is not given. For fiber nes (821) production data is given only.
  - Zambia: artichokes (366) have only production figures.
  - Zimbabwe: chili & peppers (401), chestnuts (220), carrots (426), garlic (406), beans (green) (414), peas (green) (417), mushrooms (449), broad beans (green) (420), and currants (550) have only production figures.
    Papayas (600), roots (149), chick-peas (191), cabbages (358), lettuce (372), Tung nuts (275), oilseeds nes (339), cauliflower (393), cucumbers & gherkin (397) asparagus (367), artichoke (366), green corn (maize) (446), avocados (572), and cantaloupes & other melons (568) have cultivation area and production figures data, but no water footprint value.

- Note that Macadamia nuts are not taken into account directly, but indirect. According to the CIA (2008), Macadamia nuts are cropped a lot in Malawi, so it is important to take this crop into account in the overall list of crops. The FAO takes the crop into account indirectly in the crop class nut nes (234).
- Note that horticulture is not taken into account, however this sector is very important for Zambia and probably as well for Tanzania (large scale flower production around Arusha and Moshi (Tanzanian Horticulture Association, 2004)), Zimbabwe (FAO, 2006 a) and South Africa (FAO, 2005) and maybe even more SADC countries. However precise data is lacking.
- Note that especially data of fruits and vegetables is missing. The reason for this could be that these crops are grown small-scale on plots near houses and are therefore not included in the total cultivated area of the crop.

A1.1.2 Fertilizer data

Why has been focused on nitrogen only?

To give an impression of the grey water footprint of crops, fertilizer data of nitrogen application per crop per country is taken into account. Of course also other types of inputs in agriculture are responsible for the total grey water footprint of crops (like herbicides, pesticides, fungicides, phosphorus, potassium, urea), but the goal of this study is to show the relationship between the use of chemicals in agriculture and the resulting pollution of the environment.

Another reason that only nitrogen is taken into account is that for most of the mentioned grey water sources data is lacking on the application rates per crop per country. Also it is often unknown what the effect of the application of the chemical to a crop is on water pollution; i.e. how much of the applied chemical reaches the water. Besides the lack of data, there are also constraints related data management and time because the groups of herbicides, pesticides and fungicides exist of so many different types of chemicals that not all types of chemicals can be analyzed. The Ministry of Health, Labour and Welfare of Japan (2003) has made an overview of how much chemicals used in the agricultural sector for crops are seen as hazardous in food and thus also in the environment by some countries and the Codex Alimentarious Commission. The USA for example recognizes already 326 dangerous chemicals, Japan 231, the EU 158 and Canada 151 (Ministry of Health, Labour and Welfare of Japan, 2003). Even these lists are not comprehensive enough because there are many more chemicals used in agriculture of which the precise effects are still not known.

Because the list of agricultural chemicals is so large and it is difficult to get data on the application of chemicals, it is decided to focus on the application of chemical fertilizer because of this group is relatively more data. Also the nutrients of chemical fertilizers applied, mainly nitrogen (N), phosphorus (P) and potassium (K), are, with urban activities, the major sources of nutrients to aquatic ecosystems (Carpenter et al. 1998). Especially N and P emissions from these nonpoint sources are responsibly for eutrophication, which is a widespread problem in rivers, lakes, estuaries and coastal oceans worldwide (Carpenter et al., 1998).

Of nitrogen, phosphorus, and potassium, nitrogen and phosphorus are often the most polluting substances while they are most dominant for the development of biomass (Verhoeven, Koerselman & Meuleman, 1996). Crops need all three substances for their development, but according to the law of Von Liebig always one of these nutrients will become limiting for crop and biomass development. Von Liebig states that vegetation will continue to grow till one of the sources of nutrients becomes below a certain threshold for biomass development, which limits growth. According to Verhoeven, Koerselman & Meuleman (1996) in 80% of the cases N or P is the limiting factor. Potassium is therefore less responsible for deterioration of water quality.

Nitrogen is of N and P the most polluting, because nitrogen is compared to potassium more mobile in the environment (Augustijn, 2006). Nitrogen dissolves easily in water, evaporates easily into the atmosphere and is rinsed easily away from the soil. It causes therefore more often eutrophication. Phosphorus is quite immobile in the soil and attaches to soil particles and causes therefore less water related problems. Also it is more difficult to determine how much P applied to a crop is leaching to the aquatic system, because it is often attached to soil particles first.

Nitrogen fertilizer datasets

Nitrogen fertilizer application data per crop per country is obtained from several sources, i.e. FERTISTAT (2009) (overview of nitrogen application rates for some crops in Madagascar, Malawi, Tanzania, South Africa, Zambia, and Zimbabwe), Morris et al. (2007) (data on the average fertilizer consumption per crop in sub-Saharan Africa) and FAO (2009 c) (two datasets with data from 1996 to 2002 and 2002-2006). For rice, maize, sugarcane, tobacco, tubers and the crop group 'other crops' extra data on optimum nitrogen application rates has been used to correct for unrealistic nitrogen application values. In the rest of this section the used data will be explained in more detail.

The first dataset on nitrogenous fertilizer application is obtained from FERTISTAT (FAO, 2009 e). It has more detailed data on nitrogen application rates for several crops for several SADC countries, i.e. South Africa, Zimbabwe, Zambia, Tanzania Malawi, and Madagascar. The data is however far from complete or very coarse. So it is not known for sure how much fertilizer is applied per crop.

Second fertilizer data on total amounts of nitrogenous fertilizer consumed over the period 1997-2002 has been downloaded from ResourceSTAT, Fertilizers archive (FAO, 2009 d): http://faostat.fao.org/site/422/default.aspx#ancor.
The period of this data set is overlapping for a large part with the study period 1996-2005. Data after 2002 are not available anymore in this dataset, because the FAO changed to a new database (FAOSTAT, ResourceSTAT, Fertilizers). In the dataset on fertilizers used per country of a few SADC countries no data is available: Angola and Botswana. For most SADC countries the data on nitrogenous fertilizer use is not very reliable, because the data is based on estimates for the period 1997-2002. Estimates are made for Mauritius (1998, 1999), Mozambique (only estimates), Swaziland (only estimates), Zimbabwe (only estimates), Malawi (1997-1999), Congo (2000), Lesotho (1998, 2002), Namibia (1998-2002), South Africa (1999-2002), Zambia (1997, 1998, 2001, 2002). No data reported occurred for DRC in 1997, for Namibia in 1997, and for Seychelles in 1997 and 1998. No data values have been left out in average fertilizer application computations per country.

Third data of FAO (2009 d) on total consumption of nitrogen fertilizer has been downloaded from http://faostat.fao.org/site/575/default.aspx#ancor for the period 2002-2006, because the first dataset gives no data for Angola and Botswana. In the second dataset data is missing for Botswana, DRC, Lesotho, Seychelles, Swaziland and Zambia. For Botswana the agricultural production and agricultural and climatic conditions could be compared largely with Namibia (Kort, 2009; Earle, 2001). Therefore the nitrogenous fertilizer application of Namibia has been used for Botswana as well.

In the second dataset from FAO (2009 d) much uncertainty is present in fertilizer use and application just as in the first dataset. The data is not of really good quality because there are a lot of estimates and assumptions present in the data! Data of 2006 for example exists for all countries with data over the period 2002-2006 of balance computations. For Zambia no data is available over the period 2002-2006, except for 2006 the balance computation. For Zimbabwe data from 2003 onwards is based on balance computations. The rest of the figures in the table are based on official country data.

The two datasets obtained from FAO (2009 d) are also not totally the same. The data over the period 1997-2002 includes 'Nitrogeneous Fertilizers consumed' in a country. The data over the period 2002-2006 includes 'Nitrogen (N total nutrients), consumption in nutrients'. So both datasets are not totally comparable, because they include either different types of fertilizer or the computations on the amount of nitrogen consumed are done in different ways. When data on tons of nitrogenous fertilizer consumption for the year 2002 where compared, there were quite large differences between both datasets.

Uncertainties in the older dataset are larger than in the new dataset. Also in the FAO (2006) report on fertilizer use in Zimbabwe the total consumption of nitrogen is in agreement with the data values mentioned in the newer dataset instead of with the older dataset. So therefore the newer dataset is seen as more reliable, however data quality of both sets is poor. In table 12 an overview is given of which dataset is used for each country. The older dataset is used when data in the newer dataset are lacking, which is the case for DRC, Lesotho, Swaziland, Seychelles and Zambia.

Table 1. Overview of years on which fertilizer use data per SADC country is based.

Country	Fertilizer dataset used
Angola	2002-2006
Botswana	Based on data for Namibia
DRC	1997-2002
Lesotho	1997-2002
Madagascar	2002-2006
Malawi	2002-2006
Mauritius	2002-2006
Mozambique	2002-2006
Namibia	2002-2006
Seychelles	1997-2002
South Africa	2002-2006
Swaziland	1997-2002
Tanzania	2002-2006
Zambia	1997-2002
Zimbabwe	2002-2006

The total amount of nitrogenous fertilizer consumed in a country is used to fertilize all fertilizer receiving crop types. So it is therefore important to know the average rate of kg nitrogen per ha applied and how much hectares receive fertilizer in a country.

Of a few SADC countries more detailed data is available on the fertilizer application rate for some crops trough FERTISTAT (FAO, 2009 e) for the year 2004. This database has only data available for certain crops for Madagascar, Malawi, South Africa, Tanzania, Zambia, and Zimbabwe. For these countries the extra and more accurate data is used for the crops where data is available of. For the cultivation area per crop the average of the period 1997-2003 has been taken, just as for the crop maps. For Zimbabwe however the data were not reliable. This had to be adjusted. The adjustments done are described in the next section.

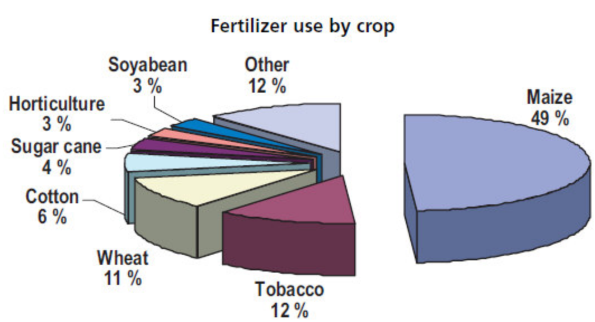


Figure 2. Fertilizer consumption by crop in Zimbabwe (FAO, 2006a: p. 33).

The total amount of fertilizer applied has been computed as well. This amount has been compared with the total amount of nitrogen consumed per country. For Madagascar, Malawi and Zimbabwe this result in negative values; this means that the total amount of fertilizer used per crop as stated by FAO (2009 e) is exceeding the total consumption of fertilizer applied according to FAO (2009 d). For Malawi and Madagascar these differences can be explained easily due to the fact that average cultivation area data per crop has been used of the period 1997-2003. For Zimbabwe however the case is differently. Here the fertilizer application rates per crop as reported by FAO (2009 e) are not correct. According to the data of FAO (2009 e) the farmers in Zimbabwe are using much more fertilizer per crop than needed according to studies on what the optimum application rate of fertilizer per crop in Zimbabwe is. This seems not quite logic! Therefore the fertilizer application rates have been adjusted to the recommended values based on the report of the FAO (2006). Even this resulted in too much fertilizer use compared to the total consumption of nitrogenous fertilizers in Zimbabwe over the period 1996-2006. Therefore the application of fertilizer in Zimbabwe has been adjusted to the percentages of fertilizer used per crop as given by Mashingaidze in the FAO report on fertilizer use in Zimbabwe (2006) (figure 42). The FAO (2006 a) reported a fertilizer consumption of 60,000 tons in Zimbabwe for the year 2002. In this way it was possible to get more realistic values for fertilizer use per crop, however the fertilizer use per crop is still not correct, because the percentages applied to other crops is still too low. Probably the errors in the data are related to the sharp fall in fertilizer use due to land reforms taking place in Zimbabwe in the period 2000-2004 (FAO, 2006a). Also the economic downturn since than has impacted Zimbabwe much. For comparison, in the period before 1995 Zimbabwe used still more than 400000 tons of fertilizer (FAO, 2006a).

For the countries Angola, Botswana, DRC, Lesotho, Mauritius, Mozambique, Namibia, Seychelles and Swaziland the amount of nitrogen fertilizer has been distributed to crops according to the diagram of Morris, Kelly & Kopicki (2007) (figure 43). They have made an overview of the average application of fertilizers per crop in twelfth countries in sub-Saharan Africa. Hence the assumption made in this study is that the application of nitrogen can be set equal to the amount of fertilizer applied to a crop. A description of the different crop classes as mentioned by Morris, Kelly & Kopicki (2007) is given in table 13. The consumed nitrogen has been applied to the whole area a crop is growing, because it is not known where fertilizers have been used and how much fertilizer has been used. This results for some crops in very low application values, however also in an overestimation of the area that is fertilized. This method gives quite reasonable and satisfying nitrogen application rates for crops in Angola, DRC and Mozambique.

The distribution of fertilizer based on Morris, Kelly & Kopicki (2007) however does not give satisfying results for Botswana, Lesotho, Mauritius, Namibia, Seychelles and Swaziland. These countries are not cropping the crops as mentioned by Morris, Kelly & Kopicki (2007) or less hectares than average in sub-Saharan Africa. For these countries a redistribution of tons of nitrogen had to be carried out. Because the real fertilizer application rates are not known, it is very difficult to know how to redistribute these values. The values have been redistributed in such a way that values obtained are at least not impossible. But if the values are good estimates is uncertain. The redistribution is done based on which crop is cultivated most (largest cultivation area) and by taking special conditions of the agricultural sector of a country into account (Mauritius for example cultivates a lot of sugarcane). The exceptions made are described in more detail hereafter.

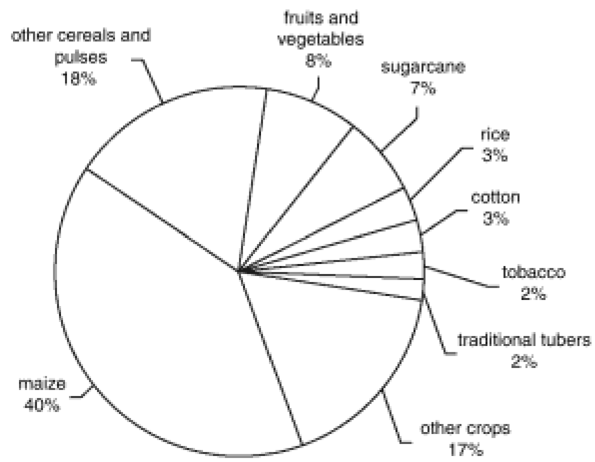


Figure 3. Fertilizer use by crop for sub-Saharan countries based on data for 12 countries in the FAO database (Morris, Kelly & Kopicki, 2007: p.26).

Exceptions in fertilizer data

In Botswana sugarcane, rice and tobacco are not cultivated. The amounts of fertilizer for these crops are redistributed to maize, while the fertilizer application to maize was very low (only 15.4 kg N/ha). For the other cereals and pulses as well the fertilizer application rate is very low; they get only 3.43 kg N/ha. The left over amount of fertilizer however has been distributed to maize, while this is the most important stable crop in sub-Saharan Africa and gets the highest rates of fertilizer (Morris, Kelly, Kopicki, 2007). For maize this results in a more acceptable fertilizer application rate of 20.2 kg N/ha for maize.

In Lesotho traditional tubers, sugarcane, rice, cotton and tobacco are not cultivated. The fertilizer application rate for 'other crops' was much too high with 100.52 kg N/ha. The nitrogen application rate for 'other crops' has been decreased to 34.24 kg N/ha while the average fertilizer application rate to crops for Lesotho is 34.24 kg N/ha according to Camara & Heinemann (2006). The fertilizer application rate for maize was too low (only 8.93 kg N/ha), however most fertilizer is going to cash crops and stable crops in the SADC. So all the left over tons N are redistributed to maize resulting in an application rate of 16.14 kg N/ha.

For the island state Mauritius the redistribution was quite straight forward. The cultivation of sugarcane is the most important on the island. So the left over tons of nitrogen are distributed to sugarcane, while the fertilizer application rate this crop was receiving was way too low (only 8.42 kg N/ha). The fertilizer application rates as computed for maize (75125.89 kg/ha), traditional tubers (2341.4 kg/ha), tobacco (174.94 kg/ha) and other crops (668.77 kg/ha) are too high and had to be redistributed to sugarcane as well. Data on the exact values of fertilizer use for sugarcane on Mauritius are not known, however the optimal rate of fertilizer application for sugarcane seems to be around 120 kg N per hectare according to Gana (2008). For maize a reasonable value in kg N per ha was obtained from the report of Jewell et al. (1994). Jewell argues that the economical optimal fertilizer application rate for maize is around 100 kg/ha. For traditional tubers the optimal fertilizer application rate is around 35 kg/ha based on a study in Nigeria on yams. However the conditions of these studies do not directly have to be valid for Mauritius, these values are at least more realistic than the old fertilizer application rates for these crops. The average fertilizer application rate for crops cultivated in Mauritius is 250 kg/ha (Camara & Heinemann, 2006). The fertilizer application rate for the group 'other crops' has been adjusted to this rate, while in this group are a lot of different types of crops. So it is assumed that this group reflects the average. The left tons of N are distributed to sugarcane. This results in a nitrogen application rate of 101.24 kg N/ha for sugarcane.

In Namibia sugarcane, rice and tobacco are not cultivated. The amounts of fertilizer for these crops are redistributed to cereals and pulses, while the fertilizer application for this crop group was very low (1.1 kg N/ha). The fertilizer rate for 'other crops' is too large and has been redistributed to cereals and pulses as well (old value 290.43 kg N/ha). The fertilizer application rate for other crops in Namibia has been adjusted to 50 kg/ha while this group exists of cash crops mainly in Namibia. After redistribution the fertilizer rate for cereals and pulses has increased to a fertilizer application rate of 2.78 kg N/ha.

On the Seychelles cereals and pulses, maize, sugarcane, rice, cotton and tobacco are not cultivated. All the fertilizer has been redistributed to 'other crops', because these crops, like cinnamon, coconut, and tea are cultivated most.

For Swaziland the fertilizer application rates for rice (1216.92) and tobacco (287.53 kg N/ha) are quite high. According to Shamiul Islam, Hasanuzzaman & Rokonuzzaman (2008) the optimum application rate of nitrogen in India for rice is around 135 kg N/ha. So an application rate of nitrogen of 1216.92 kg N/ha is assumed to be too high. Therefore the optimum as suggested by Shamiul Islam, Hasanuzzaman & Rokonuzzaman (2008) is taken as nitrogen application value. For tobacco the fertilizer application rate is probably too high as well. The optimum fertilizer rate is in the range of 35 to more than 200 kg of nitrogen per hectare depending on the type of tobacco (Peedin, 2002). According to Pearce et al. (n.d.) the optimum fertilizer application rate in Kentucky (USA) is around 125 kg of nitrogen when the soil has low levels of nitrogen following tobacco or row crops the year before. Because 125 kg N per annum is in the range reported by Peedin (2002) this seems a reasonable value. But it is important to keep in mind that these values are anyhow an estimation, because more precise data for Africa is missing.

Table 2. Crop classes based on fertilizer use by crops as given by Morris, Kelly & Kopicki (2007).

Main fertilizer receiving crops in sub-Saharan Africa	Traditional tubers	Other cereals and pulses	Fruits & vegetables		Other crops
			Fruits	Vegetables	
Maize (56) Sugarcane (156) Rice (27) Cotton (328) Tobacco (826)	Cassava (125) Sweet potato (122) Yams (137) Taro (coco yam) (136) Roots (149)	Barley (44) Millet (79) Sorghum (83) Wheat (15) Oats (75) Rye (71) Buckwheat (89) Sesame seed (289) Bean (176) Pulses (211) Peas (187) Cow-peas (195) Lentils (210) Chick-peas (191) Pigeon peas (197)	Apples (515) Avocados (572) Banana (486) Berries nes (558) Cantaloupes & other melons (568) Cashew apple (591) Currants (550) Dates (577) Figs (569) Fruit fresh nes (619) Fruit tropical fresh nes (603) Grapes (560) Mangoes (571) Papaya (600) Pears (521) Pineapple (574) Pistachios (223) Quinces (523) Strawberries (544) Watermelons (567) **Citruses:** Citrus nes (512) Grapefruit & pomelo (507) Lemons & limes (497) Orange (490) Tangerines, mandarins, Clementine's, Satsuma (495) **Stone fruits:** Apricots (526) Cherries (531) Peaches & nectarines 9534) Plums (536) Stone fruit nes, fresh (541) Raspberries (547)	Artichoke (366) Asparagus (367) Beans, green (414) Broad beans, green (420) Cabbages (358) Carrots (426) Cauliflower (393) Chili & peppers (401) Chicory roots (459) Cucumbers & Gherkins (397) Eggplants (399) Garlic (406) Green corn (446) Leak (407) Lettuce (372) Onions, green (402) Onions, dry (403) Peas, green (417) Pumpkins, squash and gourds (394) Tomatoes (388) Vegetable Fresh nes (463)	Cashew (217) Cinnamon (693) Clove (698) Cocoa beans (661) Coconut (249) Coffee, green (656) Groundnuts (242) Oil palm (254) Plantain (489) Potato (116) Pyrethrum (754) Rubber (natural) (836) Sisal (789) Sunflower seed (267) Tea (667) Vanilla (692) Soybean (236) Nuts nes (234) Lupins (210) Chestnuts (220) Castor beans (265) Tung nuts (275) Oilseeds nes (339) Mushrooms (449) Green corn (maize) (446) Pimento, allspice (689) Pepper white/long/black (687) Nutmeg, mace, cardamons (702) Anise, badian, fennel (711) Ginger (720) Alfalfa for forage + silo (641) Hops (677) Jut-like fibers (782) Spices nes (723) Fiber crop nes (821) Melon seed (299)

Nitrogen leaching

In the EU the member states have to comply with the Nitrogen Directive. In this directive it is agreed that surface and ground waters with nitrate values above 50 mg/l (11.36 mg N/l) are seen as polluted (The Council of the EU, 1998). The EPA (2009) uses almost the same standard with 10 mg N/l. The use of nitrogenous fertilizer could cause pollution of ground and surface water because not all nitrogen applied to a crop is taken up by the crop. The part which is not used by the crop is fixated by the soil or lost by denitrification, leaching or votalization. The part of nitrogen leaching away ends up into ground water or surface water and could therefore cause pollution.

The N-leaching values for each crop have been based on literature. Important to know is that the leaching of nitrogen depends on soil type, crop type, climate, rainfall events and intensiveness, irrigation events and intensiveness, cropping calendars, cropping pattern, and season. The literature on N-leaching of crops however is restricted. Most studies take only one or several of the mentioned parameters into account. Also these type of studies are not done for all regions in the world, especially data on Africa are lacking. The N leaching values as described in the literature are more or less an estimation of the nitrogen leached by crops.

In table 14 an overview is standing of the different N-leaching values. For some crops N-leaching values could not be found. For these crops values are taken of crops that belong to the same family or crop group. For cassava and sweet potato the values of potato are used, because they belong to the class of tubers. For sorghum and millet the average of the values of maize and wheat have been taken. Cloves, cashew, coconut and oil palm are all tree crops cultivated on plantations. According to Lehmann & Schroth (1999) the amount of nutrient leaching under tree crops is not clear. It was always assumed that nutrient leaching of tree crops is minimal, but other studies indicate that nutrient leaching by tree crops is substantial (Schroth et al., 1999; Lehman & Schroth, 1999). Of oranges it is known that they leach 5% of the applied nitrogen fertilizer (Hadas et al., 1999), which is a tree crop as well. It is therefore assumed that N-leaching of tree crops is 5% of applied N.

Table 3. Overview of N-leaching values (based on various authors), maximum root depth of crops and the depletion factor obtained from Allen et al. (1998).

Crop	N-leaching as percentage of total amount N applied	Literature used	Max. root depth (m)		Depletion factor p	Remarks
			Irrigated	Not irrigated		
Maize	4.6	Brye et al. (2001)	1	1.7	0.55	Grain type
Cassava		Sharma (1999)	0.6	0.9	0.375	Part of tuber family Root length average of first and second year crop
Rice	8	Yu-Hua et al. (2007)	0.5	1	0.2	Depletion factor based on saturation
Sugarcane	6	Wagner de Oliveira et al. (2002)	1.2	2	0.65	
Plantain			0.5	0.9	0.35	Tree crop/banana family
Cotton seed	15	Hadas et al. (1999)	1	1.7	0.65	
Coffee	5	Babbar & Zak (1994)	0.9	1.5	0.4	
Groundnut		Toomsan et al. (1995)	0.5	1	0.5	Legume crop, N-fixator, leaching expected to be not important
Coconut		Hadas et al. (1999); Lehman & Schroth (1999); Schroth et al. (1999)	0.7	1.1	0.65	Tree crop
Sorghum			1	2	0.55	Grain type, cereal family
Banana	5	Prasertsak et al. (2001)	0.5	0.9	0.35	
Sunflower	16.2	Rahil & Antonopoulos (2007)	0.8	1.5	0.45	
Bean		Toomsan et al. (1995)	0.6	0.9	0.45	Legume crop, N-fixator, leaching expected to be not important
Wheat	7	Addiscott (1996)	1.25	1.65	0.55	Root depth combination of spring and winter wheat
Millet			1	2	0.55	Cereal family
Oil palm		Hadas et al. (1999); Lehman & Schroth (1999); Schroth et al. (1999)	0.7	1.1	0.65	
Sweet potato			1	1.5	0.65	Part of the tuber family
Potato	17.2	Sharma (1999)	0.4	0.6	0.35	Tuber
Cashew		Hadas et al. (1999); Lehman & Schroth (1999); Schroth et al. (1999)	1	1.6	0.52	Tree crop
Clove		Hadas et al. (1999); Lehman & Schroth (1999); Schroth et al. (1999)	1	1.6	0.52	Tree crop
Orange	5	Hadas et al. (1999)	1.1	1.5	0.5	50% canopy cover assumed
Soybean		Toomsan et al. (1995)	0.6	1.3	0.5	Legume crop, N-fixator, leaching expected to be not important

A1.1.3 Irrigation data

In the report of Portmann et al. (2008) most irrigation data for the SADC region is based on the most recent FAO (2005 a) country reports of 2005 and the FAO GIEWS crop calendar of 2005. These AQUASTAT reports describe the total area equipped for irrigation (AEI), the total area irrigated and what are the main irrigated crops and the size of the irrigated hectares per crop.

The only exceptions are Malawi and Namibia. For Malawi the irrigated areas for rice and vegetables have been distributed according to the older AQUASTAT report on Africa of 1995. For Namibia the AEI as known in 1992 has been rescaled with "the ratio of new (2002) to old (1992) equipped area, under the assumption that relative areas of crops remained constant" (Portmann et al., 2008).

The largest changes in irrigated area and irrigated crops were for Swaziland. In 1995 Swaziland had several main irrigated crops besides sugarcane like 7000 ha of pineapples, 400 ha citrus and 4400 ha other crops. In 2005 only sugarcane and citrus are main irrigated crops with 41516 ha and 2513 respectively.

Crop classes

The dataset on irrigated crops of Portmann et al. (2008) exists of 26 crop classes (table 15) over the period 1998-2002. The assumption is made by Portmann et al. (2008) that a crop is irrigated when it is growing on an area that has irrigation equipment.

The crop classes others annual, others perennial, pulses, and citrus exist of more than one crop. So it is important to make clear which crops belong to these classes. For pulses and citrus the crops are taken as described in table 13, except for Zimbabwe. Here the irrigated area was distributed to pulses (211) only because Portmann et al. (2008) assumed that 10% of the area of pulses was irrigated, which matched best with the data of FAO (2009 c) on cultivated area for pulses. For the other countries this was not possible, because the cultivated area of pulses only was not large enough to get all the irrigated area as reported by Portmann et al. (2008).
For the SADC the class 'others perennial' exist mainly of specific mentioned crops like bananas (Angola, Swaziland, Tanzania, Zambia), flowers (Mauritius, Seychelles, Zimbabwe), tea (Malawi, South Africa, Zambia, Zimbabwe). For South Africa only one large crop group for other perennials is left, namely fruit and berry orchards. For this group all fruits have been taken as not mentioned separately in table 15 and that are mentioned in table 13 under fruits. For Zimbabwe also one crop group falling under the crop class other perennials is left, i.e. tree nuts, existing in this case of chestnuts (220) and nut nes (234).
The group 'other annual crops' exist often of vegetables or tobacco for most SADC countries. Exceptions are Namibia and Zambia who have both a subgroup called 'other annual crops'. For Namibia and Zimbabwe all the crops that did not fall into one of the other crop classes as recognized by Portmann et al. (2008) and are cropped whole year through when irrigated have been assumed to fall in this class. For Namibia this class exists of tomatoes, vegetables fresh nes, grapes, water melons, dates, cataloups & other melons. For Zambia other annual crops are

tobacco, fruit fresh nes, fruit tropical fresh nes, pimento all spice, pepper, spices, and sweet potato.

Table 4. Crop classes as used by Portmann et al. (2008).

Wheat	Potatoes	Date palm
Maize	Cassava	Grapes/Vine
Rice	Sugarcane	Cotton
Barley	Sugar beets	Cocoa
Rye	Oil palm	Coffee
Millet	Rapeseed/Canola	Others perennial
Sorghum	Groundnuts	Managed grassland/pasture
Soybeans	Pulses	Others annual (incl. vegetables etc.)
Sunflower	Citrus	

Uncertainties in the dataset

In the results of Portmann et al. (2008) are quite some uncertainties present. With regard to the harvested area it was often difficult to get data what is exactly matching the period of 1998-2002. Much data was older. Also there were difficulties with disaggregation or reclassification of crop classes. Especially the disaggregation of other crops was often not possible, which could result in under estimated irrigated areas for some crops like potatoes or cassava. Further it was difficult to determine the exact growing periods per country. In the distribution of irrigated hectares to crops are at last also some uncertainties present. The data of Portmann et al. (2008) are usable, while they reflect reality as good as possible. However it must be kept in mind that there could be differences in irrigated hectares and areas between reported values and reality.

Shortcomings and exceptions in overall and irrigation data

When the values for the irrigated areas per crop are seen as estimates, than for most countries the data seemed to be quite realistic. However there are a few shortcomings in the dataset for this study, to know:

- Angola: rice has two cropping seasons on approximately 7000 ha. Portmann et al. (2008) took therefore as harvested area 14000 ha. In this study just 7000 ha are assumed as irrigated.
- DRC: rice has two cropping seasons.
- Malawi: rice has two cropping seasons.
- Mozambique: irrigated area of maize as reported by Portmann et al. (2008) is based on the assumption that 'rest unattributed' as reported by AQUASTAT (2005) is mainly used for fertilizing maize.
- Namibia: pasture is not taken into account however 863 ha are irrigated.
- Seychelles: pulses and flowers do not have area, yield, and production data, however they are irrigated.
- South Africa:

  - Barley and wheat are cropped sometimes before summer crops, resulting in two harvests.
  - Grapes and cotton have slightly less irrigated area due to averaging data over the period 1997-2003.
  - Coffee has an irrigated area of 2500 ha, but data on area, yield and production is missing from FAO (2009 c).
  - Alfalfa has an irrigated area of 220000 ha, however area, yield and production data are missing.
  - Sesame has an irrigated area of 1500 ha, but area, yield and production data are missing.
  - Tobacco has a much lower cultivated area according to FAO (2009 c) than according to Portman et al. (2006). In this study only 14600 ha (FAO, 2009 c); according to Portman et al. (2006) this should be 32600 ha.
  - Area of pulses over 1997-2003 (70945 ha FAO (2009 c)) much lower than according to irrigated area as reported by Portman et al. (2006) (139400 ha).
  - Area of fruits and vegetables is less than reported by Portman et al. (2006) (108131 ha and 122988 ha versus 123449 ha and 136200 ha respectively). This could be due to the fact that here the average has been taken over 1997-2003.
- Swaziland: Only sugarcane (41516 ha) and rice (50) have slight differences in irrigated area as reported by Portman et al. (2006) due to averages obver the period 1997-2003 probably
- Zambia:
  - In the irrigated areas of sugarcane and coffee are slight differences with the reported values by Portman et al.(2006) (17571 ha and 4871 ha versus 18418 ha & 5160 ha respectively). Most likely these difference are caused by the averaging over the period 1997-2003
  - The irrigated area of bananas is much higher according to Portman et al. (2006) (3000 ha) than the growing area according to FAO (2009 c) data which report only 227 ha cultivated.
  - The irrigated area of citrus is too low. It should be 2210, but there are only irrigated oranges in this class. Maybe some of the citrusses are put into the class of tropical fruit or fruit fresh nes. This is however unclear.
- Zimbabwe:
  - Area of wheat is slightly less than reported as irrigated by Portmann et al. (2006) (47466 ha) due to averaging over 1997-2003.
  - Alfalfa, flowers and chest nuts miss area, yield and production data.

A1.1.4 Crop parameter data

Data on crop parameters, i.e. K_c-values, planting date, duration of growth stages and climatic region are obtained from Chapagain & Hoekstra (2004). The data on maximum root depth for each crop (irrigated and not irrigated) and the depletion factor of each crop are obtained from Allen et al. (1998) (table 14). For cashew and clove no data was directly available. For these crops the average of all tree crops reported in table 22 (Allen et al., 1998) has been used. For wheat the the value for winter has been taken, while this is cropped in Southern Africa according to the USDA (n.d.). For sorghum and maize the grain type is chosen, while this type is cropped mainly instead of the sweet varieties.

In table 16 an overview is given of the crop reduction factor for each crop. Most values are obtained from table 24 in the report of Allen et al. (1998). On many crops however no data is available for the yield reduction factor (K_y). For sweet potato and rice values could be found in literature, but for the other crops the values are based on assumptions. For the tree crops cashew, clove, coconut and coffee the value of the reduction factor for orange has been used, because this is a tree crop as well. The value of banana has been used for plantain, because they both belong to the family of the *Musaceae*. For cassava the value of the sweet potato has been used, because both crops belong to the root tubers.

Table 5. Overview of the crop yield reduction factor for each crop (K_y).

Crop	K_y	Literature used
1 Banana (486)	1.3	Table 24 (Allen et al., 1998)
2 Bean (176)	1.15	Table 24 (Allen et al., 1998)
3 Cashew (217)	1.2	Orange value used (tree crop)
4 Cassava (125)	1.2	Tuber family, root tuber; value same as for sweet potato
5 Clove (698)	1.2	Orange value used (assumption tree crop)
6 Coconut (249)	1.2	Orange value used (assumption tree crop)
7 Coffee, green (656)	1.2	Orange value used (assumption tree crop)
8 Cotton seed (328)	0.85	Table 24 (Allen et al., 1998)
9 Groundnuts (242)	0.7	Table 24 (Allen et al., 1998)
10 Maize (56)	1.25	Table 24 (Allen et al., 1998)
11 Millet (79)	0.9	Same value assumed as for sorghum; drought resistant crops
12 Oil palm (254)	1.2	Orange value used (assumption tree crop)
13 Orange (490)	1.2	Table 24 (Allen et al., 1998)
14 Plantain (489)	1.3	Value used of banana, similar crop type
15 Potato (116)	1.1	Table 24 (Allen et al., 1998)
16 Rice (27)	1.35	Sehpaskhah & Shaabani (n.d)
17 Sorghum (83)	0.9	Table 24 (Allen et al., 1998)
18 Soybean (236)	0.85	Table 24 (Allen et al., 1998)
19 Sugarcane (156)	1.2	Table 24 (Allen et al., 1998)
20 Sunflower (267)	0.95	Table 24 (Allen et al., 1998)
21 Sweet potato (122)	1.2	Gomes & Carr (2003)
22 Wheat (15)	1.05	Table 24 (Allen et al., 1998)

A1.2 Preparation of GIS-maps

A1.2.1 Sources of spatially explicit maps on cultivated area and yield of crops

The spatially explicit maps on the cultivated area and yield of crops are obtained from different sources. The data are obtained mainly from the database of Monfreda et al. (2008) which contains data on the cultivated area and yields of 175 crops. In this case data is obtained for the 22 crops as given in table 17. When the spatially explicit data of Monfreda et al. (2008) has no data or only poor data (rescaling ratios to FAO (2009 c) statistics higher than 8) on a specific crop in a country, as reported in table 17, and the FAO reports that this crop is cultivated, than spatially-explicit data on the cultivated area of that crop for that country is obtained from the dataset of Leff et al. (2004) when available and of better quality. The latter database contains data on 18 major crops.

Note: In the spatially explicit data of Monfreda et al. (2008) on cultivated area and yields of crops, data on Mauritius and Seychelles is missing unfortunately.

A1.2.2 Operations carried out on spatially explicit data

In this section is described which steps have been taken to get the spatially explicit data and to convert and adapt this data, so that it possible to use the data for the computation of the water footprint of crops:

- The data is downloaded from the sources as given in section 2.2. Of the world map, present in the ArcGIS 9.3 database (COUNTRY.shp), a mask of the SADC countries has been made on which the rest of the data can be clipped. The SADC mask consists of the SADC countries only. As spatial reference GWS 1984 is used.
- Of the SADC shape file has been made a raster file.
- The txt. and asc. files of crop yields and crop hectares of Ramankutty (n.d.) are converted to raster files (ASCII) for 22 crops considered. The crops have been selected based on the list of major water consuming crops as described in section 2.1.1. Also Boolean maps of the area equipped for irrigation and areas without equipment for irrigation have been made.
- The unrescaled yield and ha files of the crops (as given by Ramankutty (n.d.)) and the irrigation areas shp. and raster file (as given by Siebert et al., 2007) have been clipped on the SADC mask. In this way only the data for the SADC region is left over.
- Layer with grid size in ha placed over the world to make computations in ha possible. This layer is clipped on the SADC area as well.
- The geo-data on cultivated area per crop of Ramankutty (n.d.) are adjusted to the average cultivated area per crop over the time period 1997-2003 based on the dataset of FAO (2009 c). This time period has been used, because the data of the GIS-maps is based on this time period as well (Monfreda et al., 2008). The rescaling has been done by multiplying the crop area raster by the grid size raster (in ha) and rescaling the cultivated area in ha per crop for each country with the FAO (2009 c) cultivated area data by multiplying the GIS map with a rescaling ratio, i.e. FAO (2009 c) cultivated area

divided by cultivated area according to the GIS-data of Monfreda et al. (2008) for that country.
The maps are rescaled to the FAO (2009 c) data, because the assumption is made that the FAO (2009 c) data is more reliable than the GIS-maps for crops, because this is official data and it has yearly variations in the data compared to the GIS-data which is for the year 2000 only. Also the raster files are quite crude because of uncertainties in measuring and due to grid size restrictions. The adjustment ratios for the Monfreda et al. (2008) dataset are standing in table 18A.

In the dataset of Monfreda et al. (2008), for some countries geodata on cultivated area of a certain crop is missing while the FAO (2009 c) reports cultivated area, yield and production for that crop in that country. When the crop, of which the data is missing, is one of the 18 major crops Leff et al. (2004) investigated, the dataset of Monfreda et al. 2008) has been improved by adding data from the dataset of Leff et al. (2004). Sometimes in this dataset however the data was also lacking. If so, than it was not possible to compute a WF for this crop for the specific country.
Also geodata, as reported by Monfreda et al. (2008), was sometimes very poor for some crops in a country, because there where too few grid cells (and thus hectares) reported by them compared to the FAO (2009 c) data. This leads to very high adjustment ratios. For these crops and countries, the dataset has been tried to improve with the dataset of Leff et al. (2004). In table 18B the adjustment ratios of the improved dataset can be seen. Especially the geo-data of rice and wheat improved.

For these countries and crops no geo-data is available (table 18B):

- of Mauritius and Seychelles geo-data on crops is missing;
- banana cultivation in Swaziland;
- cashew cultivation in Angola;
- oil palm and soybean cultivation in Madagascar;
- orange cultivation in Tanzania and Zambia.

For these crops the adjustment ratios are quite large (table 18B):

- cotton in Angola and Namibia;
- coffee in Mozambique and Zambia;
- groundnuts in Swaziland;
- orange in DRC and Mozambique;
- sorghum in Madagascar;
- sweet potato in Zambia and Zimbabwe;
- wheat cultivation in Swaziland;

So it could be concluded that there are errors and shortcomings in the GIS-data, because the adjustment ratios for some crops in some countries are really high or even geo-data is missing. The rest of the data is quite and the adjustment ratios are often between 0.5 and 2, what is acceptable. These deviations are still large (50 to 100%), but the data is giving at least a crude, but quite well impression of the cultivation areas of crops for the SADC region. Better data is also not available.

- The GIS-data and the main data file containing the crop parameters are combined so that the crop water use and yield of each crop per grid cell can be computed. The FIPS-code is used for the combination. Before this operation is possible, all the data of the main data file and the GIS-data per crop need to be converted to txt. files. The resulting dataset per crop can be implemented in the crop water use model.

- The rescaled cultivation area data needs to be split into crop area that is irrigated and crop are that is not. The distribution of the irrigated area for each crop is done based on equation (40). So first the irrigated area of each crop is assigned to the overlap between the areas equipped for irrigation (based on Siebert & Döll (2008)) and the rescaled cultivation area of the crop. Second, if this area is not large enough, than the remaining part is spread evenly over the area without AEI.

  The GIS-data on irrigated area is rescaled to the irrigated area dataset of Portmann et al. (2008) which is mainly based on official FAO (2005 a) country data. It is believed that the latter dataset is more reliable, because it specifies the hectares irrigated per crop in each country based on official FAO data. Siebert & Döll (2008) mention only the area equipped for irrigation; not which crop is irrigated at each spot. In the grid data are also more uncertainties caused by grid size and measuring restrictions compared to the data of Portmann et al. (2008). In table 19 the adjustment ratios for the irrigated areas per crop are given for the AEI and for the areas without AEI.
  Some crops have very large adjustment ratios, meaning that the AEI map of Siebert & Döll (2008) or the geo-data on cultivation area of each crop are not complete or totally correct. In table 19A large adjustment ratios (greater than 1), mean that 100% of the intersection between the cultivated areas and the AEI map is irrigated for this crop. So an adjustment ratio above one is taken as one in the area distribution, so that the rest of the hectares can be assigned to the area without AEI. Hence the remaining irrigated hectares are distributed to the part cultivated that has no intersection with the AEI map (table 19B). In table 19B cells with 1 mean that the crop is 100% irrigated in that specific country.

  There is a miss match between the rescaled geo-data and the data of Portmann et al. (2008) in the reported cultivation area of coffee in South Africa. Portmann et al. (2005) report 2500 ha of irrigated coffee while FAO (2009 c), Monfreda et al. (2009) and Leff et al. (2004) report no cultivation of coffee in South Africa.

- After the computation of the water use (equations 15-24) and yield (with equation 13) of each crop in every grid cell, the yield and production data computed needs to be rescaled to FAO (2009 c) data. This is just simply done by:

$$\mathrm{Prod}_{rescaled} = \mathrm{Prod}_{tot,computed} \times \frac{\mathrm{Prod}_{FAO\ 2009\ c}}{\mathrm{Prod}_{tot,computed}} \qquad (40)$$

with *$Prod_{rescaled}$* rescaled production of specific crop (ton/yr);
$Prod_{tot,computed}$ production computed based on yield formula in equation 13 and total cultivated area of specific crop (ton/yr);
$Prod_{FAO\ 2009\ c}$ production of specific crop as reported by FAO (2009 c) (ton/yr).

Now, the WFs can be computed easily with the method described in chapter 2. In table 20 the production adjustment ratios are presented. The model showed to be very sensitive for the input parameter planting date. Because the model does not take wilting of a crop into account, it does not stop the computation when a plant is dead. This result in very low yields and a high evaporative demand of the crop that is larger than the CWR, which is not possible of course. When the planting date is adjusted, the adjustment ratios are all quite reasonable for each crop, meaning that equation 13 gives an acceptable basic relation between evapotranspiration of the crop and crop yield.

Table 17. Overview of major water consuming crops for which the spatially explicit data of Ramankutty (n.d.) have been extracted.

Crop	FAO crop code	Group	Annual/perennial	Herbaceous/shrub/tree
1 Banana	486	Fruit	Perennial	Shrub
2 Bean	176	Pulses	Annual	Herbaceous
3 Cashew	217	Tree nuts	Perennial	Tree
4 Cassava	125	Roots and tubers	Annual	Herbaceous
5 Clove	698	Other	Perennial	Tree
6 Coconut	249	Oil crops	Perennial	Tree
7 Coffee, green	656	Other	Perennial	Shrub
8 Cotton seed	328	Fiber	Annual	Herbaceous
9 Groundnuts	242	Oil crops	Annual	Herbaceous
10 Maize	56	Cereals	Annual	Herbaceous
11 Millet	79	Cereals	Annual	Herbaceous
12 Oil palm	254	Oil crops	Perennial	Tree
13 Orange	490	Fruit	Perennial	Tree
14 Plantain	489	Fruit	Perennial	Shrub
15 Potato	116	Roots and tubers	Annual	Herbaceous
16 Rice	27	Cereals	Annual	Herbaceous
17 Sorghum	83	Cereals	Annual	Herbaceous
18 Soybean	236	Oil crops	Annual	Herbaceous
19 Sugarcane	156	Sugar crops	Perennial	Herbaceous
20 Sunflower seed	267	Oil crops	Annual	Herbaceous
21 Sweet potato	122	Roots and tubers	Annual	Herbaceous
22 Wheat	15	Cereals	Annual	Herbaceous

Table 68. Cultivated area adjustment ratios for each crop. In part A the ratios are given based on Monfreda et al. (2008) data only. In part B this data has been improved with data of Leff et al. (2004). The cells with #DIV/0! mean that there is no GIS data available for this crop in that country.

A: Cultivated area adjustment ratios based on Monfreda et al. (2008) only

Country	Maize	Cas-sava	Rice	Sugar -cane	Plan -tain	Cotton	Coffee	Ground -nut	Coco-nut	Sorg-hum	Banana	Sun-flower	Bean	Wheat	Millet	Oil palm	Swt potato	Pota-to	Cashew	Clo-ve	Orange	Soy-bean
Angola	1.08	1.09	8.75	21.25	0	7.59	0.99	1.46	0	0	1.44	6.61	1.08	#DIV/0!	1.10	2.08	1.41	3.48	#DIV/0!	0	0	0
Botswana	1.21	0	0	0	0	3.36	0	1.06	0	1.06	0	1.10	0	1.66	0.64	0	0	0	0	0	0.85	0
DRC	1.00	1.00	1.03	1.20	1.10	1.12	1.07	1.00	0	0.13	1.14	0	1.04	85.36	1.22	0.87	1.30	1.07	0	0	8.80	1.35
Lesotho	1.26	0	0	0	0	0	0	0	0	1.30	0	0	1.13	1.28	0	0	0	1.14	0	0	0	0
Madagascar	1.65	1.17	1.17	1.17	0	1.20	1.01	1.46	1.13	#DIV/0!	1.09	0	1.81	7.99	0	#DIV/0!	1.55	2.29	1.39	0.98	1.52	#DIV/0
Malawi	2.21	1.58	1.75	1.63	1.42	1.59	2.30	2.05	0	2.69	1.28	2.49	1.88	3.09	2.22	0	0	1.41	0	0	0	0
Mozambique	1.36	1.91	2.38	3.89	0	1.30	70.14	1.20	1.22	1.19	2.61	1.49	0	35.91	1.07	0	6.25	5.81	1.16	0	139.67	0
Namibia	1.05	0	0	0	0	8.15	0	153.64	0	2.54	0	2.49	0	#DIV/0!	2.36	0	0	0	0	0	0	0
South Africa	1.18	0	#DIV/0!	1.22	0	1.03	0	1.13	0	1.11	1.09	1.01	1.09	1.08	1.81	0	2.19	1.15	0	0	1.08	1.05
Swaziland	0.94	0	#DIV/0!	1.02	0	0.75	0	0.96	0	1.33	#DIV/0!	0	1.02	13.21	0	0	1.14	1.05	0	0	1.00	0
Tanzania	2.08	1.77	1.74	2.56	1.11	1.20	1.11	1.12	1.09	1.46	1.19	1.13	1.15	1.11	1.25	104.90	1.10	1.37	1.11	3.56	#DIV/0!	41.32
Zambia	1.08	1.03	1.39	1.88	0	1.39	16.36	0.91	0	1.20	0.52	1.33	0	1.40	1.02	0	17.58	0.35	0	0	#DIV/0!	1.61
Zimbabwe	1.36	1.15	5.98	1.10	0	1.39	2.96	1.14	0	1.16	1.35	1.74	1.09	1.03	1.16	0	23.47	26.97	0	0	1.39	1.06

B: Cultivated area adjustment ratios based on a combination of Monfreda et al. (2008) data and Leff et al. (2004) data

Country	Maize	Cas-sava	Rice	Sugar -cane	Plan -tain	Cotton	Coffee	Ground -nut	Coco -nut	Sorg-hum	Banana	Sun-flower	Bean	Wheat	Millet	Oil palm	Swt potato	Pota-to	Cashew	Clo-ve	Orange	Soy-bean
Angola	1.08	1.09	0.22	0.50	0	7.59	0.99	1.46	0	0	1.44	6.61	1.08	0.37	1.10	2.08	1.41	3.48	#DIV/0!	0	0	0
Botswana	1.21	0	0	0	0	3.36	0	1.06	0	1.06	0	1.10	0	1.66	0.64	0	0	0	0	0	0.85	0
DRC	1.00	1.00	1.03	1.20	1.10	1.12	1.07	1.00	0	0.13	1.14	0	1.04	0.51	1.22	0.87	1.30	1.07	0	0	8.80	1.35
Lesotho	1.26	0	0	0	0	0	0	0	0	1.30	0	0	1.13	1.28	0	0	0	1.14	0	0	0	0
Madagascar	1.65	1.17	1.17	1.17	0	1.20	1.01	1.46	1.13	242.13	1.09	0	1.81	2.25	0	#DIV/0!	1.55	2.29	1.39	0.98	1.52	#DIV/0
Malawi	2.21	1.58	1.75	1.63	1.42	1.59	2.30	2.05	0	2.69	1.28	2.49	1.88	3.09	2.22	0	0	1.41	0	0	0	0
Mozambique	1.36	1.91	2.38	3.89	0	1.30	70.14	1.20	1.22	1.19	2.61	1.49	0	35.91	1.07	0	6.25	5.81	1.16	0	139.67	0
Namibia	1.05	0	0	0	0	8.15	0	0.07	0	2.54	0	2.49	0	0.53	2.36	0	0	0	0	0	0	0
South Africa	1.18	0	0.29	1.22	0	1.03	0	1.13	0	1.11	1.09	1.01	1.09	1.08	1.81	0	2.19	1.15	0	0	1.08	1.05
Swaziland	0.94	0	0.01	1.02	0	0.75	0	0.96	0	1.33	#DIV/0!	0	1.02	0	0	0	1.14	1.05	0	0	1.00	0
Tanzania	2.08	1.77	1.74	2.56	1.11	1.20	1.11	1.12	1.09	1.46	1.19	1.13	1.15	1.11	1.25	1.10	1.10	1.37	1.11	3.56	#DIV/0!	0.59
Zambia	1.08	1.03	1.39	1.88	0	1.39	16.36	0.91	0	1.20	0.52	1.33	0	1.40	1.02	0	17.58	0.35	0	0	#DIV/0!	1.61
Zimbabwe	1.36	1.15	5.98	1.10	0	1.39	2.96	1.14	0	1.16	1.35	1.74	1.09	1.03	1.16	0	23.47	1.85	0	0	1.39	1.06

Table 79. The adjustment ratios for the irrigated areas per crop. For some countries the adjustment factors are quite large especially for rice, sugarcane, and sunflower.

Country	Maize	Cas-sava	Rice	Sugar-cane	Plan-tain	Cotton	Coffee	Ground-nut	Coco-nut	Sorg-hum	Banana	Sun-flower	Bean	Wheat	Millet	Oil palm	Swt potato	Potato	Cashew	Clove	Orange	Soy-bean
A: Ratios for adjustment of areas equipped for irrigation*																						
Angola	0	0	260.31	173.30	0	0	0	0	0	0	#DIV/0!	0	0	0	0	0	0	0	0	0	0	0
Botswana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.29	0
DRC	0	0	0.44	52.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lesotho	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Madagascar	0	0	0.99	0.53	0	2.86	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Malawi	0	0	0.12	1.69	0	0	1.91	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mozambique	0.04	0	0.37	3.59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	#DIV/0!	0
Namibia	4.01	0	0	0	0	#DIV/0!	0	0	0	0	0	0	0	3.75	0	0	0	0	0	0	0	0
South Africa	0.11	0	3.61	2.26	0	3.07	#DIV/0!	0.93	0	0.38	3.41	4.09	3.24	0.66	0.38	0	0.95	2.95	0	0	2.98	0.11
Swaziland	0.05	0	3.07	7.13	0	0	0	0	0	0	#DIV/0!	0	0	0	0	0	0	0.18	0	0	1.74	0
Tanzania	0.18	0	1.47	0	0	0.82	0	0	0	0	4.53	0	0	0	0	0	0	0	0	0	0	0
Zambia	0.02	0	24.64	15.21	0	0	4.87	0	0	0	3.54	0	0	3.53	0	0	#DIV/0!	0	0	0	#DIV/0!	0
Zimbabwe	0.07	0	#DIV/0!	6.63	0	0.26	9.07	0.04	0	0.06	0	21.28	0	8.25	0	0	0	6.71	0	0	1.95	2.78
B: Ratios for adjustment of areas without equipment for irrigation**																						
Angola	0	0	1.00	0.87	0	0	0	0	0	0	0.11	0	0	0	0	0	0	0	0	0	0	0
Botswana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DRC	0	0	0	0.15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lesotho	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Madagascar	0	0	0	0	0	0.82	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Malawi	0	0	0	1.00	0	0	1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mozambique	0	0	0	0.24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.06	0
Namibia	0.08	0	0	0	0	0.22	0	0	0	0	0	0	0	0.93	0	0	0	0	0	0	0	0
South Africa	0	0	0.99	0.15	0	1.00	#DIV/0!	0	0	0	0.99	0.03	1.00	0	0	0	0	0.75	0	0	0.97	0
Swaziland	0	0	1.00	0.98	0	0	0	0	0	0	#DIV/0!	0	0	0	0	0	0	0	0	0	0.12	0
Tanzania	0	0	0.06	0	0	0	0	0	0	0	0.35	0	0	0	0	0	0	0	0	0	0	0
Zambia	0	0	0.70	1.00	0	0	1.00	0	0	0	1.00	0	0	0.87	0	0	0.07	0	0	0	#DIV/0!	0
Zimbabwe	0	0	0.95	0.77	0	0	0.85	0	0	0	0	0.10	0	1.00	0	0	0	0.93	0	0	0.14	0.24

* In part A of the table the cells with the code *#DIV/0!* are standing for countries where the GIS maps on AEI for irrigation have no overlap with the cultivation area of the specific crop.

** In part B of the table the cells with the code *#DIV/0!* are standing for countries where the GIS maps have no cultivation data for this crop in the specific country at all, however FAO (2005 a) reports irrigated areas for these crops.

Table 20. Production adjustment ratios for all crops. In part A the planting date of the grey shaded crops has not yet been adjusted, in part B they are. The model gives much better result with the correct planting date, because the adjustment ration are less high.

A: Production adjustment ratios for crops with uncorrected planting date

Country	Maize	Cas-sava	Rice	Sugar-cane	Plan-tain	Cotton	Coffee	Ground-nut	Coco-nut	Sorg-hum	Banana	Sun-flower	Bean	Wheat	Millet	Oil palm	Swt potato	Potato	Cashew	Clove	Orange	Soy-bean
Angola	4.29	10.54	0.89	0.96	0	1.79	1.69	1.28	0	0	2.16	0.92	8.23	2.79	1.69	1.85	0.76	4.96	#DIV/0!	0	0	0
Botswana	6.42	0	0	0	0	3.50	0	0.68	0	1.09	0	1.15	0	2.22	1.91	0	0	0	0	0	0.45	0
DRC	1.81	2.10	2.01	1.63	1.49	1.43	1.53	0.99	0	1.59	1.60	0	1.76	1.79	1.53	1.54	0.96	1.18	0	0	1.22	0.88
Lesotho	1.27	0	0	0	0	0	0	0	0	0.84	0	0	1.58	0.93	0	0	0	2.22	0	0	0	0
Madagascar	1.58	1.39	1.33	1.19	0	0.91	0.95	0.90	1.37	0.84	1.70	0	1.66	0.92	0	#DIV/0!	0.95	0.93	1.32	1.31	1.09	#DIV/0!
Malawi	4.76	10.74	7.05	0.85	4.02	2.08	0.86	0.92	0	1.46	4.15	0.87	4.11	1.82	1.36	0	0	1.07	0	0	0	0
Mozambique	3.32	5.18	12.36	1.55	0	2.05	1.61	0.93	2.47	1.47	4.11	0.88	0	0.70	1.38	0	1.29	1.26	2.38	0	1.91	0
Namibia	2.29	0	0	0	0	1.66	0	1.42	0	1.56	0	0.52	0	1.01	1.47	0	0	0	0	0	0	0
South Africa	2.66	0	0.90	1.27	0	0.77	0	1.36	0	1.18	0.76	0.99	0.86	1.13	1.07	0	1.28	1.03	0	0	0.85	1.56
Swaziland	1.24	0	0.83	0.84	0	0.95	0	1.08	0	0.98	#DIV/0!	0	1.85	1.29	0	0	0.89	1.70	0	0	0.99	0
Tanzania	3.49	6.82	4.52	3.12	3.33	1.71	2.31	1.02	2.24	1.56	1.52	1.07	3.20	1.57	1.46	1.89	1.17	1.28	2.05	2.07	#DIV/0!	1.04
Zambia	6.08	24.74	1.23	0.85	0	2.01	1.45	1.71	0	1.73	0.23	0.86	0	0.89	1.69	0	7.41	1.04	0	0	#DIV/0!	2.69
Zimbabwe	3.99	22.78	2.15	1.04	0	1.80	0.93	1.65	0	1.53	6.75	0.87	5.62	0.88	1.56	0	0.74	0.93	0	0	1.49	1.52

B: Production adjustment ratios for crops with corrected planting date

Country	Maize	Cas-sava	Rice	Bean	Potato	Sugar-cane	Swt potato
Angola	0.88	1.23	0.89	8.35	4.96	0.92	0.76
Botswana	0.95	0	0	0	0	0	0
DRC	1.02	1.28	1.85	1.53	1.18	1.63	0.96
Lesotho	1.34	0	0	1.85	2.13	0	0
Madagascar	0.89	1.00	1.01	2.06	0.93	1.19	0.95
Malawi	0.86	1.07	1.23	7.43	1.07	0.85	0
Mozambique	0.91	1.16	11.90	0	1.26	1.55	1.29
Namibia	2.28	0	0	0	0	0	0
South Africa	1.05	0	0.90	0.85	1.03	1.27	1.37
Swaziland	1.24	0	0.83	1.99	1.70	0.84	0.89
Tanzania	1.03	1.37	4.52	2.96	1.28	3.12	1.17
Zambia	0.86	1.12	1.22	0	0.96	0.85	7.41
Zimbabwe	0.88	1.23	2.15	5.58	0.93	1.04	0.91

* Cells with *#DIV/0!* inside are caused by the fact that the GIS maps lack cultivation data for the specific crop while FAO (2009 c) reports cultivation of the crop.

A2 Water footprint of crops

Banana

Country	Rainfed area (ha)	Irrigated area (ha)	Rainfed yield (ton/ha)	Irrigated yield (ton/ha)	Rainfed production (ton/yr)	Irrigated production (ton/yr)	WF green (m^3/ton)	WF blue (m^3/ton)	WF grey (m^3/ton)	WF total (m^3/ton)	WU green (10^6 m^3/yr)	WU blue (10^6 m^3/yr)	WU grey (10^6 m^3/yr)
Angola	27500	3500	7.97	23.23	219189	81317	807	37	4	848	242.48	11.12	1.12
Botswana	0	0	0	0	0	0	0	0	0	0	0	0	0
DRC	84225	0	3.74	0	314731	0	2580	0	2	2581	811.89	0	0.50
Lesotho	0	0	0	0	0	0	0	0	0	0	0.00	0	0
Madagascar	48500	0	5.80	0	281509	0	1848	0	0	1848	520.13	0	0
Malawi	15590	0	14.25	0	222203	0	543	0	7	550	124.89	0	1.70
Mozambique	13750	0	6.44	0	88601	0	1191	0	32	1223	105.57	0	2.83
Namibia	0	0	0	0	0	0	0	0	0	0	0	0	0
South Africa	96	13300	6.58	22.73	631	302287	297	371	104	772	102.56	128.15	36.10
Swaziland	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tanzania	36166	24994	1.07	4.26	38681	106552	3255	958	18	4231	478.57	140.80	2.69
Zambia	0	230	0	3.22	0	740	2876	4958	39	7872	2.11	3.64	0.03
Zimbabwe	17950	0	4.80	0	86100	0	2662	0	11	2673	229.27	0	0.98
SADC average			5.13	11.68			1500	163	26	1688			
SADC total	243777	42024			1251645	490896					2617.46	283.71	45.94

*For Swaziland geospatial explicit data on the areas where bananas are growing is missing. According to the FAO (2009 c) the cropped area is 120 ha/yr and average production is 500 ton/yr over the period 1996-2005.

Bean

Country	Rainfed area (ha)	Irrigated area (ha)	Rainfed yield (ton/ha)	Irrigated yield (ton/ha)	Rainfed production (ton/yr)	Irrigated production (ton/yr)	WF green (m^3/ton)	WF blue (m^3/ton)	WF grey (m^3/ton)	WF total (m^3/ton)	WU green (10^6 m^3/yr)	WU blue (10^6 m^3/yr)	WU grey (10^6 m^3/yr)
Angola	230864	0	0.35	0	80717	0	1729	0	47	1776	143.30	0	3.88
Botswana	0	0	0	0	0	0	0	0	0	0	0	0	0
DRC	223353	0	0.54	0	120835	0	3928	0	22	3951	474.68	0	2.66
Lesotho	10190	0	0.80	0	8131	0	1369	0	105	1474	11.13	0	0.86
Madagascar	82955	0	0.91	0	75875	0	1629	0	0	1629	123.78	0	0
Malawi	176853	0	0.48	0	84966	0	1969	0	61	2030	169.80	0	5.26
Mozambique	0	0	0	0	0	0	0	0	0	0	0	0	0
Namibia	0	0	0	0	0	0	0	0	0	0	0	0	0
South Africa	0	56572	0	1.30	0	73599	706	1140	1787	3633	52.39	84.67	132.63
Swaziland	4141	0	0.61	0	2519	0	2250	0	731	2980	5.24	0	1.70
Tanzania	369401	0	0.74	0	271832	0	2680	0	31	2711	727.51	0	8.38
Zambia	0	0	0	0	0	0	0	0	0	0	0	0	0
Zimbabwe	61194	0	0.75	0	45726	0	1284	0	44	1329	58.04	0	2.01
SADC average			0.60	1.3			2311	111	206	2627			
SADC total	1158951	56572			690601	73599					1765.86	84.67	157.39

Cashew

Country	Rainfed area (ha)	Irrigated area (ha)	Rainfed yield (ton/ha)	Irrigated yield (ton/ha)	Rainfed production (ton/yr)	Irrigated production (ton/yr)	WF green (m^3/ton)	WF blue (m^3/ton)	WF grey (m^3/ton)	WF total (m^3/ton)	WU green (10^6 m^3/yr)	WU blue (10^6 m^3/yr)	WU grey (10^6 m^3/yr)
Angola	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Botswana	0	0	0	0	0	0	0	0	0	0	0	0	0
DRC	0	0	0	0	0	0	0	0	0	0	0	0	0
Lesotho	0	0	0	0	0	0	0	0	0	0	0	0	0
Madagascar	16100	0	0.41	0	6600	0	19037	0	0	19037	125.60	0	0
Malawi	0	0	0	0	0	0	0	0	0	0	0	0	0
Mozambique	56580.8	0	1.00	0	56814	0	5461	0	55	5516	316.76	0	3.21
Namibia	0	0	0	0	0	0	0	0	0	0	0	0	0
South Africa	0	0	0	0	0	0	0	0	0	0	0	0	0
Swaziland	0	0	0	0	0	0	0	0	0	0	0	0	0
Tanzania	79033.8	0	1.11	0	87990	0	5743	0	40	5783	504.58	0	3.51
Zambia	0	0	0	0	0	0	0	0	0	0	0	0	0
Zimbabwe	0	0	0	0	0	0	0	0	0	0	0	0	0
SADC average			1.00	0			6210	0	44	6254			
SADC total	151715	0			151404	0					946.94	0	6.72

*For Angola geospatial explicit data on the areas where cashew is growing is missing. According to the FAO (2009 c) the cropped area is 2760 ha/yr and average production is 1090 ton/yr over the period 1996-2005.

Cassava

Country	Rainfed area (ha)	Irrigated area (ha)	Rainfed yield (ton/ha)	Irrigated yield (ton/ha)	Rainfed production (ton/yr)	Irrigated production (ton/yr)	WF green (m^3/ton)	WF blue (m^3/ton)	WF grey (m^3/ton)	WF total (m^3/ton)	WU green (10^6 m^3/yr)	WU blue (10^6 m^3/yr)	WU grey (10^6 m^3/yr)
Angola	599834	0	8.60	0	5160180	0	602	0	0	602	3001.99	0	0.79
Botswana	0	0	0	0	0	0	0	0	0	0	0	0	0
DRC	1947780	0	8.11	0	15804300	0	617	0	0	617	9751.46	0	0.92
Lesotho	0	0	0	0	0	0	0	0	0	0	0	0	0
Madagascar	356945	0	6.69	0	2388970	0	897	0	0	897	2139.73	0	0
Malawi	142720	0	12.02	0	1715800	0	473	0	2	475	804.81	0	3.13
Mozambique	995656	0	5.78	0	5758640	0	1010	0	1	1011	5838.44	0	3.29
Namibia	0	0	0	0	0	0	0	0	0	0	0	0	0
South Africa	0	0	0	0	0	0	0	0	0	0	0	0	0
Swaziland	0	0	0	0	0	0	0	0	0	0	0	0	0
Tanzania	677184	0	9.63	0	6524020	0	551	0	5	556	3604.43	0	30.78
Zambia	154011	0	5.79	0	891906	0	911	0	29	939	816.64	0	25.78
Zimbabwe	40491	0	4.27	0	173000	0	1316	0	4	1321	227.54	0	0.77
SADC average			7.82	0			682	0	2	683			
SADC total	4914621	0			38416816	0					26185.04	0	65.46

Clove

Country	Rainfed area (ha)	Irrigated area (ha)	Rainfed yield (ton/ha)	Irrigated yield (ton/ha)	Rainfed production (ton/yr)	Irrigated production (ton/yr)	WF green (m^3/ton)	WF blue (m^3/ton)	WF grey (m^3/ton)	WF total (m^3/ton)	WU green (10^6 m^3/yr)	WU blue (10^6 m^3/yr)	WU grey (10^6 m^3/yr)
Angola	0	0	0	0	0	0	0	0	0	0	0	0	0
Botswana	0	0	0	0	0	0	0	0	0	0	0	0	0
DRC	0	0	0	0	0	0	0	0	0	0	0	0	0
Lesotho	0	0	0	0	0	0	0	0	0	0	0	0	0
Madagascar	74758	0	0.18	0	13573	0	54972	0	0	54972	764.38	0	0
Malawi	0	0	0	0	0	0	0	0	0	0	0	0	0
Mozambique	0	0	0	0	0	0	0	0	0	0	0	0	0
Namibia	0	0	0	0	0	0	0	0	0	0	0	0	0
South Africa	0	0	0	0	0	0	0	0	0	0	0	0	0
Swaziland	0	0	0	0	0	0	0	0	0	0	0	0	0
Tanzania	12550	0	0.67	0	8417	0	11821	0	64	11885	98.82	0	0.54
Zambia	0	0	0	0	0	0	0	0	0	0	0	0	0
Zimbabwe	0	0	0	0	0	0	0	0	0	0	0	0	0
SADC average			0.25	0			39254	0	24	39278			
SADC total	87308	0			21990	0					863.19	0	0.54

Coconut

Country	Rainfed area (ha)	Irrigated area (ha)	Rainfed yield (ton/ha)	Irrigated yield (ton/ha)	Rainfed production (ton/yr)	Irrigated production (ton/yr)	WF green (m^3/ton)	WF blue (m^3/ton)	WF grey (m^3/ton)	WF total (m^3/ton)	WU green (10^6 m^3/yr)	WU blue (10^6 m^3/yr)	WU grey (10^6 m^3/yr)
Angola	0	0	0	0	0	0	0	0	0	0	0	0	0
Botswana	0	0	0	0	0	0	0	0	0	0	0	0	0
DRC	0	0	0	0	0	0	0	0	0	0	0	0	0
Lesotho	0	0	0	0	0	0	0	0	0	0	0	0	0
Madagascar	33000	0	2.55	0	84252	0	3815	0	0	3815	321.42	0	0
Malawi	0	0	0	0	0	0	0	0	0	0	0	0	0
Mozambique	91780	0	4.25	0	389901	0	1630	0	12	1642	635.71	0	4.80
Namibia	0	0	0	0	0	0	0	0	0	0	0	0	0
South Africa	0	0	0	0	0	0	0	0	0	0	0	0	0
Swaziland	0	0	0	0	0	0	0	0	0	0	0	0	0
Tanzania	309963	0	1.18	0	365495	0	6485	0	37	6522	2369.70	0	13.52
Zambia	0	0	0	0	0	0	0	0	0	0	0	0	0
Zimbabwe	0	0	0	0	0	0	0	0	0	0	0	0	0
SADC average			1.93	0			3945	0	22	3967			
SADC total	434743	0			839648	0					3326.83	0	18.32

Coffee, green

Country	Rainfed area (ha)	Irrigated area (ha)	Rainfed yield (ton/ha)	Irrigated yield (ton/ha)	Rainfed production (ton/yr)	Irrigated production (ton/yr)	WF green (m^3/ton)	WF blue (m^3/ton)	WF grey (m^3/ton)	WF total (m^3/ton)	WU green (10^6 m^3/yr)	WU blue (10^6 m^3/yr)	WU grey (10^6 m^3/yr)
Angola	85800	0	0.03	0	2976	0	248019	0	1081	249099	712.67	0	3.11
Botswana	0	0	0	0	0	0	0	0	0	0	0	0	0
DRC	125152	0	0.37	0	45850	0	24564	0	13	24578	1148.62	0	0.63
Lesotho	0	0	0	0	0	0	0	0	0	0	0	0	0
Madagascar	185359	0	0.34	0	62572	0	32565	0	0	32565	2072.55	0	0
Malawi	0	3140	0	1.07	0	3348	6470	6715	446	13631	21.19	22.00	1.46
Mozambique	1155	0	0.65	0	755	0	9979	0	740	10718	7.43	0	0.55
Namibia	0	0	0	0	0	0	0	0	0	0	0	0	0
South Africa	0	0	0	0	0	0	0	0	0	0	0	0	0
Swaziland	0	0	0	0	0	0	0	0	0	0	0	0	0
Tanzania	117470	0	0.40	0	47223	0	17877	0	54	17931	840.91	0	2.56
Zambia	0	4660	0	0.92	0	4306	8641	8957	54	17652	37.06	38.41	0.23
Zimbabwe	800	5200	0.64	1.55	511	8048	5191	3997	13	9200	43.81	33.73	0.11
SADC average			0.31	1.21			27816	536	49	28402			
SADC total	515736	13000			159888	15701					4884.24	94.14	8.64

Cotton seed

Country	Rainfed area (ha)	Irrigated area (ha)	Rainfed yield (ton/ha)	Irrigated yield (ton/ha)	Rainfed production (ton/yr)	Irrigated production (ton/yr)	WF green (m^3/ton)	WF blue (m^3/ton)	WF grey (m^3/ton)	WF total (m^3/ton)	WU green (10^6 m^3/yr)	WU blue (10^6 m^3/yr)	WU grey (10^6 m^3/yr)
Angola	6300	0	1.10	0	6940	0	3935	0	105	4040	29.78	0	0.79
Botswana	1055	0	2.48	0	2620	0	783	0	84	867	2.05	0	0.22
DRC	68900	0	0.41	0	28460	0	8551	0	17	8568	243.11	0	0.48
Lesotho	0	0	0	0	0	0	0	0	0	0	0	0	0
Madagascar	2480	17243	0.79	1.24	1957	21310	3121	2145	178	5444	70.45	48.41	4.03
Malawi	54470	0	0.87	0	47395	0	2683	0	26	2709	127.07	0	1.24
Mozambique	136675	0	0.53	0	72886	0	4298	0	74	4372	322.09	0	5.54
Namibia	2494	690	1.06	2.73	2640	1882	1586	463	113	2162	7.01	2.05	0.50
South Africa	0	58898	0	1.36	0	80265	2177	2812	132	5120	196.78	254.15	11.89
Swaziland	18878	0	0.77	0	14583	0	5651	0	56	5707	100.68	0	0.99
Tanzania	314533	25000	0.56	1.22	177114	30424	4862	278	160	5301	990.96	56.67	32.63
Zambia	75251	35	1.15	2.72	86455	95	2210	1	148	2359	192.59	0.09	12.88
Zimbabwe	307590	27300	0.74	1.75	226469	47747	2897	234	297	3427	808.62	65.27	82.86
SADC average			0.68	1.41			3640	502	181	4324			
SADC total	988627	129166			667519	181722					3091.21	426.64	154.07

Groundnut

Country	Rainfed area (ha)	Irrigated area (ha)	Rainfed yield (ton/ha)	Irrigated yield (ton/ha)	Rainfed production (ton/yr)	Irrigated production (ton/yr)	WF green (m^3/ton)	WF blue (m^3/ton)	WF grey (m^3/ton)	WF total (m^3/ton)	WU green (10^6 m^3/yr)	WU blue (10^6 m^3/yr)	WU grey (10^6 m^3/yr)
Angola	85275	0	0.37	0	31364	0	5258	0	89	5347	175.01	0	2.97
Botswana	1873	0	0.28	0	522	0	3520	0	1982	5502	4.58	0	2.58
DRC	487529	0	0.78	0	379315	0	4043	0	5	4048	1533.68	0	1.89
Lesotho	0	0	0	0	0	0	0	0	0	0	0	0	0
Madagascar	48310	0	0.78	0	37744	0	5541	0	0	5541	207.82	0	0
Malawi	168716	0	0.75	0	126405	0	5483	0	212	5695	679.43	0	26.24
Mozambique	277411	0	0.43	0	118346	0	10051	0	119	10170	1191.52	0	14.10
Namibia	464	0	0.51	0	237	0	2606	0	845	3451	0.63	0	0.21
South Africa	65066	23600	1.29	2.32	83694	54660	903	366	1645	2914	126.48	51.26	230.30
Swaziland	5723	0	0.97	0	5528	0	3032	0	375	3407	16.71	0	2.07
Tanzania	117481	0	0.52	0	60900	0	6822	0	82	6904	416.14	0	4.98
Zambia	104829	0	0.42	0	44179	0	3070	0	408	3477	136.98	0	18.19
Zimbabwe	213418	1399	0.54	1.00	114676	1401	2833	20	37	2890	322.07	2.32	4.15
SADC average			0.64	2.24			4542	51	290	4883			
SADC total	1576095	24999			1002911	56061					4811.06	53.59	307.67

Maize

Country	Rainfed area (ha)	Irrigated area (ha)	Rainfed yield (ton/ha)	Irrigated yield (ton/ha)	Rainfed production (ton/yr)	Irrigated production (ton/yr)	WF green (m^3/ton)	WF blue (m^3/ton)	WF grey (m^3/ton)	WF total (m^3/ton)	WU green (10^6 m^3/yr)	WU blue (10^6 m^3/yr)	WU grey (10^6 m^3/yr)
Angola	772340	0	0.64	0	494016	0	6066	0	36	6102	3017.94	0	17.93
Botswana	52058	0	0.20	0	10582	0	27067	0	1201	28267	270.37	0	11.99
DRC	1464180	0	0.80	0	1165550	0	4624	0	7	4631	5390.13	0	8.20
Lesotho	136688	0	0.87	0	118782	0	2599	0	182	2781	311.37	0	21.79
Madagascar	198242	0	1.14	0	226482	0	3831	0	0	3831	855.19	0	0
Malawi	1421350	0	1.27	0	1799170	0	3224	0	141	3365	5855.04	0	255.75
Mozambique	1214080	4249	0.99	1.06	1196600	4500	4628	0.53	57	4686	5559.83	0.63	68.66
Namibia	24722	2713	0.84	3.06	20721	8289	1891	80	412	2384	59.34	2.50	12.94
South Africa	3443570	128796	2.68	3.25	9216850	418742	1725	11	215	1950	16682.47	103.21	2077.64
Swaziland	64032	500	1.55	2.29	99352	1145	1763	3	79	1845	175.77	0.32	7.84
Tanzania	2813700	57001	0.91	1.19	2558350	68040	4245	24	101	4369	11866.39	65.94	280.94
Zambia	578542	1500	1.64	1.65	949142	2472	2545	0.07	96	2641	2400.65	0.06	90.59
Zimbabwe	1422840	18000	1.06	1.11	1514320	20011	4357	1	281	4639	6678.27	2.00	430.19
SADC average			1.42	2.46			2972	9	165	3146			
SADC total	13606345	212758			19369917	523199					59122.77	174.67	3284.48

* For Botswana the WF of maize has a minor error, because the CWR is slightly smaller than the WF (26801 m^3/ton vs. 27067 m^3/ton respectively). This means that the crop has evaporated more water than that it could do; so the crop has wilted. Probably there is an error of a few weeks in the planting date, because the deviation is so minor (see chapter 4). The deviation is so small, that the currently computed WF gives at least a good indication of the real WF of maize in Botswana.

Millet

Country	Rainfed area (ha)	Irrigated area (ha)	Rainfed yield (ton/ha)	Irrigated yield (ton/ha)	Rainfed production (ton/yr)	Irrigated production (ton/yr)	WF green (m^3/ton)	WF blue (m^3/ton)	WF grey (m^3/ton)	WF total (m^3/ton)	WU green (10^6 m^3/yr)	WU blue (10^6 m^3/yr)	WU grey (10^6 m^3/yr)
Angola	237594	0	0.47	0	111326	0	2753	0	40	2793	309.60	0	4.53
Botswana	3192	0	0.19	0	612	0	6731	0	294	7026	3.39	0	0.15
DRC	57609	0	0.66	0	38120	0	2261	0	11	2272	86.19	0	0.41
Lesotho	0	0	0	0	0	0	0	0	0	0	0	0	0
Madagascar	0	0	0	0	0	0	0	0	0	0	0	0	0
Malawi	35499	0	0.55	0	19530	0	3097	0	42	3139	60.76	0	0.82
Mozambique	92995	0	0.52	0	48073	0	3101	0	65	3166	149.85	0	3.14
Namibia	246201	0	0.26	0	64075	0	6179	0	116	6295	391.28	0	7.36
South Africa	18654	2246	0.56	0.73	10462	1638	2842	112	4590	7544	34.38	1.36	55.52
Swaziland	0	0	0	0	0	0	0	0	0	0	0	0	0
Tanzania	236837	0	0.86	0	203480	0	2096	0	25	2121	434.14	0	5.18
Zambia	70166	0	0.68	0	47791	0	2149	0	101	2250	102.30	0	4.81
Zimbabwe	190499	0	0.30	0	57612	0	4841	0	70	4911	268.41	0	3.90
SADC average			0.51	0.73			3053	2	142	3198			
SADC total	1189246	2246			601081	1638					1840.28	1.36	85.82

Oil palm

Country	Rainfed area (ha)	Irrigated area (ha)	Rainfed yield (ton/ha)	Irrigated yield (ton/ha)	Rainfed production (ton/yr)	Irrigated production (ton/yr)	WF green (m^3/ton)	WF blue (m^3/ton)	WF grey (m^3/ton)	WF total (m^3/ton)	WU green (10^6 m^3/yr)	WU blue (10^6 m^3/yr)	WU grey (10^6 m^3/yr)
Angola	22730	0	12.12	0	275497	0	647	0	2	650	178.3069	0	0.66527
Botswana	0	0	0	0	0	0	0	0	0	0	0	0	0
DRC	190018	0	5.75	0	1091900	0	1430	0	0	1430	1588.6585	0	0.410109
Lesotho	0	0	0	0	0	0	0	0	0	0	0	0	0
Madagascar	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Malawi	0	0	0	0	0	0	0	0	0	0	0	0	0
Mozambique	0	0	0	0	0	0	0	0	0	0	0	0	0
Namibia	0	0	0	0	0	0	0	0	0	0	0	0	0
South Africa	0	0	0	0	0	0	0	0	0	0	0	0	0
Swaziland	0	0	0	0	0	0	0	0	0	0	0	0	0
Tanzania	4480	0	13.82	0	61900	0	565	0	3	568	34.942029	0	0.188104
Zambia	0	0	0	0	0	0	0	0	0	0	0	0	0
Zimbabwe	0	0	0	0	0	0	0	0	0	0	0	0	0
SADC average			6.58	0			1242	0	1	1243			
SADC total	217228	0			1429297	0					1801.9074	0	1.263483

*For Madagascar geospatial explicit data on the areas where oil palms are growing is missing. According to the FAO (2009 c) the cropped area is 1800 ha/yr and average production is 21,000 ton/yr over the period 1996-2005.

Orange

Country	Rainfed area (ha)	Irrigated area (ha)	Rainfed yield (ton/ha)	Irrigated yield (ton/ha)	Rainfed production (ton/yr)	Irrigated production (ton/yr)	WF green (m^3/ton)	WF blue (m^3/ton)	WF grey (m^3/ton)	WF total (m^3/ton)	WU green (10^6 m^3/yr)	WU blue (10^6 m^3/yr)	WU grey (10^6 m^3/yr)
Angola	0	0	0	0	0	0	0	0	0	0	0	0	0
Botswana	120	20	2.62	11.98	316	234	1127	112	226	1466	0.62	0.06	0.12
DRC	12179	0	15.34	0	186849	0	469	0	0	469	87.56	0	0.07
Lesotho	0	0	0	0	0	0	0	0	0	0	0	0	0
Madagascar	13110	0	6.43	0	84350	0	1216	0	0	1216	102.61	0	0
Malawi	0	0	0.00	0	0	0	0	0	0	0	0.00	0	0
Mozambique	3282	198	3.69	9.19	12103	1824	1305	32	41	1378	18.24	0.45	0.57
Namibia	0	0	0	0	0	0	0	0	0	0	0	0	0
South Africa	1094	46116	12.40	24.95	13561	1150670	218	166	32	417	253.53	192.51	37.47
Swaziland	4934	1566	5.21	6.59	25711	10323	1364	58	21	1442	49.15	2.08	0.74
Tanzania	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Zambia	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Zimbabwe	10964	3786	4.01	11.06	43930	41870	973	125	4	1102	83.37	10.68	0.35
SADC average			8.03	23.31			378	131	25	533			
SADC total	45683	51686			366820	1204921					595.08	205.78	39.33

*For Tanzania and Zambia geospatial explicit data on the areas where oranges are growing is missing. According to the FAO (2009 c) the cropped area is 138 ha/yr and average production is 710 ton/yr over the period 1996-2005 for Tanzania. For Zambia the cropped area is 940 ha/yr and average production is 3540 ton/yr over the period 1996-2005.

Plantain

Country	Rainfed area (ha)	Irrigated area (ha)	Rainfed yield (ton/ha)	Irrigated yield (ton/ha)	Rainfed production (ton/yr)	Irrigated production (ton/yr)	WF green (m^3/ton)	WF blue (m^3/ton)	WF grey (m^3/ton)	WF total (m^3/ton)	WU green (10^6 m^3/yr)	WU blue (10^6 m^3/yr)	WU grey (10^6 m^3/yr)
Angola	0	0	0	0	0	0	0	0	0	0	0	0	0
Botswana	0	0	0	0	0	0	0	0	0	0	0	0	0
DRC	267872	0	4.47	0	1197980	0	2282	0	0	2283	2734.86	0	0.57
Lesotho	0	0	0	0	0	0	0	0	0	0	0	0	0
Madagascar	0	0	0	0	0	0	0	0	0	0	0	0	0
Malawi	37800	0	6.12	0	231301	0	1263	0	5	1268	310.75	0	1.12
Mozambique	0	0	0	0	0	0	0	0	0	0	0	0	0
Namibia	0	0	0	0	0	0	0	0	0	0	0	0	0
South Africa	0	0	0	0	0	0	0	0	0	0	0	0	0
Swaziland	0	0	0	0	0	0	0	0	0	0	0	0	0
Tanzania	263852	0	2.20	0	580923	0	4069	0	24	4093	2429.14	0	14.37
Zambia	0	0	0	0	0	0	0	0	0	0	0	0	0
Zimbabwe	0	0	0	0	0	0	0	0	0	0	0	0	0
SADC average			3.53	0			2723	0	8	2731			
SADC total	569524	0			2010204	0					5474.75	0	16.07

Potato

Country	Rainfed area (ha)	Irrigated area (ha)	Rainfed yield (ton/ha)	Irrigated yield (ton/ha)	Rainfed production (ton/yr)	Irrigated production (ton/yr)	WF green (m^3/ton)	WF blue (m^3/ton)	WF grey (m^3/ton)	WF total (m^3/ton)	WU green (10^6 m^3/yr)	WU blue (10^6 m^3/yr)	WU grey (10^6 m^3/yr)
Angola	11121	0	11.50	0	127887	0	126	0	3	129	13.36	0	0.34
Botswana	0	0	0	0	0	0	0	0	0	0	0	0	0
DRC	19377	0	4.65	0	90166	0	720	0	0	721	64.65	0	0.04
Lesotho	5180	0	16.41	0	85000	0	107	0	22	129	9.08	0	1.90
Madagascar	48061	0	5.74	0	275866	0	719	0	24	743	198.46	0	6.68
Malawi	135554	0	11.59	0	1570660	0	342	0	53	394	527.36	0	81.29
Mozambique	6130	0	12.69	0	77800	0	303	0	42	344	23.54	0	3.25
Namibia	0	0	0	0	0	0	0	0	0	0	0	0	0
South Africa	9716	44800	8.93	35.32	86738	1582400	44	73	56	173	73.51	122.97	94.74
Swaziland	2981	75	1.96	4.03	5853	303	1146	12	184	1341	7.05	0.07	1.13
Tanzania	36400	0	6.69	0	243596	0	548	0	7	555	133.69	0	1.73
Zambia	1037	0	10.99	0	11404	0	358	0	50	409	4.10	0	0.58
Zimbabwe	120	2020	2.39	16.69	287	33713	71	223	1	295	2.42	7.58	0.04
SADC average			9.34	34.47			252	31	46	329			
SADC total	275677	46895			2575257	1616416					1057	130.62	191.73

Rice

Country	Rainfed area (ha)	Irrigated area (ha)	Rainfed yield (ton/ha)	Irrigated yield (ton/ha)	Rainfed production (ton/yr)	Irrigated production (ton/yr)	WF green (m^3/ton)	WF blue (m^3/ton)	WF grey (m^3/ton)	WF total (m^3/ton)	WU green (10^6 m^3/yr)	WU blue (10^6 m^3/yr)	WU grey (10^6 m^3/yr)
Angola	0	6758	0	1.32	0	8894	3473	1166	151	4790	33.28	11.18	1.44
Botswana	0	0	0	0	0	0	0	0	0	0	0	0	0
DRC	435611	1943	0.75	1.61	327504	3131	10361	6	4	10371	3422.70	2.01	1.30
Lesotho	0	0	0	0	0	0	0	0	0	0	0	0	0
Madagascar	676072	531197	1.97	2.58	1332490	1372010	3118	227	4	3348	8422.08	611.98	10.81
Malawi	42443	2806	1.58	2.27	67218	6361	3784	50	379	4213	276.05	3.64	27.67
Mozambique	168452	4130	0.66	12.61	111895	52086	1816	9	22	1847	296.31	1.48	3.56
Namibia	0	0	0	0	0	0	0	0	0	0	0	0	0
South Africa	10	1340	0.42	2.30	4	3086	1166	1623	892	3680	3.60	5.01	2.76
Swaziland	0	48	0	4.01	0	192	706	755	321	1783	0.14	0.15	0.06
Tanzania	416380	89001	0.10	9.16	42215	815317	2055	138	116	2309	1829.70	122.63	103.55
Zambia	3342	8000	0.04	1.63	144	13053	1117	2646	147	3910	14.83	35.16	1.95
Zimbabwe	12	230	0.31	2.33	4	536	1188	1910	13	3111	0.63	1.02	0.01
SADC average			1.08	3.52			3441	191	37	3668			
SADC total	1742322	645452			1881474	2274667					14299.34	794.25	153.11

* For the DRC, South Africa and Swaziland the WF of rice has minor errors, because the CWR is slightly smaller than the WF (9821 m^3/ton vs. 10367 m^3/ton; 2600 m^3/ton vs. 2789 m^3/ton; 1440 m^3/ton vs. 1461 m^3/ton respectively). This means that the crop has evaporated more water than that it could do; so the crop has wilted. Probably there is an error of a few weeks in the planting date, because the deviation is so minor (see chapter 4). The deviation is so small, that the currently computed WF gives at least a good indication of the real WF of rice for these countries.

Sorghum

Country	Rainfed area (ha)	Irrigated area (ha)	Rainfed yield (ton/ha)	Irrigated yield (ton/ha)	Rainfed production (ton/yr)	Irrigated production (ton/yr)	WF green (m^3/ton)	WF blue (m^3/ton)	WF grey (m^3/ton)	WF total (m^3/ton)	WU green (10^6 m^3/yr)	WU blue (10^6 m^3/yr)	WU grey (10^6 m^3/yr)
Angola	0	0	0	0	0	0	0	0	0	0	0	0	0
Botswana	58576	0	0.38	0	22036	0	3557	0	142	3699	115.78	0	4.62
DRC	10093	0	0.66	0	6681	0	2653	0	11	2664	17.72	0	0.07
Lesotho	31436	0	0.84	0	26356	0	2447	0	98	2544	68.07	0	2.72
Madagascar	2001	0	0.49	0	990	0	6369	0	0	6369	6.31	0	0
Malawi	60913	0	0.65	0	39394	0	2878	0	193	3071	113.63	0	7.60
Mozambique	448264	0	0.65	0	293550	0	2697	0	52	2748	802.86	0	15.38
Namibia	22879	0	0.29	0	6557	0	6240	0	100	6341	41.06	0	0.66
South Africa	107045	11230	2.75	3.94	293891	44224	669	29	881	1580	225.27	9.67	296.62
Swaziland	1051	0	0.63	0	662	0	3932	0	647	4579	2.58	0	0.43
Tanzania	687947	0	1.01	0	692666	0	1983	0	22	2005	1371.99	0	15.05
Zambia	34940	0	0.70	0	24459	0	2266	0	257	2523	56.43	0	6.41
Zimbabwe	169513	842	0.52	0.93	88235	784	3150	8	45	3202	275.06	0.66	3.94
SADC average			0.91	3.73			2010	7	229	2246			
SADC total	1634658	12072			1495476	45008					3096.75	10.32	353.50

Soybean

Country	Rainfed area (ha)	Irrigated area (ha)	Rainfed yield (ton/ha)	Irrigated yield (ton/ha)	Rainfed production (ton/yr)	Irrigated production (ton/yr)	WF green (m^3/ton)	WF blue (m^3/ton)	WF grey (m^3/ton)	WF total (m^3/ton)	WU green (10^6 m^3/yr)	WU blue (10^6 m^3/yr)	WU grey (10^6 m^3/yr)
Angola	0	0	0	0	0	0	0	0	0	0	0	0	0
Botswana	0	0	0	0	0	0	0	0	0	0	0	0	0
DRC	25009	0	0.51	0	12653	0	4981	0	4	4985	64.89	0	0.05
Lesotho	0	0	0	0	0	0	0	0	0	0	0	0	0
Madagascar	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Malawi	0	0	0	0	0	0	0	0	0	0	0	0	0
Mozambique	0	0	0	0	0	0	0	0	0	0	0	0	0
Namibia	0	0	0	0	0	0	0	0	0	0	0	0	0
South Africa	109172	4000	1.56	2.87	170519	11479	961	26	20	1007	172.24	4.62	3.62
Swaziland	0	0	0	0	0	0	0	0	0	0	0	0	0
Tanzania	5270	0	0.37	0	1939	0	6660	0	122	6782	12.91	0	0.24
Zambia	12462	0	1.49	0	18608	0	748	0	49	796	12.90	0	0.84
Zimbabwe	39491	19400	1.15	3.12	45447	60616	633	360	356	1350	66.29	37.68	37.30
SADC average			1.30	3.08			1025	132	131	1287			
SADC total	191404	23400			249165	72095					329.22	42.30	42.05

*For Madagascar geospatial explicit data on the areas where soybeans are growing is missing. According to the FAO (2009 c) the cropped area is 50 ha/yr and average production is 54 ton/yr over the period 1996-2005.

Sugarcane

Country	Rainfed area (ha)	Irrigated area (ha)	Rainfed yield (ton/ha)	Irrigated yield (ton/ha)	Rainfed production (ton/yr)	Irrigated production (ton/yr)	WF green (m^3/ton)	WF blue (m^3/ton)	WF grey (m^3/ton)	WF total (m^3/ton)	WU green (10^6 m^3/yr)	WU blue (10^6 m^3/yr)	WU grey (10^6 m^3/yr)
Angola	1185	7875	20.03	40.16	23731	316270	191	113	64	367	64.96	38.32	21.59
Botswana	0	0	0	0	0	0	0	0	0	0	0	0	0
DRC	31698	5829	36.13	83.95	1145120	489329	161	12	3	176	265.33	19.39	4.28
Lesotho	0	0	0	0	0	0	0	0	0	0	0	0	0
Madagascar	51125	17050	28.06	46.04	1434690	784976	273	27	11	312	606.88	60.56	25.09
Malawi	0	19915	0	105.50	0	2101000	45	94	10	149	94.87	197.50	21.00
Mozambique	54874	23858	8.31	27.86	455957	664695	436	89	2	527	487.30	99.48	2.51
Namibia	0	0	0	0	0	0	0	0	0	0	0	0	0
South Africa	289932	90000	46.97	88.77	13618900	7989460	124	13	1	138	2762.21	285.05	21.20
Swaziland	731	41516	50.91	101.43	37199	4211000	70	50	0	121	299.46	213.08	0.88
Tanzania	15935	0	104.02	0	1657480	0	60	0	2	62	98.44	0	3.07
Zambia	0	18400	0	104.89	0	1930000	48	87	10	145	92.29	168.15	19.59
Zimbabwe	8713	33700	17.52	118.37	152682	3988950	42	67	4	113	175.32	276.03	15.81
SADC average			40.79	87.07			121	33	3	157			
SADC total	454192	258143			18525759	22475680					4947.06	1357.56	135.01

* For Malawi the WF of sugarcane has minor errors, because the CWR is slightly smaller than the WF (136 m^3/ton vs. 139 m^3/ton respectively). This means that the crop has evaporated more water than that it could do; so the crop has wilted. Probably there is an error of a few weeks in the planting date, because the deviation is so minor (see chapter 4). The deviation is so small, that the currently computed WF gives at least a good indication of the real WF of sugarcane for Malawi.

Sunflower seed

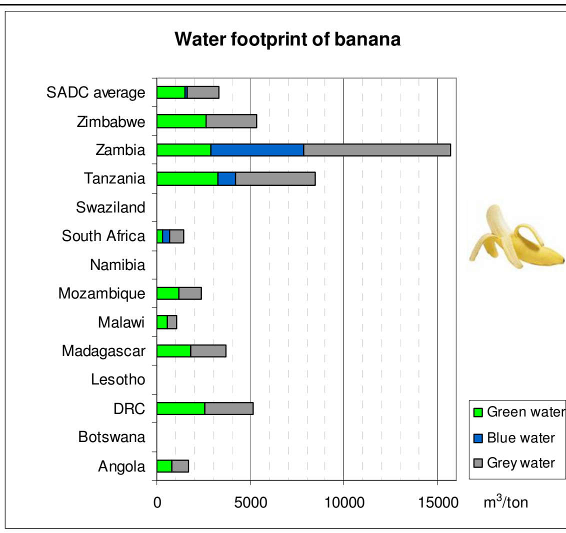
Country	Rainfed area (ha)	Irrigated area (ha)	Rainfed yield (ton/ha)	Irrigated yield (ton/ha)	Rainfed production (ton/yr)	Irrigated production (ton/yr)	WF green (m^3/ton)	WF blue (m^3/ton)	WF grey (m^3/ton)	WF total (m^3/ton)	WU green (10^6 m^3/yr)	WU blue (10^6 m^3/yr)	WU grey (10^6 m^3/yr)
Angola	14950	0	0.72	0	10800	0	5160	0	43	5203	55.71	0	0.47
Botswana	5390	0	1.10	0	5939	0	3425	0	339	3764	20.50	0	2.03
DRC	0	0	0	0	0	0	0	0	0	0	0	0	0
Lesotho	0	0	0	0	0	0	0	0	0	0	0	0	0
Madagascar	0	0	0	0	0	0	0	0	0	0	0	0	0
Malawi	8749	0	0.54	0	4758	0	7416	0	41	7457	35.48	0	0.19
Mozambique	23500	0	0.53	0	12500	0	8228	0	94	8323	102.28	0	1.17
Namibia	142	0	0.64	0	90	0	7746	0	697	8443	0.67	0	0.06
South Africa	371776	187524	1.21	1.45	449642	272671	3128	354	112	3594	2239.56	253.61	80.29
Swaziland	0	0	0	0	0	0	0	0	0	0	0	0	0
Tanzania	81690	0	0.35	0	28600	0	10230	0	125	10354	292.39	0	3.57
Zambia	21043	0	0.51	0	10663	0	8429	0	320	8748	88.69	0	3.36
Zimbabwe	32974	14113	0.49	0.53	16198	7479	8902	112	38	9051	208.43	2.61	0.89
SADC average			0.96	1.39			3715	313	112	4140			
SADC total	560214	201637			539191	280150					3043.72	256.22	92.04

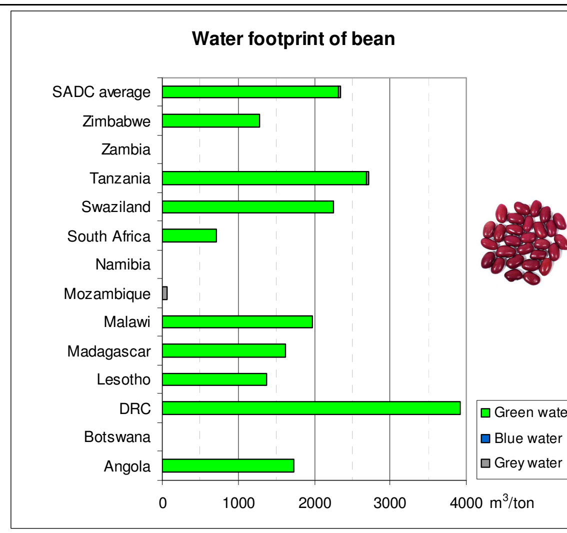
Sweet potato

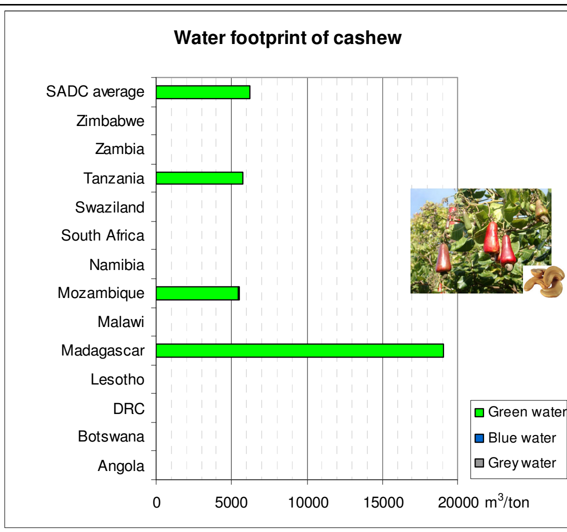
Country	Rainfed area (ha)	Irrigated area (ha)	Rainfed yield (ton/ha)	Irrigated yield (ton/ha)	Rainfed production (ton/yr)	Irrigated production (ton/yr)	WF green (m^3/ton)	WF blue (m^3/ton)	WF grey (m^3/ton)	WF total (m^3/ton)	WU green (10^6 m^3/yr)	WU blue (10^6 m^3/yr)	WU grey (10^6 m^3/yr)
Angola	75659	0	4.73	0	358207	0	876	0	0	877	392.23	0	0.13
Botswana	0	0	0	0	0	0	0	0	0	0	0	0	0
DRC	54209	0	4.94	0	267650	0	780	0	0	780	210.06	0	0.01
Lesotho	0	0	0	0	0	0	0	0	0	0	0	0	0
Madagascar	97514	0	5.62	0	548449	0	836	0	0	836	456.20	0	0
Malawi	0	0	0	0	0	0	0	0	0	0	0	0	0
Mozambique	8890	0	7.12	0	63300	0	550	0	0	550	34.79	0	0.03
Namibia	0	0	0	0	0	0	0	0	0	0	0	0	0
South Africa	11113	4100	2.94	5.11	32651	20942	803	96	987	1886	43.04	5.15	52.89
Swaziland	1344	0	1.79	0	2411	0	2774	0	27	2801	6.69	0	0.07
Tanzania	417143	0	1.86	0	773831	0	2236	0	3	2239	1714.19	0	2.17
Zambia	3464	246	14.63	17.19	50666	4226	291	2	0	293	15.96	0	0.02
Zimbabwe	745	0	2.12	0	1580	0	1414	0	1101	2516	2.23	0	1.74
SADC average			3.13	5.79			1354	2	27	1383			
SADC total	670081	4346			2098745	25168					2875.40	5.25	57.05

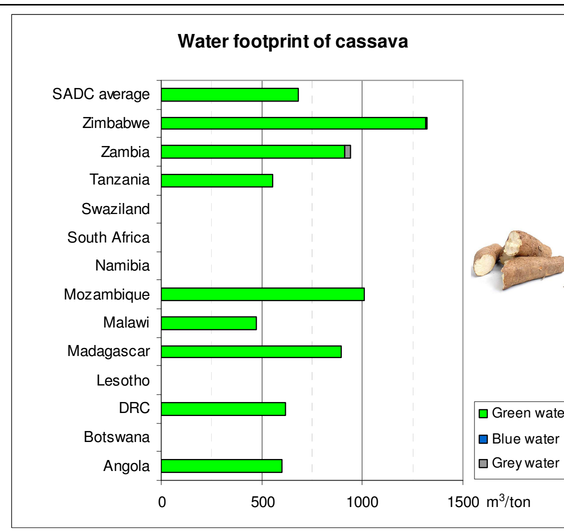
Wheat

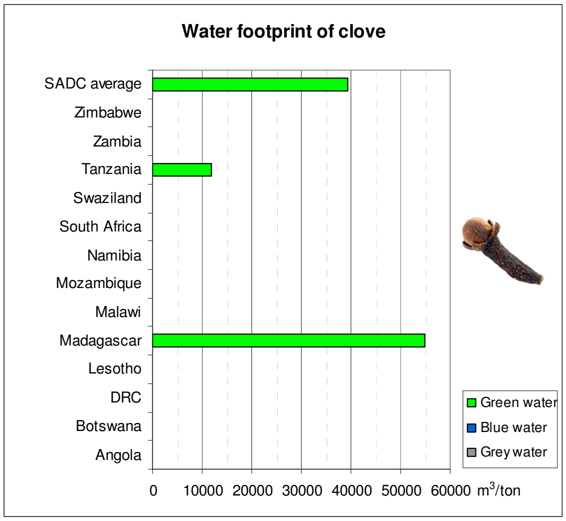
Country	Rainfed area (ha)	Irrigated area (ha)	Rainfed yield (ton/ha)	Irrigated yield (ton/ha)	Rainfed production (ton/yr)	Irrigated production (ton/yr)	WF green (m^3/ton)	WF blue (m^3/ton)	WF grey (m^3/ton)	WF total (m^3/ton)	WU green (10^6 m^3/yr)	WU blue (10^6 m^3/yr)	WU grey (10^6 m^3/yr)
Angola	2610	0	1.69	0	4400	0	921	0	20	941	4.05	0	0.09
Botswana	365	0	1.66	0	605	0	605	0	234	839	0.36	0	0.14
DRC	7289	0	1.28	0	9328	0	1558	0	8	1567	14.53	0	0.08
Lesotho	20561	0	1.44	0	29560	0	1403	0	58	1461	41.71	0	1.72
Madagascar	3700	0	2.38	0	8800	0	1042	0	361	1403	9.12	0	3.16
Malawi	2345	0	0.75	0	1763	0	2435	0	36	2471	4.30	0	0.06
Mozambique	1770	0	1.06	0	1870	0	1793	0	723	2516	3.32	0	1.34
Namibia	75	1356	1.35	5.08	102	6893	292	403	15	709	2.02	2.79	0.10
South Africa	720781	216599	2.04	3.04	1469490	657960	804	73	184	1061	1736.28	156.80	397.13
Swaziland	202	0	1.51	0	306	0	1400	0	270	1670	0.43	0	0.08
Tanzania	67779	0	1.29	0	87553	0	1644	0	37	1681	145.87	0	3.25
Zambia	1287	12200	3.17	6.60	4083	80542	322	291	29	642	27.23	24.63	2.46
Zimbabwe	0	42069	0	5.34	0	224801	259	407	159	825	57.01	89.74	35.07
SADC average			1.95	3.56			791	106	172	1068			
SADC total	828763	272224			1617859	970196					2046.24	273.96	444.69

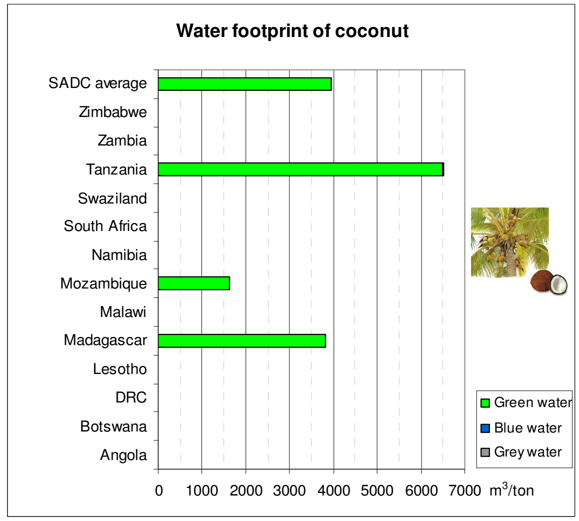


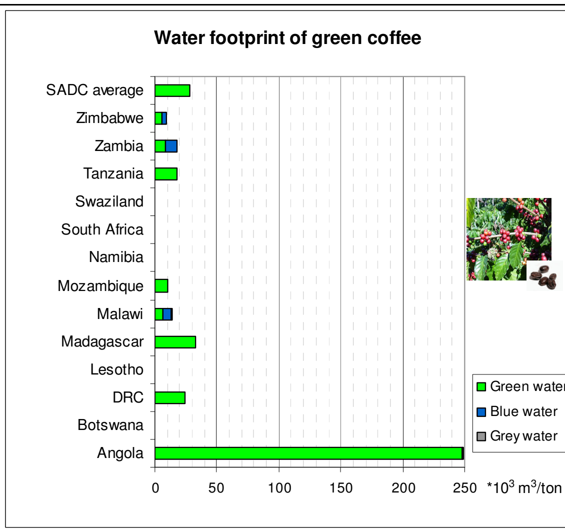


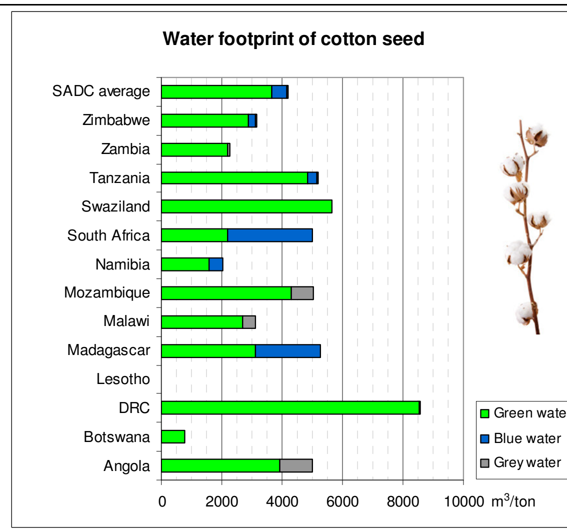


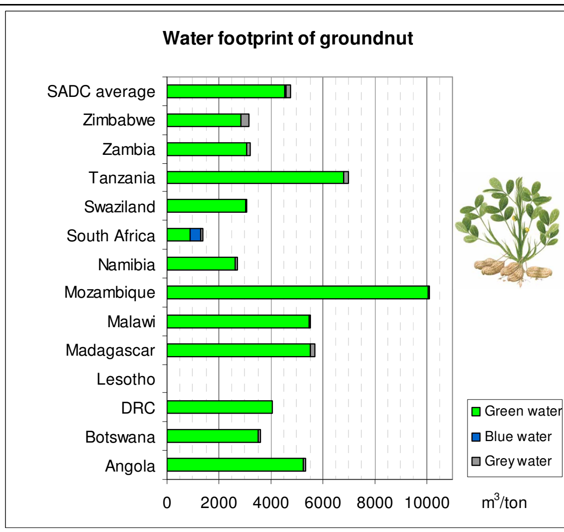


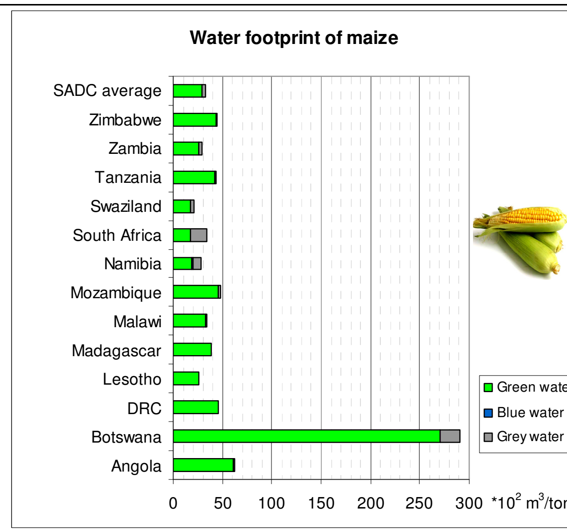

Water footprint of clove
SADC average
Zimbabwe
Zambia
Tanzania
Swaziland
South Africa
Namibia
Mozambique
Malawi
Madagascar
Lesotho
DRC
Botswana
Angola
Green water
Blue water
Grey water
0 10000 20000 30000 40000 50000 60000 m3/ton

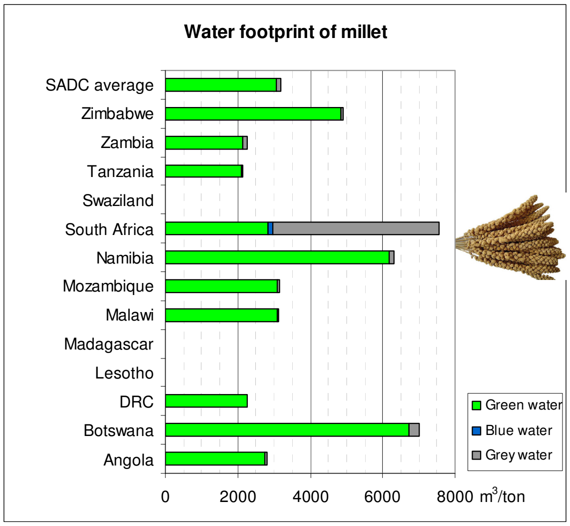

Water footprint of coconut
SADC average
Zimbabwe
Zambia
Tanzania
Swaziland
South Africa
Namibia
Mozambique
Malawi
Madagascar
Lesotho
DRC
Botswana
Angola
Green water
Blue water
Grey water
0 1000 2000 3000 4000 5000 6000 7000 m3/ton

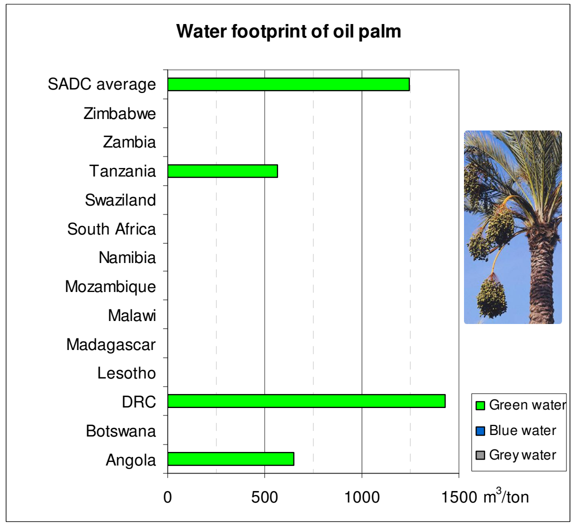

Water footprint of green coffee
SADC average
Zimbabwe
Zambia
Tanzania
Swaziland
South Africa
Namibia
Mozambique
Malawi
Madagascar
Lesotho
DRC
Botswana
Angola
Green water
Blue water
Grey water
0 50 100 150 200 250 *103 m3/ton

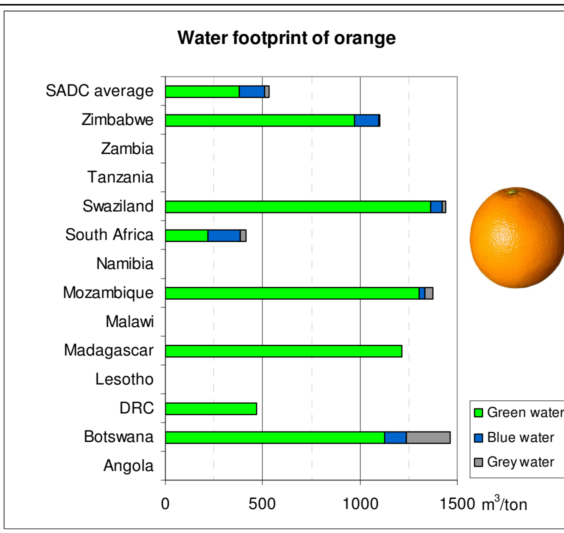

Water footprint of cotton seed
SADC average
Zimbabwe
Zambia
Tanzania
Swaziland
South Africa
Namibia
Mozambique
Malawi
Madagascar
Lesotho
DRC
Botswana
Angola
Green water
Blue water
Grey water
0 2000 4000 6000 8000 10000 m3/ton

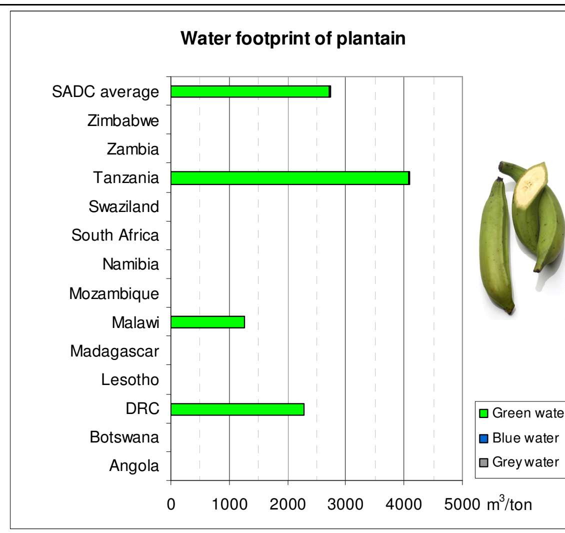

Water footprint of groundnut
SADC average
Zimbabwe
Zambia
Tanzania
Swaziland
South Africa
Namibia
Mozambique
Malawi
Madagascar
Lesotho
DRC
Botswana
Angola
Green water
Blue water
Grey water
0 2000 4000 6000 8000 10000 m3/ton

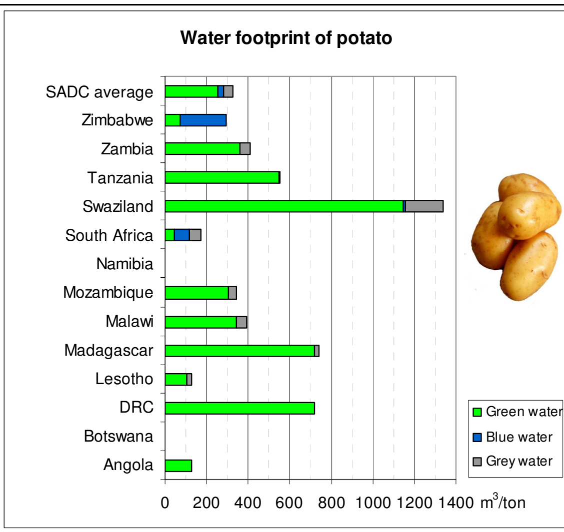

Water footprint of maize
SADC average
Zimbabwe
Zambia
Tanzania
Swaziland
South Africa
Namibia
Mozambique
Malawi
Madagascar
Lesotho
DRC
Botswana
Angola
Green water
Blue water
Grey water
0 50 100 150 200 250 300 *102 m3/ton

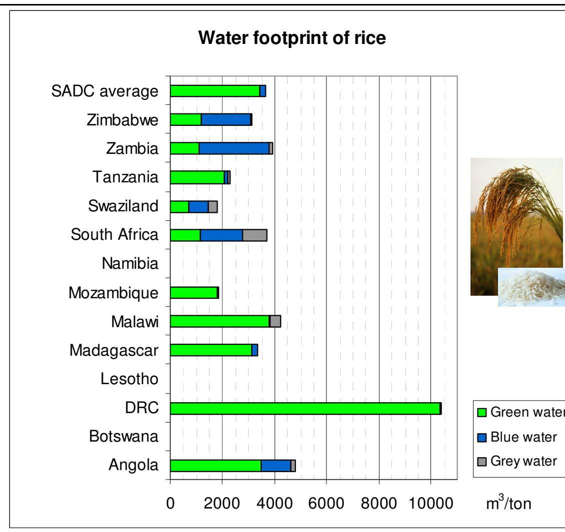

Water footprint of millet
SADC average
Zimbabwe
Zambia
Tanzania
Swaziland
South Africa
Namibia
Mozambique
Malawi
Madagascar
Lesotho
DRC
Botswana
Angola
0
2000
4000
6000
8000 m3/ton
Green water
Blue water
Grey water

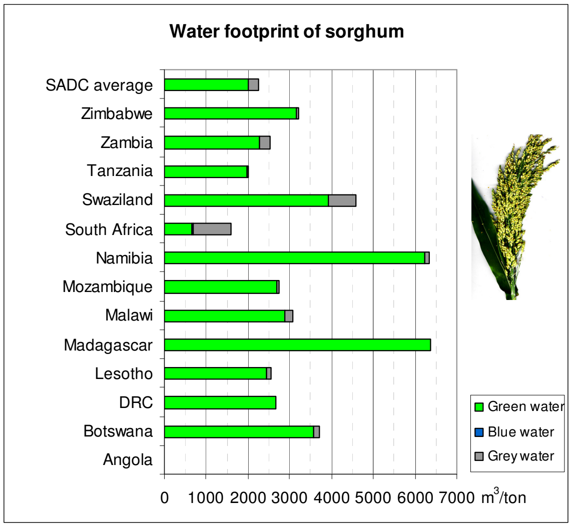

Water footprint of oil palm
SADC average
Zimbabwe
Zambia
Tanzania
Swaziland
South Africa
Namibia
Mozambique
Malawi
Madagascar
Lesotho
DRC
Botswana
Angola
0
500
1000
1500 m3/ton
Green water
Blue water
Grey water

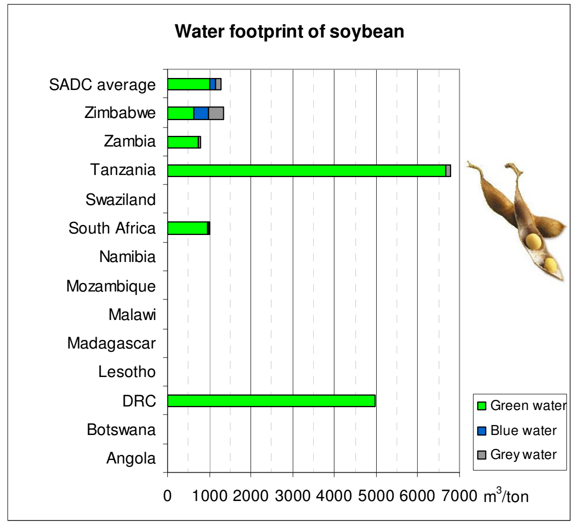

Water footprint of orange
SADC average
Zimbabwe
Zambia
Tanzania
Swaziland
South Africa
Namibia
Mozambique
Malawi
Madagascar
Lesotho
DRC
Botswana
Angola
0
500
1000
1500 m3/ton
Green water
Blue water
Grey water

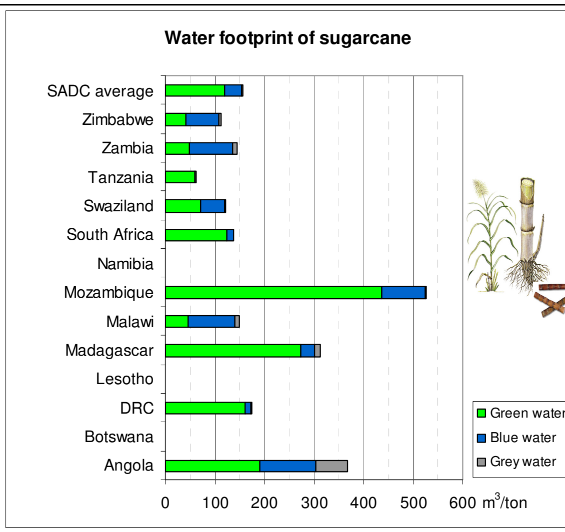

Water footprint of plantain
SADC average
Zimbabwe
Zambia
Tanzania
Swaziland
South Africa
Namibia
Mozambique
Malawi
Madagascar
Lesotho
DRC
Botswana
Angola
0
1000
2000
3000
4000
5000 m3/ton
Green water
Blue water
Grey water

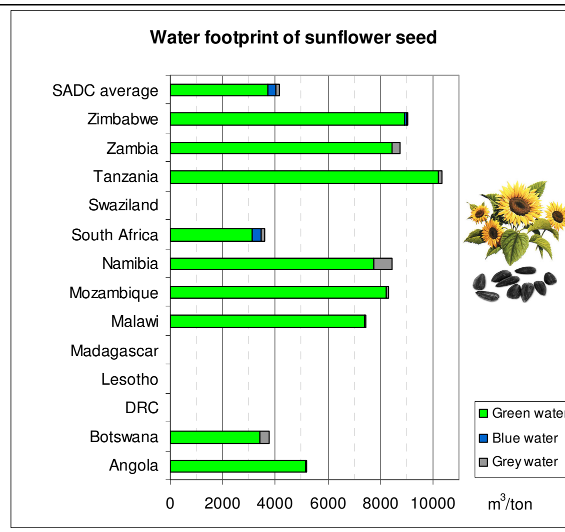

Water footprint of potato
SADC average
Zimbabwe
Zambia
Tanzania
Swaziland
South Africa
Namibia
Mozambique
Malawi
Madagascar
Lesotho
DRC
Botswana
Angola
0
200
400
600
800
1000
1200
1400 m3/ton
Green water
Blue water
Grey water

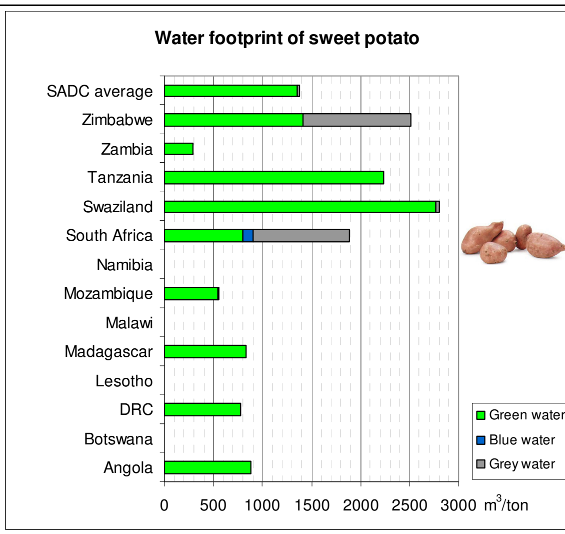

Water footprint of rice
SADC average
Zimbabwe
Zambia
Tanzania
Swaziland
South Africa
Namibia
Mozambique
Malawi
Madagascar
Lesotho
DRC
Botswana
Angola
0
2000
4000
6000
8000
10000
m3/ton
Green water
Blue water
Grey water

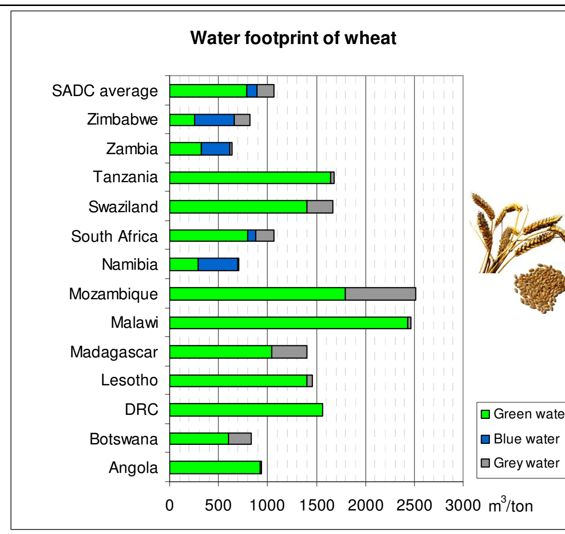

Water footprint of sorghum
SADC average
Zimbabwe
Zambia
Tanzania
Swaziland
South Africa
Namibia
Mozambique
Malawi
Madagascar
Lesotho
DRC
Botswana
Angola
0 1000 2000 3000 4000 5000 6000 7000 m3/ton
Green water
Blue water
Grey water


Water footprint of soybean
SADC average
Zimbabwe
Zambia
Tanzania
Swaziland
South Africa
Namibia
Mozambique
Malawi
Madagascar
Lesotho
DRC
Botswana
Angola
0 1000 2000 3000 4000 5000 6000 7000 m3/ton
Green water
Blue water
Grey water


Water footprint of sugarcane
SADC average
Zimbabwe
Zambia
Tanzania
Swaziland
South Africa
Namibia
Mozambique
Malawi
Madagascar
Lesotho
DRC
Botswana
Angola
0 100 200 300 400 500 600 m3/ton
Green water
Blue water
Grey water


Water footprint of sunflower seed
SADC average
Zimbabwe
Zambia
Tanzania
Swaziland
South Africa
Namibia
Mozambique
Malawi
Madagascar
Lesotho
DRC
Botswana
Angola
0 2000 4000 6000 8000 10000 m3/ton
Green water
Blue water
Grey water


Water footprint of sweet potato
SADC average
Zimbabwe
Zambia
Tanzania
Swaziland
South Africa
Namibia
Mozambique
Malawi
Madagascar
Lesotho
DRC
Botswana
Angola
0 500 1000 1500 2000 2500 3000 m3/ton
Green water
Blue water
Grey water


Water footprint of wheat
SADC average
Zimbabwe
Zambia
Tanzania
Swaziland
South Africa
Namibia
Mozambique
Malawi
Madagascar
Lesotho
DRC
Botswana
Angola
0 500 1000 1500 2000 2500 3000 m3/ton
Green water
Blue water
Grey water

A3 WF of crops: comparison between this study and Chapagain & Hoekstra (2004)

Banana

Country	Green-blue WF (this study) (1996-2005) (m³/ton)	(Green-blue) WF Chapagain et al. (2004) (1997-2001) (m³/ton)	Absolute difference (%)	A) Average yield Chapagain et al. (2004) (1997-2001) (ton/ha)	B) Average yield (this study) (1996-2005) (ton/ha)	Yield ratio (B/A) (-)	Reference WF (m³/ton)	Relative difference (%)
Angola	844	1643	-48.64	9.68	9.69	1.00	1640	-48.55
Botswana	0	0	0	0	0	0	0	0
DRC	2580	3615	-28.65	3.74	3.74	1.00	3615	-28.65
Lesotho	0	0	0	0	0	0	0	0
Madagascar	1848	2415	-23.48	5.81	5.80	1.00	2418	-23.56
Malawi	543	2962	-81.68	5.14	14.76	2.87	1031	-47.37
Mozambique	1191	2420	-50.77	6.44	6.44	1.00	2418	-50.72
Namibia	0	0	0	0	0	0	0	0
South Africa	667	1139	-41.44	15.20	25.81	1.70	671	-0.56
Swaziland	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tanzania	4213	5731	-26.48	2.46	2.40	0.98	5870	-28.23
Zambia	7834	6119	28.02	2.92	3.19	1.10	5587	40.20
Zimbabwe	2662	3690	-27.85	4.81	4.80	1.00	3701	-28.08

* No spatially explicit data available on banana cultivation for Swaziland; however cultivation reported by FAO (2009 c).

Bean

Country	Green-blue WF (this study) (1996-2005) (m³/ton)	(Green-blue) WF Chapagain et al. (2004) (1997-2001) (m³/ton)	Absolute difference (%)	A) Average yield Chapagain et al. (2004) (1997-2001) (ton/ha)	B) Average yield (this study) (1996-2005) (ton/ha)	Yield ratio (B/A) (-)	Reference WF (m³/ton)	Relative difference (%)
Angola	1729	8566	-79.81	0.38	0.36	0.93	9165	-81.13
Botswana	0	0	0	0	0	0	0	0
DRC	3928	5213	-24.65	0.54	0.54	1.00	5213	-24.64
Lesotho	1369	2215	-38.20	0.87	0.80	0.92	2418	-43.40
Madagascar	1629	2981	-45.37	0.92	0.92	1.00	2980	-45.34
Malawi	1969	7716	-74.48	0.45	0.49	1.07	7199	-72.65
Mozambique	0	0	0	0	0	0	0	0
Namibia	0	0	0	0	0	0	0	0
South Africa	1846	1924	-4.06	1.36	1.31	0.96	1996	-7.53
Swaziland	2250	2941	-23.49	0.78	0.56	0.72	4074	-44.77
Tanzania	2680	4402	-39.12	0.70	0.73	1.04	4218	-36.47
Zambia	0	0	0	0	0	0	0	0
Zimbabwe	1284	4417	-70.93	0.77	0.74	0.97	4576	-71.94

Cashew

Country	Green-blue WF (this study) (1996-2005) (m³/ton)	(Green-blue) WF Chapagain et al. (2004) (1997-2001) (m³/ton)	Absolute difference (%)	A) Average yield Chapagain et al. (2004) (1997-2001) (ton/ha)	B) Average yield (this study) (1996-2005) (ton/ha)	Yield ratio (B/A) (-)	Reference WF (m³/ton)	Relative difference (%)
Angola	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Botswana	0	0	0	0	0	0	0	0
DRC	0	0	0	0	0	0	0	0
Lesotho	0	0	0	0	0	0	0	0
Madagascar	19037	22687	-16.09	0.41	0.41	0.99	22889	-16.83
Malawi	0	0	0	0	0	0	0	0
Mozambique	5461	10878	-49.80	0.95	1.03	1.08	10028	-45.54
Namibia	0	0	0	0	0	0	0	0
South Africa	0	0	0	0	0	0	0	0
Swaziland	0	0	0	0	0	0	0	0
Tanzania	5743	7771	-26.09	1.24	1.11	0.90	8672	-33.77
Zambia	0	0	0	0	0	0	0	0
Zimbabwe	0	0	0	0	0	0	0	0

*No spatially explicit data available on cashew cultivation for Angola, however cultivation reported by FAO (2009 c).

Cassava

Country	Green-blue WF (this study) (1996-2005) (m³/ton)	(Green-blue) WF Chapagain et al. (2004) (1997-2001) (m³/ton)	Absolute difference (%)	A) Average yield Chapagain et al. (2004) (1997-2001) (ton/ha)	B) Average yield (this study) (1996-2005) (ton/ha)	Yield ratio (B/A) (-)	Reference WF (m³/ton)	Relative difference (%)
Angola	602	1094	-44.97	6.74	8.31	1.23	887	-32.09
Botswana	0	0	0	0	0	0	0	0
DRC	617	743	-16.97	8.11	8.11	1.00	743	-16.97
Lesotho	0	0	0	0	0	0	0	0
Madagascar	897	794	13.02	6.92	6.68	0.97	821	9.19
Malawi	473	687	-31.15	9.69	11.92	1.23	559	-15.33
Mozambique	1010	1061	-4.80	5.62	5.80	1.03	1029	-1.78
Namibia	0	0	0	0	0	0	0	0
South Africa	0	0	0	0	0	0	0	0
Swaziland	0	0	0	0	0	0	0	0
Tanzania	551	642	-14.19	9.64	9.66	1.00	641	-14.01
Zambia	911	1489	-38.85	5.76	5.82	1.01	1473	-38.20
Zimbabwe	1316	1765	-25.42	4.29	4.27	1.00	1773	-25.77

Clove

Country	Green-blue WF (this study) (1996-2005) (m³/ton)	(Green-blue) WF Chapagain et al. (2004) (1997-2001) (m³/ton)	Absolute difference (%)	A) Average yield Chapagain et al. (2004) (1997-2001) (ton/ha)	B) Average yield (this study) (1996-2005) (ton/ha)	Yield ratio (B/A) (-)	Reference WF (m³/ton)	Relative difference (%)
Angola	0	0	0	0	0	0	0	0
Botswana	0	0	0	0	0	0	0	0
DRC	0	0	0	0	0	0	0	0
Lesotho	0	0	0	0	0	0	0	0
Madagascar	54972	66039	-16.76	0.19	0.19	1.00	65968	-16.67
Malawi	0	0	0	0	0	0	0	0
Mozambique	0	0	0	0	0	0	0	0
Namibia	0	0	0	0	0	0	0	0
South Africa	0	0	0	0	0	0	0	0
Swaziland	0	0	0	0	0	0	0	0
Tanzania	11821	19022	-37.85	0.65	0.67	1.03	18481	-36.04
Zambia	0	0	0	0	0	0	0	0
Zimbabwe	0	0	0	0	0	0	0	0

Coconut

Country	Green-blue WF (this study) (1996-2005) (m³/ton)	(Green-blue) WF Chapagain et al. (2004) (1997-2001) (m³/ton)	Absolute difference (%)	A) Average yield Chapagain et al. (2004) (1997-2001) (ton/ha)	B) Average yield (this study) (1996-2005) (ton/ha)	Yield ratio (B/A) (-)	Reference WF (m³/ton)	Relative difference (%)
Angola	0	0	0	0	0	0	0	0
Botswana	0	0	0	0	0	0	0	0
DRC	0	0	0	0	0	0	0	0
Lesotho	0	0	0	0	0	0	0	0
Madagascar	3815	4803	-20.57	2.55	2.55	1.00	4806	-20.62
Malawi	0	0	0	0	0	0	0	0
Mozambique	1630	3312	-50.79	4.10	4.25	1.04	3196	-49.00
Namibia	0	0	0	0	0	0	0	0
South Africa	0	0	0	0	0	0	0	0
Swaziland	0	0	0	0	0	0	0	0
Tanzania	6485	10601	-38.83	1.16	1.18	1.02	10441	-37.90
Zambia	0	0	0	0	0	0	0	0
Zimbabwe	0	0	0	0	0	0	0	0

Coffee, green

Country	Green-blue WF (this study) (1996-2005) (m³/ton)	(Green-blue) WF Chapagain et al. (2004) (1997-2001) (m³/ton)	Absolute difference (%)	A) Average yield Chapagain et al. (2004) (1997-2001) (ton/ha)	B) Average yield (this study) (1996-2005) (ton/ha)	Yield ratio (B/A) (-)	Reference WF (m³/ton)	Relative difference (%)
Angola	248019	347127	-28.55	0.04	0.03	0.88	393252	-36.93
Botswana	0	0	0	0	0	0	0	0
DRC	24564	30322	-18.99	0.37	0.37	1.01	30057	-18.27
Lesotho	0	0	0	0	0	0	0	0
Madagascar	32565	37140	-12.32	0.31	0.34	1.09	33930	-4.02
Malawi	13185	10032	31.43	1.25	1.04	0.83	12022	9.67
Mozambique	9979	19250	-48.16	0.67	0.64	0.96	19965	-50.02
Namibia	0	0	0	0	0	0	0	0
South Africa	0	0	0	0	0	0	0	0
Swaziland	0	0	0	0	0	0	0	0
Tanzania	17877	29310	-39.01	0.40	0.40	1.01	29118	-38.61
Zambia	17597	13827	27.27	1.06	0.92	0.87	15939	10.40
Zimbabwe	9188	10258	-10.44	1.43	1.41	0.99	10408	-11.72

Cotton seed

Country	Green-blue WF (this study) (1996-2005) (m³/ton)	(Green-blue) WF Chapagain et al. (2004) (1997-2001) (m³/ton)	Absolute difference (%)	A) Average yield Chapagain et al. (2004) (1997-2001) (ton/ha)	B) Average yield (this study) (1996-2005) (ton/ha)	Yield ratio (B/A) (-)	Reference WF (m³/ton)	Relative difference (%)
Angola	3935	6957	-43.44	1.04	1.20	1.16	6002	-34.44
Botswana	783	2639	-70.31	2.61	2.49	0.95	2768	-71.70
DRC	8551	14320	-40.29	0.41	0.41	1.02	14056	-39.16
Lesotho	0	0	0	0	0	0	0	0
Madagascar	5266	4187	-25.46	1.42	1.14	0.81	5199	1.28
Malawi	2683	8891	-69.82	0.82	0.87	1.05	8431	-68.17
Mozambique	4298	15029	-71.40	0.47	0.55	1.18	12767	-66.33
Namibia	2049	5436	-70.82	1.34	1.39	1.03	5258	-61.03
South Africa	4989	5449	-60.04	1.34	1.53	1.15	4757	4.88
Swaziland	5651	7997	-29.34	0.75	0.94	1.25	6379	-11.41
Tanzania	5140	12193	-60.12	0.53	0.60	1.14	10679	-51.86
Zambia	2211	7038	-68.60	1.27	1.16	0.91	7706	-71.31
Zimbabwe	3131	9173	-68.42	0.92	0.83	0.91	10101	-69.01

Groundnut

Country	Green-blue WF (this study) (1996-2005) (m³/ton)	(Green-blue) WF Chapagain et al. (2004) (1997-2001) (m³/ton)	Absolute difference (%)	A) Average yield Chapagain et al. (2004) (1997-2001) (ton/ha)	B) Average yield (this study) (1996-2005) (ton/ha)	Yield ratio (B/A) (-)	Reference WF (m³/ton)	Relative difference (%)
Angola	5258	12239	-57.04	0.40	0.39	0.99	12400	-57.60
Botswana	3520	6846	-48.59	0.69	0.70	1.01	6772	-48.02
DRC	4043	4756	-14.98	0.78	0.78	1.00	4756	-14.98
Lesotho	0	0	0	0	0	0	0	0
Madagascar	5541	5790	-4.30	0.74	0.78	1.05	5513	0.51
Malawi	5483	5385	1.82	0.72	0.73	1.02	5297	3.52
Mozambique	10051	7114	41.28	0.67	0.43	0.64	11092	-9.39
Namibia	2606	8474	-69.25	0.58	0.52	0.91	9308	-72.00
South Africa	1269	2859	-55.59	1.70	1.58	0.93	3084	-58.84
Swaziland	3032	3589	-15.53	1.13	0.96	0.86	4194	-27.71
Tanzania	6822	6136	11.19	0.63	0.52	0.82	7492	-8.94
Zambia	3070	15390	-80.05	0.40	0.43	1.06	14495	-78.82
Zimbabwe	2854	2965	-3.76	1.96	0.53	0.27	10960	-73.96

Maize

Country	Green-blue WF (this study) (1996-2005) (m³/ton)	(Green-blue) WF Chapagain et al. (2004) (1997-2001) (m³/ton)	Absolute difference (%)	A) Average yield Chapagain et al. (2004) (1997-2001) (ton/ha)	B) Average yield (this study) (1996-2005) (ton/ha)	Yield ratio (B/A) (-)	Reference WF (m³/ton)	Relative difference (%)
Angola	6066	7155	-15.22	0.63	0.64	1.02	7017	-13.55
Botswana	27067	18386	47.21	0.20	0.19	0.95	19335	39.99
DRC	4624	4497	2.81	0.81	0.80	0.98	4572	1.14
Lesotho	2599	3271	-20.54	0.90	0.88	0.97	3366	-22.78
Madagascar	3831	3792	1.04	0.90	1.13	1.25	3028	26.51
Malawi	3224	3099	4.03	1.40	1.28	0.91	3405	-5.30
Mozambique	4628	4151	11.50	0.94	0.99	1.04	3975	16.43
Namibia	1971	4226	-53.35	0.96	1.14	1.19	3550	-44.47
South Africa	1736	1609	7.89	2.46	2.71	1.10	1463	18.66
Swaziland	1767	2007	-11.96	1.69	1.54	0.91	2201	-19.74
Tanzania	4269	2801	52.38	1.40	0.97	0.69	4036	5.77
Zambia	2545	4025	-36.76	1.41	1.63	1.15	3499	-27.26
Zimbabwe	4358	4027	8.23	1.25	1.06	0.85	4719	-7.64

Millet

Country	Green-blue WF (this study) (1996-2005) (m³/ton)	(Green-blue) WF Chapagain et al. (2004) (1997-2001) (m³/ton)	Absolute difference (%)	A) Average yield Chapagain et al. (2004) (1997-2001) (ton/ha)	B) Average yield (this study) (1996-2005) (ton/ha)	Yield ratio (B/A) (-)	Reference WF (m³/ton)	Relative difference (%)
Angola	2753	6161	-55.31	0.52	0.47	0.92	6719	-59.02
Botswana	6731	12292	-45.24	0.19	0.16	0.83	14813	-54.56
DRC	2261	3933	-42.52	0.66	0.66	1.00	3929	-42.46
Lesotho	0	0	0	0	0	0	0	0
Madagascar	0	0	0	0	0	0	0	0
Malawi	3097	5307	-41.64	0.55	0.55	1.00	5284	-41.39
Mozambique	3101	4412	-29.72	0.58	0.52	0.89	4965	-37.54
Namibia	6179	9859	-37.33	0.27	0.26	0.94	10497	-41.14
South Africa	2954	4509	-34.49	0.58	0.58	1.00	4492	-34.24
Swaziland	0	0	0	0	0	0	0	0
Tanzania	2096	2895	-27.60	0.95	0.87	0.92	3144	-33.34
Zambia	2149	5406	-60.24	0.72	0.68	0.94	5734	-62.52
Zimbabwe	4841	11236	-56.91	0.30	0.29	0.98	11510	-57.94

Oil palm

Country	Green-blue WF (this study) (1996-2005) (m³/ton)	(Green-blue) WF Chapagain et al. (2004) (1997-2001) (m³/ton)	Absolute difference (%)	A) Average yield Chapagain et al. (2004) (1997-2001) (ton/ha)	B) Average yield (this study) (1996-2005) (ton/ha)	Yield ratio (B/A) (-)	Reference WF (m³/ton)	Relative difference (%)
Angola	647	1091	-40.67	12.09	12.12	1.00	1088	-40.53
Botswana	0	0	0	0	0	0	0	0
DRC	1430	2510	-43.03	4.48	5.85	1.31	1922	-25.62
Lesotho	0	0	0	0	0	0	0	0
Madagascar	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Malawi	0	0	0	0	0	0	0	0
Mozambique	0	0	0	0	0	0	0	0
Namibia	0	0	0	0	0	0	0	0
South Africa	0	0	0	0	0	0	0	0
Swaziland	0	0	0	0	0	0	0	0
Tanzania	565	864	-34.62	13.52	13.81	1.02	846	-33.22
Zambia	0	0	0	0	0	0	0	0
Zimbabwe	0	0	0	0	0	0	0	0

*No spatially explicit data available on oil palm cultivation for Madagascar, however cultivation reported by FAO (2009 c).

Orange

Country	Green-blue WF (this study) (1996-2005) (m³/ton)	(Green-blue) WF Chapagain et al. (2004) (1997-2001) (m³/ton)	Absolute difference (%)	A) Average yield Chapagain et al. (2004) (1997-2001) (ton/ha)	B) Average yield (this study) (1996-2005) (ton/ha)	Yield ratio (B/A) (-)	Reference WF (m³/ton)	Relative difference (%)
Angola	0	0	0	0	0	0	0	0
Botswana	1240	2395	-48.25	3.87	3.92	1.01	2364	-47.56
DRC	469	529	-11.34	15.34	15.34	1.00	529	-11.35
Lesotho	0	0	0	0	0	0	0	0
Madagascar	1216	1305	-6.76	6.45	6.43	1.00	1307	-6.93
Malawi	0	0	0	0	0	0	0	0
Mozambique	1337	2381	-43.87	3.90	4.02	1.03	2310	-42.14
Namibia	0	0	0	0	0	0	0	0
South Africa	384	439	-12.37	23.60	24.58	1.04	421	-8.72
Swaziland	1422	1611	-11.77	5.27	5.54	1.05	1533	-7.27
Tanzania	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Zambia	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Zimbabwe	1098	1825	-39.85	5.78	5.81	1.00	1816	-39.56

*No spatially explicit data available on orange cultivation for Tanzania and Zambia, however cultivation reported by FAO (2009 c).

Plantain

Country	Green-blue WF (this study) (1996-2005) (m³/ton)	(Green-blue) WF Chapagain et al. (2004) (1997-2001) (m³/ton)	Absolute difference (%)	A) Average yield Chapagain et al. (2004) (1997-2001) (ton/ha)	B) Average yield (this study) (1996-2005) (ton/ha)	Yield ratio (B/A) (-)	Reference WF (m³/ton)	Relative difference (%)
Angola	0	0	0	0	0	0	0	0
Botswana	0	0	0	0	0	0	0	0
DRC	2282	3031	-24.70	4.46	4.47	1.00	3020	-24.43
Lesotho	0	0	0	0	0	0	0	0
Madagascar	0	0	0	0	0	0	0	0
Malawi	1263	3566	-64.58	4.27	6.51	1.52	2339	-45.99
Mozambique	0	0	0	0	0	0	0	0
Namibia	0	0	0	0	0	0	0	0
South Africa	0	0	0	0	0	0	0	0
Swaziland	0	0	0	0	0	0	0	0
Tanzania	4069	5731	-28.99	2.46	2.26	0.92	6237	-34.75
Zambia	0	0	0	0	0	0	0	0
Zimbabwe	0	0	0	0	0	0	0	0

Potato

Country	Green-blue WF (this study) (1996-2005) (m³/ton)	(Green-blue) WF Chapagain et al. (2004) (1997-2001) (m³/ton)	Absolute difference (%)	A) Average yield Chapagain et al. (2004) (1997-2001) (ton/ha)	B) Average yield (this study) (1996-2005) (ton/ha)	Yield ratio (B/A) (-)	Reference WF (m³/ton)	Relative difference (%)
Angola	126	1004	-87.46	5.09	9.54	1.87	536	-76.49
Botswana	0	0	0	0	0	0	0	0
DRC	720	900	-20.00	4.63	4.63	1.00	900	-19.99
Lesotho	107	222	-51.74	16.33	16.39	1.00	221	-51.57
Madagascar	719	798	-9.87	5.84	5.74	0.98	811	-11.39
Malawi	342	373	-8.44	11.25	11.38	1.01	369	-7.37
Mozambique	303	395	-23.29	12.62	12.69	1.01	392	-22.88
Namibia	0	0	0	0	0	0	0	0
South Africa	117	170	-31.01	28.77	30.80	1.07	158	-26.15
Swaziland	1158	2028	-42.91	2.03	2.01	0.99	2040	-43.24
Tanzania	548	556	-1.37	7.54	6.70	0.89	625	-12.34
Zambia	358	720	-50.18	9.05	11.03	1.22	590	-39.26
Zimbabwe	294	382	-23.10	15.61	15.88	1.02	376	-21.79

Rice

Country	Green-blue WF (this study) (1996-2005) (m³/ton)	(Green-blue) WF Chapagain et al. (2004) (1997-2001) (m³/ton)	Absolute difference (%)	A) Average yield Chapagain et al. (2004) (1997-2001) (ton/ha)	B) Average yield (this study) (1996-2005) (ton/ha)	Yield ratio (B/A) (-)	Reference WF (m³/ton)	Relative difference (%)
Angola	4640	11953	-61.19	0.83	1.42	1.70	7024	-33.95
Botswana	0	0	0	0	0	0	0	0
DRC	10367	12768	-18.81	0.76	0.75	1.00	12769	-18.81
Lesotho	0	0	0	0	0	0	0	0
Madagascar	3344	4347	-23.06	2.12	2.24	1.06	4112	-18.66
Malawi	3833	6080	-36.95	1.76	1.61	0.92	6636	-42.23
Mozambique	1825	9836	-81.45	1.01	0.95	0.93	10534	-82.68
Namibia	0	0	0	0	0	0	0	0
South Africa	2789	4035	-30.89	2.30	2.29	0.99	4059	-31.29
Swaziland	1461	1625	-10.07	5.12	4.12	0.81	2017	-27.57
Tanzania	2193	7171	-69.42	1.40	1.76	1.26	5689	-61.45
Zambia	3763	11532	-67.37	1.00	1.17	1.17	9870	-61.87
Zimbabwe	3098	5163	-40.00	2.08	2.20	1.06	4873	-36.42

Sorghum

Country	Green-blue WF (this study) (1996-2005) (m³/ton)	(Green-blue) WF Chapagain et al. (2004) (1997-2001) (m³/ton)	Absolute difference (%)	A) Average yield Chapagain et al. (2004) (1997-2001) (ton/ha)	B) Average yield (this study) (1996-2005) (ton/ha)	Yield ratio (B/A) (-)	Reference WF (m³/ton)	Relative difference (%)
Angola	0	0	0	0	0	0	0	0
Botswana	3557	16293	-78.17	0.18	0.56	3.17	5147	-30.89
DRC	2653	4682	-43.33	0.67	0.66	0.99	4716	-43.73
Lesotho	2447	2376	2.98	0.98	0.88	0.90	2644	-7.47
Madagascar	6369	5714	11.45	0.49	0.50	1.01	5657	12.59
Malawi	2878	5625	-48.84	0.63	0.65	1.04	5431	-47.01
Mozambique	2697	4034	-33.16	0.77	0.66	0.86	4697	-42.59
Namibia	6240	10923	-42.87	0.30	0.29	0.96	11371	-45.12
South Africa	698	1189	-41.28	2.66	2.85	1.07	1111	-37.14
Swaziland	3932	4400	-10.64	0.62	0.63	1.00	4382	-10.27
Tanzania	1983	3419	-41.99	0.97	1.01	1.04	3282	-39.57
Zambia	2266	6428	-64.75	0.73	0.71	0.98	6552	-65.42
Zimbabwe	3157	6046	-47.78	0.67	0.51	0.77	7881	-59.94

Soybean

Country	Green-blue WF (this study) (1996-2005) (m³/ton)	(Green-blue) WF Chapagain et al. (2004) (1997-2001) (m³/ton)	Absolute difference (%)	A) Average yield Chapagain et al. (2004) (1997-2001) (ton/ha)	B) Average yield (this study) (1996-2005) (ton/ha)	Yield ratio (B/A) (-)	Reference WF (m³/ton)	Relative difference (%)
Angola	0	0	0	0	0	0	0	0
Botswana	0	0	0	0	0	0	0	0
DRC	4981	4496	10.79	0.56	0.52	0.93	4838	2.97
Lesotho	0	0	0	0	0	0	0	0
Madagascar	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Malawi	0	0	0	0	0	0	0	0
Mozambique	0	0	0	0	0	0	0	0
Namibia	0	0	0	0	0	0	0	0
South Africa	987	2750	-64.12	1.55	1.58	1.02	2690	-63.31
Swaziland	0	0	0	0	0	0	0	0
Tanzania	6660	7345	-9.33	0.36	0.37	1.01	7261	-8.27
Zambia	748	4227	-82.32	1.47	1.38	0.94	4486	-83.34
Zimbabwe	993	2745	-63.81	1.97	1.78	0.90	3050	-67.43

*No spatially explicit data available on soybean cultivation for Madagascar, however cultivation reported by FAO (2009 c).

Sugarcane

Country	Green-blue WF (this study) (1996-2005) (m³/ton)	(Green-blue) WF Chapagain et al. (2004) (1997-2001) (m³/ton)	Absolute difference (%)	A) Average yield Chapagain et al. (2004) (1997-2001) (ton/ha)	B) Average yield (this study) (1996-2005) (ton/ha)	Yield ratio (B/A) (-)	Reference WF (m³/ton)	Relative difference (%)
Angola	304	359	-15.30	37.56	37.50	1.00	359	-15.44
Botswana	0	0	0	0	0	0	0	0
DRC	173	236	-26.56	47.51	43.82	0.92	256	-32.26
Lesotho	0	0	0	0	0	0	0	0
Madagascar	301	349	-13.96	32.68	32.56	1.00	351	-14.27
Malawi	139	126	10.63	103.27	105.34	1.02	124	12.84
Mozambique	525	881	-40.40	14.60	14.20	0.97	906	-42.05
Namibia	0	0	0	0	0	0	0	0
South Africa	137	197	-30.35	70.85	58.49	0.83	239	-42.51
Swaziland	121	111	9.08	103.79	100.65	0.97	114	5.77
Tanzania	60	132	-54.03	90.14	102.15	1.13	116	-47.91
Zambia	135	147	-8.66	105.23	105.06	1.00	148	-8.80
Zimbabwe	109	144	-23.96	104.58	97.50	0.93	154	-29.10

Sunflower seed

Country	Green-blue WF (this study) (1996-2005) (m^3/ton)	(Green-blue) WF Chapagain et al. (2004) (1997-2001) (m^3/ton)	Absolute difference (%)	A) Average yield Chapagain et al. (2004) (1997-2001) (ton/ha)	B) Average yield (this study) (1996-2005) (ton/ha)	Yield ratio (B/A) (-)	Reference WF (m^3/ton)	Relative difference (%)
Angola	5160	5315	-2.92	0.71	0.72	1.02	5234	-1.41
Botswana	3425	4436	-22.78	1.07	1.11	1.04	4278	-19.93
DRC	0	0	0	0	0	0	0	0
Lesotho	0	0	0	0	0	0	0	0
Madagascar	0	0	0	0	0	0	0	0
Malawi	7416	6744	9.97	0.53	0.55	1.02	6583	12.66
Mozambique	8228	8133	1.17	0.55	0.53	0.97	8394	-1.97
Namibia	7746	6584	17.65	0.75	0.61	0.82	8029	-3.52
South Africa	3482	4356	-20.06	1.27	1.28	1.00	4335	-19.68
Swaziland	0	0	0	0	0	0	0	0
Tanzania	10230	10522	-2.78	0.35	0.35	1.00	10489	-2.47
Zambia	8429	8284	1.74	0.45	0.50	1.11	7459	13.00
Zimbabwe	9013	7799	15.57	0.57	0.50	0.87	8949	0.72

Sweet potato

Country	Green-blue WF (this study) (1996-2005) (m^3/ton)	(Green-blue) WF Chapagain et al. (2004) (1997-2001) (m^3/ton)	Absolute difference (%)	A) Average yield Chapagain et al. (2004) (1997-2001) (ton/ha)	B) Average yield (this study) (1996-2005) (ton/ha)	Yield ratio (B/A) (-)	Reference WF (m^3/ton)	Relative difference (%)
Angola	876	668	31.16	6.69	5.92	0.88	756	15.98
Botswana	0	0	0	0	0	0	0	0
DRC	780	761	2.49	5.02	4.97	0.99	769	1.44
Lesotho	0	0	0	0	0	0	0	0
Madagascar	836	827	1.11	5.61	5.60	1.00	829	0.83
Malawi	0	0	0	0	0	0	0	0
Mozambique	550	778	-29.32	7.02	7.12	1.01	767	-28.32
Namibia	0	0	0	0	0	0	0	0
South Africa	899	1600	-43.81	4.03	3.52	0.87	1831	-50.89
Swaziland	2774	2800	-0.94	1.80	1.79	1.00	2810	-1.30
Tanzania	2236	2328	-3.93	1.84	1.84	1.00	2335	-4.21
Zambia	293	336	-12.82	14.74	14.79	1.00	335	-12.53
Zimbabwe	1414	2677	-47.18	2.11	2.12	1.00	2665	-46.93

Wheat

Country	Green-blue WF (this study) (1996-2005) (m^3/ton)	(Green-blue) WF Chapagain et al. (2004) (1997-2001) (m^3/ton)	Absolute difference (%)	A) Average yield Chapagain et al. (2004) (1997-2001) (ton/ha)	B) Average yield (this study) (1996-2005) (ton/ha)	Yield ratio (B/A) (-)	Reference WF (m^3/ton)	Relative difference (%)
Angola	921	2616	-64.79	1.71	1.69	0.99	2646	-65.19
Botswana	605	1690	-64.22	1.67	1.65	0.98	1720	-64.84
DRC	1558	2595	-39.96	1.29	1.28	0.99	2611	-40.31
Lesotho	1403	1869	-24.89	1.27	1.45	1.14	1639	-14.40
Madagascar	1042	1162	-10.34	2.43	2.37	0.97	1192	-12.58
Malawi	2435	4522	-46.16	0.76	0.75	0.99	4584	-46.89
Mozambique	1793	2970	-39.65	1.00	1.05	1.05	2835	-36.77
Namibia	694	610	13.81	5.75	4.85	0.84	724	-4.13
South Africa	877	1366	-35.78	2.43	2.30	0.95	1442	-39.17
Swaziland	1400	1904	-26.47	1.52	1.51	0.99	1914	-26.86
Tanzania	1644	2526	-34.93	1.35	1.31	0.97	2597	-36.70
Zambia	613	791	-22.49	6.34	6.27	0.99	799	-23.25
Zimbabwe	666	782	-14.85	5.44	5.24	0.96	811	-17.92

A4 Water footprint of livestock

Green water footprint of livestock & livestock products in the SADC for the period 1996-2005

Average green water footprint of livestock over the period 1996-2005 (m^3/ton)

Livestock commodity	ANGOLA	BOTSWANA	D.R.CONGO	LESOTHO	MADAGASCAR	MALAWI	MAURITIUS	MOZAMBIQUE	NAMIBIA	SEYCHELLES	SOUTH AFRICA	SWAZILAND	TANZANIA	ZAMBIA	ZIMBABWE	SADC average
Horses	3184	5548	7496	2811	2737	3196	3882	2005	3980	4023	2288	1738	2583	1513	1231	3214
Asses, mules, hinnies	3184	5548	7496	2811	2737	3196	3882	2005	3980	4023	2288	1738	2583	1513	1231	3214
Bov.animals, pure for breeding	7342	11979	12647	6805	6485	7273	6199	5848	6449	6668	5725	4683	6773	4894	3085	6857
Other bovine animals	7342	11979	12647	6805	6485	7273	6199	5848	6449	6668	5725	4683	6773	4894	3085	6857
Swine,pure for breeding	9669	46938	25534	8770	10328	10577	11559	6590	13262	14263	14316	12791	9625	5594	3274	13539
Other swine, live	9669	46938	25534	8770	10328	10577	11559	6590	13262	14263	14316	12791	9625	5594	3274	13539
Sheep, live	3895	6799	5942	3716	3514	3834	3521	3326	3687	3790	3744	3061	3983	3010	1712	3836
Goats, live	4009	10209	6228	3392	3428	3519	3490	3178	3866	4004	3504	2893	3939	2709	2029	4027
Poultry, live up to 185g	18097	38592	30349	13351	13986	17359	6358	14778	7251	8765	5347	6184	20441	7442	11392	14646
Poultry, live over 185g	18097	38592	30349	13351	13986	17359	6358	14778	7251	8765	5347	6184	20441	7442	11392	14646
Other live animals	7342	11979	12647	6805	6485	7273	6199	5848	6449	6668	5725	4683	6773	4894	3085	6857
Dairy cattle, live	77036	578641	90901	52041	59138	58706	71699	62641	96611	108929	90027	84764	76890	43550	52273	106923
Laying hens, live	73391	185452	122703	54225	56461	69847	30231	59620	34597	41559	25484	29131	82954	30225	44803	62712

Average green water footprint of livestock commodities over the period 1996-2005 (m^3/ton)

Livestock commodity	ANGOLA	BOTSWANA	D.R.CONGO	LESOTHO	MADAGASCAR	MALAWI	MAURITIUS	MOZAMBIQUE	NAMIBIA	SEYCHELLES	SOUTH AFRICA	SWAZILAND	TANZANIA	ZAMBIA	ZIMBABWE	SADC average
Meat of horses,mules,etc. (0124)	4038	7147	9614	3640	3553	4079	5024	2608	5152	5202	2966	2244	3353	1989	1611	4148
Bovine meat, with bones (01121)	11479	18799	19745	10627	10134	11370	9682	9127	10076	10413	8955	7315	10596	7655	4831	10720
Bovine meat, boneless (01122)	16171	26480	27813	14970	14276	16017	13639	12858	14195	14669	12615	10306	14927	10785	6807	15102
Meat of poultry (0174)	23214	49490	38922	17130	17944	22268	8164	18959	9309	11250	6868	7941	26219	9554	14617	18790
Meat of goats (01213)	7040	17812	10909	5943	6001	6178	6106	5569	6758	6999	6142	5077	6903	4748	3575	7051
Meat of sheep (01212)	6946	12108	10579	6621	6261	6833	6272	5927	6567	6748	6673	5458	7096	5366	3061	6834
Meat of swine (01222)	10331	48163	27091	9638	11172	11272	12386	7353	14150	15115	15265	13500	10499	6314	3657	14394
Bovine hides,skins (21111)	8991	14532	15574	8395	8016	8946	7666	7254	7966	8247	7051	5785	8321	6045	3831	8441
Leather of bovine (6113)	18033	29114	31198	16839	16082	17941	15383	14559	15981	16543	14152	11620	16691	12140	7711	16933
Leather of swine (61171)	30786	85100	48795	26856	27583	27315	28080	25269	31310	32383	27714	22655	31329	21774	15727	32178
Goatskin leather (61162)	6950	18266	10900	5996	6105	6131	6233	5630	6928	7169	6168	5080	6932	4823	3518	7122
Sheepskin leather (61152)	3259	5771	4996	3152	2992	3234	3002	2831	3141	3236	3156	2594	3370	2564	1474	3252
Birds' eggs, in shell (0251)	14547	25371	24627	10545	11550	13727	4010	11837	4668	5434	3374	3732	16833	6147	8106	10967
Raw milk	1117	5791	1317	754	858	851	718	908	968	1091	902	849	1114	631	757	1242
Processed cheese (0242)	6015	31087	7083	4087	4636	4584	3908	4907	5254	5903	4883	4579	6009	3432	4018	6692

Blue water footprint of livestock & livestock products in the SADC for the period 1996-2005

Average blue water footprint of livestock over the period 1996-2005 (m^3/ton)

Livestock commodity	ANGOLA	BOTSWANA	D.R.CONGO	LESOTHO	MADAGASCAR	MALAWI	MAURITIUS	MOZAMBIQUE	NAMIBIA	SEYCHELLES	SOUTH AFRICA	SWAZILAND	TANZANIA	ZAMBIA	ZIMBABWE	SADC average
Horses	966	477	72	186	207	100	239	74	248	239	1517	800	158	1775	1258	554
Asses, mules, hinnies	966	477	72	186	207	100	239	74	248	239	1517	800	158	1775	1258	554
Bov.animals, pure for breeding	1273	681	99	231	257	131	230	100	308	230	1308	706	202	2126	1540	628
Other bovine animals	1273	681	99	231	257	131	230	100	308	230	1308	706	202	2126	1540	628
Swine,pure for breeding	3003	2309	232	590	658	319	339	238	631	339	770	552	502	5631	4592	1380
Other swine, live	3003	2309	232	590	658	319	339	238	631	339	770	552	502	5631	4592	1380
Sheep, live	559	408	134	178	186	145	170	134	201	170	535	334	169	819	620	317
Goats, live	680	601	144	198	208	157	198	144	219	198	696	421	188	976	722	383
Poultry, live up to 185g	3998	2530	405	668	719	469	502	397	1126	502	1884	1160	625	5055	4056	1606
Poultry, live over 185g	3998	2530	405	668	719	469	502	397	1126	502	1884	1160	625	5055	4056	1606
Other live animals	1273	681	99	231	257	131	230	100	308	230	1308	706	202	2126	1540	628
Dairy cattle, live	9405	28138	1290	1663	1735	1380	2848	1231	5843	2848	8508	5543	1698	8083	6365	5772
Laying hens, live	16355	12324	1627	2691	2894	1885	2370	1595	5337	2370	8915	5469	2527	20497	16349	6880

Average blue water footprint of livestock commodities over the period 1996-2005 (m^3/ton)

Livestock commodity	ANGOLA	BOTSWANA	D.R.CONGO	LESOTHO	MADAGASCAR	MALAWI	MAURITIUS	MOZAMBIQUE	NAMIBIA	SEYCHELLES	SOUTH AFRICA	SWAZILAND	TANZANIA	ZAMBIA	ZIMBABWE	SADC average
Meat of horses,mules,etc. (0124)	1261	668	131	276	304	165	346	133	357	346	1977	1050	242	2344	1658	750
Bovine meat, with bones (01121)	1969	1022	171	377	416	221	375	172	498	375	2056	1114	332	3342	2421	991
Bovine meat, boneless (01122)	2777	1442	243	534	588	314	531	245	704	531	2899	1572	470	4710	3413	1398
Meat of poultry (0174)	5138	3256	532	869	934	614	656	522	1456	656	2428	1500	814	6493	5213	2072
Meat of goats (01213)	1209	1061	270	363	381	293	363	269	400	363	1236	755	345	1718	1279	687
Meat of sheep (01212)	1013	741	256	333	348	275	320	256	375	320	968	611	317	1472	1119	582
Meat of swine (01222)	3064	2516	274	647	720	361	387	280	688	387	892	635	552	5970	4828	1480
Bovine hides,skins (21111)	1629	963	147	309	341	186	308	148	402	308	1633	893	272	2627	1914	805
Leather of bovine (6113)	3309	1976	344	668	731	422	665	346	854	665	3316	1835	594	5305	3878	1661
Leather of swine (61171)	5203	4939	1249	1672	1753	1346	1676	1244	1853	1676	5542	3287	1594	8100	5806	3129
Goatskin leather (61162)	1209	1145	290	384	402	312	385	289	423	385	1250	758	366	1780	1302	712
Sheepskin leather (61152)	490	376	148	184	192	157	178	148	204	178	481	310	177	727	553	300
Birds' eggs, in shell (0251)	3339	1718	326	546	585	377	316	320	734	316	1189	717	517	4378	3341	1248
Raw milk	137	284	19	24	25	20	29	18	59	29	85	56	25	117	92	68
Processed cheese (0242)	782	1528	169	198	203	176	221	164	382	221	523	364	200	697	561	426

Grey water footprint of livestock & livestock products in the SADC for the period 1996-2005

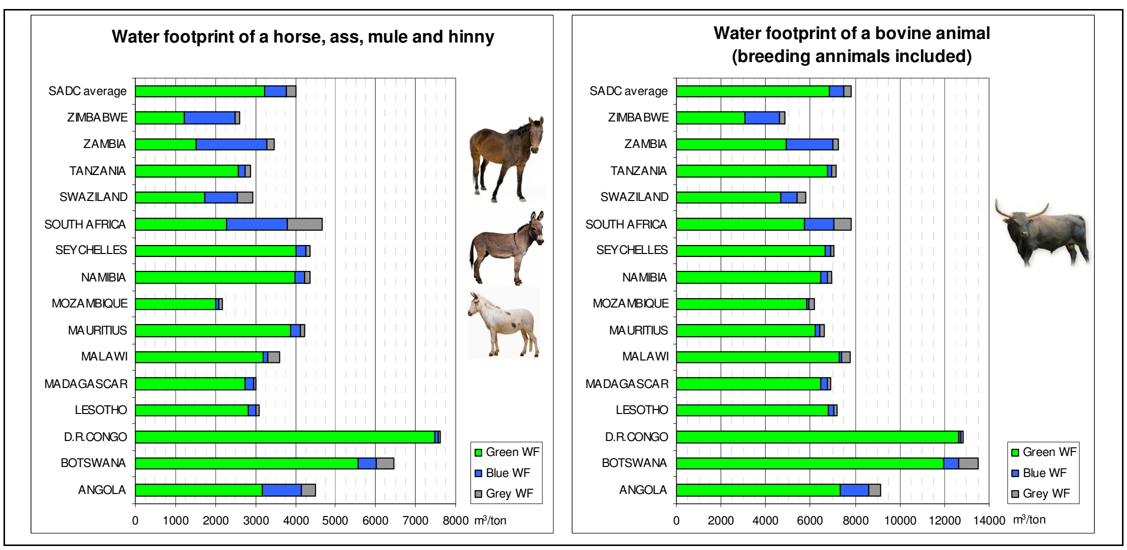
Average grey water footprint of livestock over the period 1996-2005 (m^3/ton)

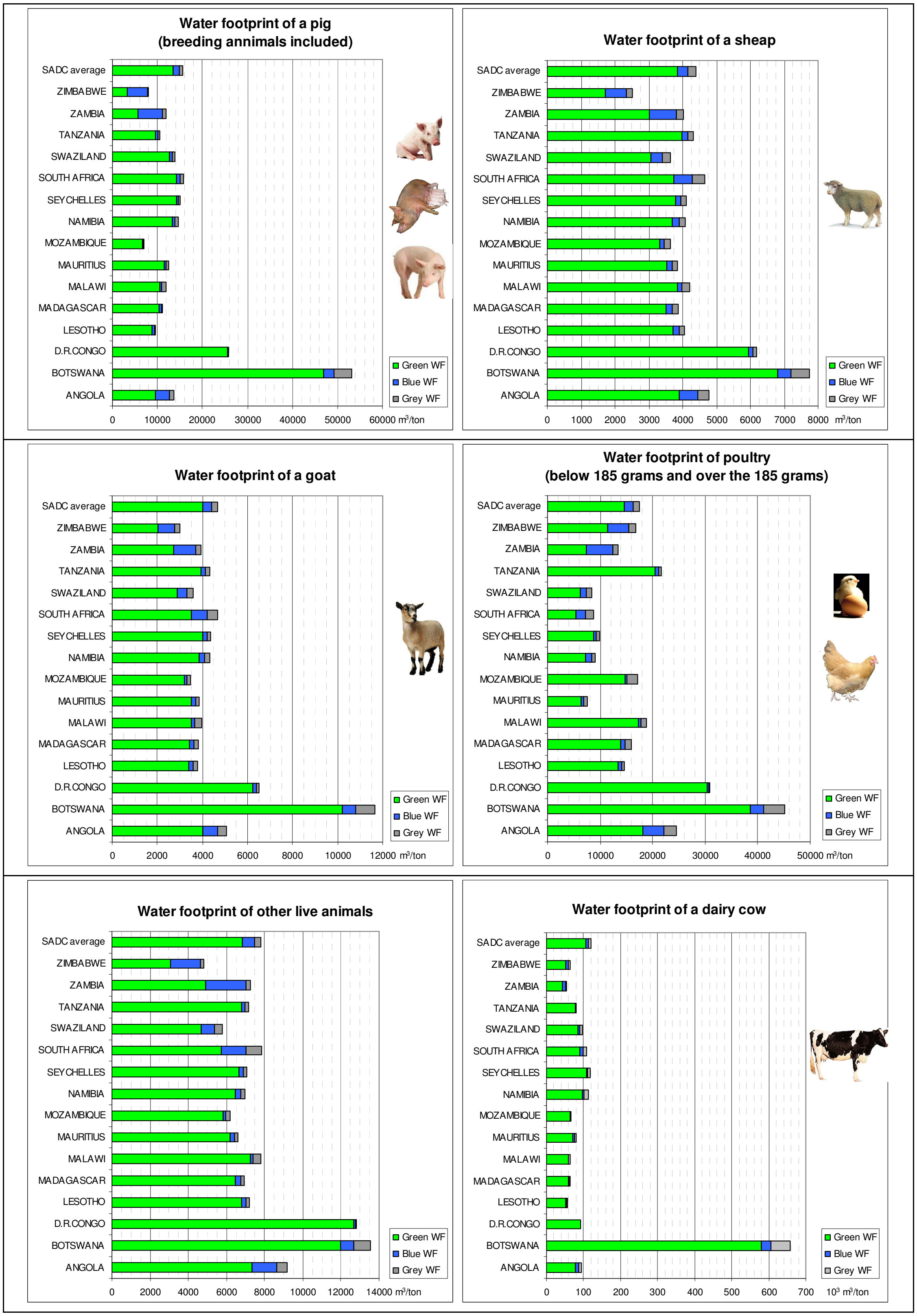
Livestock commodity	ANGOLA	BOTSWANA	D.R.CONGO	LESOTHO	MADAGASCAR	MALAWI	MAURITIUS	MOZAMBIQUE	NAMIBIA	SEYCHELLES	SOUTH AFRICA	SWAZILAND	TANZANIA	ZAMBIA	ZIMBABWE	SADC average
Horses	349	435	61	99	80	312	111	89	131	111	872	385	147	185	108	232
Asses, mules, hinnies	349	435	61	99	80	312	111	89	131	111	872	385	147	185	108	232
Bov.animals, pure for breeding	545	874	65	152	176	388	158	231	200	158	814	397	190	242	212	320
Other bovine animals	545	874	65	152	176	388	158	231	200	158	814	397	190	242	212	320
Swine,pure for breeding	961	3913	84	255	198	1032	523	290	838	523	822	625	370	661	211	754
Other swine, live	961	3913	84	255	198	1032	523	290	838	523	822	625	370	661	211	754
Sheep, live	320	538	116	159	165	235	153	178	185	153	375	231	168	200	197	225
Goats, live	395	857	127	188	174	281	180	158	258	180	482	272	195	240	241	282
Poultry, live up to 185g	2419	3979	45	630	1220	1000	627	1915	719	627	1527	1036	548	859	1319	1231
Poultry, live over 185g	2419	3979	45	630	1220	1000	627	1915	719	627	1527	1036	548	859	1319	1231
Other live animals	545	874	65	152	176	388	158	231	200	158	814	397	190	242	212	320
Dairy cattle, live	7399	50227	723	2688	3063	3010	5227	3019	10175	5227	9353	5657	2118	2876	4701	7698
Laying hens, live	9994	19275	176	2548	4896	4034	2958	7669	3433	2958	7227	4869	2219	3511	5215	5399

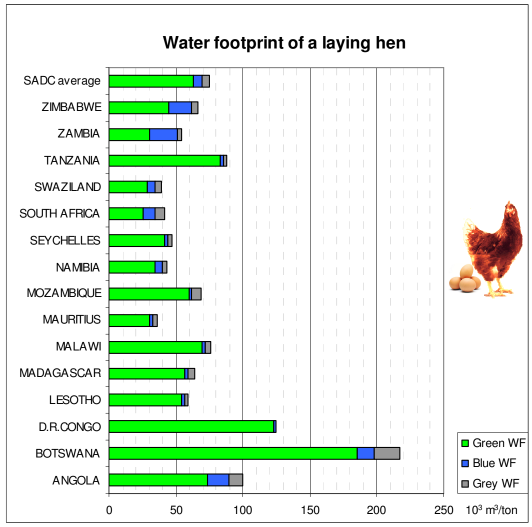
Average grey water footprint of livestock commodities over the period 1996-2005 (m^3/ton)

Livestock commodity	ANGOLA	BOTSWANA	D.R.CONGO	LESOTHO	MADAGASCAR	MALAWI	MAURITIUS	MOZAMBIQUE	NAMIBIA	SEYCHELLES	SOUTH AFRICA	SWAZILAND	TANZANIA	ZAMBIA	ZIMBABWE	SADC average
Meat of horses,mules,etc. (0124)	497	616	117	165	140	432	180	152	206	180	1153	526	227	280	176	336
Bovine meat, with bones (01121)	824	1327	117	253	290	621	263	376	329	263	1285	633	312	397	347	509
Bovine meat, boneless (01122)	1164	1872	168	359	412	878	373	532	467	373	1813	894	442	561	491	720
Meat of poultry (0174)	3114	5114	70	821	1577	1295	817	2468	935	817	1971	1341	715	1114	1704	1591
Meat of goats (01213)	705	1506	240	346	322	509	332	294	468	332	861	494	359	434	440	509
Meat of sheep (01212)	587	973	225	301	312	436	290	334	346	290	684	429	316	372	369	418
Meat of swine (01222)	1042	4130	118	304	243	1084	568	339	894	568	914	687	417	738	262	820
Bovine hides,skins (21111)	767	1190	105	211	241	499	219	310	269	219	1025	512	256	324	287	429
Leather of bovine (6113)	1584	2430	260	472	532	1049	488	671	588	488	2100	1074	563	698	624	908
Leather of swine (61171)	3205	7141	1115	1574	1488	2281	1538	1360	2219	1538	3897	2190	1663	2041	1979	2349
Goatskin leather (61162)	747	1605	260	364	343	523	354	315	500	354	880	506	380	473	454	537
Sheepskin leather (61152)	301	487	133	169	174	232	165	185	191	165	349	227	176	204	202	224
Birds' eggs, in shell (0251)	2068	2668	36	491	988	797	389	1559	470	389	961	638	455	809	976	913
Raw milk	108	505	10	39	44	44	52	44	102	52	94	57	31	42	68	86
Processed cheese (0242)	629	2714	125	276	306	301	348	302	617	348	569	370	233	294	426	524

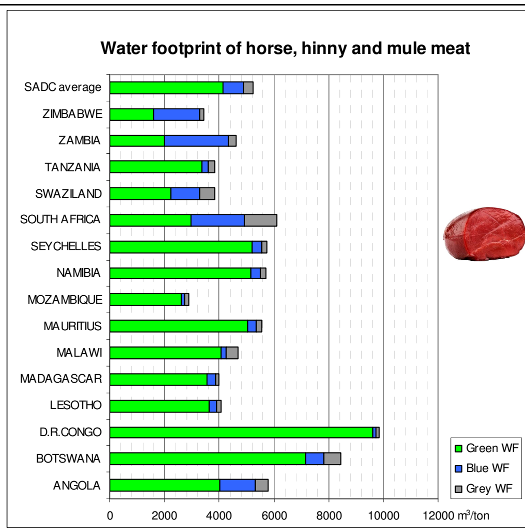
Water footprint of live animals in the SADC region for the period 1996-2005

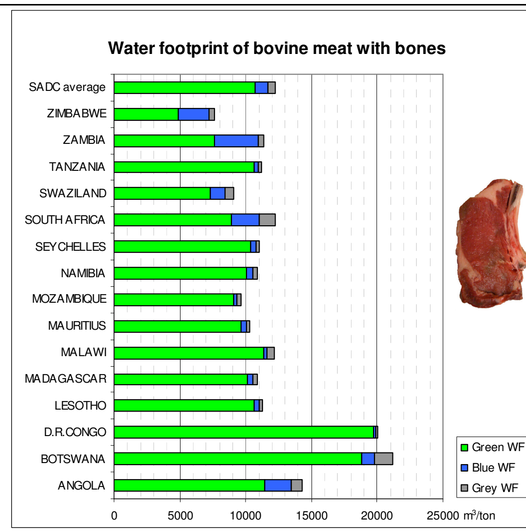


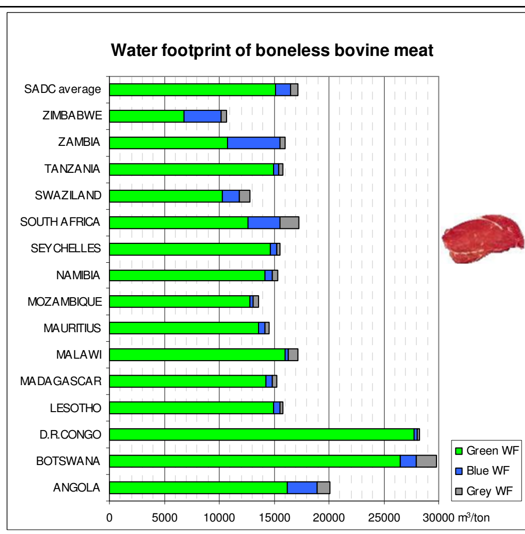

Water footprint of a pig
(breeding annimals included)
SADC average
ZIMBABWE
ZAMBIA
TANZANIA
SWAZILAND
SOUTH AFRICA
SEYCHELLES
NAMIBIA
MOZAMBIQUE
MAURITIUS
MALAWI
MADAGASCAR
LESOTHO
D.R.CONGO
BOTSWANA
ANGOLA
Green WF
Blue WF
Grey WF
0 10000 20000 30000 40000 50000 60000 m³/ton
Water footprint of a sheap
0 1000 2000 3000 4000 5000 6000 7000 8000 m³/ton
Water footprint of a goat
0 2000 4000 6000 8000 10000 12000 m³/ton
Water footprint of poultry
(below 185 grams and over the 185 grams)
0 10000 20000 30000 40000 50000 m³/ton
Water footprint of other live animals
0 2000 4000 6000 8000 10000 12000 14000 m³/ton
Water footprint of a dairy cow
0 100 200 300 400 500 600 700 10³ m³/ton

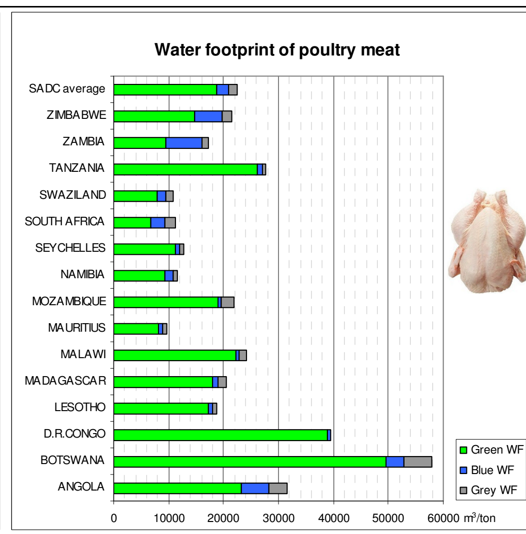


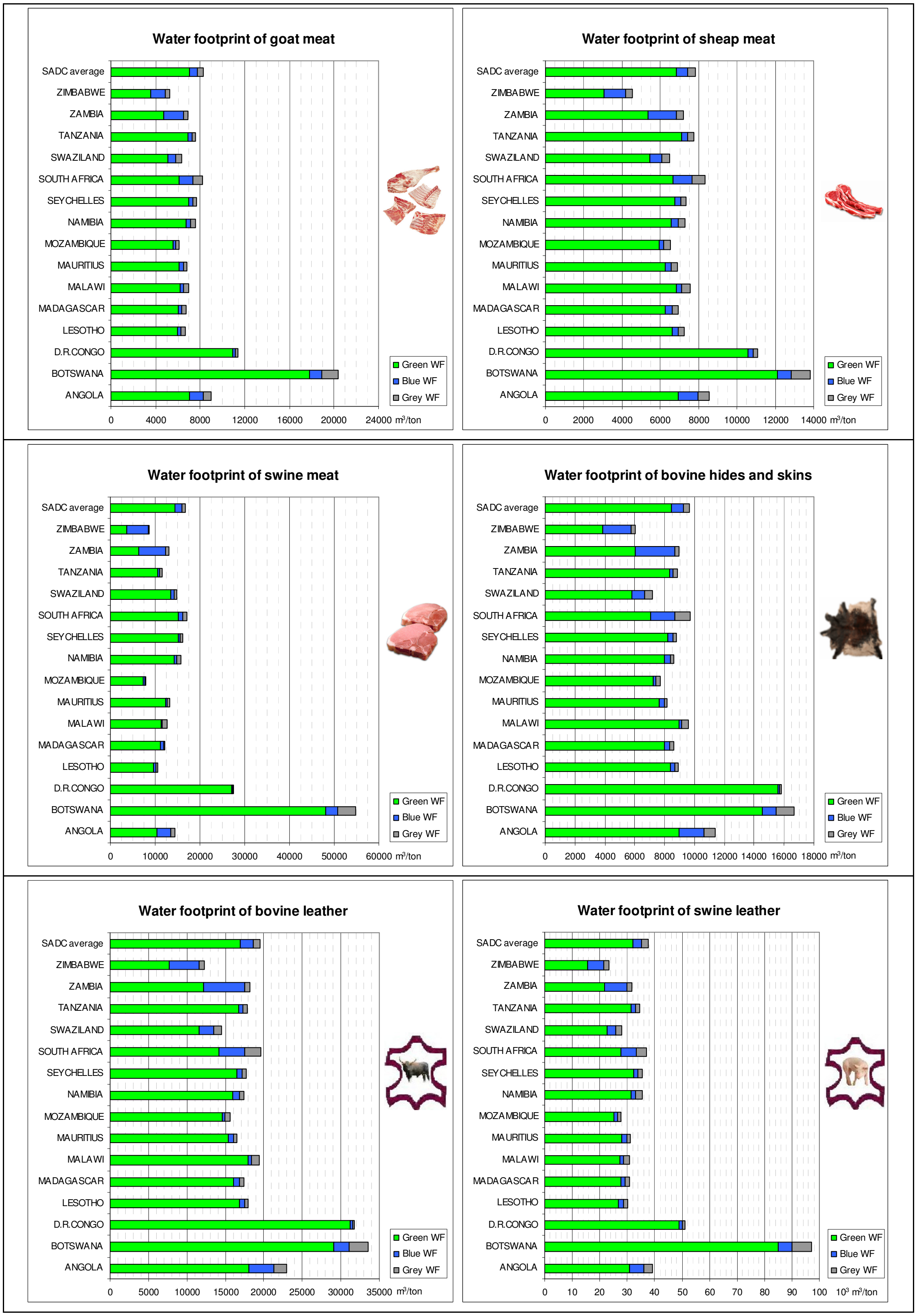
Water footprint of livestock products for the SADC region for the period 1996-2005

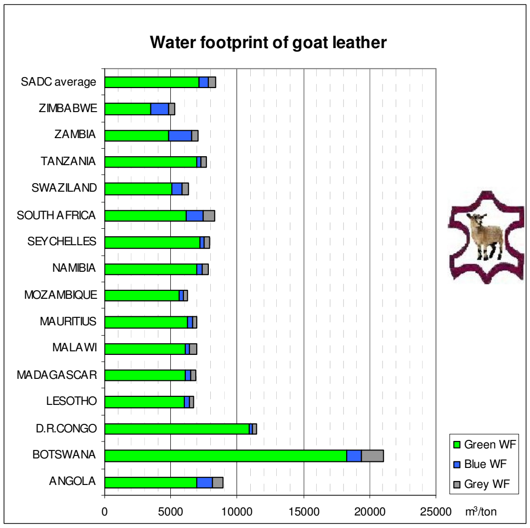


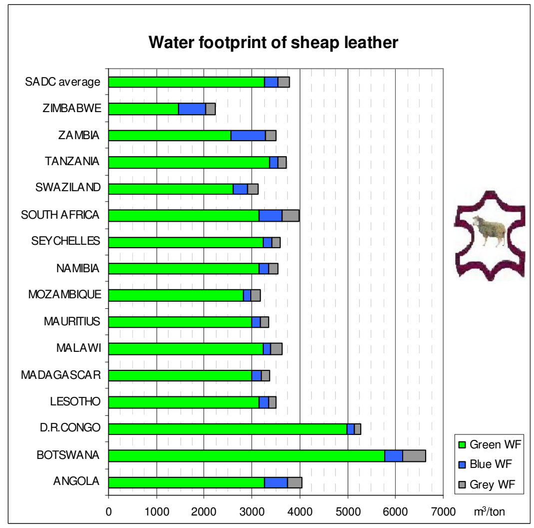


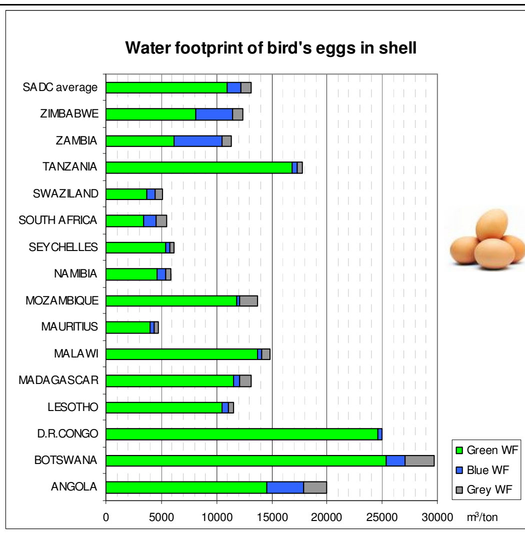


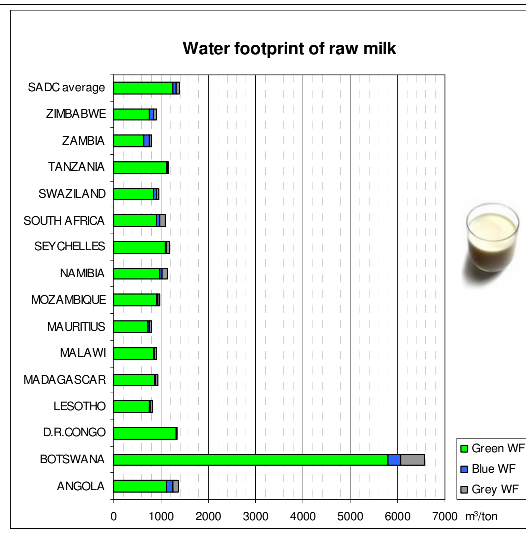


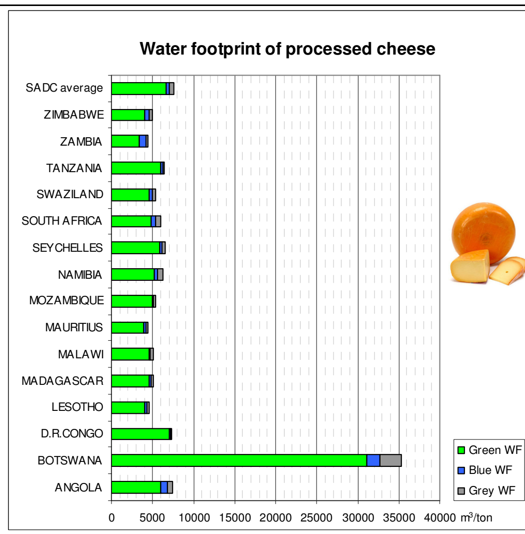

Water footprint of goat meat
SADC average
ZIMBABWE
ZAMBIA
TANZANIA
SWAZILAND
SOUTH AFRICA
SEYCHELLES
NAMIBIA
MOZAMBIQUE
MAURITIUS
MALAWI
MADAGASCAR
LESOTHO
D.R.CONGO
BOTSWANA
ANGOLA
Green WF
Blue WF
Grey WF
0 4000 8000 12000 16000 20000 24000 m³/ton
Water footprint of sheap meat
SADC average
ZIMBABWE
ZAMBIA
TANZANIA
SWAZILAND
SOUTH AFRICA
SEYCHELLES
NAMIBIA
MOZAMBIQUE
MAURITIUS
MALAWI
MADAGASCAR
LESOTHO
D.R.CONGO
BOTSWANA
ANGOLA
Green WF
Blue WF
Grey WF
0 2000 4000 6000 8000 10000 12000 14000 m³/ton
Water footprint of swine meat
SADC average
ZIMBABWE
ZAMBIA
TANZANIA
SWAZILAND
SOUTH AFRICA
SEYCHELLES
NAMIBIA
MOZAMBIQUE
MAURITIUS
MALAWI
MADAGASCAR
LESOTHO
D.R.CONGO
BOTSWANA
ANGOLA
Green WF
Blue WF
Grey WF
0 10000 20000 30000 40000 50000 60000 m³/ton
Water footprint of bovine hides and skins
SADC average
ZIMBABWE
ZAMBIA
TANZANIA
SWAZILAND
SOUTH AFRICA
SEYCHELLES
NAMIBIA
MOZAMBIQUE
MAURITIUS
MALAWI
MADAGASCAR
LESOTHO
D.R.CONGO
BOTSWANA
ANGOLA
Green WF
Blue WF
Grey WF
0 2000 4000 6000 8000 10000 12000 14000 16000 18000 m³/ton
Water footprint of bovine leather
SADC average
ZIMBABWE
ZAMBIA
TANZANIA
SWAZILAND
SOUTH AFRICA
SEYCHELLES
NAMIBIA
MOZAMBIQUE
MAURITIUS
MALAWI
MADAGASCAR
LESOTHO
D.R.CONGO
BOTSWANA
ANGOLA
Green WF
Blue WF
Grey WF
0 5000 10000 15000 20000 25000 30000 35000 m³/ton
Water footprint of swine leather
SADC average
ZIMBABWE
ZAMBIA
TANZANIA
SWAZILAND
SOUTH AFRICA
SEYCHELLES
NAMIBIA
MOZAMBIQUE
MAURITIUS
MALAWI
MADAGASCAR
LESOTHO
D.R.CONGO
BOTSWANA
ANGOLA
Green WF
Blue WF
Grey WF
0 10 20 30 40 50 60 70 80 90 100 10³ m³/ton


Water footprint of goat leather
SADC average
ZIMBABWE
ZAMBIA
TANZANIA
SWAZILAND
SOUTH AFRICA
SEYCHELLES
NAMIBIA
MOZAMBIQUE
MAURITIUS
MALAWI
MADAGASCAR
LESOTHO
D.R.CONGO
BOTSWANA
ANGOLA
0 5000 10000 15000 20000 25000 m³/ton
Green WF
Blue WF
Grey WF


Water footprint of sheap leather
SADC average
ZIMBABWE
ZAMBIA
TANZANIA
SWAZILAND
SOUTH AFRICA
SEYCHELLES
NAMIBIA
MOZAMBIQUE
MAURITIUS
MALAWI
MADAGASCAR
LESOTHO
D.R.CONGO
BOTSWANA
ANGOLA
0 1000 2000 3000 4000 5000 6000 7000 m³/ton
Green WF
Blue WF
Grey WF


Water footprint of bird's eggs in shell
SADC average
ZIMBABWE
ZAMBIA
TANZANIA
SWAZILAND
SOUTH AFRICA
SEYCHELLES
NAMIBIA
MOZAMBIQUE
MAURITIUS
MALAWI
MADAGASCAR
LESOTHO
D.R.CONGO
BOTSWANA
ANGOLA
0 5000 10000 15000 20000 25000 30000 m³/ton
Green WF
Blue WF
Grey WF


Water footprint of raw milk
SADC average
ZIMBABWE
ZAMBIA
TANZANIA
SWAZILAND
SOUTH AFRICA
SEYCHELLES
NAMIBIA
MOZAMBIQUE
MAURITIUS
MALAWI
MADAGASCAR
LESOTHO
D.R.CONGO
BOTSWANA
ANGOLA
0 1000 2000 3000 4000 5000 6000 7000 m³/ton
Green WF
Blue WF
Grey WF


Water footprint of processed cheese
SADC average
ZIMBABWE
ZAMBIA
TANZANIA
SWAZILAND
SOUTH AFRICA
SEYCHELLES
NAMIBIA
MOZAMBIQUE
MAURITIUS
MALAWI
MADAGASCAR
LESOTHO
D.R.CONGO
BOTSWANA
ANGOLA
0 5000 10000 15000 20000 25000 30000 35000 40000 m³/ton
Green WF
Blue WF
Grey WF

A5 Water footprint of industry

Country	Average industrial water withdrawal 1996-2005	Value added in industry										
		1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Average 1996 - 2005
	10^6 m^3/yr	10^6 US$/yr	10^6 US$/yr	10^6 US$/yr	10^6 US$/yr	10^6 US$/yr	10^6 US$/yr	10^6 US$/yr	10^6 US$/yr	10^6 US$/yr	10^6 US$/yr	10^6 US$/yr
Angola	60	4426	4650	3597	4474	6585	5798	7193	8336	13820	21928	8081
Botswana	35	2012	2500	2414	2084	2278	2342	2391	3452	3903	4258	2764
DRC	60	1867	1294	1245	1034	1055	1045	1171	1189	1510	1765	1318
Lesotho	20	326	387	311	340	320	289	263	383	468	546	363
Madagascar	230	558	487	523	521	591	689	678	877	735	897	655
Malawi	50	279	289	294	294	282	261	281	255	283	348	287
Mauritius	20	1253	1140	1130	1165	1241	1258	1285	1482	1610	1509	1307
Mozambique	10	463	600	850	903	919	937	984	1221	1573	1804	1025
Namibia	14	846	906	878	826	873	892	896	1173	1648	1681	1062
Seychelles	0	119	137	157	169	178	175	210	196	185	210	174
South Africa	756	43989	44463	39287	37752	38387	34795	33383	47744	59736	66083	44562
Swaziland	12	447	489	449	438	431	384	347	527	680	737	493
Tanzania	25	846	999	1195	1245	1319	1386	1456	1546	1730	1952	1368
Zambia	130	1002	1179	837	694	730	827	870	1035	1409	2028	1061
Zimbabwe	298	1967	1904	1273	1132	905	746	545	669	752	512	1041
SADC total	1720	60401	61424	54440	53072	56093	51825	51953	70086	90043	106259	65560
World total	775117	8683598	8566663	8178070	8425173	8806361	8438688	8631356	9703382	11053854	12197051	9268420

Country	Water withdrawal per unit value added										
	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Average 1996 - 2005
	m^3/US$	m^3/US$	m^3/US$	m^3/US$	m^3/US$	m^3/US$	m^3/US$	m^3/US$	m^3/US$	m^3/US$	m^3/US$
Angola	0.014	0.013	0.017	0.013	0.009	0.010	0.008	0.007	0.004	0.003	0.007
Botswana	0.017	0.014	0.014	0.017	0.015	0.015	0.015	0.010	0.009	0.008	0.013
DRC	0.032	0.046	0.048	0.058	0.057	0.057	0.051	0.050	0.040	0.034	0.046
Lesotho	0.061	0.052	0.064	0.059	0.063	0.069	0.076	0.052	0.043	0.037	0.055
Madagascar	0.412	0.473	0.440	0.442	0.389	0.334	0.339	0.262	0.313	0.257	0.351
Malawi	0.179	0.173	0.170	0.170	0.177	0.192	0.178	0.196	0.177	0.144	0.174
Mauritius	0.016	0.018	0.018	0.017	0.016	0.016	0.016	0.013	0.012	0.013	0.015
Mozambique	0.022	0.017	0.012	0.011	0.011	0.011	0.010	0.008	0.006	0.006	0.010
Namibia	0.017	0.015	0.016	0.017	0.016	0.016	0.016	0.012	0.008	0.008	0.013
Seychelles	0.089	0.090	0.095	0.092	0.088	0.092	0.090	0.080	0.070	0.064	0.084
South Africa	0.017	0.017	0.019	0.020	0.020	0.022	0.023	0.016	0.013	0.011	0.017
Swaziland	0.027	0.025	0.027	0.027	0.028	0.031	0.035	0.023	0.018	0.016	0.024
Tanzania	0.030	0.025	0.021	0.020	0.019	0.018	0.017	0.016	0.014	0.013	0.018
Zambia	0.130	0.110	0.155	0.187	0.178	0.157	0.150	0.126	0.092	0.064	0.123
Zimbabwe	0.151	0.157	0.234	0.263	0.329	0.399	0.546	0.445	0.396	0.582	0.286
SADC average	0.028	0.028	0.032	0.032	0.031	0.033	0.033	0.025	0.019	0.016	0.026
World average	0.089	0.090	0.095	0.092	0.088	0.092	0.090	0.080	0.070	0.064	0.084

A6 Virtual water trade

Total trade of commodities

Virtual water flows related to trade in agricultural and industrial products (average over the period 1996-2005)

Country	Import (green & blue water): Related to crop products (10^6 m^3/yr)	Import: Related to livestock products (10^6 m^3/yr)	Import: Related to industry products (10^6 m^3/yr)	Import: Total VWI# by products (10^6 m^3/yr)		Country	Export (green & blue water): Related to crop products (10^6 m^3/yr)	Export: Related to livestock products (10^6 m^3/yr)	Export: Related to industry products (10^6 m^3/yr)	Export: Total VWE^ by products (10^6 m^3/yr)
Angola	1180	665	147	1992		Angola	418	4	63	485
Botswana	277	64	38	380		Botswana	10	351	22	383
DRC	507	0	41	548		DRC	528	0	58	586
Lesotho	177	0	31	208		Lesotho	97	0	20	117
Madagascar	859	10	101	970		Madagascar	2011	30	157	2198
Malawi	584	306	42	932		Malawi	255	3	11	270
Mauritius*	1188	167	197	1553		Mauritius	755	18	20	792
Mozambique	1489	155	40	1684		Mozambique	590	5	7	602
Namibia	255	182	32	469		Namibia	47	215	9	271
Seychelles*	82	10	15	107		Seychelles	8	1	3	12
South Africa	7864	636	1949	10450		South Africa	4490	1734	585	6809
Swaziland	582	876	21	1479		Swaziland	365	145	8	517
Tanzania	1748	18	103	1869		Tanzania	1463	61	5	1529
Zambia	489	11	73	573		Zambia	348	19	170	538
Zimbabwe	863	29	78	970		Zimbabwe	876	478	342	1696
SADC total	18145	3131	2908	24184		SADC total	12262	3064	1478	16805

* Water footprints of agricultural products based on SADC average water footprint of these products

VWI: Virtual water import

^ VWE: Virtual water export

Average volumes of intra SADC virtual water trade of agricultural and industrial products (1996-2005)

Country	Crop products: Import: Virtual water import (10^6 m^3/yr)	Crop products: Import: Share of intra SADC trade (%)	Crop products: Export: Virtual water export (10^6 m^3/yr)	Crop products: Export: Share of intra SADC trade (%)	Livestock products: Import: Virtual water import (10^6 m^3/yr)	Livestock products: Import: Share of intra SADC trade (%)	Livestock products: Export: Virtual water export (10^6 m^3/yr)	Livestock products: Export: Share of intra SADC trade (%)	Industrial products: Import: Virtual water import (10^6 m^3/yr)	Industrial products: Import: Share of intra SADC trade (%)	Industrial products: Export: Virtual water export (10^6 m^3/yr)	Industrial products: Export: Share of intra SADC trade (%)
ANGOLA	42	1.45	3	0.11	27	1.99	3	0.25	4.18	1.74	0.36	0.15
BOTSWANA	114	3.90	6	0.22	40	3.02	3	0.24	11.18	4.66	1.14	0.48
CONGO, D.R.	131	4.47	9	0.30	9	0.69	0	0.00	5.12	2.13	1.78	0.74
LESOTHO	2	0.06	0	0.01	0.02	0.00	0.01	0.00	2.44	1.02	0.03	0.01
MADAGASCAR	59	2.01	25	0.84	1	0.08	3	0.20	2.62	1.09	8.74	3.65
MALAWI	305	10.44	116	3.98	300	22.50	1	0.05	19.52	8.14	8.33	3.47
MAURITIUS	105	3.59	33	1.13	42	3.18	1	0.07	12.68	5.29	1.63	0.68
MOZAMBIQUE	351	12.01	260	8.89	194	14.55	3	0.22	10.17	4.24	0.71	0.30
NAMIBIA	97	3.33	41	1.40	109	8.17	8	0.61	8.41	3.51	1.07	0.45
SEYCHELLES	13	0.44	6	0.20	1	0.11	0.004	0.00	0.72	0.30	0.22	0.09
SOUTH AFRICA	383	13.12	1678	57.44	36	2.73	808	60.60	93.79	39.12	68.78	28.69
SWAZILAND	288	9.85	63	2.16	529	39.65	139	10.39	4.29	1.79	0.88	0.37
TANZANIA, U.R	98	3.36	139	4.76	7	0.53	0.13	0.01	5.21	2.17	0.74	0.31
ZAMBIA	346	11.84	150	5.13	10	0.76	7	0.54	40.05	16.70	14.37	6.00
ZIMBABWE	588	20.13	392	13.42	27	2.04	358	26.83	19.39	8.09	130.96	54.62
Total intra SADC trade	2921	100.00	2921	100.00	1333	100.00	1333	100.00	239.75	100.00	239.75	100.00

Average share of intra regional virtual water trade related to crop products makes up 23.82% of total virtual water trade related to crop products

Average share of intra regional virtual water trade related to livestock products makes up 43.51% of total virtual water trade related to livestock products

Average share of intra regional virtual water trade related to industrial products makes up 16.22% of total virtual water trade related to industrial products

Trade of crop products

Overview of green, blue and grey virtual water flows per SADC nation related to the export of crop products from 22 crops (average 1996-2005; values exist of green & blue water)

Virtual water export of green water per SADC country

Country	Green virtual water export 1996 (10^6 m^3/yr)	Green virtual water export 1997 (10^6 m^3/yr)	Green virtual water export 1998 (10^6 m^3/yr)	Green virtual water export 1999 (10^6 m^3/yr)	Green virtual water export 2000 (10^6 m^3/yr)	Green virtual water export 2001 (10^6 m^3/yr)	Green virtual water export 2002 (10^6 m^3/yr)	Green virtual water export 2003 (10^6 m^3/yr)	Green virtual water export 2004 (10^6 m^3/yr)	Green virtual water export 2005 (10^6 m^3/yr)	Average green virtual water export 1996-2005 (10^6 m^3/yr)
ANGOLA	844.10	701.85	557.59	759.65	387.68	242.75	196.58	241.41	197.19	36.86	416.57
BOTSWANA	0.00	0.00	0.00	0.00	12.08	11.12	18.76	1.29	2.65	3.24	8.19
CONGO, D.R.	1561.10	842.20	725.13	616.18	461.07	289.64	123.49	125.98	240.25	186.26	517.13
LESOTHO	0.00	0.00	0.00	0.00	33.58	49.31	108.61	122.79	94.45	24.49	72.20
MADAGASCAR	2283.93	2788.11	2662.61	2405.46	3124.45	2395.47	827.04	1257.65	1091.33	589.72	1942.58
MALAWI	126.74	186.08	170.09	92.24	121.72	194.66	114.01	252.58	258.58	146.89	166.36
MAURITIUS	572.04	540.54	570.45	694.21	494.29	553.98	720.88	619.15	529.09	452.19	574.68
MOZAMBIQUE	316.56	477.65	239.06	343.14	491.00	188.78	1366.06	427.72	487.53	1057.38	539.49
NAMIBIA	0.00	0.00	0.00	0.00	121.58	16.12	61.05	21.15	7.05	11.72	39.78
SEYCHELLES	1.27	0.40	0.51	1.17	0.87	1.71	0.77	0.14	56.42	14.31	7.76
SOUTH AFRICA	3466.80	4015.47	2623.83	3464.60	4152.81	5506.42	4681.67	3367.38	2475.07	4680.26	3843.43
SWAZILAND	0.00	0.00	0.00	0.00	270.66	259.34	270.15	283.26	195.73	292.39	261.92
TANZANIA, U.R	1188.79	1417.53	1185.29	1019.05	1439.62	1116.71	1220.73	2124.77	1628.90	1789.76	1413.12
ZAMBIA	98.24	97.52	144.57	166.06	205.20	271.60	203.80	184.38	489.10	484.71	234.52
ZIMBABWE	667.00	2094.96	851.73	497.15	553.41	595.29	643.24	403.73	409.18	509.93	722.56
Grand Total	11126.56	13162.31	9730.88	10058.92	11870.03	11692.90	10556.84	9433.38	8162.51	10280.12	10760.28

Virtual water export of blue water per SADC country

Country	Blue virtual water export 1996 (10^6 m^3/yr)	Blue virtual water export 1997 (10^6 m^3/yr)	Blue virtual water export 1998 (10^6 m^3/yr)	Blue virtual water export 1999 (10^6 m^3/yr)	Blue virtual water export 2000 (10^6 m^3/yr)	Blue virtual water export 2001 (10^6 m^3/yr)	Blue virtual water export 2002 (10^6 m^3/yr)	Blue virtual water export 2003 (10^6 m^3/yr)	Blue virtual water export 2004 (10^6 m^3/yr)	Blue virtual water export 2005 (10^6 m^3/yr)	Average blue virtual water export 1996-2005 (10^6 m^3/yr)
ANGOLA	2.00	1.73	1.77	2.84	1.18	0.52	1.95	0.66	0.41	0.25	1.33
BOTSWANA	0.00	0.00	0.00	0.00	2.95	1.46	2.60	1.48	2.24	2.82	2.26
CONGO, D.R.	29.01	18.85	16.84	13.23	11.12	5.87	2.69	2.54	4.31	3.90	10.84
LESOTHO	0.00	0.00	0.00	0.00	10.91	16.12	28.43	34.62	32.49	28.79	25.23
MADAGASCAR	50.19	53.85	52.72	61.47	74.37	69.27	58.40	75.63	103.28	83.57	68.28
MALAWI	72.53	66.78	64.66	70.29	68.36	118.71	92.09	145.28	122.34	68.67	88.97
MAURITIUS	166.91	159.14	172.90	170.71	151.50	188.28	204.64	188.23	198.30	197.82	179.84
MOZAMBIQUE	33.14	61.90	28.25	21.52	62.74	21.96	84.69	57.52	46.76	84.92	50.34
NAMIBIA	0.00	0.00	0.00	0.00	12.96	1.70	14.48	4.76	4.78	5.79	7.41
SEYCHELLES	0.02	0.05	0.05	0.12	0.03	0.03	0.02	0.01	5.30	0.34	0.60
SOUTH AFRICA	299.54	403.99	393.85	563.30	1051.75	793.59	1522.09	555.80	446.69	437.98	646.86
SWAZILAND	0.00	0.00	0.00	0.00	95.92	123.99	96.31	91.93	110.41	98.52	102.85
TANZANIA, U.R	45.63	56.04	49.36	37.86	47.71	42.31	41.84	56.68	55.05	63.15	49.56
ZAMBIA	36.44	52.22	98.94	112.67	95.99	189.30	148.16	95.17	91.46	217.17	113.75
ZIMBABWE	219.45	163.94	147.46	147.27	219.77	171.56	119.40	91.14	151.09	106.19	153.73
Grand Total	954.86	1038.49	1026.80	1201.29	1907.26	1744.66	2417.76	1401.46	1374.90	1399.90	1501.83

Virtual water export of grey water per SADC country

Country	Grey virtual water export 1996 (10^6 m^3/yr)	Grey virtual water export 1997 (10^6 m^3/yr)	Grey virtual water export 1998 (10^6 m^3/yr)	Grey virtual water export 1999 (10^6 m^3/yr)	Grey virtual water export 2000 (10^6 m^3/yr)	Grey virtual water export 2001 (10^6 m^3/yr)	Grey virtual water export 2002 (10^6 m^3/yr)	Grey virtual water export 2003 (10^6 m^3/yr)	Grey virtual water export 2004 (10^6 m^3/yr)	Grey virtual water export 2005 (10^6 m^3/yr)	Average grey virtual water export 1996-2005 (10^6 m^3/yr)
ANGOLA	3.81	3.06	2.44	3.48	1.76	1.06	1.55	1.38	0.86	0.20	1.96
BOTSWANA	0.00	0.00	0.00	0.00	3.50	2.02	2.52	1.40	2.75	3.07	2.54
CONGO, D.R.	0.86	0.48	0.40	0.33	0.25	0.17	0.09	0.08	0.38	0.24	0.33
LESOTHO	0.00	0.00	0.00	0.00	12.81	18.97	29.22	37.52	39.78	33.16	28.58
MADAGASCAR	13.50	25.60	16.60	20.01	25.26	26.20	16.25	22.61	34.50	31.60	23.21
MALAWI	12.71	11.07	16.37	11.57	12.67	19.55	13.34	24.67	20.17	12.53	15.46
MAURITIUS	57.88	61.72	61.00	65.76	66.41	68.96	72.78	70.09	64.24	58.13	64.70
MOZAMBIQUE	3.34	4.69	3.93	52.03	7.05	3.41	26.56	15.93	14.19	100.47	23.16
NAMIBIA	0.00	0.00	0.00	0.00	19.67	1.65	3.53	5.53	5.42	4.22	6.67
SEYCHELLES	0.00	0.02	0.01	0.08	0.02	0.01	0.01	0.02	1.98	0.34	0.25
SOUTH AFRICA	504.21	505.27	281.69	304.20	603.75	697.06	827.97	406.45	253.95	525.06	490.96
SWAZILAND	0.00	0.00	0.00	0.00	10.12	7.71	12.95	19.02	14.67	25.38	14.97
TANZANIA, U.R	13.33	22.11	18.09	11.94	15.60	10.98	17.51	34.01	18.95	28.59	19.11
ZAMBIA	6.35	8.23	13.39	17.05	18.92	23.52	20.05	11.93	23.90	38.48	18.18
ZIMBABWE	68.50	145.07	57.44	52.68	60.73	51.68	55.38	33.97	33.45	44.38	60.33
Grand Total	684.48	787.32	471.36	539.12	858.51	932.96	1099.71	684.59	529.19	905.83	770.41

Overview of most important trading partners of SADC nations related to trade in 22 major water consuming crops (average 1996-2005; values exist of green & blue water)

		Vitual water import				Vitual water export	
Country	Partner countries	Average (1996-2005) (10^6 m^3/yr)	Share (%)		Partner countries	Average (1996-2005) (10^6 m^3/yr)	Share (%)
ANGOLA	THAILAND	225.47	19.10		PORTUGAL	213.60	51.11
	BELGIUM	172.54	14.62		SPAIN	128.14	30.66
	BRAZIL	169.31	14.35		ITALY	59.60	14.26
	USA	153.89	13.04		BELGIUM	4.84	1.16
	FRANCE	76.13	6.45		NAMIBIA	2.72	0.65
	SOUTH AFRICA	73.92	6.26		MOROCCO	2.48	0.59
	PORTUGAL	65.32	5.53		FRANCE	2.08	0.50
	ARGENTINA	54.89	4.65		ALGERIA	1.65	0.40
	ITALY	32.24	2.73		GHANA	0.71	0.17
	NAMIBIA	26.42	2.24		SOUTH AFRICA	0.63	0.15
	OTHER	130.08	11.02		OTHER	1.45	0.35
	TOTAL	1180.21	100.00		TOTAL	417.90	100.00

		Vitual water import				Vitual water export	
Country	Partner countries	Average (1996-2005) (10^6 m^3/yr)	Share (%)		Partner countries	Average (1996-2005) (10^6 m^3/yr)	Share (%)
BOTSWANA	SOUTH AFRICA	204.27	73.68		ZAMBIA	4.27	40.83
	ZIMBABWE	28.04	10.11		USA	1.84	17.58
	AUSTRALIA	13.37	4.82		CONGO, D.R.	1.44	13.83
	USA	7.10	2.56		UNITED KINGDOM	0.75	7.16
	USA Pacific Terr.	5.39	1.94		NIGERIA	0.70	6.74
	CHINA	4.88	1.76		MALAWI	0.45	4.27
	INDIA	3.53	1.27		GERMANY	0.29	2.74
	ZAMBIA	2.55	0.92		ZIMBABWE	0.22	2.09
	ARGENTINA	2.04	0.73		FRANCE	0.14	1.38
	TAIWAN (POC)	0.99	0.36		BELGIUM	0.06	0.56
	OTHER	5.07	1.83		OTHER	0.29	2.81
	TOTAL	277.23	100.00		TOTAL	10.45	100

		Vitual water import				Vitual water export	
Country	Partner countries	Average (1996-2005) (10^6 m^3/yr)	Share (%)		Partner countries	Average (1996-2005) (10^6 m^3/yr)	Share (%)
CONGO, D.R.	UGANDA	99.35	19.60		ITALY	330.40	62.58
	USA	78.44	15.47		FRANCE	38.99	7.39
	SOUTH AFRICA	75.91	14.97		SPAIN	30.63	5.80
	ZAMBIA	51.93	10.24		BELGIUM	25.09	4.75
	BELGIUM	47.85	9.44		GERMANY	22.93	4.34
	TANZANIA, U.R	29.51	5.82		NETHERLANDS	17.86	3.38
	FRANCE	21.83	4.30		AUSTRIA	9.53	1.80
	ARGENTINA	14.83	2.93		SOUTH AFRICA	8.31	1.57
	SINGAPORE	10.47	2.06		HUNGARY	5.40	1.02
	BRAZIL	9.65	1.90		MOROCCO	5.14	0.97
	OTHER	67.23	13.26		OTHER	33.68	6.38
	TOTAL	506.99	100.00		TOTAL	527.97	100.00

	Vitual water import				Vitual water export	
Country	Partner countries	Average (1996-2005) (10^6 m^3/yr)	Share (%)	Partner countries	Average (1996-2005) (10^6 m^3/yr)	Share (%)
LESOTHO	HONG KONG	43.44	24.55	USA	93.63	96.10
	PAKISTAN	39.93	22.56	CANADA	1.81	1.86
	TAIWAN (POC)	29.77	16.82	UNITED KINGDOM	1.29	1.32
	INDIA	14.66	8.28	ZAMBIA	0.14	0.14
	CHINA	12.65	7.15	FRANCE	0.12	0.12
	USA	11.67	6.59	MAURITIUS	0.09	0.10
	MALAWI	8.97	5.07	HONG KONG	0.09	0.09
	ZIMBABWE	6.64	3.75	BOTSWANA	0.06	0.06
	PHILIPPINES	2.48	1.40	JAPAN	0.06	0.06
	INDONESIA	1.96	1.11	MEXICO	0.04	0.04
	OTHER	4.80	2.71	OTHER	0.10	0.11
	TOTAL	176.97	100.00	TOTAL	97.43	100.00

	Vitual water import				Vitual water export	
Country	Partner countries	Average (1996-2005) (10^6 m^3/yr)	Share (%)	Partner countries	Average (1996-2005) (10^6 m^3/yr)	Share (%)
MADAGASCAR	PAKISTAN	325.43	37.88	SINGAPORE	513.71	25.55
	INDIA	83.32	9.70	FRANCE	319.09	15.87
	THAILAND	64.77	7.54	INDONESIA	226.21	11.25
	SOUTH AFRICA	58.96	6.86	USA	157.48	7.83
	CHINA	54.49	6.34	ALGERIA	142.37	7.08
	MALAYSIA	40.12	4.67	ITALY	109.84	5.46
	USA	36.19	4.21	SPAIN	63.32	3.15
	ARGENTINA	28.61	3.33	INDIA	49.42	2.46
	FRANCE	27.18	3.16	BELGIUM	42.47	2.11
	MAURITIUS	19.69	2.29	POLAND	36.47	1.81
	OTHER	120.30	14.00	OTHER	350.47	17.43
	TOTAL	859.05	100.00	TOTAL	2010.85	100.00

	Vitual water import				Vitual water export	
Country	Partner countries	Average (1996-2005) (10^6 m^3/yr)	Share (%)	Partner countries	Average (1996-2005) (10^6 m^3/yr)	Share (%)
MALAWI	MOZAMBIQUE	227.83	39.03	SOUTH AFRICA	61.63	24.14
	SOUTH AFRICA	86.17	14.76	ZIMBABWE	35.46	13.89
	USA	60.98	10.45	KENYA	26.86	10.52
	ZIMBABWE	37.00	6.34	GERMANY	26.27	10.29
	United Arab Emirates	30.52	5.23	PORTUGAL	17.60	6.89
	TANZANIA, U.R	17.93	3.07	USA	15.61	6.11
	ARGENTINA	15.84	2.71	UNITED KINGDOM	15.46	6.06
	ZAMBIA	13.12	2.25	MOZAMBIQUE	7.08	2.77
	SINGAPORE	9.87	1.69	FRANCE	6.73	2.64
	ITALY	9.55	1.64	ZAMBIA	5.13	2.01
	OTHER	74.95	12.84	OTHER	37.50	14.69
	TOTAL	583.76	100.00	TOTAL	255.33	100.00

		Vitual water import				Vitual water export	
Country	Partner countries	Average (1996-2005) (10^6 m^3/yr)	Share (%)		Partner countries	Average (1996-2005) (10^6 m^3/yr)	Share (%)
MAURITIUS	INDIA	335.58	28.24		UNITED KINGDOM	472.58	62.63
	PAKISTAN	197.89	16.65		USA	55.52	7.36
	AUSTRALIA	112.58	9.47		FRANCE	49.69	6.59
	SOUTH AFRICA	103.34	8.70		PORTUGAL	43.88	5.82
	ARGENTINA	102.47	8.62		GERMANY	15.72	2.08
	FRANCE	62.93	5.30		MADAGASCAR	13.75	1.82
	THAILAND	62.71	5.28		ITALY	12.22	1.62
	CHINA	41.00	3.45		BELGIUM	10.12	1.34
	MALI	21.05	1.77		NETHERLANDS	9.67	1.28
	MALAYSIA	20.19	1.70		SPAIN	7.59	1.01
	OTHER	128.55	10.82		OTHER	63.79	8.45
	TOTAL	1188.28	100.00		TOTAL	754.53	100.00

		Vitual water import				Vitual water export	
Country	Partner countries	Average (1996-2005) (10^6 m^3/yr)	Share (%)		Partner countries	Average (1996-2005) (10^6 m^3/yr)	Share (%)
MOZAMBIQUE	SOUTH AFRICA	339.45	22.79		MALAWI	179.36	30.41
	USA	262.74	17.64		USA	89.73	15.21
	THAILAND	191.16	12.84		PORTUGAL	47.00	7.97
	INDIA	118.09	7.93		SOUTH AFRICA	41.46	7.03
	PAKISTAN	98.05	6.58		KENYA	20.54	3.48
	ARGENTINA	80.56	5.41		ZIMBABWE	18.32	3.11
	ZIMBABWE	71.93	4.83		MOROCCO	17.15	2.91
	SINGAPORE	58.30	3.91		INDIA	15.21	2.58
	CANADA	52.28	3.51		INDONESIA	14.93	2.53
	BRAZIL	35.57	2.39		UNITED KINGDOM	14.41	2.44
	OTHER	181.12	12.16		OTHER	131.73	22.33
	TOTAL	1489.27	100.00		TOTAL	589.83	100.00

		Vitual water import				Vitual water export	
Country	Partner countries	Average (1996-2005) (10^6 m^3/yr)	Share (%)		Partner countries	Average (1996-2005) (10^6 m^3/yr)	Share (%)
NAMIBIA	SOUTH AFRICA	95.11	37.37		ANGOLA	39.89	84.53
	USA	19.19	7.54		USA	4.56	9.66
	ZIMBABWE	8.37	3.29		ZAMBIA	1.07	2.27
	ANGOLA	5.68	2.23		NIGERIA	0.54	1.14
	FRANCE	5.54	2.18		ITALY	0.36	0.76
	COTE DIVOIRE	2.26	0.89		ERITREA	0.14	0.30
	CHINA	2.16	0.85		TAIWAN (POC)	0.12	0.25
	MOROCCO	1.59	0.62		CONGO	0.09	0.19
	CANADA	1.41	0.55		FRANCE	0.05	0.10
	MALAYSIA	1.38	0.54		UGANDA	0.05	0.10
	OTHER	111.83	43.94		OTHER	0.32	0.68
	TOTAL	254.54	100.00		TOTAL	47.19	100.00

	Vitual water import			Vitual water export	
Country	Partner countries	Average (1996-2005) (10^6 m^3/yr)	Share (%)	Partner countries	Average (1996-2005) (10^6 m^3/yr)	Share (%)
SEYCHELLES	INDIA	27.27	33.45	ZIMBABWE	3.42	40.95
	SINGAPORE	16.75	20.54	MALAWI	2.36	28.24
	UKRAINE	14.36	17.62	GEORGIA	1.69	20.18
	MAURITIUS	4.28	5.25	AUSTRIA	0.14	1.73
	UNITED KINGDOM	4.03	4.94	FRANCE	0.11	1.37
	SOUTH AFRICA	3.86	4.73	GERMANY	0.11	1.35
	MADAGASCAR	3.09	3.78	HUNGARY	0.10	1.19
	ZIMBABWE	1.03	1.27	MACEDONIA, TFYR	0.08	1.00
	SWITZERLAND	0.98	1.20	YUGOSLAVIA	0.08	0.93
	MOLDOVA REP.	0.89	1.09	MAURITIUS	0.07	0.82
	OTHER	5.00	6.13	OTHER	0.19	2.24
	TOTAL	81.53	100.00	TOTAL	8.35	100.00

		Vitual water import			Vitual water export	
Country	Partner countries	Average (1996-2005) (10^6 m^3/yr)	Share (%)	Partner countries	Average (1996-2005) (10^6 m^3/yr)	Share (%)
SOUTH AFRICA	THAILAND	1764.72	22.44	JAPAN	623.90	13.89
	ARGENTINA	1323.57	16.83	ZIMBABWE	488.45	10.88
	USA	938.01	11.93	SWAZILAND	283.17	6.31
	INDIA	844.81	10.74	KENYA	271.76	6.05
	ZIMBABWE	446.12	5.67	MOZAMBIQUE	232.05	5.17
	INDONESIA	408.76	5.20	KOREA REPUBLIC	207.29	4.62
	MALAYSIA	404.86	5.15	ZAMBIA	163.93	3.65
	AUSTRALIA	290.72	3.70	USA	136.11	3.03
	ZAMBIA	194.21	2.47	IRAN (ISLM.R)	112.83	2.51
	CHINA	144.33	1.84	MALAYSIA	111.92	2.49
	OTHER	1104.18	14.04	OTHER	1858.88	41.40
	TOTAL	7864.28	100.00	TOTAL	4490.29	100

		Vitual water import			Vitual water export	
Country	Partner countries	Average (1996-2005) (10^6 m^3/yr)	Share (%)	Partner countries	Average (1996-2005) (10^6 m^3/yr)	Share (%)
SWAZILAND	SOUTH AFRICA	323.78	92.65	USA	74.74	20.49
	MOZAMBIQUE	7.01	2.01	UNITED KINGDOM	72.42	19.85
	TAIWAN (POC)	3.79	1.08	FRANCE	51.25	14.05
	USA	3.01	0.86	MOZAMBIQUE	48.38	13.26
	HONG KONG	2.81	0.80	FINLAND	16.42	4.50
	CHINA	1.77	0.51	PORTUGAL	14.42	3.95
	TANZANIA, U.R	1.77	0.51	NETHERLANDS	12.65	3.47
	UGANDA	0.95	0.27	KENYA	12.13	3.33
	THAILAND	0.72	0.21	TANZANIA, U.R	9.59	2.63
	GUYANA	0.54	0.15	RUSSIAN FED.	7.69	2.11
	OTHER	236.31	0.95	OTHER	45.08	12.36
	TOTAL	582.46	100.00	TOTAL	364.77	100.00

	Vitual water import			Vitual water export	
Country	**Partner countries**	**Average (1996-2005) (10^6 m^3/yr)**	**Share (%)**	**Partner countries**	**Average (1996-2005) (10^6 m^3/yr)**	**Share (%)**
TANZANIA	INDONESIA	257.21	14.72	GERMANY	259.80	17.76
	AUSTRALIA	212.16	12.14	JAPAN	165.49	11.31
	INDIA	172.31	9.86	KENYA	80.04	5.47
	PAKISTAN	169.46	9.69	ZAMBIA	61.95	4.24
	VIET NAM	138.91	7.95	BURUNDI	58.03	3.97
	THAILAND	114.53	6.55	BELGIUM	51.77	3.54
	SOUTH AFRICA	102.00	5.84	INDONESIA	50.53	3.45
	USA	83.79	4.79	NETHERLANDS	47.81	3.27
	MALAYSIA	64.12	3.67	ST.HELENA	45.09	3.08
	ARGENTINA	47.24	2.70	ITALY	43.46	2.97
	OTHER	386.22	22.10	OTHER	598.71	40.93
	TOTAL	1747.94	100.00	TOTAL	1462.68	100.00

		Vitual water import		Vitual water export		
Country	**Partner countries**	**Average (1996-2005) (10^6 m^3/yr)**	**Share (%)**	**Partner countries**	**Average (1996-2005) (10^6 m^3/yr)**	**Share (%)**
ZAMBIA	SOUTH AFRICA	183.95	37.59	SOUTH AFRICA	65.80	18.89
	ZIMBABWE	136.49	27.89	CONGO	51.85	14.89
	TANZANIA, U.R	45.34	9.26	CONGO, D.R.	39.92	11.46
	KENYA	24.46	5.00	GERMANY	31.73	9.11
	THAILAND	11.64	2.38	ZIMBABWE	28.44	8.17
	INDIA	11.56	2.36	PORTUGAL	20.85	5.99
	PAKISTAN	10.68	2.18	FINLAND	16.83	4.83
	MALAWI	8.49	1.73	BELGIUM	15.02	4.31
	UGANDA	7.87	1.61	UNITED KINGDOM	7.44	2.14
	GERMANY	7.31	1.49	CHINA	7.37	2.12
	OTHER	41.58	8.50	OTHER	63.02	18.10
	TOTAL	489.37	100.00	TOTAL	348.27	100.00

		Vitual water import		Vitual water export		
Country	**Partner countries**	**Average (1996-2005) (10^6 m^3/yr)**	**Share (%)**	**Partner countries**	**Average (1996-2005) (10^6 m^3/yr)**	**Share (%)**
ZIMBABWE	SOUTH AFRICA	480.15	55.63	SOUTH AFRICA	174.11	19.87
	USA	53.16	6.16	ZAMBIA	104.79	11.96
	MALAWI	52.46	6.08	KENYA	90.07	10.28
	ZAMBIA	47.82	5.54	MOZAMBIQUE	61.25	6.99
	MOZAMBIQUE	34.76	4.03	GERMANY	52.44	5.98
	ARGENTINA	29.08	3.37	THAILAND	49.88	5.69
	AUSTRALIA	26.33	3.05	UNITED KINGDOM	40.63	4.64
	THAILAND	18.05	2.09	PORTUGAL	33.75	3.85
	INDIA	17.63	2.04	MALAWI	28.41	3.24
	CHINA	12.50	1.45	ITALY	23.12	2.64
	OTHER	91.22	10.57	OTHER	217.85	24.86
	TOTAL	863.15	100.00	TOTAL	876.29	100.00

Overview of most important traded crop products of SADC members related to trade in 22 major water consuming crops (average 1996-2005; values exist of green & blue water)

	Vitual water import				Vitual water export		
Country	**Product**	**Average (1996-2005) (10^6 m^3/yr)**	**Share (%)**		**Product**	**Average (1996-2005) (10^6 m^3/yr)**	**Share (%)**
ANGOLA	Rice	275.27	23.32		Coffee, green	412.94	98.81
	Wheat	242.20	20.52		Millet	1.93	0.46
	Sugarcane	227.77	19.30		Wheat	1.05	0.25
	Maize	189.22	16.03		Oil palm	0.50	0.12
	Soybean	121.21	10.27		Cotton seed	0.48	0.12
	Oil palm	42.48	3.60		Sugarcane	0.38	0.09
	Cotton seed	34.38	2.91		Maize	0.24	0.06
	Sunflower seed	16.57	1.40		Rice	0.19	0.04
	Sorghum	10.20	0.86		Soybean	0.09	0.02
	Potato	9.89	0.84		Sunflower seed	0.09	0.02
	OTHER	11.03	0.93		OTHER	0.00	0.001
	TOTAL	1180.21	100.00		TOTAL	417.90	100.00

	Vitual water import				Vitual water export		
Country	**Product**	**Average (1996-2005) (10^6 m^3/yr)**	**Share (%)**		**Product**	**Average (1996-2005) (10^6 m^3/yr)**	**Share (%)**
BOTSWANA	Sugarcane	50.58	18.24		Maize	3.77	36.10
	Cotton seed	45.73	16.50		Cotton seed	3.28	31.43
	Maize	42.31	15.26		Sunflower seed	1.71	16.36
	Wheat	37.94	13.68		Sugarcane	0.70	6.74
	Sunflower seed	28.33	10.22		Wheat	0.53	5.10
	Rice	28.16	10.16		Sorghum	0.11	1.06
	Sorghum	18.07	6.52		Soybean	0.09	0.91
	Potato	7.98	2.88		Groundnut	0.09	0.84
	Coffee, green	5.58	2.01		Coffee, green	0.09	0.83
	Soybean	4.84	1.75		Orange	0.03	0.31
	OTHER	7.71	2.78		OTHER	0.03	0.33
	TOTAL	277.23	100.00		TOTAL	10.45	100.00

	Vitual water import				Vitual water export		
Country	**Product**	**Average (1996-2005) (10^6 m^3/yr)**	**Share (%)**		**Product**	**Average (1996-2005) (10^6 m^3/yr)**	**Share (%)**
CONGO, D.R.	Wheat	197.68	38.99		Coffee, green	507.08	96.04
	Maize	127.06	25.06		Maize	10.96	2.08
	Sugarcane	50.13	9.89		Oil palm	6.85	1.30
	Rice	49.20	9.70		Sugarcane	1.10	0.21
	Oil palm	26.22	5.17		Cotton seed	1.10	0.21
	Sunflower seed	18.26	3.60		Rice	0.45	0.09
	Cotton seed	17.54	3.46		Banana	0.19	0.04
	Soybean	11.66	2.30		Soybean	0.14	0.03
	Groundnut	4.61	0.91		Potato	0.08	0.02
	Coffee, green	3.14	0.62		Clove	0.01	0.003
	OTHER	1.50	0.30		OTHER	0.01	0.002
	TOTAL	506.99	100.00		TOTAL	527.97	100.00

		Vitual water import				Vitual water export	
Country	Product	Average (1996-2005) (10^6 m^3/yr)	Share (%)		Product	Average (1996-2005) (10^6 m^3/yr)	Share (%)
LESOTHO	Cotton seed	114.56	64.74		Cotton seed	96.19	98.73
	Rice	46.94	26.52		Maize	1.01	1.04
	Maize	11.66	6.59		Orange	0.11	0.12
	Wheat	3.02	1.71		Wheat	0.06	0.06
	Sorghum	0.50	0.28		Sugarcane	0.03	0.03
	Soybean	0.09	0.05		Sorghum	0.02	0.02
	Sunflower seed	0.09	0.05		Rice	0.01	0.01
	Cassava	0.07	0.04		Groundnut	0.002	0.002
	Sugarcane	0.05	0.03		Potato	0.002	0.002
					Oil palm	0.001	0.001
	OTHER	0.00	0.00		OTHER	0.001	0.001
	TOTAL	176.97	100.00		TOTAL	97.43	100.00

		Vitual water import				Vitual water export	
Country	Product	Average (1996-2005) (10^6 m^3/yr)	Share (%)		Product	Average (1996-2005) (10^6 m^3/yr)	Share (%)
MADAGASCAR	Rice	548.14	63.81		Clove	1021.95	50.82
	Soybean	105.04	12.23		Coffee, green	785.65	39.07
	Sugarcane	77.38	9.01		Cotton seed	113.53	5.65
	Wheat	68.28	7.95		Sugarcane	44.81	2.23
	Cotton seed	27.53	3.20		Maize	23.12	1.15
	Oil palm	17.85	2.08		Oil palm	8.19	0.41
	Maize	8.48	0.99		Groundnut	6.47	0.32
	Sunflower seed	3.11	0.36		Rice	3.85	0.19
	Coconut	2.91	0.34		Wheat	2.55	0.13
	Coffee, green	0.12	0.01		Cassava	0.43	0.02
	OTHER	0.21	0.02		OTHER	0.32	0.02
	TOTAL	859.05	100.00		TOTAL	2010.85	100.00

		Vitual water import				Vitual water export	
Country	Product	Average (1996-2005) (10^6 m^3/yr)	Share (%)		Product	Average (1996-2005) (10^6 m^3/yr)	Share (%)
MALAWI	Maize	190.59	32.65		Sugarcane	83.62	32.75
	Wheat	141.11	24.17		Coffee, green	44.47	17.42
	Sorghum	93.90	16.09		Cotton seed	40.15	15.72
	Soybean	47.45	8.13		Maize	25.51	9.99
	Cotton seed	36.57	6.27		Groundnut	21.28	8.33
	Rice	25.34	4.34		Rice	14.55	5.70
	Oil palm	17.28	2.96		Sunflower seed	14.04	5.50
	Sunflower seed	15.66	2.68		Soybean	9.11	3.57
	Groundnut	5.82	1.00		Oil palm	1.72	0.68
	Sugarcane	4.74	0.81		Wheat	0.65	0.26
	OTHER	5.30	0.91		OTHER	0.22	0.09
	TOTAL	583.76	100.00		TOTAL	255.33	100.00

		Vitual water import				Vitual water export	
Country	Product	Average (1996-2005) (10^6 m^3/yr)	Share (%)		Product	Average (1996-2005) (10^6 m^3/yr)	Share (%)
MAURITIUS	Cotton seed	424.94	35.76		Sugarcane	540.89	71.69
	Rice	322.02	27.10		Cotton seed	174.51	23.13
	Wheat	176.54	14.86		Wheat	19.38	2.57
	Soybean	93.33	7.85		Oil palm	10.48	1.39
	Sugarcane	75.39	6.34		Rice	3.34	0.44
	Maize	43.15	3.63		Sunflower seed	2.91	0.39
	Sunflower seed	25.19	2.12		Clove	1.13	0.15
	Oil palm	8.29	0.70		Coffee, green	0.78	0.10
	Groundnut	7.66	0.64		Maize	0.51	0.07
	Clove	4.20	0.35		Soybean	0.45	0.06
	OTHER	7.58	0.64		OTHER	0.14	0.02
	TOTAL	1188.28	100.00		TOTAL	754.53	100.00

		Vitual water import				Vitual water export	
Country	Product	Average (1996-2005) (10^6 m^3/yr)	Share (%)		Product	Average (1996-2005) (10^6 m^3/yr)	Share (%)
MOZAMBIQUE	Rice	434.97	29.21		Sugarcane	216.47	36.70
	Wheat	276.64	18.58		Maize	141.38	23.97
	Sugarcane	261.99	17.59		Cotton seed	100.33	17.01
	Maize	232.75	15.63		Wheat	44.71	7.58
	Oil palm	101.03	6.78		Sorghum	37.39	6.34
	Sunflower seed	58.09	3.90		Coconut	25.14	4.26
	Cotton seed	42.61	2.86		Rice	12.17	2.06
	Soybean	35.24	2.37		Groundnut	6.01	1.02
	Groundnut	19.28	1.29		Oil palm	2.69	0.46
	Orange	9.02	0.61		Orange	0.90	0.15
	OTHER	17.66	1.19		OTHER	2.63	0.45
	TOTAL	1489.27	100.00		TOTAL	589.83	100.00

		Vitual water import				Vitual water export	
Country	Product	Average (1996-2005) (10^6 m^3/yr)	Share (%)		Product	Average (1996-2005) (10^6 m^3/yr)	Share (%)
NAMIBIA	Sunflower seed	53.13	20.87		Potato	14.63	31.01
	Wheat	48.07	18.89		Sugarcane	12.41	26.30
	Maize	42.16	16.56		Sunflower seed	6.19	13.13
	Cotton seed	36.09	14.18		Cotton seed	5.47	11.60
	Rice	27.76	10.90		Maize	4.19	8.88
	Sugarcane	20.55	8.07		Rice	2.82	5.98
	Coffee, green	9.53	3.75		Soybean	0.71	1.49
	Millet	8.26	3.25		Wheat	0.42	0.89
	Soybean	2.10	0.82		Coffee, green	0.20	0.43
	Potato	1.96	0.77		Groundnut	0.04	0.09
	OTHER	4.93	1.94		OTHER	0.09	0.20
	TOTAL	254.54	100.00		TOTAL	47.19	100.00

		Vitual water import				Vitual water export	
Country	Product	Average (1996-2005) (10^6 m^3/yr)	Share (%)		Product	Average (1996-2005) (10^6 m^3/yr)	Share (%)
SEYCHELLES	Sunflower seed	29.62	36.33		Oil palm	4.29	51.32
	Rice	26.81	32.88		Sugarcane	1.69	20.19
	Maize	6.47	7.94		Soybean	1.57	18.74
	Soybean	6.16	7.55		Coffee, green	0.37	4.41
	Oil palm	4.77	5.85		Cotton seed	0.17	2.08
	Wheat	2.54	3.12		Banana	0.13	1.58
	Sugarcane	2.07	2.53		Coconut	0.10	1.18
	Cotton seed	1.64	2.01		Potato	0.02	0.21
	Coffee, green	1.08	1.32		Sunflower seed	0.01	0.13
	Potato	0.17	0.21		Maize	0.01	0.12
	OTHER	0.21	0.26		OTHER	0.00	0.04
	TOTAL	81.53	100.00		TOTAL	8.35	100.00

		Vitual water import				Vitual water export	
Country	Product	Average (1996-2005) (10^6 m^3/yr)	Share (%)		Product	Average (1996-2005) (10^6 m^3/yr)	Share (%)
SOUTH AFRICA	Rice	2839.14	36.10		Maize	1678.32	37.38
	Cotton seed	975.95	12.41		Sugarcane	1389.83	30.95
	Wheat	916.28	11.65		Cotton seed	485.92	10.82
	Sunflower seed	694.99	8.84		Orange	232.30	5.17
	Soybean	676.00	8.60		Sunflower seed	198.86	4.43
	Oil palm	598.16	7.61		Coffee, green	101.23	2.25
	Maize	523.73	6.66		Rice	97.64	2.17
	Coffee, green	360.59	4.59		Wheat	80.45	1.79
	Groundnut	100.17	1.27		Groundnut	74.88	1.67
	Sugarcane	52.58	0.67		Soybean	61.83	1.38
	OTHER	126.69	1.61		OTHER	89.03	1.98
	TOTAL	7864.28	100.00		TOTAL	4490.29	100.00

		Vitual water import				Vitual water export	
Country	Product	Average (1996-2005) (10^6 m^3/yr)	Share (%)		Product	Average (1996-2005) (10^6 m^3/yr)	Share (%)
SWAZILAND	Cotton seed	400.37	68.74		Sugarcane	216.42	59.33
	Maize	45.03	7.73		Cotton seed	67.95	18.63
	Rice	41.01	7.04		Orange	22.94	6.29
	Sunflower seed	28.61	4.91		Sunflower seed	15.88	4.35
	Wheat	25.38	4.36		Wheat	15.10	4.14
	Coconut	10.80	1.85		Groundnut	13.19	3.62
	Groundnut	8.38	1.44		Maize	9.07	2.49
	Sugarcane	7.82	1.34		Coffee, green	1.59	0.44
	Coffee, green	5.20	0.89		Coconut	0.81	0.22
	Soybean	2.58	0.44		Soybean	0.80	0.22
	OTHER	7.27	1.25		OTHER	1.02	0.28
	TOTAL	582.46	100.00		TOTAL	364.77	100.00

		Vitual water import				Vitual water export	
Country	Product	Average (1996-2005) (10^6 m^3/yr)	Share (%)		Product	Average (1996-2005) (10^6 m^3/yr)	Share (%)
TANZANIA	Wheat	498.15	28.50		Coffee, green	827.07	56.54
	Rice	467.90	26.77		Cotton seed	235.04	16.07
	Oil palm	349.64	20.00		Maize	165.45	11.31
	Sugarcane	189.89	10.86		Clove	61.90	4.23
	Maize	134.03	7.67		Sunflower seed	39.86	2.72
	Cotton seed	56.06	3.21		Wheat	35.85	2.45
	Sunflower seed	24.45	1.40		Rice	35.15	2.40
	Soybean	21.03	1.20		Groundnut	34.20	2.34
	Groundnut	2.97	0.17		Sugarcane	17.21	1.18
	Potato	1.91	0.11		Soybean	3.95	0.27
	OTHER	1.91	0.11		OTHER	7.02	0.48
	TOTAL	1747.94	100.00		TOTAL	1462.68	100.00

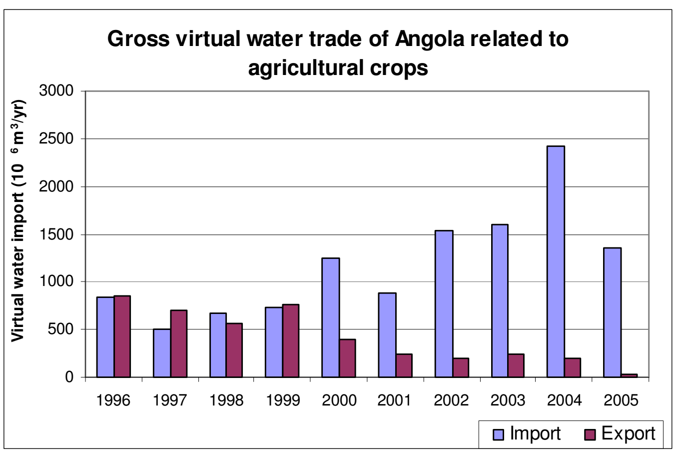
		Vitual water import				Vitual water export	
Country	Product	Average (1996-2005) (10^6 m^3/yr)	Share (%)		Product	Average (1996-2005) (10^6 m^3/yr)	Share (%)
ZAMBIA	Maize	180.28	36.84		Sugarcane	110.17	31.63
	Rice	65.59	13.40		Cotton seed	86.83	24.93
	Wheat	60.57	12.38		Coffee, green	75.30	21.62
	Soybean	50.07	10.23		Maize	51.48	14.78
	Oil palm	44.02	9.00		Soybean	6.42	1.84
	Cotton seed	33.18	6.78		Potato	5.62	1.61
	Sunflower seed	23.68	4.84		Groundnut	3.67	1.05
	Orange	7.87	1.61		Wheat	3.45	0.99
	Banana	6.41	1.31		Sunflower seed	1.83	0.53
	Sugarcane	5.78	1.18		Rice	1.36	0.39
	OTHER	11.93	2.44		OTHER	2.15	0.62
	TOTAL	489.37	100.00		TOTAL	348.27	100.00

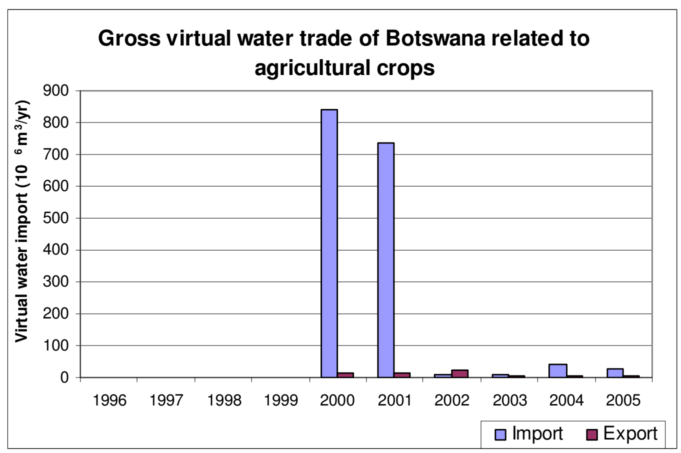
		Vitual water import				Vitual water export	
Country	Product	Average (1996-2005) (10^6 m^3/yr)	Share (%)		Product	Average (1996-2005) (10^6 m^3/yr)	Share (%)
ZIMBABWE	Maize	428.57	49.65		Cotton seed	272.36	31.08
	Wheat	114.57	13.27		Maize	258.34	29.48
	Soybean	101.57	11.77		Sugarcane	120.69	13.77
	Rice	78.92	9.14		Coffee, green	69.00	7.87
	Cotton seed	44.22	5.12		Orange	57.04	6.51
	Sunflower seed	37.42	4.34		Sunflower seed	30.73	3.51
	Oil palm	27.16	3.15		Wheat	23.78	2.71
	Sorghum	10.44	1.21		Groundnut	13.85	1.58
	Sugarcane	7.98	0.92		Soybean	13.04	1.49
	Groundnut	6.88	0.80		Banana	9.89	1.13
	OTHER	5.41	0.63		OTHER	7.58	0.86
	TOTAL	863.15	100.00		TOTAL	876.29	100.00

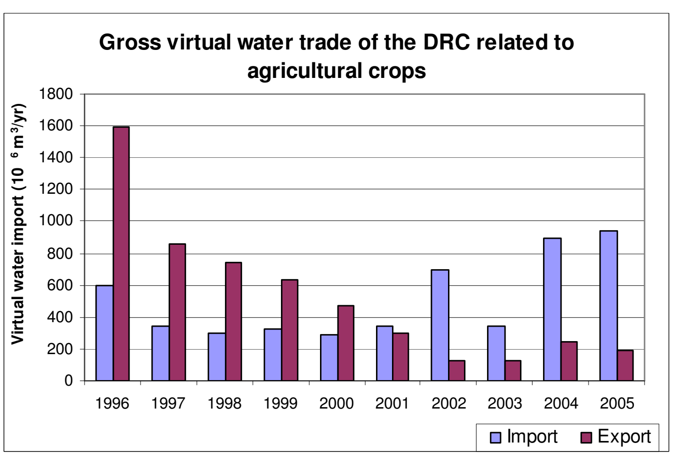
Virtual water volumes traded between SADC members and other world regions related to crop products of 22 major water consuming crops (1996-2005; values exist of green & blue water)

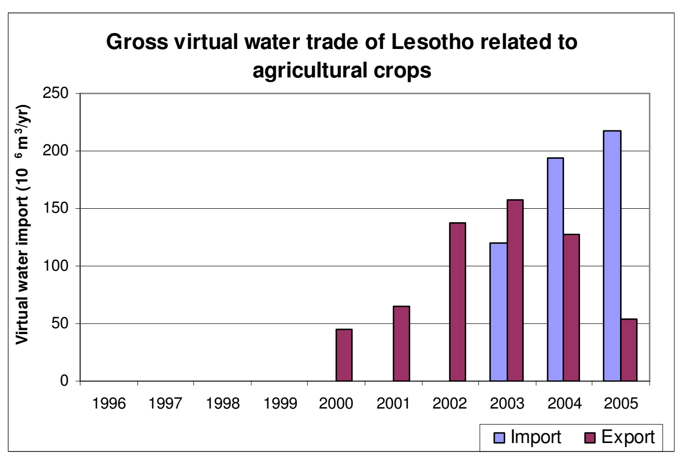
World region	Virtual water import (10^6 m^3/yr)		Virtual water export (10^6 m^3/yr)		Net virtual-water import (10^6 m^3/yr)
Central Africa	261		819		-558
Central America	57		65		-8
Central and South Asia	3129		1490		1639
Eastern Europe	24		206		-182
Middle East	121		295		-174
North Africa	189		393		-204
North America	1917		718		1199
Oceania	665		13		652
South America	2152		122		2029
South East Asia	4218		1280		2938
Western Europe	884		3754		-2870
FSU	128		120		8
Other	0		3		-3
Total of SADC	13744		9278		4466

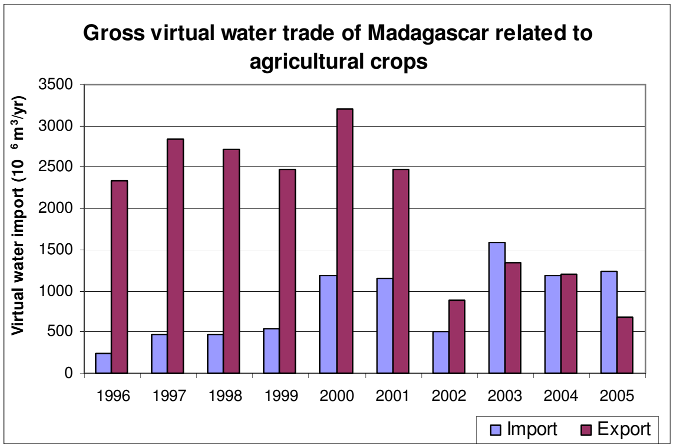
Size of virtual water volumes traded by SADC members related to crop products of 22 major water consuming crops (1996-2005; values exist of green & blue water)

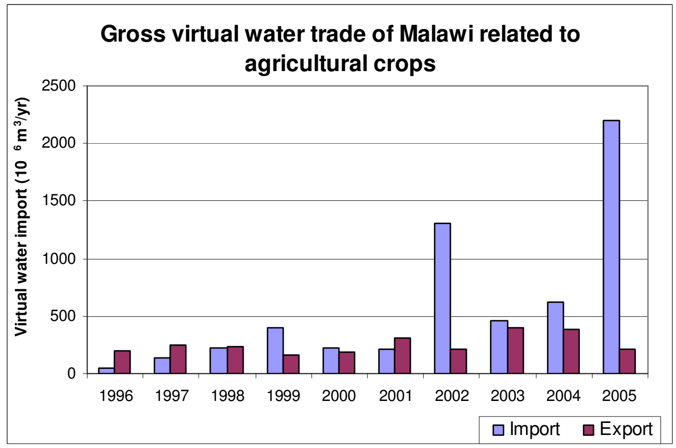


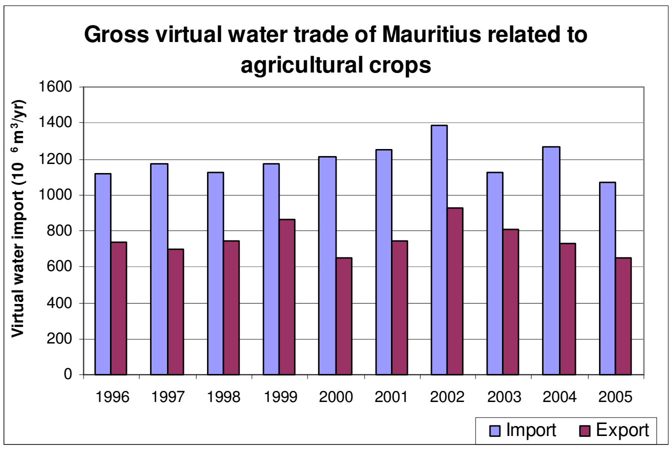


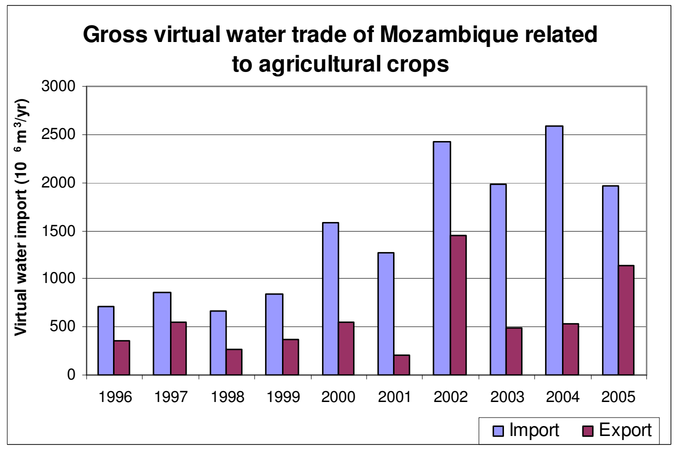


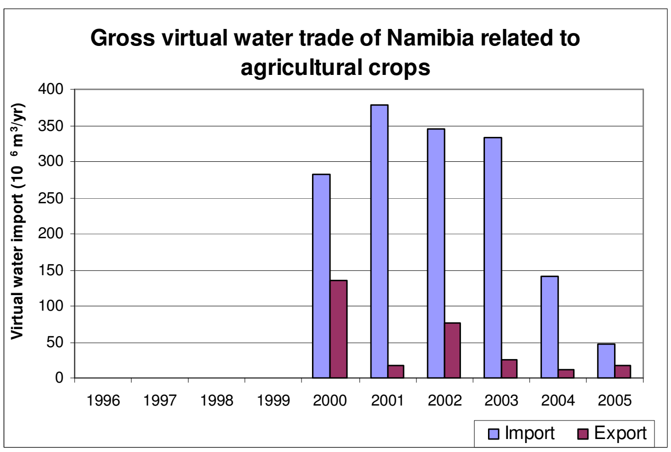


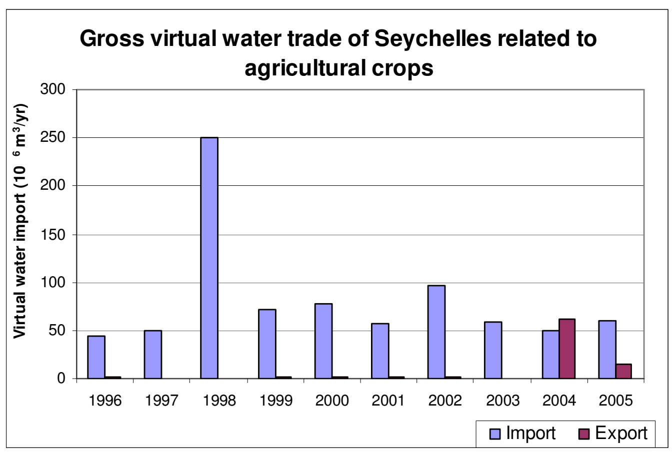

Gross virtual water trade of Madagascar related to agricultural crops
Virtual water import (10 ⁶ m³/yr)
3500
3000
2500
2000
1500
1000
500
0
1996 1997 1998 1999 2000 2001 2002 2003 2004 2005
Import Export

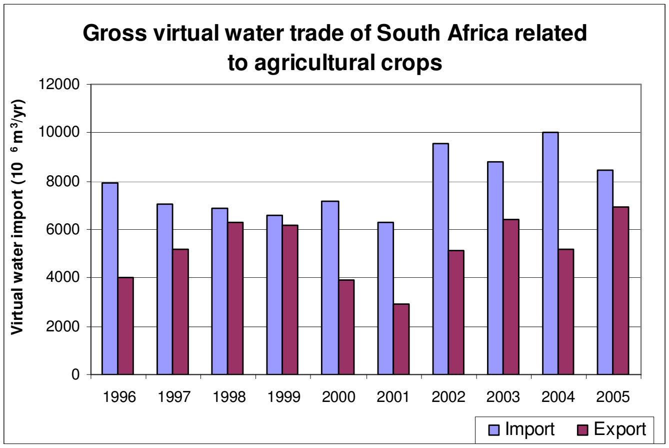

Gross virtual water trade of Malawi related to agricultural crops
Virtual water import (10 ⁶ m³/yr)
2500
2000
1500
1000
500
0
1996 1997 1998 1999 2000 2001 2002 2003 2004 2005
Import Export

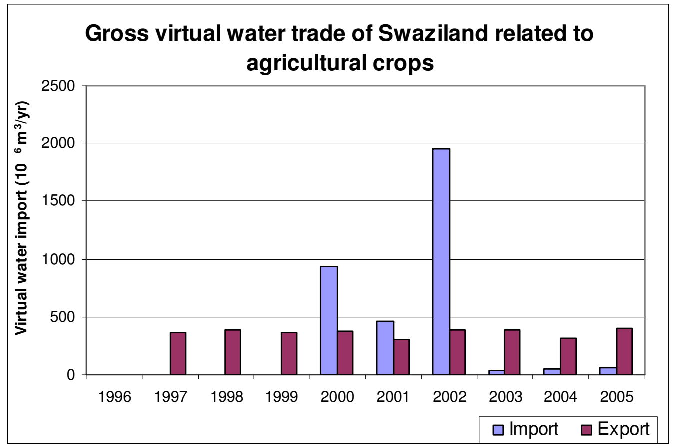

Gross virtual water trade of Mauritius related to agricultural crops
Virtual water import (10 ⁶ m³/yr)
1600
1400
1200
1000
800
600
400
200
0
1996 1997 1998 1999 2000 2001 2002 2003 2004 2005
Import Export

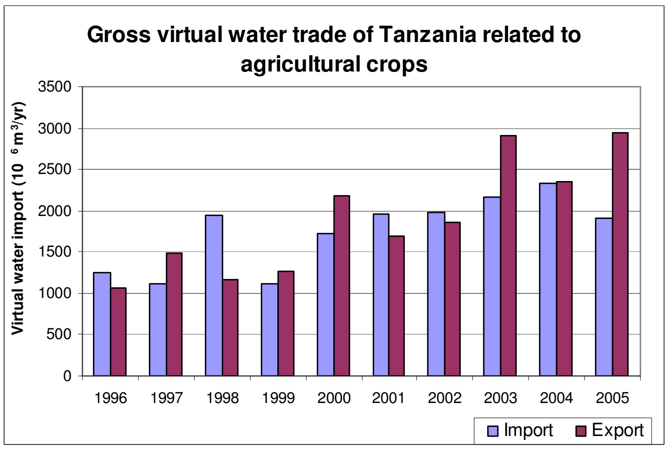

Gross virtual water trade of Mozambique related to agricultural crops
Virtual water import (10 ⁶ m³/yr)
3000
2500
2000
1500
1000
500
0
1996 1997 1998 1999 2000 2001 2002 2003 2004 2005
Import Export

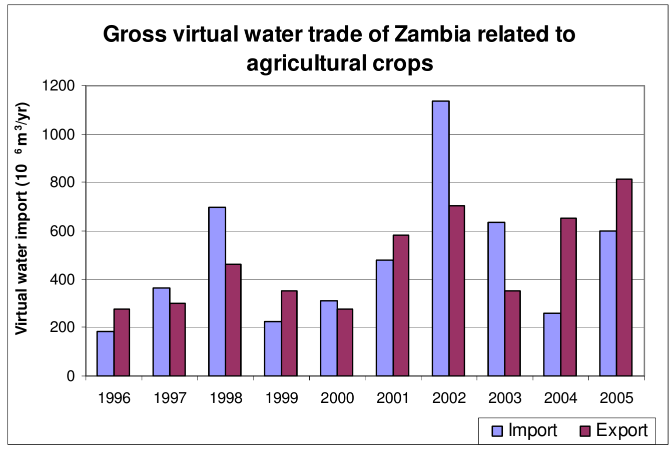

Gross virtual water trade of Namibia related to agricultural crops
Virtual water import (10 ⁶ m³/yr)
400
350
300
250
200
150
100
50
0
1996 1997 1998 1999 2000 2001 2002 2003 2004 2005
Import Export

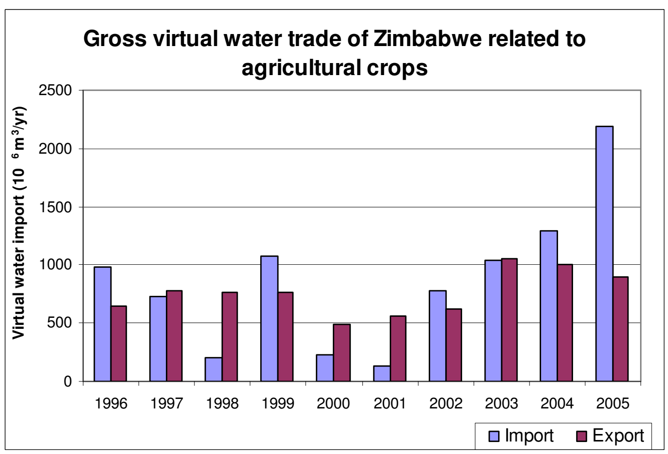

Gross virtual water trade of Seychelles related to agricultural crops
Virtual water import (10 ⁶ m³/yr)
300
250
200
150
100
50
0
1996 1997 1998 1999 2000 2001 2002 2003 2004 2005
Import Export


Gross virtual water trade of South Africa related to agricultural crops
Virtual water import (10 6 m3/yr)
0
2000
4000
6000
8000
10000
12000
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
Import
Export


Gross virtual water trade of Swaziland related to agricultural crops
Virtual water import (10 6 m3/yr)
0
500
1000
1500
2000
2500
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
Import
Export


Gross virtual water trade of Tanzania related to agricultural crops
Virtual water import (10 6 m3/yr)
0
500
1000
1500
2000
2500
3000
3500
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
Import
Export


Gross virtual water trade of Zambia related to agricultural crops
Virtual water import (10 6 m3/yr)
0
200
400
600
800
1000
1200
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
Import
Export


Gross virtual water trade of Zimbabwe related to agricultural crops
Virtual water import (10 6 m3/yr)
0
500
1000
1500
2000
2500
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
Import
Export

Trade of livestock products

Overview of most important trading partners of SADC nations related to livestock trade in 8 animal categories (average 1996-2005; values exist of green & blue water)

		Vitual water import				Vitual water export	
Country	**Partner countries**	**Average (1996-2005) (10^6 m^3/yr)**	**Share (%)**		**Partner countries**	**Average (1996-2005) (10^6 m^3/yr)**	**Share (%)**
ANGOLA	INDIA	341.81	51.39		NAMIBIA	3.28	85.02
	BRAZIL	86.78	13.05		NIGERIA	0.32	8.27
	ITALY	54.38	8.18		PORTUGAL	0.22	5.68
	PORTUGAL	45.41	6.83		JAPAN	0.03	0.82
	FRANCE	32.59	4.90		INDONESIA	0.01	0.19
	SOUTH AFRICA	22.04	3.31		GERMANY	0.00	0.02
	ARGENTINA	18.60	2.80				
	BELGIUM	13.37	2.01				
	PARAGUAY	9.21	1.38				
	USA	8.76	1.32				
	OTHER	32.21	4.84		OTHER	0.00	0.00
	TOTAL	665.16	100.00		TOTAL	3.86	100.00

		Vitual water import				Vitual water export	
Country	**Partner countries**	**Average (1996-2005) (10^6 m^3/yr)**	**Share (%)**		**Partner countries**	**Average (1996-2005) (10^6 m^3/yr)**	**Share (%)**
BOTSWANA	SOUTH AFRICA	49.99	77.75		UNITED KINGDOM	153.63	43.75
	ZIMBABWE	9.79	15.22		ITALY	56.97	16.22
	NAMIBIA	3.69	5.74		GREECE	45.84	13.05
	POLAND	0.56	0.86		GERMANY	43.35	12.34
	ZAMBIA	0.07	0.11		NORWAY	30.73	8.75
	PARAGUAY	0.06	0.10		FRANCE	13.41	3.82
	FRANCE	0.05	0.08		ZIMBABWE	1.64	0.47
	UNITED KINGDOM	0.02	0.03		Netherlands Antilles	1.47	0.42
	NEW ZEALAND	0.02	0.03		BELGIUM	1.24	0.35
	INDONESIA	0.02	0.03		MAURITIUS	0.94	0.27
	OTHER	0.03	0.05		OTHER	1.95	0.55
	TOTAL	64.29	100.00		TOTAL	351.17	100.00

The Democratic Republic of Congo does not report trade in livestock products or has been reported as trading partner for livestock products

		Vitual water import				Vitual water export	
Country	**Partner countries**	**Average (1996-2005) (10^6 m^3/yr)**	**Share (%)**		**Partner countries**	**Average (1996-2005) (10^6 m^3/yr)**	**Share (%)**
LESOTHO	MADAGASCAR	0.04	48.35		FRANCE	0.15	69.77
	TOGO	0.02	28.76		PAKISTAN	0.04	20.78
	USA	0.01	11.48		BOTSWANA	0.01	6.96
	SWITZERLAND	0.01	11.41		THAILAND	0.01	2.49
	OTHER	0.00	0.00		OTHER	0.00	0.00
	TOTAL	0.08	100.00		TOTAL	0.21	100.00

	Vitual water import				Vitual water export		
Country	Partner countries	Average (1996-2005) (10^6 m^3/yr)	Share (%)		Partner countries	Average (1996-2005) (10^6 m^3/yr)	Share (%)
MADAGASCAR	FRANCE	2.39	23.89		HONG KONG	17.21	57.45
	MOROCCO	1.46	14.65		GERMANY	3.78	12.62
	SINGAPORE	1.21	12.14		COMOROS	3.57	11.92
	INDIA	0.70	6.97		MAURITIUS	2.01	6.71
	SOUTH AFRICA	0.66	6.63		ITALY	1.07	3.58
	MALAYSIA	0.46	4.65		SOUTH AFRICA	0.61	2.05
	BRAZIL	0.36	3.62		UNITED KINGDOM	0.51	1.70
	MAURITIUS	0.36	3.60		FRANCE	0.34	1.12
	USA	0.35	3.47		CHINA	0.31	1.04
	BELGIUM	0.29	2.95		TURKEY	0.10	0.35
	OTHER	1.74	17.42		OTHER	0.44	1.45
	TOTAL	9.98	100.00		TOTAL	29.96	100.00

	Vitual water import				Vitual water export		
Country	Partner countries	Average (1996-2005) (10^6 m^3/yr)	Share (%)		Partner countries	Average (1996-2005) (10^6 m^3/yr)	Share (%)
MALAWI	ZIMBABWE	299.45	97.91		GREECE	0.86	29.86
	SOUTH AFRICA	3.71	1.21		ITALY	0.65	22.39
	AUSTRALIA	0.43	0.14		HONG KONG	0.58	19.95
	USA	0.42	0.14		MOZAMBIQUE	0.30	10.28
	ZAMBIA	0.29	0.10		SOUTH AFRICA	0.22	7.70
	NEW ZEALAND	0.29	0.10		TANZANIA, U.R	0.11	3.69
	IRELAND	0.21	0.07		ZAMBIA	0.07	2.26
	MALAYSIA	0.14	0.05		TAIWAN (POC)	0.06	2.11
	KENYA	0.13	0.04		PAKISTAN	0.03	1.11
	INDONESIA	0.12	0.04		BENIN	0.02	0.54
	OTHER	0.64	0.21		OTHER	0.00	0.12
	TOTAL	305.84	100.00		TOTAL	2.88	100.00

	Vitual water import				Vitual water export		
Country	Partner countries	Average (1996-2005) (10^6 m^3/yr)	Share (%)		Partner countries	Average (1996-2005) (10^6 m^3/yr)	Share (%)
MAURITIUS	INDIA	48.88	29.19		UNITED KINGDOM	15.41	86.51
	AUSTRALIA	42.38	25.30		FRANCE	0.64	3.62
	SOUTH AFRICA	28.31	16.90		KENYA	0.46	2.59
	ZIMBABWE	7.98	4.76		MADAGASCAR	0.36	2.04
	NEW ZEALAND	7.10	4.24		SOUTH AFRICA	0.28	1.58
	FRANCE	6.06	3.62		SEYCHELLES	0.17	0.96
	UNITED KINGDOM	5.51	3.29		THAILAND	0.12	0.67
	CHINA	3.60	2.15		COMOROS	0.09	0.51
	BRAZIL	3.42	2.04		SINGAPORE	0.06	0.32
	MOZAMBIQUE	2.72	1.62		GHANA	0.03	0.16
	OTHER	11.53	6.88		OTHER	0.18	1.04
	TOTAL	167.48	100.00		TOTAL	17.82	100.00

		Vitual water import				Vitual water export	
Country	Partner countries	Average (1996-2005) (10^6 m^3/yr)	Share (%)		Partner countries	Average (1996-2005) (10^6 m^3/yr)	Share (%)
MOZAMBIQUE	SWAZILAND	82.52	53.37		MAURITIUS	2.75	57.91
	SOUTH AFRICA	53.43	34.56		PORTUGAL	0.75	15.88
	United Arab Emirates	8.24	5.33		ITALY	0.47	9.84
	BRAZIL	2.71	1.75		THAILAND	0.17	3.56
	CANADA	1.38	0.90		OMAN	0.11	2.41
	ZIMBABWE	1.35	0.87		GERMANY	0.09	1.80
	USA	0.91	0.59		HONG KONG	0.06	1.24
	PORTUGAL	0.79	0.51		NIGERIA	0.06	1.23
	SINGAPORE	0.42	0.27		ZIMBABWE	0.05	1.06
	MALAWI	0.30	0.19		MALAWI	0.05	0.98
	OTHER	2.57	1.66		OTHER	0.19	4.10
	TOTAL	154.62	100.00		TOTAL	4.74	100.00

		Vitual water import				Vitual water export	
Country	Partner countries	Average (1996-2005) (10^6 m^3/yr)	Share (%)		Partner countries	Average (1996-2005) (10^6 m^3/yr)	Share (%)
NAMIBIA	SOUTH AFRICA	173.73	95.27		UNITED KINGDOM	89.85	41.73
	ANGOLA	4.49	2.46		ITALY	56.40	26.20
	BRAZIL	0.98	0.54		GERMANY	22.06	10.25
	PORTUGAL	0.96	0.53		NORWAY	17.15	7.97
	SPAIN	0.55	0.30		FRANCE	8.16	3.79
	GERMANY	0.39	0.21		GREECE	6.21	2.88
	UNITED KINGDOM	0.21	0.12		BOTSWANA	3.74	1.74
	NORWAY	0.19	0.11		ANGOLA	3.25	1.51
	ZIMBABWE	0.17	0.09		BELGIUM	2.56	1.19
	BOTSWANA	0.15	0.08		HONG KONG	1.49	0.69
	OTHER	0.54	0.30		OTHER	4.41	2.05
	TOTAL	182.36	100.00		TOTAL	215.28	100.00

		Vitual water import				Vitual water export	
Country	Partner countries	Average (1996-2005) (10^6 m^3/yr)	Share (%)		Partner countries	Average (1996-2005) (10^6 m^3/yr)	Share (%)
SEYCHELLES	SINGAPORE	1.62	15.65		GEORGIA	0.61	71.12
	AUSTRALIA	1.24	11.97		NIGERIA	0.13	14.98
	IRELAND	0.95	9.16		THAILAND	0.08	9.04
	UNITED KINGDOM	0.85	8.28		AUSTRIA	0.02	1.80
	SOUTH AFRICA	0.84	8.10		LEBANON	0.01	1.31
	BRAZIL	0.76	7.39		ISRAEL	0.01	0.82
	INDIA	0.76	7.34		FRANCE	0.00	0.49
	NETHERLANDS	0.65	6.30		MAURITIUS	0.00	0.44
	DENMARK	0.58	5.65				
	ZIMBABWE	0.44	4.30				
	OTHER	1.64	15.86		OTHER	0.00	0.00
	TOTAL	10.32	100.00		TOTAL	0.85	100.00

		Vitual water import			Vitual water export	
Country	Partner countries	Average (1996-2005) (10^6 m^3/yr)	Share (%)	Partner countries	Average (1996-2005) (10^6 m^3/yr)	Share (%)
SOUTH AFRICA	AUSTRALIA	135.00	21.23	SWAZILAND	528.56	30.48
	BRAZIL	110.99	17.45	ITALY	472.70	27.26
	FRANCE	67.65	10.64	NAMIBIA	105.42	6.08
	BELGIUM	41.46	6.52	UNITED KINGDOM	95.43	5.50
	ZIMBABWE	31.19	4.90	HONG KONG	77.25	4.46
	IRELAND	25.16	3.96	MOZAMBIQUE	53.84	3.10
	ARGENTINA	25.07	3.94	CHINA	51.65	2.98
	INDIA	24.41	3.84	GERMANY	37.87	2.18
	UNITED KINGDOM	22.48	3.54	BOTSWANA	30.43	1.76
	CANADA	21.95	3.45	MAURITIUS	28.56	1.65
	OTHER	130.55	20.53	OTHER	252.24	14.55
	TOTAL	635.92	100.00	TOTAL	1733.94	100.00

		Vitual water import			Vitual water export	
Country	Partner countries	Average (1996-2005) (10^6 m^3/yr)	Share (%)	Partner countries	Average (1996-2005) (10^6 m^3/yr)	Share (%)
SWAZILAND	SOUTH AFRICA	874.52	99.80	MOZAMBIQUE	138.38	95.61
	BELGIUM	0.36	0.04	UNITED KINGDOM	3.96	2.74
	POLAND	0.31	0.04	FRANCE	0.85	0.59
	FRANCE	0.22	0.03	YEMEN	0.77	0.53
	UNITED KINGDOM	0.19	0.02	INDONESIA	0.30	0.21
	ARGENTINA	0.17	0.02	THAILAND	0.08	0.05
	GERMANY	0.11	0.01	SAUDI ARABIA	0.07	0.05
	AUSTRALIA	0.09	0.01	SOUTH AFRICA	0.07	0.04
	MOZAMBIQUE	0.06	0.01	PORTUGAL	0.06	0.04
	FINLAND	0.05	0.01	MALAWI	0.03	0.02
	OTHER	0.21	0.02	OTHER	0.17	0.12
	TOTAL	876.30	100.00	TOTAL	144.73	100.00

		Vitual water import			Vitual water export	
Country	Partner countries	Average (1996-2005) (10^6 m^3/yr)	Share (%)	Partner countries	Average (1996-2005) (10^6 m^3/yr)	Share (%)
TANZANIA	ZIMBABWE	4.29	24.20	HONG KONG	29.36	47.77
	KENYA	3.99	22.53	PAKISTAN	13.29	21.63
	United Arab Emirates	2.65	14.95	ITALY	5.67	9.23
	SOUTH AFRICA	1.88	10.63	KENYA	4.85	7.89
	NETHERLANDS	1.16	6.57	United Arab Emirates	2.93	4.77
	ZAMBIA	0.71	4.00	SPAIN	0.83	1.35
	UNITED KINGDOM	0.41	2.33	COMOROS	0.78	1.27
	SAUDI ARABIA	0.37	2.09	RWANDA	0.62	1.00
	AUSTRALIA	0.27	1.55	INDIA	0.56	0.92
	INDIA	0.26	1.48	EGYPT	0.48	0.78
	OTHER	1.72	9.68	OTHER	2.08	3.39
	TOTAL	17.72	100.00	TOTAL	61.46	100.00

		Vitual water import				Vitual water export	
Country	Partner countries	Average (1996-2005) (10^6 m^3/yr)	Share (%)		Partner countries	Average (1996-2005) (10^6 m^3/yr)	Share (%)
ZAMBIA	SOUTH AFRICA	6.37	3.49		CONGO	5.03	25.92
	ZIMBABWE	3.36	1.84		ITALY	4.10	21.12
	NEW ZEALAND	0.33	0.18		SOUTH AFRICA	2.44	12.58
	SWITZERLAND	0.12	0.06		CHINA	2.23	11.47
	UNITED KINGDOM	0.09	0.05		CONGO, D.R.	1.69	8.70
	BOTSWANA	0.07	0.04		ZIMBABWE	1.30	6.68
	MALAWI	0.06	0.04		TANZANIA, U.R	0.74	3.81
	KENYA	0.05	0.03		ANGOLA	0.69	3.58
	FRANCE	0.05	0.03		HONG KONG	0.47	2.43
	USA	0.05	0.03		MALAWI	0.30	1.54
	OTHER	0.54	0.30		OTHER	0.42	2.17
	TOTAL	11.09	6.08		TOTAL	19.41	100.00

		Vitual water import				Vitual water export	
Country	Partner countries	Average (1996-2005) (10^6 m^3/yr)	Share (%)		Partner countries	Average (1996-2005) (10^6 m^3/yr)	Share (%)
ZIMBABWE	SOUTH AFRICA	23.71	13.00		MALAWI	299.58	62.69
	ZAMBIA	1.26	0.69		ITALY	58.72	12.29
	BOTSWANA	0.89	0.49		UNITED KINGDOM	41.60	8.71
	BRAZIL	0.74	0.41		SOUTH AFRICA	31.64	6.62
	KENYA	0.66	0.36		MAURITIUS	8.08	1.69
	AUSTRALIA	0.52	0.29		United Arab Emirates	7.64	1.60
	NEW ZEALAND	0.18	0.10		GREECE	6.22	1.30
	IRELAND	0.15	0.08		BOTSWANA	6.00	1.26
	GERMANY	0.15	0.08		TANZANIA, U.R	4.30	0.90
	NAMIBIA	0.13	0.07		ZAMBIA	3.45	0.72
	OTHER	0.87	0.48		OTHER	10.62	2.22
	TOTAL	29.26	16.04		TOTAL	477.86	100.00

Overview of most important traded livestock products of SADC nations related to livestock trade in 8 animal categories (average 1996-2005; values exist of green & blue water)

		Vitual water import				Vitual water export	
Country	Product	Average (1996-2005) (10^6 m^3/yr)	Share (%)		Product	Average (1996-2005) (10^6 m^3/yr)	Share (%)
ANGOLA	Bovine meat,frz,boneless	213.36	32.08		Bovine hides,skins,fresh	2.06	53.43
	Birds' eggs, in shell	175.75	26.42		Other bovine animals	1.08	27.99
	Bov.meat,prpd,prsrvd,nes	58.82	8.84		Milk,crm solid 1.5%+ fat	0.26	6.85
	Meat of swine, frozen	40.92	6.15		Goats, live	0.16	4.04
	Bov.meat,dried,smkd,salt	32.70	4.92		Bovine hides,skins,other	0.09	2.35
	Pork,prepred,presrvd,nes	25.21	3.79		Milk,cream unsweetened	0.05	1.42
	Edible offal,bov.,frozen	21.52	3.23		Other swine, live	0.04	1.12
	Milk,crm solid 1.5%+ fat	13.61	2.05		Whole bovin.hide<8kg dry	0.04	1.10
	Oth.pigmeat,dry,salt,smk	12.80	1.92		Bovine meat,frz,boneless	0.03	0.82
	Bovine meat,frozn,w.bone	11.73	1.76		Bov.animals,pure,breedng	0.01	0.26
	OTHER	58.73	8.83		OTHER	0.02	0.62
	TOTAL	665.16	100.00		TOTAL	3.86	100.00

		Vitual water import				Vitual water export	
Country	Product	Average (1996-2005) (10^6 m^3/yr)	Share (%)		Product	Average (1996-2005) (10^6 m^3/yr)	Share (%)
BOTSWANA	Milk,fat cont.1% or less	13.09	20.35		Bovine meat,frz,boneless	142.99	40.72
	Milk,crm solid 1.5%+ fat	8.02	12.48		Bovine meat,fh,ch,bnless	140.18	39.92
	Milk,cream unsweetened	6.40	9.96		Oth.bov.,eqn.lthr,tanned	55.94	15.93
	Bov.meat,prpd,prsrvd,nes	3.16	4.92		Bov.meat,prpd,prsrvd,nes	9.22	2.63
	Poultry, live,over 185g	3.06	4.75		Whole bovin.hide<8kg dry	1.24	0.35
	Poultry, live, to 185g	3.03	4.71		Whole bovine skin leathr	0.49	0.14
	Swine,pure,for breeding	2.64	4.10		Bovine hides,skins,fresh	0.28	0.08
	Milk,solid, to 1.5% fat	2.45	3.81		Sheep, live	0.17	0.05
	Pork,prepred,presrvd,nes	2.32	3.61		Goat,kid skin,ex.furskin	0.13	0.04
	Cheese, powdered, grated	2.17	3.37		Bovine meat,frozn,w.bone	0.10	0.03
	OTHER	17.97	27.94		OTHER	0.43	0.12
	TOTAL	64.29	100.00		TOTAL	351.17	100.00

The Democratic Republic of Congo does not report trade in livestock products or has been reported as trading partner for livestock products

		Vitual water import				Vitual water export	
Country	Product	Average (1996-2005) (10^3 m^3/yr)	Share (%)		Product	Average (1996-2005) (10^3 m^3/yr)	Share (%)
LESOTHO	Whole bovin.hide<8kg dry	0.04	48.35		Meat of swine,frsh,chlld	0.05	24.83
	Milk,crm solid 1.5%+ fat	0.03	40.17		Bovine meat,frz,boneless	0.05	22.22
	Bovine meat,frz,boneless	0.01	11.48		Goat,kid skin,ex.furskin	0.04	20.78
					Bovine meat,fh,ch,bnless	0.03	16.53
					Bellies (streaky)	0.01	4.42
					Birds' eggs, in shell	0.01	3.47
					Other bovine animals	0.01	2.49
					Meat of sheep,frsh,chlld	0.004	1.78
					Poultry, live, to 185g	0.004	1.76
					Milk,cream fat cont.1-6%	0.002	1.14
	OTHER	0.00	0.00		OTHER	0.001	0.59
	TOTAL	0.08	100.00		TOTAL	0.21	100.00

		Vitual water import				Vitual water export	
Country	Product	Average (1996-2005) (10^6 m^3/yr)	Share (%)		Product	Average (1996-2005) (10^6 m^3/yr)	Share (%)
MADAGASCAR	Milk,solid, to 1.5% fat	2.68	26.87		Bovine hides,skins,fresh	10.41	34.76
	Milk,crm solid 1.5%+ fat	2.38	23.87		Whole bovin.hide<8kg dry	7.48	24.96
	Processed cheese, whole	2.04	20.45		Other bovine animals	4.27	14.26
	Milk,cream, sweetened	1.08	10.80		Bovine meat,frz,boneless	3.98	13.27
	Bov.meat,prpd,prsrvd,nes	0.32	3.17		Oth.bov.,eqn.lthr,tanned	1.04	3.48
	Meat of swine, frozen	0.20	1.99		Oth.bov.,eqn.lthr,preprd	0.82	2.73
	Bovine hides,skins,fresh	0.19	1.88		Bov.animals,pure,breedng	0.62	2.06
	Birds' eggs, in shell	0.16	1.61		Bovine hides,skins,other	0.55	1.82
	Other cheese, curd	0.14	1.42		Goats, live	0.31	1.05
	Pork,prepred,presrvd,nes	0.13	1.29		Whole bovine skin leathr	0.13	0.44
	OTHER	0.67	6.66		OTHER	0.35	1.17
	TOTAL	9.98	100.00		TOTAL	29.96	100.00

		Vitual water import				Vitual water export	
Country	Product	Average (1996-2005) (10^6 m^3/yr)	Share (%)		Product	Average (1996-2005) (10^6 m^3/yr)	Share (%)
MALAWI	Poultry, live, to 185g	286.03	93.52		Whole bovin.hide<8kg dry	0.89	30.73
	Birds' eggs, in shell	10.30	3.37		Bovine hides,skins,fresh	0.84	29.25
	Milk,crm solid 1.5%+ fat	3.18	1.04		Goat,kid skin,ex.furskin	0.44	15.23
	Milk,cream fat cont.1-6%	1.13	0.37		Birds' eggs, in shell	0.28	9.88
	Milk,solid, to 1.5% fat	0.96	0.31		Oth.bov.,eqn.lthr,tanned	0.24	8.25
	Milk,cream, sweetened	0.63	0.20		Bovine hides,skins,other	0.12	4.15
	Milk,fat cont.1% or less	0.60	0.19		Milk,crm solid 1.5%+ fat	0.02	0.60
	Bovine semen	0.49	0.16		Milk,cream, sweetened	0.02	0.54
	Meat of swine, frozen	0.44	0.14		Poultry, live, to 185g	0.01	0.37
	Bovine meat,frozn,w.bone	0.36	0.12		Milk,cream fat cont.1-6%	0.01	0.25
	OTHER	1.73	0.57		OTHER	0.02	0.75
	TOTAL	305.84	100.00		TOTAL	2.88	100.00

		Vitual water import				Vitual water export	
Country	Product	Average (1996-2005) (10^6 m^3/yr)	Share (%)		Product	Average (1996-2005) (10^6 m^3/yr)	Share (%)
MAURITIUS	Bovine meat,frz,boneless	58.35	34.84		Bov.meat,prpd,prsrvd,nes	15.90	89.25
	Other bovine animals	25.49	15.22		Bovine hides,skins,fresh	0.43	2.42
	Milk,crm solid 1.5%+ fat	24.64	14.71		Horses	0.38	2.11
	Meat of sheep, frozen	8.65	5.17		Bovine meat,frz,boneless	0.27	1.51
	Edible offal,bov.,frozen	7.14	4.26		Milk,crm solid 1.5%+ fat	0.18	1.01
	Bov.animals,pure,breedng	5.79	3.45		Birds' eggs, in shell	0.15	0.83
	Milk,solid, to 1.5% fat	4.94	2.95		Milk,solid, to 1.5% fat	0.13	0.75
	Processed cheese, whole	4.77	2.85		Milk,cream, sweetened	0.10	0.58
	Bov.meat,prpd,prsrvd,nes	4.66	2.78		Poultry, live, to 185g	0.07	0.40
	Meat of swine, frozen	4.37	2.61		Processed cheese, whole	0.06	0.33
	OTHER	18.68	11.15		OTHER	0.14	0.81
	TOTAL	167.48	100.00		TOTAL	17.82	100.00

		Vitual water import				Vitual water export	
Country	Product	Average (1996-2005) (10^6 m^3/yr)	Share (%)		Product	Average (1996-2005) (10^6 m^3/yr)	Share (%)
MOZAMBIQUE	Bov.animals,pure,breedng	62.86	40.66		Other bovine animals	2.34	49.30
	Poultry, live, to 185g	31.92	20.64		Bovine hides,skins,fresh	0.71	14.96
	Milk,solid, to 1.5% fat	11.60	7.50		Oth.bov.,eqn.lthr,tanned	0.46	9.73
	Milk,crm solid 1.5%+ fat	5.12	3.31		Milk,crm solid 1.5%+ fat	0.41	8.64
	Meat of swine,frsh,chlld	4.05	2.62		Bov.animals,pure,breedng	0.36	7.67
	Milk,cream fat cont.1-6%	3.98	2.57		Meat of sheep, frozen	0.12	2.54
	Bovine meat,fh,ch,w.bone	3.81	2.47		Whole bovin.hide<8kg dry	0.10	2.13
	Birds' eggs, in shell	3.33	2.15		Milk,solid, to 1.5% fat	0.10	2.01
	Bovine meat,frozn,w.bone	3.17	2.05		Goats, live	0.04	0.81
	Swine,pure,for breeding	2.57	1.66		Milk,cream, sweetened	0.03	0.54
	OTHER	22.22	14.37		OTHER	0.08	1.66
	TOTAL	154.62	100.00		TOTAL	4.74	100.00

		Vitual water import				Vitual water export	
Country	Product	Average (1996-2005) (10^6 m^3/yr)	Share (%)		Product	Average (1996-2005) (10^6 m^3/yr)	Share (%)
NAMIBIA	Meat of swine,frsh,chlld	38.74	21.24		Bovine meat,fh,ch,bnless	55.83	43.23
	Meat of swine, frozen	36.05	19.77		Bovine meat,frz,boneless	32.79	25.38
	Other cheese, curd	26.74	14.66		Oth.bov.,eqn.lthr,tanned	31.26	24.20
	Meat of sheep,frsh,chlld	13.29	7.29		Whole bovine skin leathr	1.79	1.38
	Bovine meat,frz,boneless	12.53	6.87		Bov.meat,prpd,prsrvd,nes	1.36	1.05
	Bov.meat,prpd,prsrvd,nes	9.40	5.15		Bovine hides,skins,fresh	1.13	0.88
	Pig,poultry fat unrendrd	4.09	2.24		Sheep, live	0.60	0.46
	Milk,crm solid 1.5%+ fat	3.36	1.84		Whole bovin.hide<8kg dry	0.54	0.41
	Bovine hides,skins,fresh	2.97	1.63		Meat of sheep, frozen	0.50	0.39
	Other bovine animals	2.63	1.44		Other bovine animals	0.45	0.35
	OTHER	32.57	17.86		OTHER	2.92	2.26
	TOTAL	182.36	100.00		TOTAL	129.17	100.00

		Vitual water import				Vitual water export	
Country	Product	Average (1996-2005) (10^6 m^3/yr)	Share (%)		Product	Average (1996-2005) (10^6 m^3/yr)	Share (%)
SEYCHELLES	Meat of swine, frozen	2.09	20.23		Bovine meat,frz,boneless	0.61	71.79
	Milk,solid, to 1.5% fat	1.79	17.37		Milk,solid, to 1.5% fat	0.13	14.98
	Bovine meat,frz,boneless	1.78	17.22		Bovine hides,skins,fresh	0.08	9.04
	Bov.meat,prpd,prsrvd,nes	1.30	12.57		Meat of swine, frozen	0.02	2.07
	Milk,crm solid 1.5%+ fat	0.62	6.03		Other cheese, curd	0.01	1.31
	Poultry,prprd,prsrvd,nes	0.55	5.28		Milk,cream, sweetened	0.01	0.82
	Pork,prepred,presrvd,nes	0.37	3.59				
	Other cheese, curd	0.27	2.58				
	Milk,cream, sweetened	0.21	2.06				
	Processed cheese, whole	0.21	2.02				
	OTHER	1.14	11.05		OTHER	0.00	0.00
	TOTAL	10.32	100.00		TOTAL	0.85	100.00

		Vitual water import				Vitual water export	
Country	Product	Average (1996-2005) (10^6 m^3/yr)	Share (%)		Product	Average (1996-2005) (10^6 m^3/yr)	Share (%)
SOUTH AFRICA	Meat of swine, frozen	153.20	24.09		Oth.bov.,eqn.lthr,tanned	505.37	29.15
	Bovine meat,frz,boneless	131.41	20.66		Other bovine animals	260.85	15.04
	Oth.bov.,eqn.lthr,tanned	60.52	9.52		Bov.animals,pure,breedng	183.33	10.57
	Meat of sheep, frozen	53.19	8.36		Bovine meat,fh,ch,bnless	99.26	5.72
	Edible offal,bov.,frozen	47.17	7.42		Bovine meat,frz,boneless	93.71	5.40
	Bovine hides,skins,fresh	40.75	6.41		Bovine hides,skins,fresh	77.42	4.47
	Oth.bov.,eqn.lthr,preprd	36.86	5.80		Swine,pure,for breeding	43.04	2.48
	Milk,solid, to 1.5% fat	16.50	2.60		Milk,crm solid 1.5%+ fat	33.20	1.91
	Whole bovine skin leathr	10.00	1.57		Meat of swine,frsh,chlld	32.43	1.87
	Bovine meat,frozn,w.bone	8.94	1.41		Meat of swine, frozen	31.74	1.83
	OTHER	77.37	12.17		OTHER	373.60	21.55
	TOTAL	635.92	100.00		TOTAL	1733.94	100.00

		Vitual water import				Vitual water export	
Country	Product	Average (1996-2005) (10^6 m^3/yr)	Share (%)		Product	Average (1996-2005) (10^6 m^3/yr)	Share (%)
SWAZILAND	Other bovine animals	381.42	43.53		Bov.animals,pure,breedng	96.06	66.37
	Bov.animals,pure,breedng	286.67	32.71		Poultry, live, to 185g	36.53	25.24
	Swine,pure,for breeding	63.79	7.28		Bovine meat,fh,ch,bnless	4.92	3.40
	Bovine meat,frozn,w.bone	27.53	3.14		Bovine meat,fh,ch,w.bone	1.98	1.37
	Milk,cream, sweetened	18.49	2.11		Milk,crm solid 1.5%+ fat	1.05	0.73
	Horses	15.89	1.81		Birds' eggs, in shell	0.89	0.62
	Asses, mules, hinnies	14.37	1.64		Edible offal,bov.frsh,ch	0.81	0.56
	Bovine meat,fh,ch,w.bone	6.21	0.71		Milk,solid, to 1.5% fat	0.60	0.42
	Bov.meat,prpd,prsrvd,nes	5.98	0.68		Meat of swine,frsh,chlld	0.57	0.39
	Meat of swine,frsh,chlld	5.89	0.67		Oth.bov.,eqn.lthr,preprd	0.23	0.16
	OTHER	50.07	5.71		OTHER	1.07	0.74
	TOTAL	876.30	100.00		TOTAL	144.73	100.00

		Vitual water import				Vitual water export	
Country	Product	Average (1996-2005) (10^6 m^3/yr)	Share (%)		Product	Average (1996-2005) (10^6 m^3/yr)	Share (%)
TANZANIA	Birds' eggs, in shell	5.82	32.84		Bovine hides,skins,fresh	25.68	41.78
	Milk,crm solid 1.5%+ fat	3.22	18.16		Whole bovin.hide<8kg dry	18.38	29.90
	Milk,solid, to 1.5% fat	2.21	12.49		Oth.bov.,eqn.lthr,tanned	5.55	9.03
	Poultry, live, to 185g	1.24	6.99		Bovine semen	3.48	5.66
	Milk,cream fat cont.1-6%	0.86	4.87		Goat,kid skin,ex.furskin	3.04	4.94
	Oth.pigmeat,dry,salt,smk	0.78	4.38		Bovine hides,skins,other	1.05	1.71
	Cream,fat content 6%+	0.56	3.15		Whole bovine skin leathr	0.76	1.23
	Milk,cream, sweetened	0.35	1.99		Other bovine animals	0.59	0.97
	Milk,fat cont.1% or less	0.22	1.27		Goatskin leather,tanned	0.57	0.93
	Meat of sheep,frsh,chlld	0.20	1.15		Milk,crm solid 1.5%+ fat	0.44	0.72
	OTHER	2.25	12.71		OTHER	1.92	3.13
	TOTAL	17.72	100.00		TOTAL	61.46	100.00

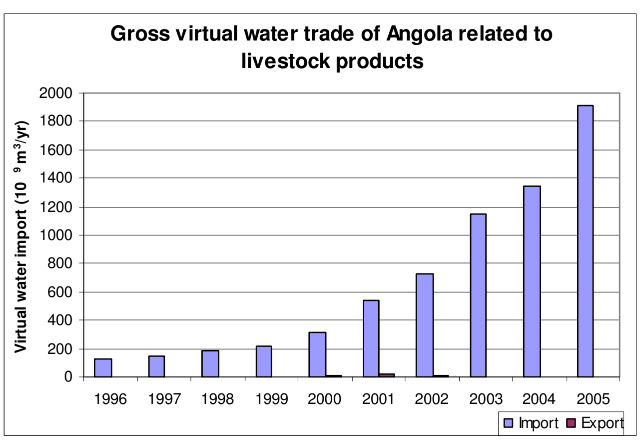
		Vitual water import				Vitual water export	
Country	Product	Average (1996-2005) (10^6 m^3/yr)	Share (%)		Product	Average (1996-2005) (10^6 m^3/yr)	Share (%)
ZAMBIA	Milk,crm solid 1.5%+ fat	4.21	37.95		Oth.bov.,eqn.lthr,tanned	8.87	45.69
	Bov.meat,prpd,prsrvd,nes	1.72	15.48		Birds' eggs, in shell	6.40	33.00
	Oth.pigmeat,dry,salt,smk	0.94	8.48		Poultry, live, to 185g	1.15	5.94
	Milk,cream fat cont.1-6%	0.84	7.56		Whole bovine skin leathr	0.96	4.94
	Milk,solid, to 1.5% fat	0.55	4.94		Bovine hides,skins,fresh	0.42	2.18
	Pork,prepred,presrvd,nes	0.53	4.76		Oth.bov.,eqn.lthr,preprd	0.24	1.25
	Other cheese, curd	0.44	4.00		Bovine meat,fh,ch,w.bone	0.20	1.02
	Birds' eggs, in shell	0.25	2.21		Meat of swine, frozen	0.19	0.99
	Milk,cream, sweetened	0.22	1.98		Whole bovin.hide<8kg dry	0.19	0.97
	Processed cheese, whole	0.14	1.23		Meat of sheep,frsh,chlld	0.12	0.60
	OTHER	1.27	11.41		OTHER	0.66	3.41
	TOTAL	11.09	100.00		TOTAL	19.41	100.00

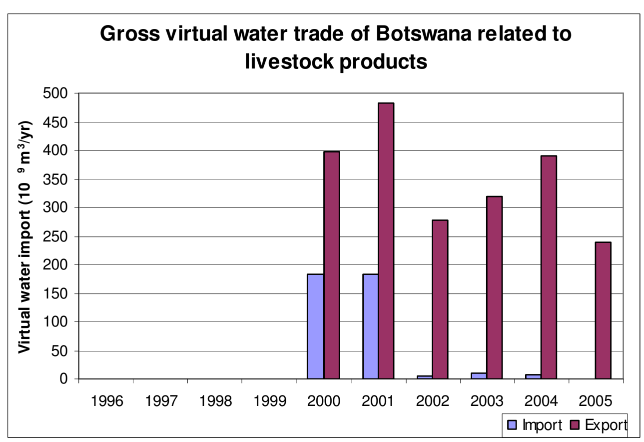
		Vitual water import				Vitual water export	
Country	Product	Average (1996-2005) (10^6 m^3/yr)	Share (%)		Product	Average (1996-2005) (10^6 m^3/yr)	Share (%)
ZIMBABWE	Other bovine animals	10.97	37.50		Poultry, live, to 185g	288.83	60.44
	Bovine hides,skins,fresh	3.85	13.14		Oth.bov.,eqn.lthr,tanned	65.44	13.69
	Oth.bov.,eqn.lthr,tanned	3.82	13.05		Bovine meat,fh,ch,bnless	36.24	7.58
	Milk,crm solid 1.5%+ fat	2.19	7.49		Birds' eggs, in shell	19.17	4.01
	Milk,solid, to 1.5% fat	1.57	5.38		Bovine meat,frz,boneless	18.09	3.79
	Meat of swine,frsh,chlld	0.74	2.54		Bov.meat,prpd,prsrvd,nes	12.65	2.65
	Whole bovin.hide<8kg dry	0.66	2.26		Meat of swine, frozen	7.71	1.61
	Whole bovine skin leathr	0.64	2.20		Milk,crm solid 1.5%+ fat	6.78	1.42
	Oth.bov.,eqn.lthr,preprd	0.60	2.07		Pork,prepred,presrvd,nes	4.88	1.02
	Bovine meat,frz,boneless	0.43	1.46		Other bovine animals	3.73	0.78
	OTHER	3.78	12.92		OTHER	14.35	3.00
	TOTAL	29.26	100.00		TOTAL	477.86	100.00

Virtual water volumes traded between SADC nations and other world regions related to trade in livestock products from 8 animal categories (1996-2005; values exist of green & blue water)

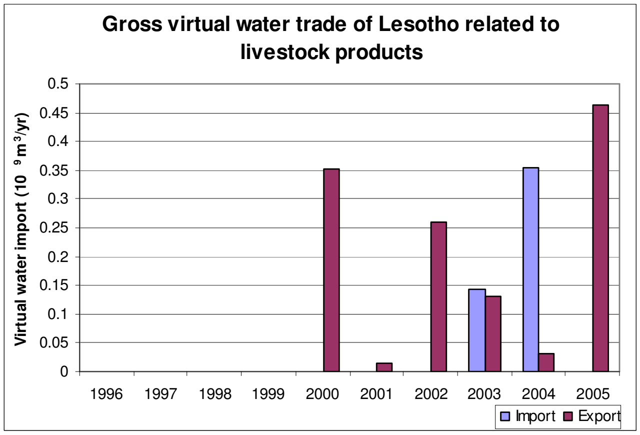
World region	Virtual water import (10^6 m^3/yr)		Virtual water export (10^6 m^3/yr)		Net virtual-water import (10^6 m^3/yr)
Central Africa	8		27		-19
Central America	2		2		0.34
Central and South Asia	430		223		207
Eastern Europe	18		80		-61
Middle East	21		46		-26
North Africa	10		9		1
North America	54		2		51
Oceania	203		3		200
South America	279		2		277
South East Asia	13		30		-17
Western Europe	387		1302		-915
FSU	0.36		1		-1
Other	0		0.01		-0.01
Total of SADC	1425		1727		-302

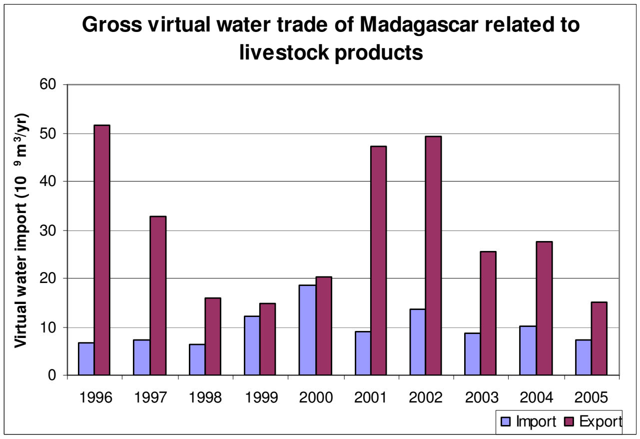
Size of virtual water volumes traded by SADC nations related to livestock products from 8 animal categories (average 1996-2005; values exist of green & blue water)

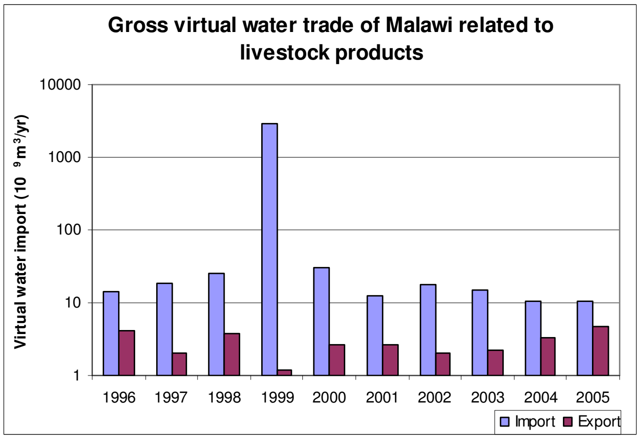


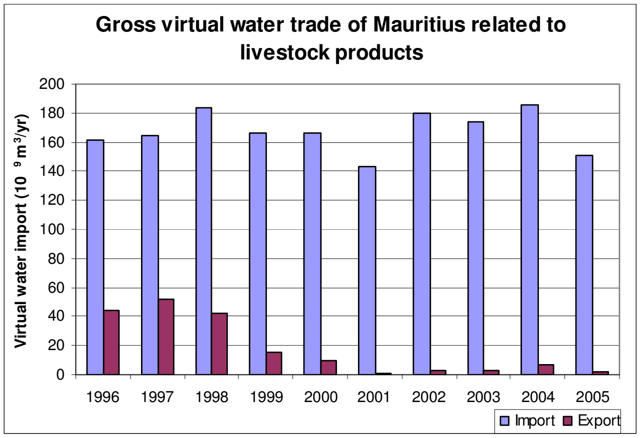


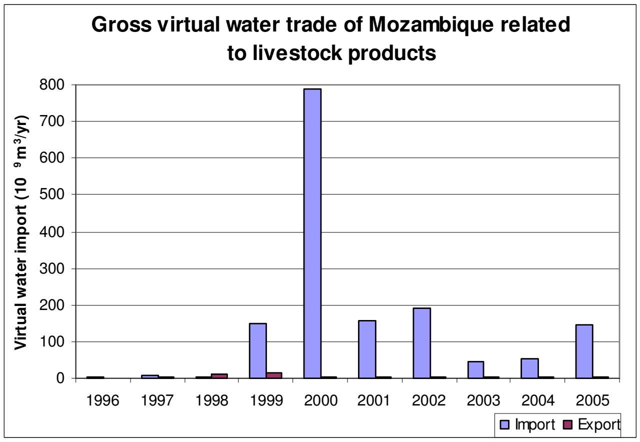
The Democratic Republic of Congo does not report trade in livestock products or has been reported as trading partner for livestock products

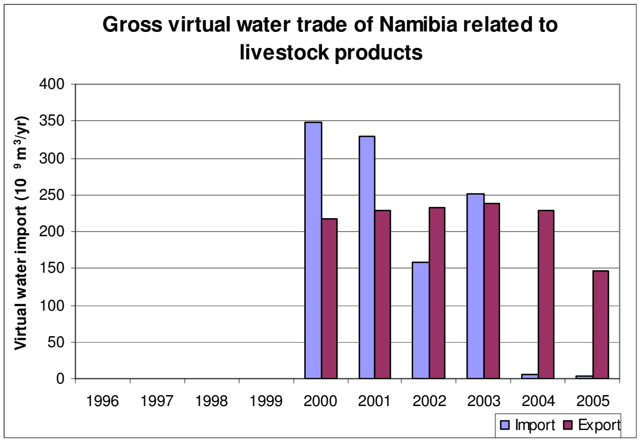


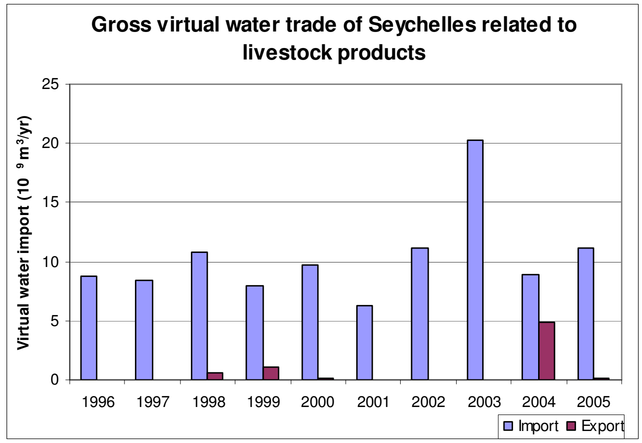


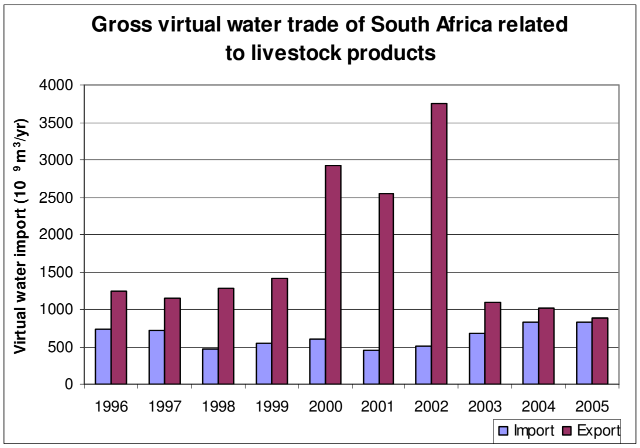


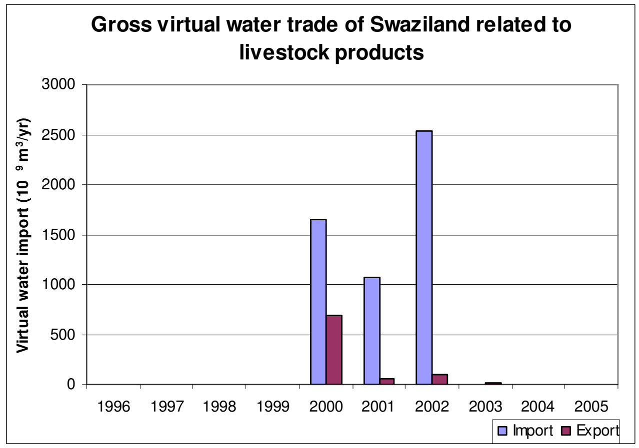


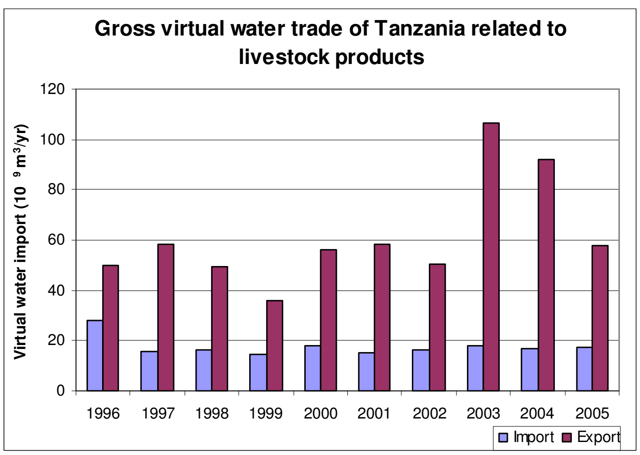


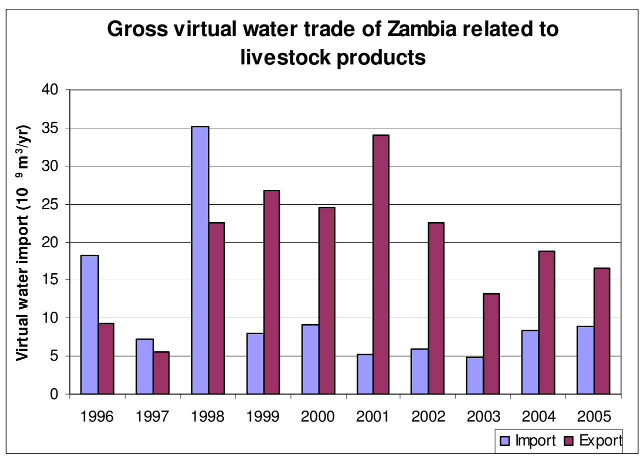

Gross virtual water trade of Namibia related to livestock products
Virtual water import (10 9 m3/yr)
0 50 100 150 200 250 300 350 400
1996 1997 1998 1999 2000 2001 2002 2003 2004 2005
Import Export

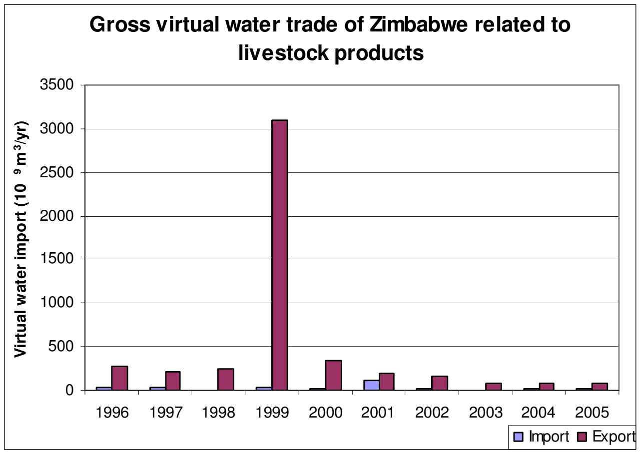

Gross virtual water trade of Seychelles related to livestock products
Virtual water import (10 9 m3/yr)
0 5 10 15 20 25
1996 1997 1998 1999 2000 2001 2002 2003 2004 2005
Import Export


Gross virtual water trade of South Africa related to livestock products
Virtual water import (10 9 m3/yr)
0 500 1000 1500 2000 2500 3000 3500 4000
1996 1997 1998 1999 2000 2001 2002 2003 2004 2005
Import Export


Gross virtual water trade of Swaziland related to livestock products
Virtual water import (10 9 m3/yr)
0 500 1000 1500 2000 2500 3000
1996 1997 1998 1999 2000 2001 2002 2003 2004 2005
Import Export


Gross virtual water trade of Tanzania related to livestock products
Virtual water import (10 9 m3/yr)
0 20 40 60 80 100 120
1996 1997 1998 1999 2000 2001 2002 2003 2004 2005
Import Export


Gross virtual water trade of Zambia related to livestock products
Virtual water import (10 9 m3/yr)
0 5 10 15 20 25 30 35 40
1996 1997 1998 1999 2000 2001 2002 2003 2004 2005
Import Export


Gross virtual water trade of Zimbabwe related to livestock products
Virtual water import (10 9 m3/yr)
3500
3000
2500
2000
1500
1000
500
0
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
Import
Export

Trade of industrial products

Overview of most important trading partners of SADC nations related to industrial trade (average 1996-2005; values exist of blue water only)

	Vitual water import				Vitual water export		
Country	Partner countries	Average (1996-2005) (10^3 m^3/yr)	Share (%)		Partner countries	Average (1996-2005) (10^3 m^3/yr)	Share (%)
ANGOLA	USA	32.70	22.24		USA	32.44	51.44
	CHINA	18.85	12.82		CHINA	10.61	16.82
	PORTUGAL	14.29	9.72		BELGIUM	3.93	6.24
	FRANCE	13.26	9.02		FRANCE	3.62	5.74
	RUSSIAN FED	7.37	5.01		TAIWAN (POC)	2.85	4.51
	BELGIUM	6.68	4.54		KOREA REP.	2.61	4.14
	KOREA REP.	6.28	4.27		SPAIN	1.15	1.83
	BRAZIL	5.37	3.65		GERMANY	0.88	1.39
	INDIA	5.01	3.41		ITALY	0.85	1.35
	UKRAINE	4.18	2.84		CHILE	0.64	1.02
	OTHER	33.06	22.48		OTHER	3.47	5.51
	TOTAL	147.06	100.00		TOTAL	63.06	100

	Vitual water import				Vitual water export		
Country	Partner countries	Average (1996-2005) (10^3 m^3/yr)	Share (%)		Partner countries	Average (1996-2005) (10^3 m^3/yr)	Share (%)
BOTSWANA	ZIMBABWE	9.52	24.75		UNITED KINGDOM	17.74	81.25
	SOUTH AFRICA	8.25	21.47		NORWAY	1.54	7.03
	CHINA	5.28	13.72		ZIMBABWE	0.57	2.63
	USA	2.22	5.77		USA	0.54	2.45
	FRANCE	1.87	4.86		SOUTH AFRICA	0.42	1.93
	INDIA	1.62	4.21		THAILAND	0.42	1.90
	TAIWAN (POC)	1.37	3.55		JAPAN	0.11	0.50
	ITALY	1.13	2.95		ZAMBIA	0.07	0.34
	HONG KONG	0.90	2.34		BELGIUM	0.06	0.28
	SWEDEN	0.87	2.27		GERMANY	0.06	0.26
	OTHER	5.42	14.11		OTHER	0.31	1.43
	TOTAL	38.44	100.00		TOTAL	21.83	100.00

	Vitual water import				Vitual water export		
Country	Partner countries	Average (1996-2005) (10^3 m^3/yr)	Share (%)		Partner countries	Average (1996-2005) (10^3 m^3/yr)	Share (%)
CONGO, D.R.	BELGIUM	11.46	28.26		BELGIUM	33.56	57.44
	CHINA	7.41	18.27		USA	10.68	18.28
	HONG KONG	2.79	6.89		FINLAND	5.07	8.67
	INDIA	2.68	6.62		JAPAN	2.24	3.83
	SOUTH AFRICA	2.03	5.02		CHINA	1.33	2.27
	USA	1.89	4.67		SOUTH AFRICA	0.93	1.60
	ZAMBIA	1.87	4.62		INDIA	0.66	1.13
	GERMANY	1.85	4.56		ZIMBABWE	0.59	1.01
	FRANCE	1.52	3.75		GERMANY	0.48	0.81
	ZIMBABWE	1.05	2.60		FRANCE	0.42	0.72
	OTHER	5.98	14.75		OTHER	2.48	4.24
	TOTAL	40.54	100.00		TOTAL	58.43	100.00

Country	Partner countries	Vitual water import Average (1996-2005) (10^3 m^3/yr)	Share (%)		Partner countries	Vitual water export Average (1996-2005) (10^3 m^3/yr)	Share (%)
LESOTHO	TAIWAN (POC)	10.32	33.00		USA	18.16	92.90
	HONG KONG	9.06	28.96		BELGIUM	0.69	3.53
	CHINA	5.46	17.46		CANADA	0.37	1.88
	SOUTH AFRICA	3.83	12.25		UNITED KINGDOM	0.09	0.45
	INDIA	0.99	3.18		GUINEA	0.06	0.33
	GERMANY	0.34	1.09		FRANCE	0.02	0.13
	USA	0.23	0.75		SAUDI ARABIA	0.02	0.11
	ZIMBABWE	0.19	0.60		JAPAN	0.02	0.08
	PHILIPPINES	0.13	0.40		BOTSWANA	0.01	0.07
	MALAYSIA	0.10	0.33		GERMANY	0.01	0.06
	OTHER	0.62	1.98		OTHER	0.09	0.47
	TOTAL	31.28	100.00		TOTAL	19.55	100.00

Country	Partner countries	Vitual water import Average (1996-2005) (10^3 m^3/yr)	Share (%)		Partner countries	Vitual water export Average (1996-2005) (10^3 m^3/yr)	Share (%)
MADAGASCAR	FRANCE	28.19	28.03		FRANCE	51.09	32.50
	CHINA	26.81	26.65		USA	44.84	28.52
	HONG KONG	10.80	10.74		GERMANY	12.83	8.16
	INDIA	7.56	7.52		MAURITIUS	8.29	5.27
	USA	3.69	3.67		UNITED KINGDOM	8.21	5.22
	BELGIUM	2.96	2.95		ITALY	7.54	4.80
	TAIWAN (POC)	2.88	2.86		FREE ZONES	3.82	2.43
	GERMANY	2.14	2.13		BELGIUM	3.61	2.30
	IRAN (ISLM.R)	1.95	1.94		SPAIN	3.41	2.17
	ITALY	1.51	1.50		NETHERLANDS	2.46	1.57
	OTHER	12.07	12.01		OTHER	11.11	7.06
	TOTAL	100.57	100.00		TOTAL	157.23	100.00

Country	Partner countries	Vitual water import Average (1996-2005) (10^3 m^3/yr)	Share (%)		Partner countries	Vitual water export Average (1996-2005) (10^3 m^3/yr)	Share (%)
MALAWI	ZIMBABWE	14.56	34.50		SOUTH AFRICA	6.28	55.66
	INDIA	7.65	18.14		USA	2.00	17.75
	SOUTH AFRICA	3.98	9.43		MOZAMBIQUE	0.99	8.77
	TAIWAN (POC)	3.39	8.03		ZIMBABWE	0.35	3.06
	CHINA	2.78	6.60		ZAMBIA	0.33	2.96
	USA	1.19	2.82		TANZANIA, U.R	0.31	2.78
	UNITED KINGDOM	0.93	2.20		UNITED KINGDOM	0.21	1.90
	GERMANY	0.79	1.88		NIGERIA	0.18	1.62
	HONG KONG	0.77	1.83		GERMANY	0.15	1.35
	FRANCE	0.77	1.82		FRANCE	0.06	0.55
	OTHER	5.38	12.75		OTHER	0.41	3.59
	TOTAL	42.20	100.00		TOTAL	11.29	100.00

	Vitual water import				Vitual water export		
Country	Partner countries	Average (1996-2005) (10^3 m^3/yr)	Share (%)		Partner countries	Average (1996-2005) (10^3 m^3/yr)	Share (%)
MAURITIUS	INDIA	50.58	25.68		FRANCE	5.31	26.70
	CHINA	39.55	20.08		USA	3.95	19.87
	FRANCE	20.11	10.21		UNITED KINGDOM	3.33	16.77
	HONG KONG	19.18	9.74		MADAGASCAR	1.15	5.78
	TAIWAN (POC)	12.09	6.14		BELGIUM	0.93	4.70
	MADAGASCAR	8.29	4.21		GERMANY	0.93	4.68
	USA	6.47	3.28		ITALY	0.93	4.68
	GERMANY	4.79	2.43		SPAIN	0.49	2.47
	SOUTH AFRICA	3.82	1.94		NETHERLANDS	0.36	1.82
	BELGIUM	3.56	1.81		SWITZERLAND	0.28	1.43
	OTHER	28.49	14.47		OTHER	2.21	11.12
	TOTAL	196.92	100.00		TOTAL	19.88	100.00

	Vitual water import				Vitual water export		
Country	Partner countries	Average (1996-2005) (10^3 m^3/yr)	Share (%)		Partner countries	Average (1996-2005) (10^3 m^3/yr)	Share (%)
MOZAMBIQUE	INDIA	8.46	21.07		BELGIUM	2.98	42.05
	SOUTH AFRICA	6.64	16.54		ITALY	0.88	12.36
	CHINA	5.69	14.16		GERMANY	0.76	10.70
	FRANCE	2.80	6.96		SPAIN	0.56	7.85
	PORTUGAL	2.61	6.51		UNITED KINGDOM	0.36	5.07
	ZIMBABWE	2.33	5.79		NETHERLANDS	0.31	4.35
	USA	1.75	4.35		ZIMBABWE	0.27	3.88
	HONG KONG	1.02	2.53		SOUTH AFRICA	0.24	3.37
	MALAWI	0.99	2.46		AUSTRIA	0.20	2.84
	ITALY	0.83	2.05		FRANCE	0.13	1.84
	OTHER	7.05	17.56		OTHER	0.40	5.69
	TOTAL	40.16	100.00		TOTAL	7.08	100.00

	Vitual water import				Vitual water export		
Country	Partner countries	Average (1996-2005) (10^3 m^3/yr)	Share (%)		Partner countries	Average (1996-2005) (10^3 m^3/yr)	Share (%)
NAMIBIA	SOUTH AFRICA	13.39	41.32		UNITED KINGDOM	3.12	35.73
	CHINA	4.66	14.39		USA	1.32	15.15
	USA	2.85	8.79		ANGOLA	0.80	9.15
	GERMANY	1.67	5.14		CHINA	0.54	6.17
	INDIA	1.34	4.14		FRANCE	0.53	6.06
	UKRAINE	1.07	3.31		ITALY	0.47	5.36
	FRANCE	0.69	2.14		GERMANY	0.33	3.79
	BULGARIA	0.60	1.86		CANADA	0.27	3.12
	HONG KONG	0.58	1.78		BELGIUM	0.18	2.09
	BELGIUM	0.52	1.61		SOUTH AFRICA	0.18	2.03
	OTHER	5.03	15.53		OTHER	0.99	11.36
	TOTAL	32.40	100.00		TOTAL	8.73	100.00

	Vitual water import				Vitual water export	
Country	Partner countries	Average (1996-2005) (10^3 m^3/yr)	Share (%)	Partner countries	Average (1996-2005) (10^3 m^3/yr)	Share (%)
SEYCHELLES	RUSSIAN FED	3.31	22.04	UNITED KINGDOM	0.78	30.71
	USA	2.87	19.12	USA	0.34	13.38
	FRANCE	1.38	9.19	SPAIN	0.31	12.24
	ITALY	1.14	7.59	FRANCE	0.15	5.81
	INDIA	0.92	6.15	SOUTH AFRICA	0.11	4.41
	GERMANY	0.80	5.36	HUNGARY	0.10	3.80
	UKRAINE	0.57	3.82	MALDIVES	0.09	3.71
	SOUTH AFRICA	0.45	3.03	MADAGASCAR	0.07	2.92
	CHINA	0.43	2.88	CANADA	0.07	2.62
	UNITED KINGDOM	0.41	2.71	ETHIOPIA	0.06	2.35
	OTHER	2.72	18.12	OTHER	0.46	18.05
	TOTAL	15.00	100.00	TOTAL	2.54	100.00

	Vitual water import				Vitual water export	
Country	Partner countries	Average (1996-2005) (10^3 m^3/yr)	Share (%)	Partner countries	Average (1996-2005) (10^3 m^3/yr)	Share (%)
SOUTH AFRICA	CHINA	368.18	18.89	USA	90.72	15.52
	USA	310.73	15.94	JAPAN	67.59	11.56
	TAIWAN (POC)	182.23	9.35	UNITED KINGDOM	59.88	10.24
	GERMANY	178.02	9.13	GERMANY	49.87	8.53
	FRANCE	122.50	6.28	CHINA	19.46	3.33
	HONG KONG	91.25	4.68	KOREA REP.	18.85	3.22
	INDIA	84.54	4.34	BELGIUM	17.46	2.99
	ZIMBABWE	76.32	3.92	ITALY	16.55	2.83
	ITALY	50.36	2.58	ZIMBABWE	14.63	2.50
	BELGIUM	45.02	2.31	TAIWAN (POC)	13.36	2.29
	OTHER	440.28	22.59	OTHER	216.28	36.99
	TOTAL	1949.43	100.00	TOTAL	584.65	100.00

	Vitual water import				Vitual water export	
Country	Partner countries	Average (1996-2005) (10^3 m^3/yr)	Share (%)	Partner countries	Average (1996-2005) (10^3 m^3/yr)	Share (%)
SWAZILAND	SOUTH AFRICA	7.07	34.20	USA	2.85	37.89408
	TAIWAN (POC)	4.46	21.56	KOREA REP.	1.10	14.59529
	HONG KONG	3.26	15.75	THAILAND	0.37	4.873732
	INDIA	2.09	10.11	KENYA	0.28	3.695396
	CHINA	1.76	8.49	ZIMBABWE	0.24	3.243527
	USA	0.46	2.25	UGANDA	0.19	2.465243
	KOREA REP.	0.21	1.01	TANZANIA, U.R	0.18	2.39236
	ITALY	0.19	0.93	MEXICO	0.14	1.896378
	GERMANY	0.19	0.92	BANGLADESH	0.13	1.714088
	GUYANA	0.12	0.57	AUSTRALIA	0.13	1.68557
	OTHER	0.87	4.22	OTHER	1.92	25.54434
	TOTAL	20.68	100.00	TOTAL	7.53	100

	Vitual water import				Vitual water export	
Country	Partner countries	Average (1996-2005) (10^3 m^3/yr)	Share (%)	Partner countries	Average (1996-2005) (10^3 m^3/yr)	Share (%)
TANZANIA, U.R.	INDIA	28.32	27.52	UNITED KINGDOM	0.42	9.21
	CHINA	19.70	19.14	JAPAN	0.41	8.93
	USA	4.75	4.62	MALAYSIA	0.40	8.86
	KENYA	4.37	4.24	USA	0.29	6.26
	GERMANY	3.22	3.13	ZAMBIA	0.28	6.16
	SOUTH AFRICA	3.03	2.94	INDIA	0.25	5.49
	FRANCE	2.77	2.69	CHINA	0.23	5.06
	UKRAINE	2.57	2.50	UGANDA	0.19	4.16
	HONG KONG	2.57	2.50	SPAIN	0.15	3.22
	BELGIUM	2.31	2.25	CONGO, D.R.	0.14	3.04
	OTHER	29.30	28.46	OTHER	1.81	39.60
	TOTAL	102.93	100.00	TOTAL	4.56	100.00

	Vitual water import				Vitual water export	
Country	Partner countries	Average (1996-2005) (10^3 m^3/yr)	Share (%)	Partner countries	Average (1996-2005) (10^3 m^3/yr)	Share (%)
ZAMBIA	ZIMBABWE	29.23	40.15	JAPAN	25.41	14.94
	SOUTH AFRICA	9.76	13.41	SAUDI ARABIA	21.93	12.89
	INDIA	9.06	12.45	THAILAND	20.22	11.88
	CHINA	6.18	8.50	CHINA	12.74	7.49
	UNITED KINGDOM	2.73	3.75	INDIA	8.08	4.75
	FRANCE	2.52	3.47	TAIWAN (POC)	7.94	4.67
	USA	1.79	2.46	SOUTH AFRICA	7.78	4.57
	TAIWAN (POC)	1.23	1.70	USA	7.57	4.45
	HONG KONG	1.04	1.43	KOREA REP.	7.48	4.39
	GERMANY	0.99	1.35	FRANCE	6.46	3.80
	OTHER	8.25	11.34	OTHER	44.54	26.17
	TOTAL	72.79	100.00	TOTAL	170.16	100.00

	Vitual water import				Vitual water export	
Country	Partner countries	Average (1996-2005) (10^3 m^3/yr)	Share (%)	Partner countries	Average (1996-2005) (10^3 m^3/yr)	Share (%)
ZIMBABWE	SOUTH AFRICA	14.63	18.74	SOUTH AFRICA	76.32	22.32
	CHINA	12.47	15.97	JAPAN	59.75	17.48
	USA	6.97	8.92	USA	32.14	9.40
	INDIA	6.72	8.61	ZAMBIA	29.23	8.55
	TAIWAN (POC)	4.76	6.10	GERMANY	22.95	6.71
	HONG KONG	4.37	5.60	ITALY	22.67	6.63
	GERMANY	4.03	5.16	MALAWI	14.56	4.26
	FRANCE	3.72	4.76	UNITED KINGDOM	13.52	3.95
	ZAMBIA	2.56	3.28	SPAIN	8.65	2.53
	UNITED KINGDOM	2.00	2.55	INDIA	6.75	1.97
	OTHER	15.86	20.31	OTHER	55.34	16.19
	TOTAL	78.09	100.00	TOTAL	341.88	100.00

Overview of most important traded industrial products of SADC nations related to industrial trade (average 1996-2005; values exist of blue water only)

		Vitual water import				Vitual water export	
Country	**Product group**	**Average (1996-2005) (10^3 m^3/yr)**	**Share (%)**		**Product group**	**Average (1996-2005) (10^3 m^3/yr)**	**Share (%)**
ANGOLA	27 - Crude fertilizer,mineral	0.33	0.22		27 - Crude fertilizer	0.00002	0.00
	28 - Metalliferous ore,scrap	0.01	0.01		27 - Crude fertilizer,mineral	0.04	0.06
	3 - Fuels, lubricants, etc.	3.50	2.38		28 - Metalliferous ore,scrap	0.02	0.03
	5 - Chemicals,reltd.prod.nes	5.80	3.94		3 - Fuels, lubricants, etc.	58.72	93.11
	5 - Chemicals,reltd.prod.nes	3.48	2.37		5 - Chemicals,reltd.prod.nes	0.00	0.01
	6 - Manufactured goods	26.82	18.24		6 - Manufactured goods	4.03	6.39
	68 - Non-ferrous metals	0.25	0.17		6 - Manufactured goods	0.11	0.18
	7 - Machines,transport equip	85.42	58.08		68 - Non-ferrous metals	0.01	0.01
	8 - Misc manufactured artcls	21.45	14.59		7 - Machines,transport equip	0.11	0.17
					8 - Misc manufactured artcls	0.03	0.04
	TOTAL	147.06	100.00		TOTAL	63.06	100

		Vitual water import				Vitual water export	
Country	**Product group**	**Average (1996-2005) (10^3 m^3/yr)**	**Share (%)**		**Product group**	**Average (1996-2005) (10^3 m^3/yr)**	**Share (%)**
BOTSWANA	27 - Crude fertilizer,mineral	0.52	1.35		27 - Crude fertilizer	0.00	0.02
	28 - Metalliferous ore,scrap	0.39	1.02		27 - Crude fertilizer,mineral	0.15	0.69
	3 - Fuels, lubricants, etc.	0.91	2.36		28 - Metalliferous ore,scrap	2.02	9.24
	5 - Chemicals,reltd.prod.nes	2.39	6.23		3 - Fuels, lubricants, etc.	0.01	0.06
	5 - Chemicals,reltd.prod.nes	0.13	0.33		5 - Chemicals,reltd.prod.nes	0.07	0.32
	6 - Manufactured goods	11.85	30.84		6 - Manufactured goods	1.11	5.09
	68 - Non-ferrous metals	0.09	0.24		6 - Manufactured goods	17.98	82.37
	7 - Machines,transport equip	14.62	38.04		68 - Non-ferrous metals	0.00	0.02
	8 - Misc manufactured artcls	7.53	19.59		7 - Machines,transport equip	0.15	0.67
					8 - Misc manufactured artcls	0.33	1.52
	TOTAL	38.44	100.00		TOTAL	21.83	100.00

		Vitual water import				Vitual water export	
Country	**Product group**	**Average (1996-2005) (10^3 m^3/yr)**	**Share (%)**		**Product group**	**Average (1996-2005) (10^3 m^3/yr)**	**Share (%)**
CONGO, D.R.	27 - Crude fertilizer	11.46	28.26		27 - Crude fertilizer	0.01	0.01
	27 - Crude fertilizer,mineral	7.41	18.27		27 - Crude fertilizer,mineral	1.27	2.17
	28 - Metalliferous ore,scrap	2.79	6.89		28 - Metalliferous ore,scrap	4.73	8.09
	3 - Fuels, lubricants, etc.	2.68	6.62		3 - Fuels, lubricants, etc.	7.86	13.44
	5 - Chemicals,reltd.prod.nes	2.03	5.02		5 - Chemicals,reltd.prod.nes	0.27	0.47
	6 - Manufactured goods	1.89	4.67		6 - Manufactured goods	36.26	62.05
	6 - Manufactured goods	1.87	4.62		6 - Manufactured goods	3.39	5.80
	68 - Non-ferrous metals	1.85	4.56		68 - Non-ferrous metals	4.22	7.23
	7 - Machines,transport equip	1.52	3.75		7 - Machines,transport equip	0.25	0.42
	8 - Misc manufactured artcls	1.05	2.60		8 - Misc manufactured artcls	0.19	0.32
	TOTAL	40.54	100.00		TOTAL	58.43	100.00

		Vitual water import				Vitual water export	
Country	**Product group**	**Average (1996-2005) (10^3 m^3/yr)**	**Share (%)**		**Product group**	**Average (1996-2005) (10^3 m^3/yr)**	**Share (%)**
LESOTHO	27 - Crude fertilizer,mineral	0.09	0.28		27 - Crude fertilizer	0.00	0.00
	28 - Metalliferous ore,scrap	0.18	0.58		27 - Crude fertilizer,mineral	0.00	0.02
	3 - Fuels, lubricants, etc.	0.78	2.50		28 - Metalliferous ore,scrap	0.00	0.00
	5 - Chemicals,reltd.prod.nes	1.70	5.43		3 - Fuels, lubricants, etc.	0.00	0.01
	5 - Chemicals,reltd.prod.nes	0.08	0.25		5 - Chemicals,reltd.prod.nes	0.02	0.08
	6 - Manufactured goods	20.92	66.89		6 - Manufactured goods	0.81	4.14
	68 - Non-ferrous metals	0.01	0.03		6 - Manufactured goods	0.14	0.69
	7 - Machines,transport equip	3.62	11.59		68 - Non-ferrous metals	0.00	0.00
	8 - Misc manufactured artcls	3.90	12.46		7 - Machines,transport equip	0.04	0.22
		0.00			8 - Misc manufactured artcls	18.54	94.83
	TOTAL	31.28	100.00		TOTAL	19.55	100.00

Country	Product group	Vitual water import Average (1996-2005) (10^3 m^3/yr)	Share (%)		Product group	Vitual water export Average (1996-2005) (10^3 m^3/yr)	Share (%)
MADAGASCAR	27 - Crude fertilizer,mineral	0.05	0.05		27 - Crude fertilizer	0.91	0.58
	28 - Metalliferous ore,scrap	0.09	0.09		27 - Crude fertilizer,mineral	3.08	1.96
	3 - Fuels, lubricants, etc.	4.48	4.45		28 - Metalliferous ore,scrap	2.01	1.28
	5 - Chemicals,reltd.prod.nes	10.07	10.02		3 - Fuels, lubricants, etc.	6.64	4.22
	5 - Chemicals,reltd.prod.nes	0.60	0.60		5 - Chemicals,reltd.prod.nes	3.68	2.34
	6 - Manufactured goods	41.72	41.48		6 - Manufactured goods	10.78	6.86
	68 - Non-ferrous metals	0.40	0.40		6 - Manufactured goods	0.56	0.36
	7 - Machines,transport equip	30.28	30.11		68 - Non-ferrous metals	0.01	0.01
	8 - Misc manufactured artcls	12.89	12.82		7 - Machines,transport equip	2.63	1.67
		0.00			8 - Misc manufactured artcls	126.92	80.73
	TOTAL	100.57	100.00		TOTAL	157.23	100.00

Country	Product group	Vitual water import Average (1996-2005) (10^3 m^3/yr)	Share (%)		Product group	Vitual water export Average (1996-2005) (10^3 m^3/yr)	Share (%)
MALAWI	27 - Crude fertilizer,mineral	0.70	1.67		27 - Crude fertilizer,mineral	0.01	0.08
	28 - Metalliferous ore,scrap	0.00	0.01		28 - Metalliferous ore,scrap	0.13	1.11
	3 - Fuels, lubricants, etc.	1.65	3.92		3 - Fuels, lubricants, etc.	0.24	2.09
	5 - Chemicals,reltd.prod.nes	7.09	16.80		5 - Chemicals,reltd.prod.nes	0.38	3.38
	5 - Chemicals,reltd.prod.nes	0.09	0.21		6 - Manufactured goods	1.88	16.65
	6 - Manufactured goods	15.42	36.54		6 - Manufactured goods	0.23	2.06
	68 - Non-ferrous metals	0.11	0.27		68 - Non-ferrous metals	0.04	0.34
	7 - Machines,transport equip	12.27	29.07		7 - Machines,transport equip	0.83	7.36
	8 - Misc manufactured artcls	4.86	11.52		8 - Misc manufactured artcls	7.56	66.93
	TOTAL	42.20	100.00		TOTAL	11.29	100.00

Country	Product group	Vitual water import Average (1996-2005) (10^3 m^3/yr)	Share (%)		Product group	Vitual water export Average (1996-2005) (10^3 m^3/yr)	Share (%)
MAURITIUS	27 - Crude fertilizer,mineral	1.20	0.61		27 - Crude fertilizer	0.00	0.00
	28 - Metalliferous ore,scrap	0.01	0.00		27 - Crude fertilizer,mineral	0.01	0.03
	3 - Fuels, lubricants, etc.	9.59	4.87		28 - Metalliferous ore,scrap	0.08	0.39
	5 - Chemicals,reltd.prod.nes	14.62	7.42		3 - Fuels, lubricants, etc.	0.01	0.06
	6 - Manufactured goods	104.54	53.08		5 - Chemicals,reltd.prod.nes	0.36	1.80
	68 - Non-ferrous metals	1.13	0.57		6 - Manufactured goods	1.92	9.67
	7 - Machines,transport equip	41.33	20.99		6 - Manufactured goods	0.25	1.25
	8 - Misc manufactured artcls	24.51	12.45		68 - Non-ferrous metals	0.01	0.04
					7 - Machines,transport equip	0.88	4.43
					8 - Misc manufactured artcls	16.37	82.33
	TOTAL	196.92	100.00		TOTAL	19.88	100.00

Country	Product group	Vitual water import Average (1996-2005) (10^3 m^3/yr)	Share (%)		Product group	Vitual water export Average (1996-2005) (10^3 m^3/yr)	Share (%)
MOZAMBIQUE	27 - Crude fertilizer,mineral	0.21	0.52		27 - Crude fertilizer	0.00	0.03
	28 - Metalliferous ore,scrap	0.04	0.09		27 - Crude fertilizer,mineral	0.12	1.62
	3 - Fuels, lubricants, etc.	2.04	5.08		28 - Metalliferous ore,scrap	0.06	0.89
	5 - Chemicals,reltd.prod.nes	3.87	9.64		3 - Fuels, lubricants, etc.	0.49	6.94
	5 - Chemicals,reltd.prod.nes	0.73	1.81		5 - Chemicals,reltd.prod.nes	0.02	0.28
	6 - Manufactured goods	10.70	26.64		6 - Manufactured goods	2.95	41.70
	68 - Non-ferrous metals	0.13	0.33		6 - Manufactured goods	0.17	2.47
	7 - Machines,transport equip	16.68	41.54		68 - Non-ferrous metals	3.01	42.46
	8 - Misc manufactured artcls	5.76	14.34		7 - Machines,transport equip	0.17	2.35
					8 - Misc manufactured artcls	0.09	1.25
	TOTAL	40.16	100.00		TOTAL	7.08	100.00

Country	Product group	Vitual water import Average (1996-2005) (10^3 m^3/yr)	Share (%)		Product group	Vitual water export Average (1996-2005) (10^3 m^3/yr)	Share (%)
NAMIBIA	27 - Crude fertilizer,mineral	0.27	0.84		27 - Crude fertilizer	0.12	1.40
	28 - Metalliferous ore,scrap	0.49	1.50		27 - Crude fertilizer,mineral	0.13	1.46
	3 - Fuels, lubricants, etc.	2.07	6.38		28 - Metalliferous ore,scrap	0.09	1.08
	5 - Chemicals,reltd.prod.nes	2.72	8.39		3 - Fuels, lubricants, etc.	0.26	2.94
	5 - Chemicals,reltd.prod.nes	0.27	0.83		5 - Chemicals,reltd.prod.nes	1.20	13.70
	6 - Manufactured goods	7.35	22.69		6 - Manufactured goods	1.38	15.76
	68 - Non-ferrous metals	0.13	0.41		6 - Manufactured goods	3.49	40.00
	7 - Machines,transport equip	13.48	41.62		68 - Non-ferrous metals	1.03	11.85
	8 - Misc manufactured artcls	5.62	17.34		7 - Machines,transport equip	0.46	5.31
					8 - Misc manufactured artcls	0.57	6.49
	TOTAL	32.40	100.00		TOTAL	8.73	100.00

Country	Product group	Vitual water import Average (1996-2005) (10^3 m^3/yr)	Share (%)		Product group	Vitual water export Average (1996-2005) (10^3 m^3/yr)	Share (%)
SEYCHELLES	27 - Crude fertilizer,mineral	0.15	1.00		27 - Crude fertilizer,mineral	0.01	0.36
	28 - Metalliferous ore,scrap	0.01	0.08		28 - Metalliferous ore,scrap	0.02	0.68
	3 - Fuels, lubricants, etc.	0.20	1.33		3 - Fuels, lubricants, etc.	0.34	13.32
	5 - Chemicals,reltd.prod.nes	0.73	4.87		5 - Chemicals,reltd.prod.nes	0.09	3.56
	5 - Chemicals,reltd.prod.nes	0.04	0.28		5 - Chemicals,reltd.prod.nes	0.01	0.27
	6 - Manufactured goods	4.81	32.04		6 - Manufactured goods	0.07	2.75
	68 - Non-ferrous metals	0.74	4.90		6 - Manufactured goods	0.02	0.80
	7 - Machines,transport equip	6.74	44.94		68 - Non-ferrous metals	0.01	0.25
	8 - Misc manufactured artcls	1.58	10.54		7 - Machines,transport equip	1.02	40.13
					8 - Misc manufactured artcls	0.96	37.87
	TOTAL	15.00	100.00		TOTAL	2.54	100.00

Country	Product group	Vitual water import Average (1996-2005) (10^3 m^3/yr)	Share (%)		Product group	Vitual water export Average (1996-2005) (10^3 m^3/yr)	Share (%)
SOUTH AFRICA	27 - Crude fertilizer,mineral	9.60	0.49		27 - Crude fertilizer	0.72	0.12
	28 - Metalliferous ore,scrap	43.08	2.21		27 - Crude fertilizer,mineral	10.01	1.71
	3 - Fuels, lubricants, etc.	92.80	4.76		28 - Metalliferous ore,scrap	37.25	6.37
	5 - Chemicals,reltd.prod.nes	252.75	12.97		3 - Fuels, lubricants, etc.	62.27	10.65
	6 - Manufactured goods	331.18	16.99		5 - Chemicals,reltd.prod.nes	40.28	6.89
	68 - Non-ferrous metals	27.22	1.40		6 - Manufactured goods	153.85	26.31
	7 - Machines,transport equip	871.14	44.69		6 - Manufactured goods	75.03	12.83
	8 - Misc manufactured artcls	321.65	16.50		68 - Non-ferrous metals	87.07	14.89
					7 - Machines,transport equip	92.01	15.74
					8 - Misc manufactured artcls	26.17	4.48
	TOTAL	1949.43	100.00		TOTAL	584.65	100.00

Country	Product group	Vitual water import Average (1996-2005) (10^3 m^3/yr)	Share (%)		Product group	Vitual water export Average (1996-2005) (10^3 m^3/yr)	Share (%)
SWAZILAND	27 - Crude fertilizer,mineral	0.05	0.22		27 - Crude fertilizer,mineral	0.03	0.44
	28 - Metalliferous ore,scrap	0.01	0.05		28 - Metalliferous ore,scrap	0.06	0.83
	3 - Fuels, lubricants, etc.	1.23	5.93		3 - Fuels, lubricants, etc.	0.11	1.45
	5 - Chemicals,reltd.prod.nes	1.66	8.04		5 - Chemicals,reltd.prod.nes	1.88	24.96
	5 - Chemicals,reltd.prod.nes	0.14	0.69		6 - Manufactured goods	0.52	6.90
	6 - Manufactured goods	11.01	53.25		6 - Manufactured goods	0.18	2.36
	68 - Non-ferrous metals	0.06	0.29		68 - Non-ferrous metals	0.11	1.52
	7 - Machines,transport equip	3.85	18.62		7 - Machines,transport equip	1.52	20.18
	8 - Misc manufactured artcls	2.67	12.91		8 - Misc manufactured artcls	3.11	41.36
	TOTAL	20.68	100.00		TOTAL	7.53	100

Country	Product group	Vitual water import Average (1996-2005) (10^3 m^3/yr)	Share (%)	Product group	Vitual water export Average (1996-2005) (10^3 m^3/yr)	Share (%)
TANZANIA, U.R.	27 - Crude fertilizer,mineral	0.32	0.31	27 - Crude fertilizer	0.00	0.07
	28 - Metalliferous ore,scrap	0.01	0.01	27 - Crude fertilizer,mineral	0.05	1.19
	3 - Fuels, lubricants, etc.	4.82	4.69	28 - Metalliferous ore,scrap	0.61	13.45
	5 - Chemicals,reltd.prod.nes	17.78	17.27	3 - Fuels, lubricants, etc.	0.52	11.44
	6 - Manufactured goods	30.20	29.35	5 - Chemicals,reltd.prod.nes	0.18	3.87
	68 - Non-ferrous metals	0.94	0.91	6 - Manufactured goods	1.40	30.56
	7 - Machines,transport equip	37.84	36.76	6 - Manufactured goods	0.60	13.10
	8 - Misc manufactured artcls	11.01	10.70	68 - Non-ferrous metals	0.46	10.17
				7 - Machines,transport equip	0.34	7.48
				8 - Misc manufactured artcls	0.40	8.68
	TOTAL	102.93	100.00	TOTAL	4.56	100.00

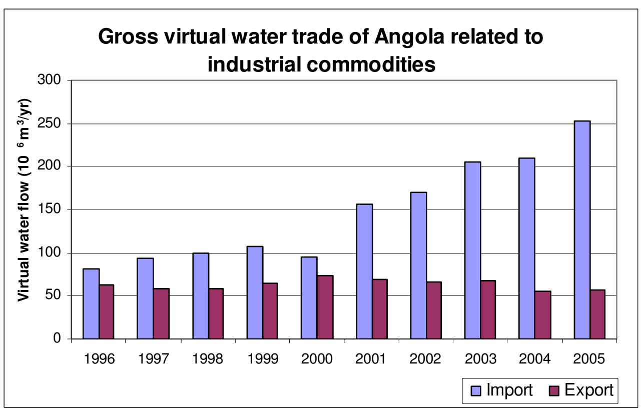
Country	Product group	Vitual water import Average (1996-2005) (10^3 m^3/yr)	Share (%)	Product group	Vitual water export Average (1996-2005) (10^3 m^3/yr)	Share (%)
ZAMBIA	27 - Crude fertilizer,mineral	2.12	2.92	27 - Crude fertilizer	0.00	0.00
	28 - Metalliferous ore,scrap	0.27	0.38	27 - Crude fertilizer,mineral	0.47	0.28
	3 - Fuels, lubricants, etc.	6.80	9.34	28 - Metalliferous ore,scrap	3.94	2.32
	5 - Chemicals,reltd.prod.nes	13.95	19.17	3 - Fuels, lubricants, etc.	1.27	0.75
	5 - Chemicals,reltd.prod.nes	0.31	0.43	5 - Chemicals,reltd.prod.nes	1.54	0.90
	6 - Manufactured goods	2.56	3.51	6 - Manufactured goods	77.66	45.64
	6 - Manufactured goods	14.75	20.27	6 - Manufactured goods	7.97	4.68
	68 - Non-ferrous metals	0.28	0.39	68 - Non-ferrous metals	74.32	43.68
	7 - Machines,transport equip	22.81	31.33	7 - Machines,transport equip	2.24	1.32
	8 - Misc manufactured artcls	8.93	12.27	8 - Misc manufactured artcls	0.75	0.44
	TOTAL	72.79	100.00	TOTAL	170.16	100.00

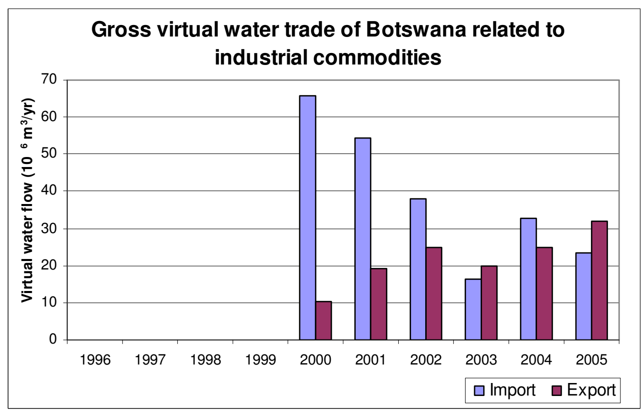
Country	Product group	Vitual water import Average (1996-2005) (10^3 m^3/yr)	Share (%)	Product group	Vitual water export Average (1996-2005) (10^3 m^3/yr)	Share (%)
ZIMBABWE	27 - Crude fertilizer,mineral	0.22	0.28	27 - Crude fertilizer	0.66	0.19
	28 - Metalliferous ore,scrap	0.45	0.57	27 - Crude fertilizer,mineral	23.78	6.95
	3 - Fuels, lubricants, etc.	3.58	4.58	28 - Metalliferous ore,scrap	40.43	11.83
	5 - Chemicals,reltd.prod.nes	13.02	16.68	3 - Fuels, lubricants, etc.	10.38	3.04
	5 - Chemicals,reltd.prod.nes	1.12	1.43	5 - Chemicals,reltd.prod.nes	15.78	4.62
	6 - Manufactured goods	18.51	23.70	6 - Manufactured goods	122.46	35.82
	68 - Non-ferrous metals	0.98	1.25	6 - Manufactured goods	34.36	10.05
	7 - Machines,transport equip	33.76	43.23	68 - Non-ferrous metals	47.63	13.93
	8 - Misc manufactured artcls	6.46	8.27	7 - Machines,transport equip	16.18	4.73
				8 - Misc manufactured artcls	30.21	8.84
	TOTAL	78.09	100.00	TOTAL	341.88	100.00

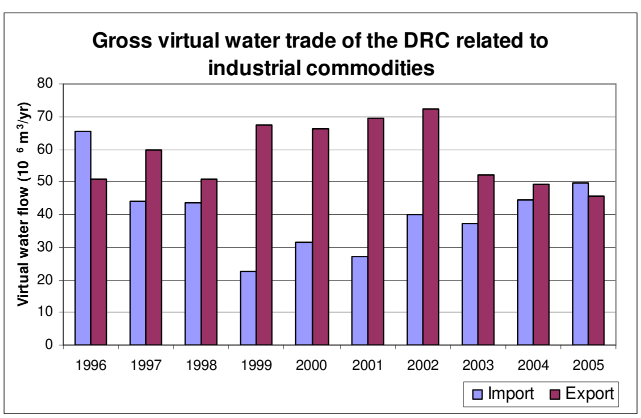
Virtual water volumes traded between SADC nations and other world regions related to industrial products (1996-2005; values exist of green & blue water)

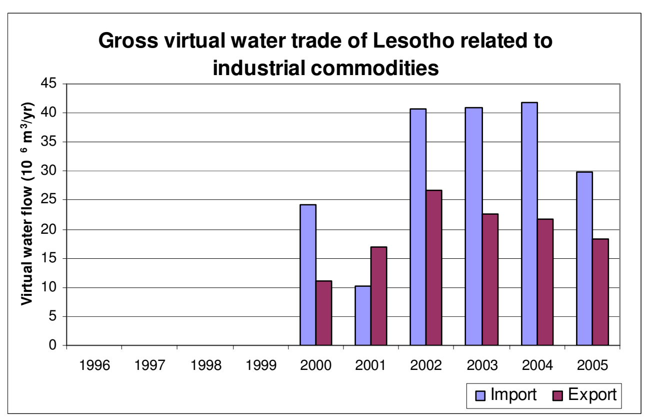
World region	Virtual water import (10^6 m^3/yr)		Virtual water export (10^6 m^3/yr)		Net virtual-water import (10^6 m^3/yr)
Central Africa	9		14		-5
Central America	5		5		0.001
Central and South Asia	1178		306		872
Eastern Europe	56		8		48
Middle East	49		41		9
North Africa	16		17		-1
North America	417		259		158
Oceania	18		20		-2
South America	30		15		15
South East Asia	62		52		10
Western Europe	746		497		249
FSU	67.43		1		66
Other	0		0		0
Total of SADC	2652		1234		1419

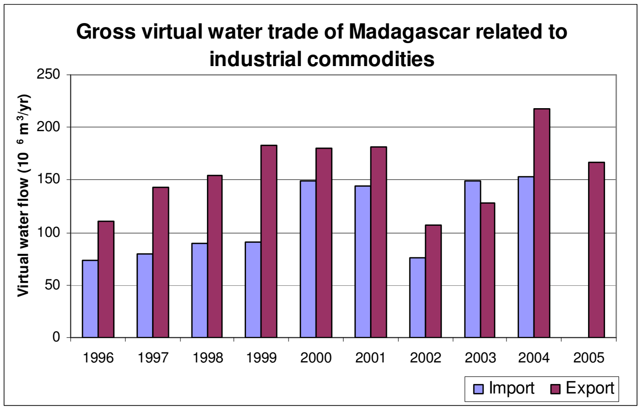
Size of virtual water volumes traded by SADC nations related to industrial products (1996-2005; values exist of blue water only)

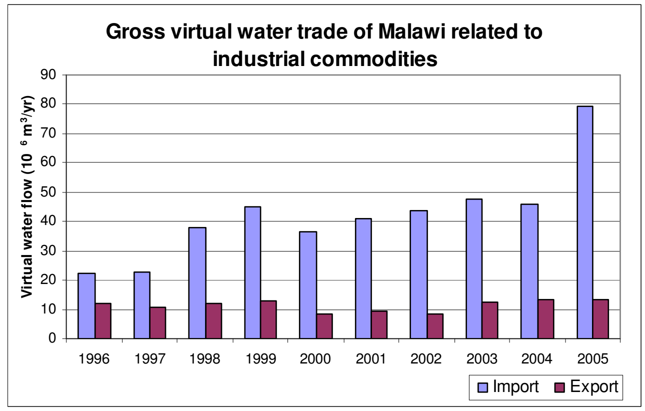


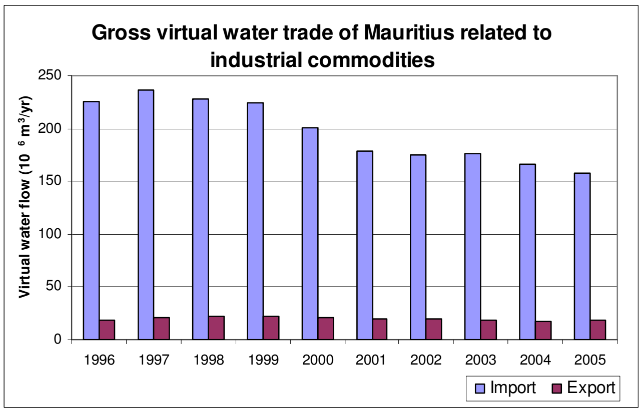


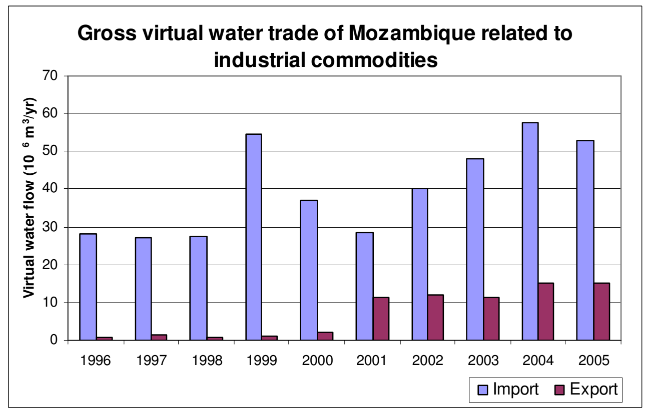


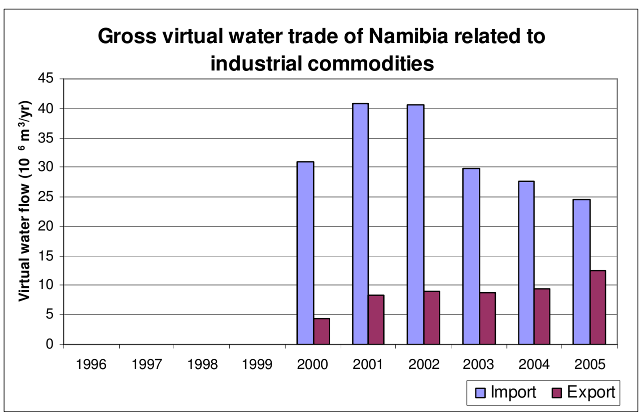


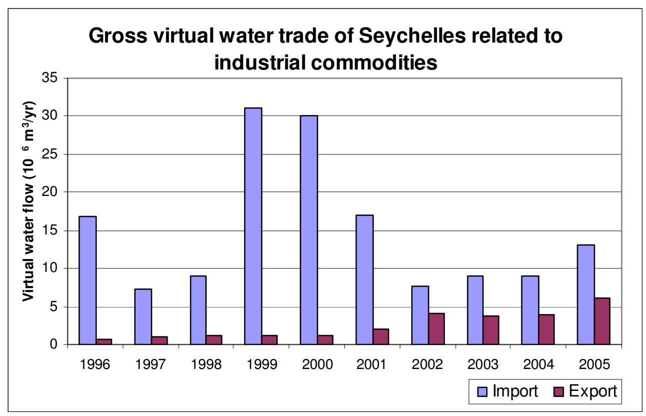

Gross virtual water trade of Madagascar related to industrial commodities
Virtual water flow (10 6 m3/yr)
0 50 100 150 200 250
1996 1997 1998 1999 2000 2001 2002 2003 2004 2005
Import Export

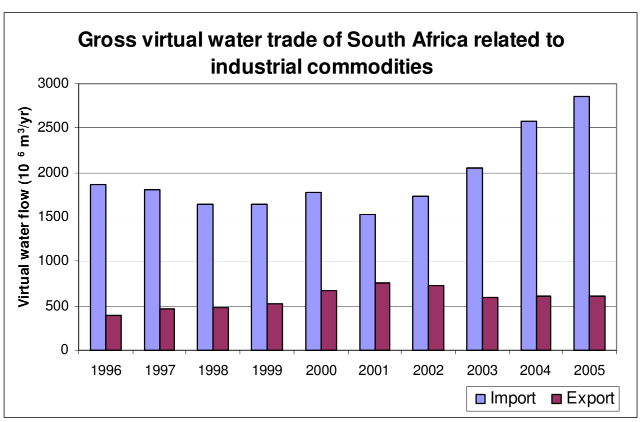

Gross virtual water trade of Malawi related to industrial commodities
Virtual water flow (10 6 m3/yr)
0 10 20 30 40 50 60 70 80 90
1996 1997 1998 1999 2000 2001 2002 2003 2004 2005
Import Export

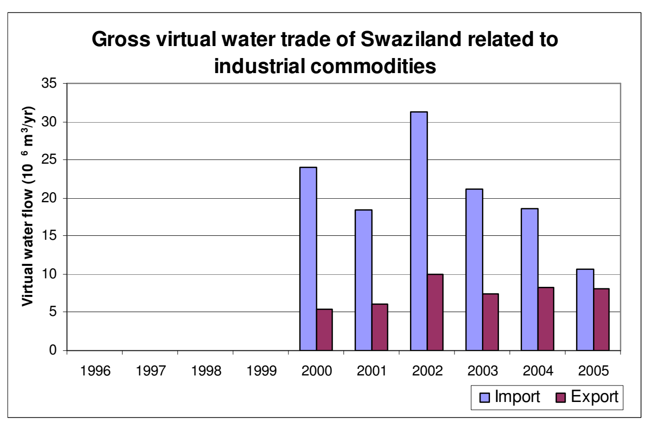

Gross virtual water trade of Mauritius related to industrial commodities
Virtual water flow (10 6 m3/yr)
0 50 100 150 200 250
1996 1997 1998 1999 2000 2001 2002 2003 2004 2005
Import Export

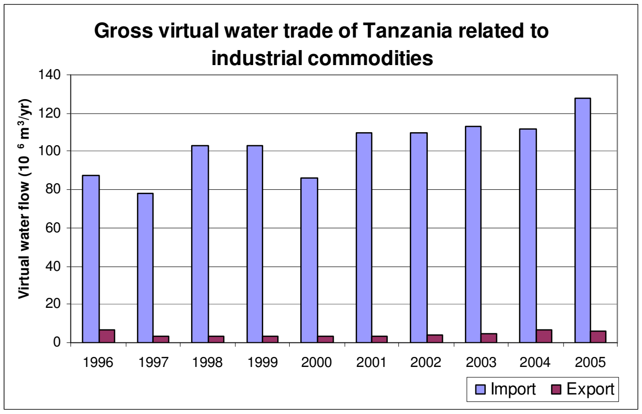

Gross virtual water trade of Mozambique related to industrial commodities
Virtual water flow (10 6 m3/yr)
0 10 20 30 40 50 60 70
1996 1997 1998 1999 2000 2001 2002 2003 2004 2005
Import Export

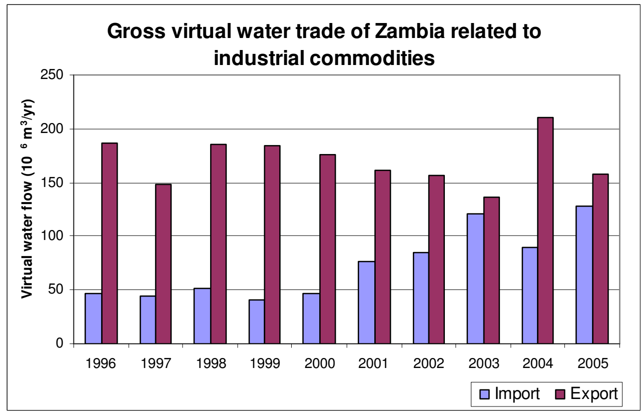

Gross virtual water trade of Namibia related to industrial commodities
Virtual water flow (10 6 m3/yr)
0 5 10 15 20 25 30 35 40 45
1996 1997 1998 1999 2000 2001 2002 2003 2004 2005
Import Export

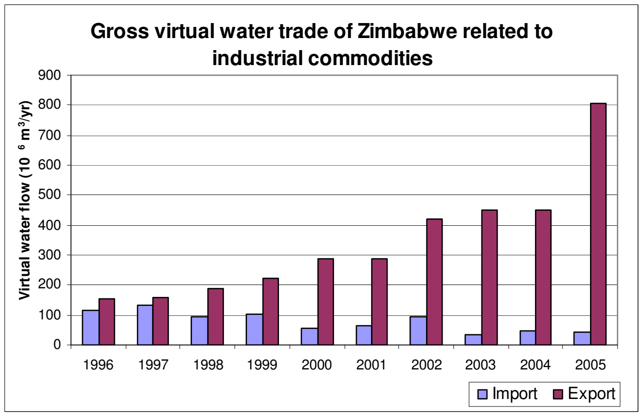

Gross virtual water trade of Seychelles related to industrial commodities
Virtual water flow (10 6 m3/yr)
0 5 10 15 20 25 30 35
1996 1997 1998 1999 2000 2001 2002 2003 2004 2005
Import Export


Gross virtual water trade of South Africa related to industrial commodities
Virtual water flow (10 6 m3/yr)
0 500 1000 1500 2000 2500 3000
1996 1997 1998 1999 2000 2001 2002 2003 2004 2005
Import Export


Gross virtual water trade of Swaziland related to industrial commodities
Virtual water flow (10 6 m3/yr)
0 5 10 15 20 25 30 35
1996 1997 1998 1999 2000 2001 2002 2003 2004 2005
Import Export


Gross virtual water trade of Tanzania related to industrial commodities
Virtual water flow (10 ⁶ m³/yr)
0
20
40
60
80
100
120
140
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
Import
Export


Gross virtual water trade of Zambia related to industrial commodities
Virtual water flow (10 ⁶ m³/yr)
0
50
100
150
200
250
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
Import
Export


Gross virtual water trade of Zimbabwe related to industrial commodities
Virtual water flow (10 ⁶ m³/yr)
0
100
200
300
400
500
600
700
800
900
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
Import
Export

A7 Water use and water availability in the SADC

Green water

Average green water footprint of each SADC country (1996-2005)

Country	Green WUº agriculture* (in model) ($10^6 m^3/yr$)	% of total agricultural* green WUº in country	Total green WUº agriculture* (in model) ($10^6 m^3/yr$)	Total available green water (evapotranspiration) (GWSP, 2008) ($10^{16} m^3/yr$)
Angola	8375	94.92	8823	84
Botswana	418	87.50	477	22
DRC	27911	94.44	29554	189
Lesotho	441	90.25	489	2
Madagascar	17003	90.00	18892	45
Malawi	9205	83.70	10998	5
Mauritius	N/A	0.00	N/A	N/A
Mozambique	15896	81.15	19588	54
Namibia	502	83.36	602	21
Seychelles	N/A	0.00	N/A	N/A
South Africa	24704	78.80	31351	54
Swaziland	664	94.07	706	1
Tanzania	30395	89.12	34106	60
Zambia	4001	90.79	4407	42
Zimbabwe	9507	92.83	10241	22
SADC total	149022	85.91	173469	603

WU: Water Use
ºGreen WU is equal to green WF
*Only agriculture is using green water in the SADC region

Blue water

Average blue and grey water footprint of industry, households and agriculture per SADC country (1996-2005)

Country	Industrial blue WF** (in model) ($10^6 m^3/yr$)	Industrial grey WF** (in model) ($10^6 m^3/yr$)	Industrial blue & grey WF (in model) ($10^6 m^3/yr$)	Industrial blue WU (FAO#, 2009) ($10^6 m^3/yr$)	Domestic blue WF^ (in model) ($10^6 m^3/yr$)	Domestic grey WF^ (in model) ($10^6 m^3/yr$)	Domestic blue & grey WF (in model) ($10^6 m^3/yr$)	Domestic blue WU (FAO#, 2009) ($10^6 m^3/yr$)	Agricultural blue WF (modelled) ($10^6 m^3/yr$)	Agricultural grey WF (modelled) ($10^6 m^3/yr$)	Total agriculture blue & grey WF (modelled) ($10^6 m^3/yr$)	% of total agricultural WF in country (based on Chapagain & Hoekstra, 2004)	Agricultural blue WU (FAO#, 2009) ($10^6 m^3/yr$)
Angola	11.20	54.71	65.91	60	9.42	69.10	78.52	80	287	39.98	326.68	94.92	210
Botswana	5.85	28.54	34.39	35	9.51	69.76	79.27	79	0.33	14.38	14.71	87.50	80
DRC	10.58	51.66	62.24	60	22.76	166.93	189.70	190	266	12.52	278.35	94.44	110
Lesotho	3.43	16.76	20.19	20	2.42	17.74	20.16	20	10	29.26	39.53	90.25	10
Madagascar*	0.00	0.00	0.00	230	50.13	367.58	417.71	420	929	49.36	978.11	90.00	14300
Malawi	8.54	41.72	50.26	50	18.10	132.76	150.86	150	270	422.51	692.88	83.70	810
Mauritius"	N/A	N/A	N/A	20	N/A	N/A	N/A	214	N/A	N/A	N/A	N/A	491
Mozambique	1.77	8.62	10.39	10	8.56	62.81	71.37	70	705	133.35	838.39	81.15	550
Namibia	2.39	11.67	14.06	14	8.76	64.27	73.03	73	89	14.78	104.13	83.36	213
Seychelles"	N/A	N/A	N/A	3	N/A	N/A	N/A	8	N/A	N/A	N/A	N/A	1
South Africa	128.53	627.54	756.07	756	467.31	3426.95	3894.26	3900	4123	3425.42	7548.49	78.80	7840
Swaziland	2.08	10.17	12.25	12	2.85	20.94	23.79	24	246	17.02	262.55	94.07	1010
Tanzania	4.27	20.86	25.13	25	62.47	458.14	520.61	527	4860	397.98	5257.66	89.12	4630
Zambia	21.72	106.05	127.77	130	70.53	517.22	587.75	290	323	163.85	486.82	90.79	1320
Zimbabwe	50.52	246.64	297.16	298	70.53	517.22	587.75	589	1544	595.32	2139.71	92.83	3320
SADC total	250.89	1224.93	1475.82	1723	803.37	5891.40	6695	6634	13652	5315.73	18968.00	85.91	34895

WU: Water Use
*For Madagascar GIS-data on industrial WU is missing, so it is not taken into account in WU maps
Water withdrawal values obtained from FAO (2009 a) for the year 2000
**According to Shiklomanov (1997) industry consumes about 17% of total water withdrawn in Africa; hence 83% is grey WF
^According to Shiklomanov (1997) households consume about 12% of total water withdrawn in Africa; hence 88% is grey WF
"Spatial explicit data for Mauritius and Seyclelles are missing

Average blue and grey WF and TRWR available per SADC country (1996-2005)

Country	Total blue WF (in model) (10^6 m^3/yr)	Total grey WF (in model) (10^6 m^3/yr)	Total blue & grey WF (in model) (10^6 m^3/yr)	Total blue WU (FAO#, 2009) ($10^6 m^3$/yr)	TRWR available (blue water) (FAO, 2009 a) (10^6 m^3/yr)
Angola	307	164	471	350	148000
Botswana	16	113	128	194	12200
DRC	299	231	530	360	1283000
Lesotho	16	64	80	50	3020
Madagascar*	979	417	1396	14950	337000
Malawi	297	597	894	1010	17300
Mauritius"	N/A	N/A	N/A	725	2360
Mozambique	715	205	920	630	217000
Namibia	101	91	191	300	650
Seychelles"	N/A	N/A	N/A	12	N/A
South Africa	4719	7480	12199	12496	50000
Swaziland	250	48	299	1046	4510
Tanzania	4926	877	5803	5182	96300
Zambia	415	787	1202	1740	105000
Zimbabwe	1665	1359	3025	4207	20000
SADC total	14707	12432	27139	43252	2296340

WU: Water Use or water withdrawal existing of the blue and grey water footprint

TRWR: Total Renewable Water Resources (blue water) obtained from FAO (2009 a)

*For Madagascar spatially explicit data on industrial water withdrawals are missing

Water withdrawal values obtained from FAO (2009 a) for the year 2000

**According to Shiklomanov (1997) industry consumes about 17% of the total industrial blue water withdrawals in Africa; hence 83% is grey WF

^According to Shiklomanov (1997) households consume about 12% of the total blue domestic water withdrawals in Africa; hence 88% is grey WF

"Spatial explicit data for Mauritius and Seyclelles are missing

Shares of industrial, domestic and agricultural blue water withdrawal on total blue water withdrawal (for the period 1996-2005)

Country	Industrial share of total blue WF (in model) (%)	Industrial share of total grey WF (in model) (%)	Industrial share of total blue & grey WF (in model) (%)	Industrial share in blue total WU (FAO, 2009) (%)	Domestic share of total blue WF (%)	Domestic share of total grey WF (%)	Domestic share of total blue & grey WF (%)	Domestic share in total blue WU (FAO, 2009) (%)	Agricultural share in total blue WF (in model) (%)	Agricultural share in total grey WF (in model) (%)	Agricultural share in total blue & grey WF (in model) (%)	Agricultural share in total blue WU (FAO, 2009) (%)
Angola	4	33	14	17	3	42	17	22	93	24	69	60
Botswana	37	25	27	18	61	62	62	41	2	13	11	41
DRC	4	22	12	16	8	72	36	52	89	5	52	30
Lesotho	21	26	25	40	15	28	25	40	64	46	49	20
Madagascar	0	0	0	1	5	88	30	2	95	12	70	95
Malawi	3	7	6	4	6	22	17	14	91	71	78	80
Mauritius"	N/A	N/A	N/A	3	N/A	N/A	N/A	30	N/A	N/A	N/A	68
Mozambique	0	4	1	1	1	31	8	11	99	65	91	87
Namibia	2	13	7	5	9	71	38	24	89	16	54	71
Seychelles"	N/A	N/A	N/A	24	N/A	N/A	N/A	65	N/A	N/A	N/A	11
South Africa	3	8	6	6	10	46	32	31	87	46	62	63
Swaziland	1	21	4	1	1	44	8	2	98	35	88	97
Tanzania	0	2	0	0	1	52	9	10	99	45	91	89
Zambia	5	13	11	7	17	66	49	16	78	21	40	75
Zimbabwe	3	18	10	7	4	38	19	14	93	44	71	79
SADC total	2	10	5	4	5	47	25	15	93	43	70	81

WF: Water footprint

WU: Water Use

"Spatial explicit data for Mauritius and Seyclelles are missing

Water withdrawal values obtained from FAO (2009 a) for the year 2000

A8 Water footprint related to consumption

Water footprint related to consumption of agricultural products

Country	Total B_v (10^6 m^3/yr)	WF[#] (10^6 m^3/yr)	WFe[#] (10^6 m^3/yr)	WFi[#] (10^6 m^3/yr)	Ve,r (10^6 m^3/yr)	Ve,d (10^6 m^3/yr)	WF[#] per capita (m^3/yr)
Angola	10955	10533	1774	8759	71	351	843
Botswana	819	458	191	267	151	211	254
DRC	30327	29799	498	29301	9	519	448
Lesotho	677	579	152	427	26	72	276
Madagascar	20690	18649	783	17866	86	1955	931
Malawi	12158	11900	871	11029	19	239	856
Mauritius*	1381	608	597	11	758	14	468
Mozambique	21937	21343	1599	19743	45	550	1002
Namibia	1128	866	335	531	102	161	412
Seychelles*	93	84	83	1	9	0	1019
South Africa	43974	37750	7297	30453	1203	5021	774
Swaziland	2410	1901	1150	750	308	201	1728
Tanzania	40732	39207	1700	37508	66	1458	975
Zambia	5230	4862	465	4397	35	332	416
Zimbabwe	12678	11324	797	10527	95	1259	993
SADC total	208397	193070	19711	173359	1565	13762	758

*Only blue water included. Total available blue water resources based on FAO AQUASTAT (2009)

[#]The water footprint contains in this computation only the green and blue WF, because this water is actually consumed

Water footprint related to consumption of industrial products

Country	Total B_v (10^6 m^3/yr)	WF[#] (10^6 m^3/yr)	WFe[#] (10^6 m^3/yr)	WFi[#] (10^6 m^3/yr)	Ve,r (10^6 m^3/yr)	Ve,d (10^6 m^3/yr)	WF[#] per capita (m^3/yr)
Angola	213	150	104	46	44	20	12
Botswana	73	51	27	24	12	10	28
DRC	103	44	17	27	23	35	1
Lesotho	51	32	19	13	12	8	15
Madagascar	331	173	53	121	48	109	9
Malawi	92	81	37	44	5	6	6
Mauritius*	217	197	179	18	18	2	14
Mozambique	51	43	35	9	6	1	2
Namibia	46	38	26	11	6	3	18
Seychelles*	18	16	13	3	2	0.5	193
South Africa	2706	2121	1528	593	421	163	43
Swaziland	33	25	16	9	5	3	23
Tanzania	128	123	99	24	4	1	3
Zambia	201	30	11	19	62	108	3
Zimbabwe	375	33	7	26	71	271	3
SADC total	4384	2906	1928	978	981	498	11

*Only blue water included. Total available blue water resources based on FAO AQUASTAT (2009)

[#]The water footprint contains in this computation only the green and blue WF, because this water is actually consumed

Water footprint related to consumption of domestic water

Country	Total B_v (10^6 m^3/yr)	WF[#] (10^6 m^3/yr)	WFe[#] (10^6 m^3/yr)	WFi[#] (10^6 m^3/yr)	Ve,r (10^6 m^3/yr)	Ve,d (10^6 m^3/yr)	WF[#] per capita (m^3/yr)
Angola	9	9	0	9	0	0	0.73
Botswana	9	9	0	9	0	0	5.10
DRC	22	22	0	22	0	0	0.33
Lesotho	2	2	0	2	0	0	1.11
Madagascar	48	48	0	48	0	0	2.37
Malawi	17	17	0	17	0	0	1.26
Mauritius*	25	25	0	25	0	0	19.05
Mozambique	8	8	0	8	0	0	0.39
Namibia	8	8	0	8	0	0	4.03
Seychelles*	1	1	0	1	0	0	11.29
South Africa	451	451	0	451	0	0	9.24
Swaziland	3	3	0	3	0	0	2.50
Tanzania	60	60	0	60	0	0	1.50
Zambia	68	68	0	68	0	0	5.81
Zimbabwe	68	68	0	68	0	0	5.97
SADC total	775	775	0	775	0	0	3.04

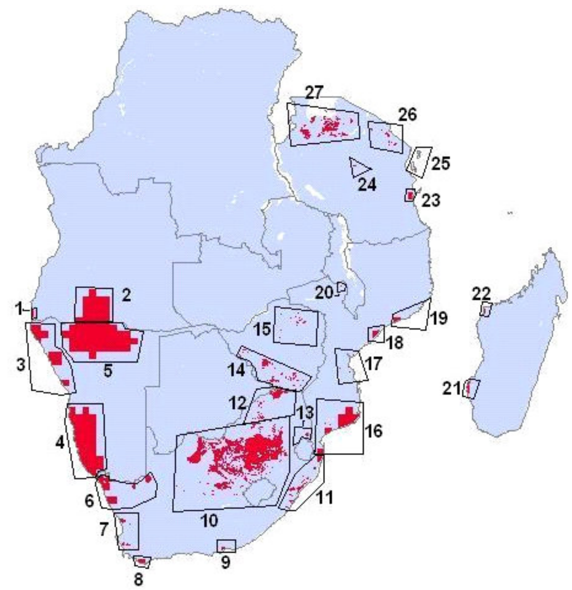
*Only blue water included. Total available blue water resources based on FAO AQUASTAT (2009)

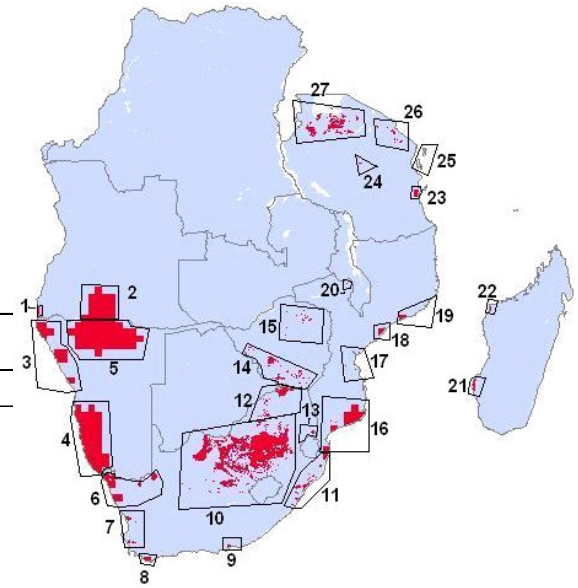
[#]The water footprint contains in this computation only the green and blue WF, because this water is actually consumed

A9 Water consumption in water scarce areas

Blue water consumption in areas where more or almost more blue & grey water is consumed than naturally available
(< 5 mm water of blue water resources left in area after subtracting blue & grey water consumption from blue water availability)

Area No.	Country & area name	Blue WF (km^3/yr)	Share in total blue WF per area (%) Agriculture (by crops)	Households	Industry	Share in total blue WF per area of major water consuming crops (%)		
	Angola							
1	South-west Angola (Coast: Parque Nacional do Iona)	4	0.00	100.00	0.00			
2	South Angola (Cunene Province)	1369	81.49	17.75	0.75	Banana 81.49		
	Namibia							
3	North-west coast Namibia (Kunene Region)	402	39.88	47.93	12.19	Maize 39.88		
4	South-west coast Namibia (Area round Uubvlei - Elizabeth Bay - Walvisbaai)	1789	6.04	82.10	11.86	Maize 4.23	Wheat 1.81	
5	Central-north Namibia (Ohangwena, Omusati, Oshana & Oshikoto Regions)	45858	96.19	2.55	1.26	Maize 55.31	Cotton 40.45	Wheat 0.43
	Madagascar							
21	South-west coast Madagascar	1935	72.93	27.07	0.00	Rice 55.64	Sugarcane 17.29	
22	North-west coast Madagascar (Area between Ampanihira & Sarobakony)	146	0.00	100.00	0.00			
	Mozambique							
16	South Mozambique (Area around Maputo - Xai Xai - Inhamme)	31321	94.46	3.85	1.68	Sugarcane 79.03	Rice 8.02	Maize 7.41
17	Central Mozambique (near Beira)	5093	84.43	11.16	4.41	Sugarcane 84.43		
18	Mid-East coast Mozambique (near Quelimane)	149	0.00	73.22	26.78			
19	North-mid-east coast Mozambique (Area between Bauala & Lumbo)	245	59.37	34.94	5.69	Rice 43.34	Maize 16.03	
20	North Mozambique (Area between the border with Malawi and Vila Coutinho)	6650	97.30	2.20	0.49	Orange 92.25	Sugarcane 5.05	

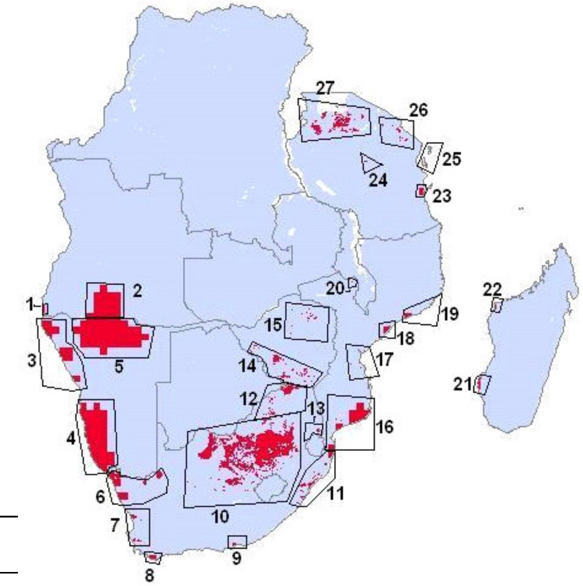




Blue water consumption in areas where more or almost more blue & grey water is consumed than naturally available

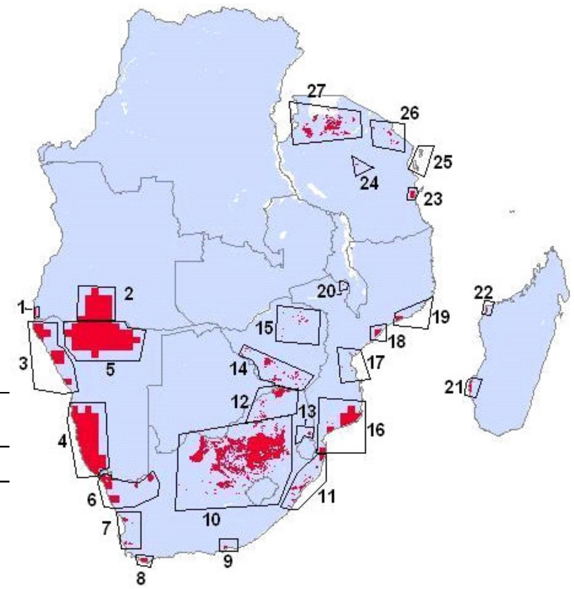
(< 5 mm water of blue water resources left in area after subtracting blue & grey water consumption from blue water availability)

			Share in total blue WF per area (%)			Share in total blue WF per area of major water consuming crops (%)														
Area No.	Country & area name	Blue WF (km^3/yr)	Agriculture (by crops)	Households	Industry															
	South Africa																			
						Maize	Cotton	Potato	Wheat											
6	North-west South Africa (Namakwa & Siyanda Districts)	14400	3.32	95.65	1.03	1.16	0.94	0.78	0.44											
						Wheat	Soybean	Groundnut	Cotton	Potato	Sweet potato	Orange								
7	West Coast District, South Africa	37843	10.83	63.98	25.19	8.53	0.70	0.45	0.39	0.31	0.27	0.17								
						Maize	Wheat	Sweet potato	Soybean											
8	Overberg District, South Africa	1204	14.22	78.55	7.22	9.33	2.70	1.29	0.91											
						Orange	Potato	Maize	Soybean	Sunflower										
9	Port Elizabeth, South Africa (Nelson Mandela Bay Metropolitan Municipality)	10364	3.24	69.20	27.56	2.47	0.28	0.23	0.13	0.12										
						Maize	Wheat	Potato	Millet	Banana	Groundnut	Cotton	Bean	Soybean	Sunflower	Orange	Sorghum	Sweet potato		
10	Free State, North West & Gauteng Provinces, South Africa (Area between Kagisano Rural & Johannesburg)	2043717	80.29	14.62	5.09	47.74	10.89	3.34	0.19	2.94	2.85	2.80	2.71	1.97	1.73	1.71	1.22	0.22		
						Sugarcane	Banana	Potato	Cotton	Orange	Bean	Rice	Soybean							
11	South-east South Africa (Area between Amatole & Umkhanyakude Districts)	1187760	97.67	1.71	0.62	97.34	0.13	0.07	0.06	0.03	0.02	0.01	0.01							
						Orange	Cotton	Banana	Potato	Soybean	Maize	Sugarcane	Sorghum	Sunflower	Wheat	Groundnut	Coffee	Millet	Sweet potato	Bean
12	North South Africa (Vhembe, Capricorn, Waterberg Districts)	131052	80.24	19.14	0.61	24.98	23.25	7.91	6.66	4.20	3.18	2.53	1.86	1.52	1.45	1.31	0.68	0.31	0.31	0.09
						Sugarcane	Banana	Rice	Cotton	Orange	Soybean	Bean	Potato	Maize						
13	East South Africa (Ehlanzeni District)	67457	98.34	1.14	0.52	95.29	0.92	0.49	0.44	0.24	0.24	0.36	0.23	0.13						
	Tanzania																			
						Banana														
23	Area near Mohoro, Rufiji District, Pwani Region, Tanzania	827	9.81	90.19	0.00	9.81														
						Rice	Maize	Banana	Cotton											
24	Dodoma, Dodoma Region, Tanzania	4488	71.51	25.13	3.36	38.86	12.53	12.49	7.63											
25	Pemba & Zanzibar, Tanzania	176	0.00	74.97	25.03															
						Maize	Rice	Cotton	Banana											
26	Arusha & Kilimanjaro Regions, Tanzania	152844	97.41	2.39	0.20	74.42	9.60	9.13	4.27											
						Rice	Maize	Banana	Cotton											
27	Mara, Mwanza, Shinyanga & Arusha Regions, Tanzania	958209	99.20	0.77	0.03	85.60	6.56	4.75	2.30											
	Zimbabwe																			
						Sugarcane	Soybean	Coffee	Orange	Wheat	Groundnut	Sorghum	Sunflower	Maize	Cotton	Potato				
14	South Zimbabwe (Masvingo Province, Matabeleland North & South Province)	123735	78.45	12.55	9.00	31.64	13.43	9.92	7.42	5.66	4.41	2.26	1.78	0.91	0.84	0.19				
						Cotton	Groundnut	Sugarcane	Maize	Sorghum	Soybean	Wheat	Orange	Coffee	Potato	Sunflower				
15	North Zimbabwe (Mashonaland West & Central Provinces)	225966	76.73	11.54	11.73	64.79	4.91	1.92	1.41	1.12	1.04	0.52	0.48	0.26	0.19	0.09				



Grey water consumption in areas where more blue & grey water is consumed than naturally available
(< 5 mm water of blue water resources left in area after subtracting blue & grey water consumption from blue water availability)

Area No.	Country & area name	Grey WF (km^3/yr)	Share in total blue WF per area (%): Agriculture (by crops)	Households	Industry	Share in total blue WF per area of major water consuming crops (%)													
	Angola																		
1	South-west Angola (Coast: Parque Nacional do Iona)	31	0.00	100.00	0.00														
2	South Angola (Cunene Province)	2339	10.81	76.22	2.15	Maize 4.79	Millet 1.92	Bean 1.84	Coffee 0.93	Groundnuts 0.72	Cassava 0.38	Banana 0.16	Oilpalm 0.05	Sweet potato 0.03					
	Namibia																		
3	North-west coast Namibia (Kunene Region)	1714	1.74	82.54	13.98	Maize 1.74													
4	South-west coast Namibia (Area round Uubvlei - Elizabeth Bay - Walvisbaai)	11833	0.10	91.05	8.76	Maize 0.09	Wheat 0.01												
5	Central-north Namibia (Ohangwena, Omusati, Oshana & Oshikoto Regions)	30463	31.31	28.12	9.26	Millet 20.33	Maize 7.33	Cotton 1.68	Sorghum 1.95	Wheat 0.01									
	Madagascar																		
21	South-west coast Madagascar	3874	0.42	99.15	0.00	Sugarcane 0.35	Rice 0.07												
22	North-west coast Madagascar (Area between Ampanihira & Sarobakony)	1074	0.25	99.49	0.00	Rice 0.25													
	Mozambique																		
16	South Mozambique (Area around Maputo - Xai Xai - Inhamme)	24474	26.65	36.18	10.53	Maize 11.50	Sugarcane 6.61	Groundnuts 4.21	Sorghum 1.50	Cassava 0.61	Rice 0.53	Banana 0.45	Coconut 0.32	Potato 0.31	Sunflower 0.22	Millet 0.20	Cashew 0.18	Cotton 0.01	
17	Central Mozambique (near Beira)	5999	6.11	69.49	18.29	Maize 2.86	Sugarcane 1.45	Rice 0.70	Sorghum 0.57	Groundnuts 0.21	Cotton 0.09	Coconut 0.07	Cashew 0.05	Millet 0.04	Cassava 0.03	Sunflower 0.03			
18	Mid-East coast Mozambique (near Quelimane)	1016	0.99	78.82	19.20	Maize 0.83	Cassava 0.06	Groundnuts 0.05	Rice 0.05										
19	North-mid-east coast Mozambique (Area between Bauala & Lumbo)	904	11.49	69.50	7.53	Maize 5.87	Rice 2.85	Cassava 1.28	Groundnuts 0.79	Sorghum 0.20	Cotton 0.17	Millet 0.12	Coconut 0.11	Cashew 0.10					
20	North Mozambique (Area between the border with Malawi and Vila Coutinho)	2265	22.73	47.46	7.08	Maize 12.02	Orange 8.34	Groundnuts 0.79	Banana 0.31	Coconut 0.26	Sugarcane 0.21	Sorghum 0.21	Cashew 0.17	Millet 0.17	Potato 0.10	Sunflower 0.08	Cotton 0.05	Cassava 0.02	Sweet potato 0.01



Grey water consumption in areas where more blue & grey water is consumed than naturally available

(< 5 mm water of blue water resources left in area after subtracting blue & grey water consumption from blue water availability)

Area No.	Country & area name	Grey WF (km^3/yr)	Share in total blue WF per area (%) Agriculture (by crops)	Households	Industry	Share in total blue WF per area of major water consuming crops (%)																	
	South Africa																						
						Groundnuts	Wheat	Maize	Potato	Cotton	Sunflower												
6	North-west South Africa (Namakwa & Siyanda Districts)	102913	0.58	98.14	0.71	0.25	0.19	0.06	0.06	0.01	0.01												
						Wheat	Sunflower	Sweet potato	Millet	Groundnuts	Potato	Soybean											
7	West Coast District, South Africa	240106	3.34	73.95	19.38	2.79	0.16	0.15	0.13	0.06	0.03	0.01											
						Wheat	Sunflower	Millet	Maize	Sweet potato	Soybean												
8	Overberg District, South Africa	10102	13.56	68.68	4.20	8.84	1.81	1.19	0.90	0.72	0.08												
						Wheat	Sunflower	Sweet potato	Millet	Groundnuts	Potato	Soybean											
9	Port Elizabeth, South Africa (Nelson Mandela Bay Metropolitan Municipality)	66865	3.34	73.95	19.38	2.79	0.16	0.15	0.13	0.06	0.03	0.01											
						Maize	Sorghum	Groundnuts	Wheat	Bean	Potato	Millet	Sunflower	Sweet potato	Banana	Orange	Cotton	Soybean					
10	Free State, North West & Gauteng Provinces, South Africa (Area between Kagisano Rural & Johannesburg)	6534006	29.35	33.54	7.77	19.77	3.43	1.56	1.36	1.28	0.54	0.37	0.34	0.29	0.24	0.10	0.04	0.02					
						Sugarcane	Maize	Millet	Potato	Sunflower	Banana	Bean	Sweet potato	Orange	Rice	Cotton	Soybean						
11	South-east South Africa (Area between Amatole & Umkhanyakude Districts)	656333	35.93	22.70	5.44	34.92	0.28	0.14	0.14	0.14	0.11	0.08	0.05	0.04	0.02	0.01	0.01						
						Sorghum	Maize	Orange	Potato	Groundnuts	Millet	Banana	Cotton	Bean	Soybean	Sugarcane	Sunflower	Sweet potato	Wheat				
12	North South Africa (Vhembe, Capricorn, Waterberg Districts)	261903	14.13	70.25	1.50	2.47	2.69	1.54	1.41	1.29	1.00	0.83	0.47	0.19	0.11	0.03	0.77	1.08	0.24				
						Sugarcane	Bean	Maize	Rice	Banana	Potato	Orange	Sunflower	Cotton	Soybean								
13	East South Africa (Ehlanzeni District)	30703	38.03	18.36	5.57	32.34	1.94	1.25	0.82	0.71	0.39	0.26	0.22	0.08	0.01								
	Tanzania																						
						Cotton	Maize	Coconut	Cassava	Groundnuts	Coffee	Sweet potato	Banana	Cashew	Oilpalm	Sorghum	Soybean	Sunflower					
23	Area near Mohoro, Rufiji District, Pwani Region, Tanzania	5552	0.76	98.48	0.00	0.26	0.18	0.11	0.07	0.04	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01					
						Maize	Sorghum	Millet	Cotton	Cassava	Rice	Coconut	Groundnuts	Cashew	Sunflower	Banana	Coffee	Potato	Sweet potato				
24	Dodoma, Dodoma Region, Tanzania	9863	4.35	83.84	7.46	2.55	0.53	0.39	0.23	0.22	0.17	0.10	0.04	0.03	0.03	0.02	0.02	0.02	0.02				
						Oilpalm	Soybean																
25	Pemba & Zanzibar, Tanzania	1184	0.05	81.73	18.17	0.03	0.02																
						Maize	Cotton	Rice	Coconut	Cassava	Wheat	Bean	Groundnuts	Sunflower	Cashew	Banana	Millet	Coffee	Sorghum	Sweet potato	Potato	Clove	Sugarcane
26	Arusha & Kilimanjaro Regions, Tanzania	36696	11.48	72.90	4.15	8.44	0.82	0.56	0.34	0.20	0.19	0.14	0.13	0.10	0.09	0.07	0.07	0.07	0.07	0.06	0.05	0.04	0.03
						Maize	Rice	Sorghum	Cassava	Cotton	Coconut	Millet	Groundnuts	Sunflower	Bean	Cashew	Banana	Coffee	Sweet potato	Potato	Sugarcane	Clove	
27	Mara, Mwanza, Shinyanga & Arusha Regions, Tanzania	144718	30.79	37.56	0.86	17.50	6.06	1.90	1.82	1.35	0.57	0.41	0.22	0.16	0.15	0.15	0.12	0.11	0.09	0.08	0.06	0.05	
	Zimbabwe																						
						Maize	Soybean	Wheat	Sorghum	Cotton	Millet	Groundnuts	Sugarcane	Bean	Cassava	Banana	Coffee	Orange	Sunflower				
14	South Zimbabwe (Masvingo Province, Matabeleland North & South Province)	227679	13.04	50.02	23.89	9.45	1.38	1.43	0.20	0.13	0.13	0.11	0.10	0.04	0.03	0.02	0.01	0.01	0.01				
						Maize	Cotton	Soybean	Wheat	Groundnuts	Millet	Sugarcane	Sorghum										
15	North Zimbabwe (Mashonaland West & Central Provinces)	352690	4.54	54.24	36.69	2.40	1.87	0.11	0.11	0.02	0.01	0.01	0.01										

A10 National water savings

Country	FAO crop code	Crop name	Net green water saving (10^6 m^3/yr)	Net blue water saving (10^6 m^3/yr)	Net grey water saving (10^6 m^3/yr)	Net total water saving (10^6 m^3/yr)
Angola	15	Wheat	206.4	23.9	4.5	234.8
	27	Rice	415.2	139.4	18.0	572.6
	56	Maize	992.3	1.5	5.9	999.7
	79	Millet	-0.7	0.0	0.0	-0.7
	83	Sorghum	6.7	0.0	0.8	7.6
	116	Potato	13.9	1.3	0.4	15.5
	156	Sugarcane	267.5	157.8	88.9	514.2
	236	Soybean	85.8	11.4	11.3	108.5
	242	Groundnut	4.0	0.0	0.1	4.1
	254	Oil palm	36.5	0.0	0.1	36.6
	267	Sunflower seed	23.9	1.6	0.2	25.7
	328	Cotton seed	22.4	6.1	6.1	34.6
	490	Orange	0.8	0.2	0.0	1.1
	656	Coffee, green	-354.3	-0.9	-1.5	-356.7
Angola total			1720.5	342.5	134.8	2197.7

Country	FAO crop code	Crop name	Net green water saving (10^6 m^3/yr)	Net blue water saving (10^6 m^3/yr)	Net grey water saving (10^6 m^3/yr)	Net total water saving (10^6 m^3/yr)
Botswana	15	Wheat	12.7	2.0	5.0	19.7
	27	Rice	24.4	1.5	0.5	26.4
	56	Maize	90.9	0.1	4.2	95.2
	79	Millet	198.2	0.1	7.9	206.2
	116	Potato	10.5	0.0	0.5	11.0
	122	Sweet potato	0.7	0.1	0.1	0.9
	125	Cassava	3.2	0.0	0.1	3.3
	156	Sugarcane	21.9	5.8	0.6	28.3
	242	Groundnut	0.5	0.1	0.1	0.6
	328	Cotton seed	32.6	5.9	5.3	43.7
	656	Coffee, green	2.6	0.7	0.1	3.4
Botswana total			398.1	16.4	24.3	438.7

Country	FAO crop code	Crop name	Net green water saving (10^6 m^3/yr)	Net blue water saving (10^6 m^3/yr)	Net grey water saving (10^6 m^3/yr)	Net total water saving (10^6 m^3/yr)
Congo, D.R.	15	Wheat	292.9	11.5	1.0	305.4
	27	Rice	119.2	0.1	0.0	119.3
	56	Maize	44.1	0.1	0.1	44.3
	79	Millet	107.3	7.3	0.6	115.2
	242	Groundnut	0.7	0.0	0.0	0.7
	254	Oil palm	12.0	1.1	0.4	13.6
	328	Cotton seed	25.8	1.9	1.9	29.6
	490	Orange	-495.1	-10.7	-0.3	-506.0
	698	Clove	1.1	0.0	0.0	1.2
Congo, D.R. total			108.0	11.3	3.8	123.2

Country	FAO crop code	Crop name	Net green water saving (10^6 m^3/yr)	Net blue water saving (10^6 m^3/yr)	Net grey water saving (10^6 m^3/yr)	Net total water saving (10^6 m^3/yr)
Lesotho	15	Wheat	8.9	0.7	0.1	9.7
	27	Rice	4.3	0.1	0.1	4.5
	56	Maize	19.4	4.7	5.4	29.5
	83	Sorghum	1.8	0.0	0.1	1.9
	486	Banana	-23.4	-5.0	-5.6	-33.9
Lesotho total			10.9	0.5	0.1	11.6

Country	FAO crop code	Crop name	Net green water saving (10^6 m^3/yr)	Net blue water saving (10^6 m^3/yr)	Net grey water saving (10^6 m^3/yr)	Net total water saving (10^6 m^3/yr)
Madagascar	15	Wheat	32.1	2.9	11.0	46.0
	27	Rice	538.3	40.3	0.3	578.8
	56	Maize	0.6	0.2	0.1	0.9
	79	Millet	8.1	0.0	0.3	8.5
	125	Cassava	0.3	0.3	0.1	0.7
	236	Soybean	2.6	1.9	0.4	4.9
	242	Groundnut	-1.3	0.1	0.0	-1.2
	254	Oil palm	4.1	3.5	1.5	9.1
	328	Cotton seed	-40.0	-34.8	-15.0	-89.7
	656	Coffee, green	0.5	0.1	0.1	0.7
Madagascar total			545.4	14.5	-1.2	558.7

Country	FAO crop code	Crop name	Net green water saving (10^6 m^3/yr)	Net blue water saving (10^6 m^3/yr)	Net grey water saving (10^6 m^3/yr)	Net total water saving (10^6 m^3/yr)
Malawi	15	Wheat	218.1	8.9	2.5	229.5
	27	Rice	29.0	0.3	2.8	32.1
	56	Maize	244.2	0.9	10.8	255.9
	83	Sorghum	112.9	0.2	7.6	120.6
	156	Sugarcane	-21.7	-22.5	-1.5	-45.7
	236	Soybean	5.8	2.0	2.4	10.2
	242	Groundnut	-10.8	-1.7	-0.7	-13.3
	249	Coconut	23.7	0.0	0.0	23.7
	254	Oil palm	8.1	0.0	0.0	8.1
	267	Sunflower seed	20.1	0.9	0.1	21.0
	328	Cotton seed	8.7	2.1	2.1	12.9
Malawi total			637.9	-9.0	26.1	655.1

Country	FAO crop code	Crop name	Net green water saving (10^6 m^3/yr)	Net blue water saving (10^6 m^3/yr)	Net grey water saving (10^6 m^3/yr)	Net total water saving (10^6 m^3/yr)
Mauritius	15	Wheat	101.7	13.5	22.0	137.2
	27	Rice	308.0	12.3	-4.5	315.7
	56	Maize	41.0	0.5	10.1	51.6
	83	Sorghum	-0.3	-0.2	-0.2	-0.7
	116	Potato	7.1	0.0	0.0	7.1
	156	Sugarcane	-15.8	-5.5	-0.5	-21.9
	176	Bean	1.6	0.5	0.1	2.3
	254	Oil palm	-0.8	-0.1	0.0	-0.9
	267	Sunflower seed	2.4	0.3	0.3	3.0
	328	Cotton seed	70.7	3.1	-9.0	64.9
	656	Coffee, green	1.4	0.0	0.0	1.4
Mauritius total			517.1	24.5	18.2	559.8

Country	FAO crop code	Crop name	Net green water saving (10^6 m^3/yr)	Net blue water saving (10^6 m^3/yr)	Net grey water saving (10^6 m^3/yr)	Net total water saving (10^6 m^3/yr)
Mozambique	15	Wheat	357.6	21.2	138.8	517.5
	27	Rice	256.2	1.3	3.1	260.7
	56	Maize	144.4	5.4	1.7	151.5
	156	Sugarcane	-12.6	-2.6	-0.1	-15.2
	236	Soybean	34.4	0.3	0.5	35.2
	242	Groundnut	4.5	0.2	0.2	5.0
	249	Coconut	34.5	0.0	0.0	34.5
	254	Oil palm	89.5	0.0	0.0	89.5
	267	Sunflower seed	-6.8	-0.9	-0.1	-7.8
	328	Cotton seed	-25.6	-0.1	6.4	-19.3
	656	Coffee, green	1.8	0.1	0.1	2.0
Mozambique total			877.9	24.9	150.8	1053.7

Country	FAO crop code	Crop name	Net green water saving (10^6 m^3/yr)	Net blue water saving (10^6 m^3/yr)	Net grey water saving (10^6 m^3/yr)	Net total water saving (10^6 m^3/yr)
Namibia	15	Wheat	10.0	13.7	0.7	24.4
	27	Rice	20.7	1.0	0.2	22.0
	56	Maize	53.3	1.5	10.9	65.7
	83	Sorghum	-0.5	-0.4	-0.4	-1.3
	125	Cassava	0.8	0.1	0.1	1.0
	156	Sugarcane	3.4	0.7	0.1	4.2
	328	Cotton seed	173.0	7.2	18.8	199.0
	656	Coffee, green	2.6	0.3	0.0	2.9
Namibia total			263.4	24.1	30.4	317.9

Country	FAO crop code	Crop name	Net green water saving (10^6 m^3/yr)	Net blue water saving (10^6 m^3/yr)	Net grey water saving (10^6 m^3/yr)	Net total water saving (10^6 m^3/yr)
Seychelles	27	Rice	31.7	1.9	0.4	34.0
	79	Millet	0.6	0.0	0.0	0.6
	236	Soybean	1.2	0.3	0.1	1.6
	328	Cotton seed	31.1	2.7	1.2	35.0
Seychelles total			64.6	4.9	1.7	71.1

Country	FAO crop code	Crop name	Net green water saving (10^6 m^3/yr)	Net blue water saving (10^6 m^3/yr)	Net grey water saving (10^6 m^3/yr)	Net total water saving (10^6 m^3/yr)
South Africa	15	Wheat	567.4	51.9	129.9	749.2
	27	Rice	1003.4	1396.7	767.1	3167.3
	56	Maize	-858.2	-3.7	-105.0	-966.8
	79	Millet	-27.5	-33.3	-16.9	-77.7
	116	Potato	0.4	0.6	0.3	1.2
	125	Cassava	-0.1	-0.2	-0.2	-0.5
	156	Sugarcane	-966.3	-99.7	-7.4	-1073.5
	236	Soybean	28.5	35.1	-51.1	12.5
	242	Groundnut	356.0	9.6	7.8	373.4
	249	Coconut	-0.3	-0.4	0.0	-0.8
	254	Oil palm	2.0	-0.3	0.0	1.7
	267	Sunflower seed	58.2	6.5	2.1	66.8
	328	Cotton seed	1878.1	175.5	20.8	2074.4
	656	Coffee, green	-26.3	-2.7	-0.2	-29.3
South Africa total			2015.2	1535.5	747.2	4298.0

Country	FAO crop code	Crop name	Net green water saving (10^6 m^3/yr)	Net blue water saving (10^6 m^3/yr)	Net grey water saving (10^6 m^3/yr)	Net total water saving (10^6 m^3/yr)
Swaziland	15	Wheat	195.9	17.1	20.9	233.9
	27	Rice	5.5	8.6	3.3	17.4
	56	Maize	54.0	0.2	2.4	56.6
	79	Millet	8.1	0.0	1.3	9.5
	156	Sugarcane	-119.8	-85.2	-0.4	-205.3
	236	Soybean	0.9	0.0	0.0	0.9
	254	Oil palm	2.6	0.2	0.0	2.9
	267	Sunflower seed	9.4	0.5	0.1	10.0
	328	Cotton seed	190.4	22.3	20.1	232.8
	486	Banana	-18.8	-0.8	-0.3	-19.8
	656	Coffee, green	-6.5	-4.6	0.0	-11.1
Swaziland total			321.9	-41.8	47.5	327.6

Country	FAO crop code	Crop name	Net green water saving (10^6 m^3/yr)	Net blue water saving (10^6 m^3/yr)	Net grey water saving (10^6 m^3/yr)	Net total water saving (10^6 m^3/yr)
Tanzania	15	Wheat	505.6	31.0	11.4	548.0
	27	Rice	401.8	27.0	22.9	451.6
	56	Maize	150.6	1.8	3.4	155.8
	79	Millet	-0.9	-0.1	-0.1	-1.1
	116	Potato	1.3	0.0	0.0	1.4
	122	Sweet potato	0.5	0.0	0.0	0.5
	156	Sugarcane	0.6	0.4	0.0	1.0
	236	Soybean	-0.9	0.0	0.0	-0.9
	254	Oil palm	71.7	2.4	0.9	75.0
	267	Sunflower seed	-1.8	0.0	0.0	-1.8
	328	Cotton seed	360.1	2.6	5.4	368.1
	656	Coffee, green	-1.6	0.0	0.0	-1.7
Tanzania total			1487.0	65.1	43.9	1595.9

Country	FAO crop code	Crop name	Net green water saving (10^6 m^3/yr)	Net blue water saving (10^6 m^3/yr)	Net grey water saving (10^6 m^3/yr)	Net total water saving (10^6 m^3/yr)
Zambia	15	Wheat	16.2	14.5	1.6	32.2
	27	Rice	19.1	44.9	2.6	66.7
	56	Maize	1.6	0.7	0.1	2.4
	116	Potato	-5.1	-0.4	-0.7	-6.2
	156	Sugarcane	-36.6	-37.8	-0.2	-74.6
	236	Soybean	-16.4	0.5	-1.1	-17.1
	242	Groundnut	-2.9	-0.5	-0.3	-3.7
	249	Coconut	3.0	0.0	0.0	3.0
	254	Oil palm	2.1	0.0	-2.9	-0.8
	267	Sunflower seed	43.2	1.5	1.6	46.3
	328	Cotton seed	-9.2	1.2	0.9	-7.1
	486	Banana	5.2	9.0	0.1	14.3
	490	Orange	1.7	0.4	0.1	2.2
Zambia total			21.8	34.1	1.8	57.8

Country	FAO crop code	Crop name	Net green water saving (10^6 m^3/yr)	Net blue water saving (10^6 m^3/yr)	Net grey water saving (10^6 m^3/yr)	Net total water saving (10^6 m^3/yr)
Zimbabwe	15	Wheat	14.4	20.9	8.1	43.4
	27	Rice	24.1	38.7	0.3	63.0
	56	Maize	2219.9	0.9	140.4	2361.2
	83	Sorghum	20.3	0.1	0.3	20.7
	125	Cassava	1.9	0.0	0.0	1.9
	156	Sugarcane	-38.2	-29.4	-0.1	-67.7
	176	Bean	-49.4	-6.3	-0.2	-55.9
	236	Soybean	17.4	9.9	9.8	37.2
	242	Groundnut	-19.1	-0.3	-0.2	-19.6
	254	Oil palm	18.5	0.0	0.0	18.5
	267	Sunflower seed	27.6	0.3	0.1	28.1
	328	Cotton seed	-197.0	-17.0	-21.2	-235.2
	490	Orange	-1.6	-2.6	-0.1	-4.4
Zimbabwe total			2038.8	15.1	137.2	2191.1