

Quantifying Virtual Water Flows in the 12 Continental Countries of SADC

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Abstract The Climate Resilient Infrastructure Development Facility (CRIDF) has developed a data platform for Virtual Water transfers amongst the 12 continental countries of the Southern African Development Community (SADC) and with the rest of the world, embedded in agricultural products and in electricity supplies. This, together with a Global Social and Development Index database, has formed the basis for many of the analyses in other Chapters of this book. This Chapter provides a summary of the processes and source data used in developing the databases, as well as some examples of the potential use of the data platform. The final section provides a brief summary of the techniques involved in economic accounting of water, and the current position of the continental SADC countries in that regard. Notably, economic accounting of water relates to blue water in isolation, but the technique nevertheless provides useful complementary information to that obtained through considerations of the rest of the water footprint and the economy behind Virtual Water transfers.

1 Introduction

The Climate Resilient Infrastructure Development Facility (CRIDF) is an initiative of the Department for International Development (DfID) of the United Kingdom Government. CRIDF seeks to develop climate resilience in poor communities through the construction of infrastructure in the continental countries of the Southern African Development Community (SADC), thereby promoting the peaceful management of

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shared waters. However, CRIDF has recognised that in the longer term, peaceful cooperation in the increasingly water-stressed SADC region also requires attention to larger strategic infrastructure investment and planning. This wider focus is inherently pro-poor, protecting access to water for community-based small-scale infrastructure, but also supporting shared economic growth by planning water-related investments which recognise the potential for Virtual Water trading as a means of addressing regional water, food and energy security.

Virtual Water represents water that is ‘embedded’ in crops, livestock, and industrial items and services, having been used to produce these. The basic concept of Virtual Water was developed in the early 1990s (Allan 1998), but has only been adopted relatively recently by the international community as a component of the analysis of water security. The transfers of Virtual Water in traded products can play a critical role in determining water security, especially where regions (or trading partners) display a range in water resource stress or water scarcity. The continental SADC countries exhibit a wide range in water resource availability, the southern portions of the African continent being much more water-stressed than the northern SADC states. Changes to international trading patterns could help to alleviate such stress, and can sometimes be mutually beneficial to partner countries—in certain instances, reducing the expenditure and infrastructure required to develop additional blue water resources,¹ and building regional climate resilience. From one perspective, agricultural production and international trade patterns are driven by a wide range of factors, many of which are intractable and not easily changed or influenced. However, large multi-national companies present in most or all of the SADC countries may minimise their climate change risk by considering Virtual Water in their supply chains. In any event, sound and politically aware arguments will be needed to underpin any shifts in attitudes towards regional rather than sovereign water and energy security, and climate resilience.

This chapter outlines the data assembled on Virtual Water transfers in agricultural products and in electrical supplies traded by the continental SADC countries (with each other and in some cases with the rest of the world), and has been created to act as a partial basis for further work with the intention to help the development of sound arguments and an evidence base grounded in improved resource management and shared economic benefits.

¹Blue water is present in surface waters and aquifers, and is the classical focus of studies on the hydrosphere. However, green water (known sometimes as soil moisture) is also of great importance in the agricultural sector in particular, and grey water (volumes required to account for polluting effects) can also be of significance.

2 Data Sources: Quality Assurance/Quality Control

2.1 Data Relating to Agricultural Products

As noted in greater detail in the following section, the Virtual Water components and transfers relating to all internationally traded agricultural products (crops and livestock) for all of the 12 continental countries within SADC are identified.

In most cases, the resources available precluded the collation of primary data from specific agricultural sectors, or the data available from SADC states which are not accessible through the internet. The primary databases employed were therefore mainly of a global nature, and included:

- Chapagain and Hoekstra (2004) for bulk Virtual Water transfers;
- Mekonnen and Hoekstra (2011) for water footprints;
- Statistics from the Water Footprint Network (<http://www.waterfootprint.org>);
- Import and export data from Trade Map (<http://www.trademap.org/>), which rely on statistics from UN Comtrade (<http://comtrade.un.org/>); and
- National and regional data for South Africa from the Department of Agriculture, Forestry and Fisheries (<http://www.daff.gov.za/>), supplemented in particular scenarios by other national/regional data.

The first four sources cited above are those utilised by most or all researchers on Virtual Water internationally, and are widely recognised as offering state-of-the-art information that has been comprehensively quality-assured by the respective authors. There is nevertheless some controversy concerning detailed levels of water footprint data, and it is cautioned that some authorities suggest that such detailed water footprint estimates should be treated with caution. The current authors have noted that such caution is merited, on occasion.

The Trade Map and UN Comtrade data include some inconsistencies which have been noted by the project team. These involve occasional mismatches between the export statistics for a specific product involving a particular country of destination and time period, and the mirror-image import statistics of the country of importation for the same product and time period. In order to complete a comprehensive Quality Assurance check in line with best practice, the following advice from UN Comtrade has been followed:

UN Comtrade disclaimer: "Imports reported by one country do not coincide with exports reported by its trading partner". (Point 5)

In such circumstances, UN Comtrade recommends the use of data for imports when evaluating trade patterns, as such data are independently verified through the customs protocol of a receiving country. The Virtual Water trade database for agricultural products has therefore been constructed in this way to ensure that the most accurate and verifiable data sets have been used (UN Statistics 2014).

The national statistics for South Africa were derived directly from the primary governmental source of such information, and this is also the case for other specific

state-centric data used in the examples quoted in the present report. Trade-related data for various countries have been compared in general terms to information in the FAOSTAT database of the Food and Agricultural Organisation, and this acted as a further quality assurance check.

The data used to compile the agriculturally-related database for the 12 continental SADC states are of a country-specific nature and are hence broad in scope. While the specific treatment of these data adds considerable value and creates a data platform to support the development of regional water and food scenarios, scope remains for more detailed analyses within specific sectors.

At the present stage of the work, data for the trade in electricity amongst the SADC countries have been provided primarily by Eskom and by the staff of the SAPP offices in Harare, Zimbabwe.² Further information of relevance (and to support the primary sources) was accessed from online sources of the US Energy Information Administration, which is an entity under the United States Department of Energy based in Washington D.C. Various published sources were employed to check the general patterns of trade in electricity which are subject to a degree of change over time (Economic Consulting Associates 2009a, b; South African Power Pool 2009; Southern Africa Regional Integration Strategy Paper 2011).

Data reported here on the consumptive use of water in the generation of electricity and on the renewable water resources of specific countries were abstracted primarily from three sources:

- National statistics for South Africa, compiled by Eskom (see footnote [2] below);
- The report of Beilfuss (2012) for hydroelectric facilities; and
- The FAOSTAT database of the Food and Agricultural Organisation³.

Cross-checks on these data were completed using published information for the consumptive use of water by electricity generating facilities elsewhere in the world (Torcellini et al. 2003; World Bank 2010). There is considerable variation in the methodologies used internationally to calculate consumptive water use in the generation of electricity. The current study does not seek to provide highly precise full life-cycle estimates of consumptive water use at each specific facility of relevance in the 12 continental countries of SADC. Such precise estimates are in any event not of utility in the context of this work, which relates to the introduction of Virtual Water and nexus-based thinking into the regional debate on water resource management and development. Hence, the estimates of consumptive water use in the generation of electricity as shown here are of an indicative nature, and it is argued that this is more than sufficient to act as the backdrop for future discussions of preferred approaches to electricity generation in the future in the region.

Data on economic accounting of water were amassed from a number of sources internationally and within SADC.

²Data from Eskom were provided by Dr. Dave Lucas, and those from SAPP were provided by Dr. Lawrence Musaba.

³FAOSTAT database available at <http://www.fao.org/statistics/en/>.

3 Virtual Water Transfers in Agricultural Products

3.1 *The Development and General Structure of the Database*

The data platform that has been established provides information at three distinct tiers of detail which are inter-related, as shown in Fig. 1. These are described below, with examples of their use also being provided.

- The top-tier data are of a generic nature, involving net and gross estimates at country level of all internationally traded crops and livestock (separately in those two categories). External trading parties are identified specifically within the continental SADC group of 12 states, while trade with the rest of the world is cited as a single entity in the main platform. These data characterise international trade patterns in a broad manner, showing whether specific countries are net importers or exporters of Virtual Water. With more detailed interrogation, the data platform can reveal ‘water savings’ either for particular countries or globally, given the existing trade pattern or following pre-supposed changes to the existing pattern. Trade with the rest of the world can also be broken down into imports/exports involving specific individual countries or groups of countries, where this is of interest.
- The middle tier of detail provides data on specific traded items (including all crops and livestock subject to international trade involving SADC countries), as either single products or small groups of products according to the citations in the available trade data (as 4-digit categories of the Harmonised System, these

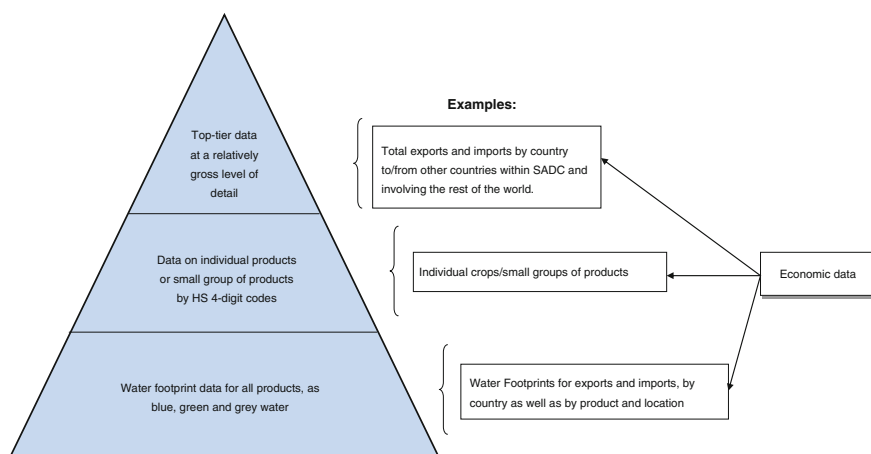


Fig. 1 Diagram of the types of data available for the trade in agricultural products amongst the continental SADC countries

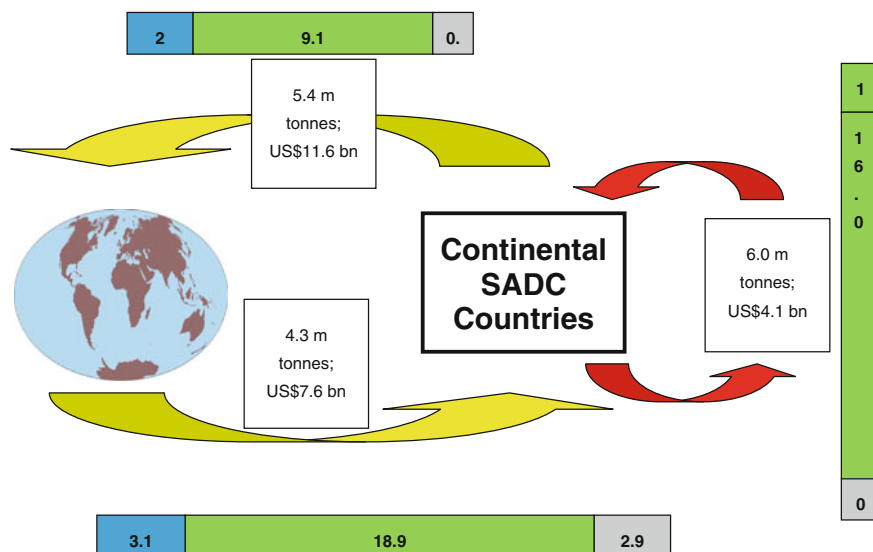


Fig. 2 Imports and exports of agricultural products (in total) in 2012 amongst the continental SADC countries, and between these and the rest of the world (Tonnages and values are shown in text boxes; the accompanying Virtual Water transfers are shown by ‘colour’ in cubic kilometres)

numbering 117 products in total in the present context⁴). Data are available in this tier of detail as country-wide exports and imports, with tonnages and total Virtual Water equivalents being provided. Regional data (within countries) can also sometimes be accessed.

- The lower tier of detail superimposes water footprints onto each product and country pairing, with blue, green and grey water all being identified in full. While this averages the footprint information across single countries, it provides a useful starting point for more detailed analysis, which can again involve regional differences where these are of interest.

The tiers of the data platform inter-relate, in the sense that information derived from one tier can be related to that in any other tier. Figure 2 shows an example of this, and also provides an overview of the trade in agricultural products between the continental SADC countries and the rest of the world. It is notable that the overview shown in Fig. 2 suggests that the trade pattern as a whole is generally coherent in relation to the continental SADC states, at least in terms of the water-stressed countries.

⁴The Harmonised System—also known as the Harmonised Commodity Description and Coding System—was introduced in 1988 and is used by most countries in the world to characterise trade. It is run and maintained by the World Customs Organisation based in Brussels, which has over 170 members.

Thus, the 12 continental SADC countries import agricultural products of lower tonnage and lower value from the rest of the world than they export thereto, but the imported products have about twice the Virtual Water content compared to the exports. The trade in agricultural products amongst the continental SADC countries is of a generally similar order of magnitude to the external trade, but of lower total value—and this is also accompanied by significant Virtual Water transfers. Greater levels of detail within the data platform reveal more nuanced patterns, however, not all of which appear so strategically coherent. Thus, for example, the exports from the continental SADC countries to the rest of the world have a higher percentage of blue water, compared to the imports (see Fig. 3)—and this would appear at first sight to be contrary to the interests of the water-stressed countries within the SADC group of states.

It is also notable that agricultural products imported into SADC from the rest of the world tend to have a proportionally larger grey water content than those derived from and traded internally within SADC. The water footprint of agricultural products in the SADC countries contains only a minor grey water component, although the proportions of the water footprint taken up by blue water and green water vary considerably for some products, from country to country and also from place to place within a single country. Certain examples which follow here have ignored the grey water component of the overall water footprint for commodities traded within SADC, for simplicity.

As shown in Fig. 1, the economic values of agricultural products have also been captured in the creation of the data platform, these being abstracted from the Trade

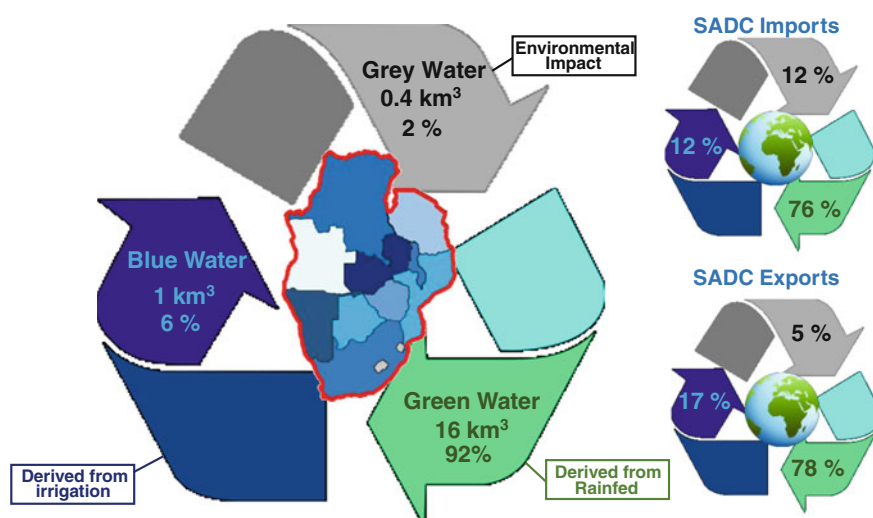


Fig. 3 Virtual Water components of imports and exports of agricultural products (in total) in 2012 amongst the continental SADC countries, and between these and the rest of the world (Virtual Water transfers are shown by 'colour' in cubic kilometres and also in percentage terms in relation to trade with the rest of the world)

Map and UN Comtrade statistics. The economic data can be utilised in a variety of different fashions, e.g. to calculate standard ‘water productivity’ values (US dollars generated per unit of blue water). A reliance on green water or grey water has a significant effect on the standard ‘water productivity’ values, and ‘Virtual Water productivity’ is proposed as a more useful indicator. It is also notable that the Virtual Water productivity of specific crops has been found to vary widely from one location to another within southern Africa, this being ascribed to a combination of the efficiency of irrigation, the yields achieved in crop production, and the prices paid for the exported crops. Such variations are of obvious significance in terms of the potential for poverty reduction in specific circumstances, but the caveats noted previously in terms of the robustness of water footprint data at high levels of detail should be kept in mind during such analyses. These regional differences notwithstanding, the Virtual Water productivity of SADC imports from the rest of the world is approximately US\$ 0.3/m³, while that of SADC exports to the rest of the world is US\$ 1.00/m³ (see Fig. 2).

The complete agricultural dataset is very substantial, the file size in Excel being almost 18 megabytes; the database can be requested from CRIDF. The data are made available for each of the 12 SADC countries addressed by the work as a whole, as well as individually. This assists users of the database to access information relating to their own specific interest. The units employed have been chosen to create sufficient precision, while avoiding the use of decimal points (i.e. a rounding up/down method has been utilised). This rounding up/down technique occasionally results in minor differences between information synthesised from the data platform, and that published by Mekonnen and Hoekstra, but such distinctions are not of any significance.

4 Examples of the Use of the Agricultural Data Platform

Given the very considerable breadth of the data platform and its inherent detail, many examples could be provided of its use relating to traded agricultural commodities. However, in the interests of simplicity and brevity, this Chapter is restricted to only a few of these.

4.1 *Examples of Top-Tier Data*

Table 1 shows data for the net transfers of Virtual Water in the imports and exports of crops, livestock and industrial products amongst the 12 continental SADC countries.

Five of the 12 countries are net exporters of Virtual Water in traded products (Malawi, Mozambique, Tanzania, Zambia and Zimbabwe). However, it is cautioned that these high-level data are derived from Chapagain and Hoekstra (2004)

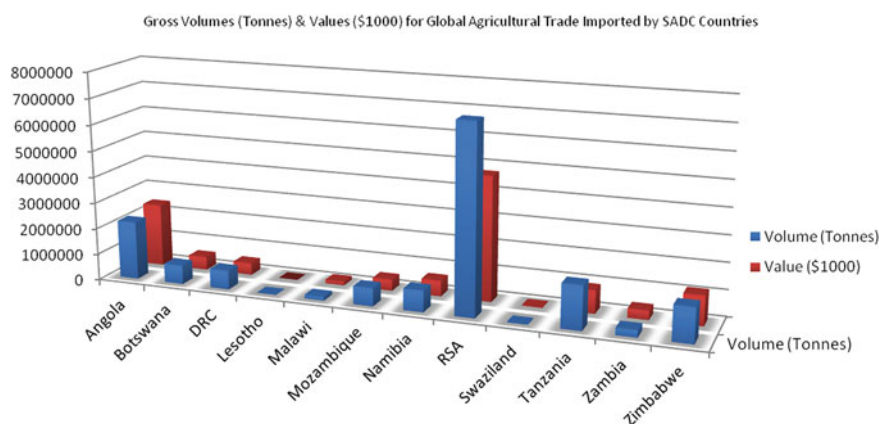
Table 1 Net Virtual Water imports/exports internationally for the 12 continental countries of SADC

Country	Net virtual water imports (MCM/year)			
	Crop products	Livestock products	Industrial products	Total trade
Angola	206	447	140	793
Botswana	376	−62	54	369
DRC	136	107	59	302
Lesotho	ND	ND	ND	ND
Malawi	−646	8	32	−607
Mozambique	−1112	−6	54	−1064
Namibia	45	−96	88	37
South Africa	1426	−293	1011	2145
Swaziland	134	41	41	216
Tanzania	−2203	−41	83	−2161
Zambia	−271	−14	−38	−323
Zimbabwe	−3032	−319	103	−3247

Data from Chapagain and Hoekstra (2004). *ND* No data

and refer to the late 1990s and early 2000s. Trade patterns for agricultural products change somewhat over time, and more recent data reveal subtle differences to the pattern shown in Table 1, these being explained below.

To break the net data down and add a layer of detail (albeit still at the top tier of the pyramid as presented in Fig. 1), Figs. 4 and 5 show country data for imports and exports of agricultural products (crops and livestock together) during the year 2012 by the individual SADC countries, and the respective values of those traded products (as thousands of US dollars).

**Fig. 4** Imports of agricultural products by the continental SADC countries, and their total values

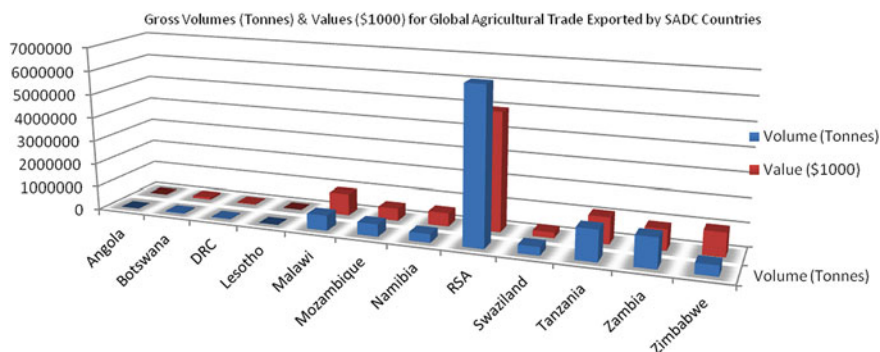


Fig. 5 Exports of agricultural products by the continental SADC countries, and their total values

South Africa dominates the overall profile for traded agricultural products in SADC, with high volumes for both imports and exports. The tonnages of imports outstrip those of exports (as is the case for the Virtual Water transfers shown in Table 1), but the economic values show a reverse trend, with exports being of greater total value than imports. In general terms (and as would be expected), the Virtual Water transfers shown in Table 1 align well with the data on traded tonnages and values in Figs. 4 and 5.

A number of the continental SADC countries are presently significant net importers of agricultural products (and Virtual Water), these including Angola, Botswana, the DRC, Tanzania, and Zimbabwe. Mismatches appear between the gross Virtual Water data shown in Table 1 and the data in Figs. 4 and 5, for both Tanzania and Zimbabwe. These relate to the distinct ages of the datasets, the annually averaged data in Table 1 referring to a five-year period in the late 1990s and the early 2000s, whilst the information in Figs. 4 and 5 pertains to the year 2012.

Notably, Malawi, Swaziland and Zambia are presently net exporters of Virtual Water, and are also substantial net earners of foreign exchange in agricultural products. While South Africa is a net foreign exchange earner in agricultural products, it remains a net importer of Virtual Water. However, when data are contextualised against the size of the economy, Malawi, Swaziland and Zambia stand out as substantial exporters of agricultural products in terms of both Virtual Water transfers and value—perhaps making these countries particularly vulnerable to reduced rainfall and run-off due to climate change.

4.2 Examples of Middle-Tier Data

As noted in Fig. 1, the ‘middle tier’ of the data platform is populated by product-related data the precise products included being listed in Annex 1. Certain

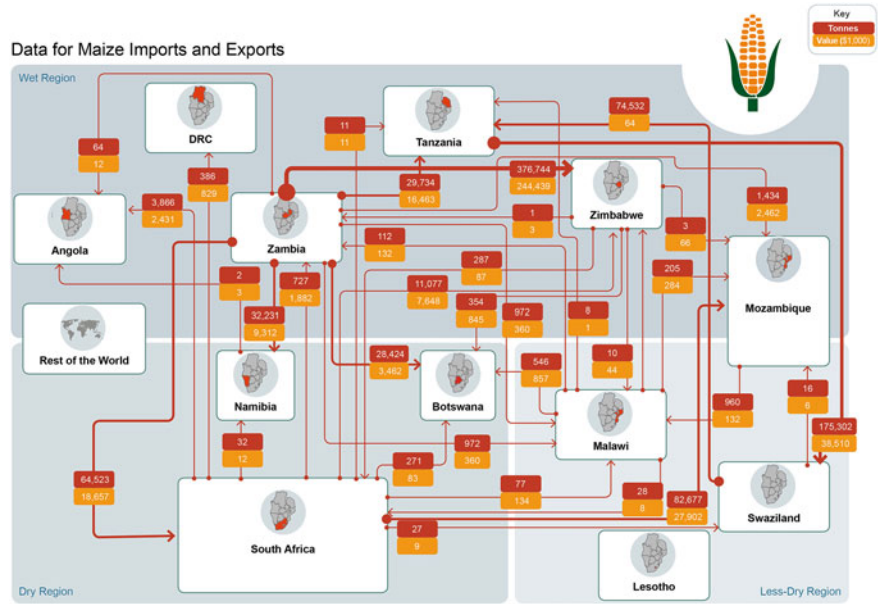


Fig. 6 Import and export of maize within SADC, in terms of tonnages and respective values (Trade data with the rest of the world are not shown)

products stand out amongst the internationally-traded commodities in SADC, and maize is one of these—and is also of course important as a staple foodstuff, being produced in all of the SADC countries to assist in feeding their respective national populations.⁵

Figure 6 Shows the tonnages and values of maize imports and exports amongst the SADC countries only. It is noted that data involving trade with the rest of the world are not shown, and are minor by comparison in any event. The trade pattern within SADC is complex, and maize represents a product of significant interest to the present studies as a result (see also the data on water footprints for traded maize, in the following sub-section).

The detailed trade patterns for ground nuts and sugar provide examples of three very different agricultural products. The tonnages and values of ground nuts and sugar traded within SADC are shown at Figs. 7 and 8, respectively. Information of this type can be provided from the data platform for any of the single products or groups of products.

⁵It is notable in passing here that the data platform created concentrates on internationally traded items, as possible changes to the Virtual Water transfers internationally are the primary issue of interest. However, countries can also free up blue water resources by altering their patterns of crop and livestock production to feed their own national population, and this represents an area which could well be of major interest to the Virtual Water studies in southern Africa in the future.

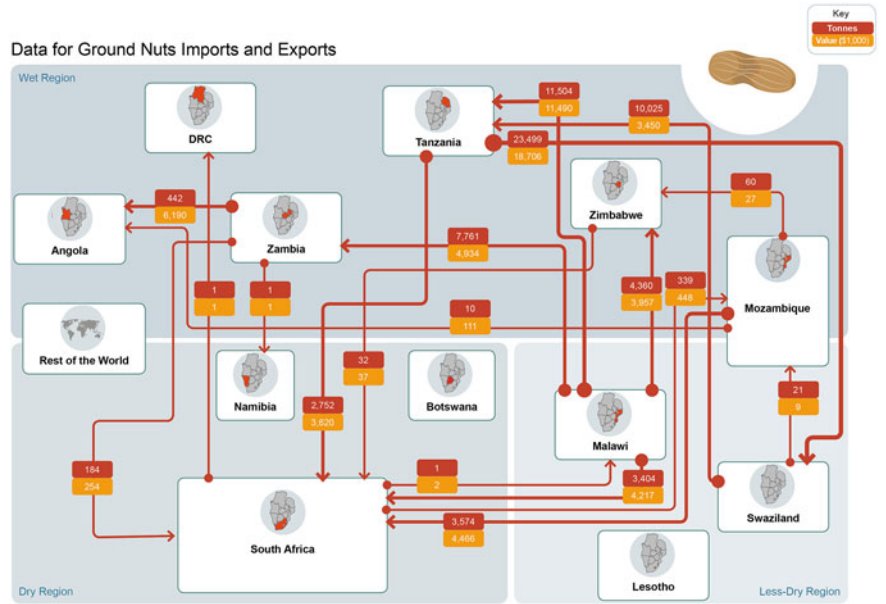


Fig. 7 Import and export of ground nuts within SADC, in terms of tonnages and respective values (Trade data with the rest of the world are not shown)

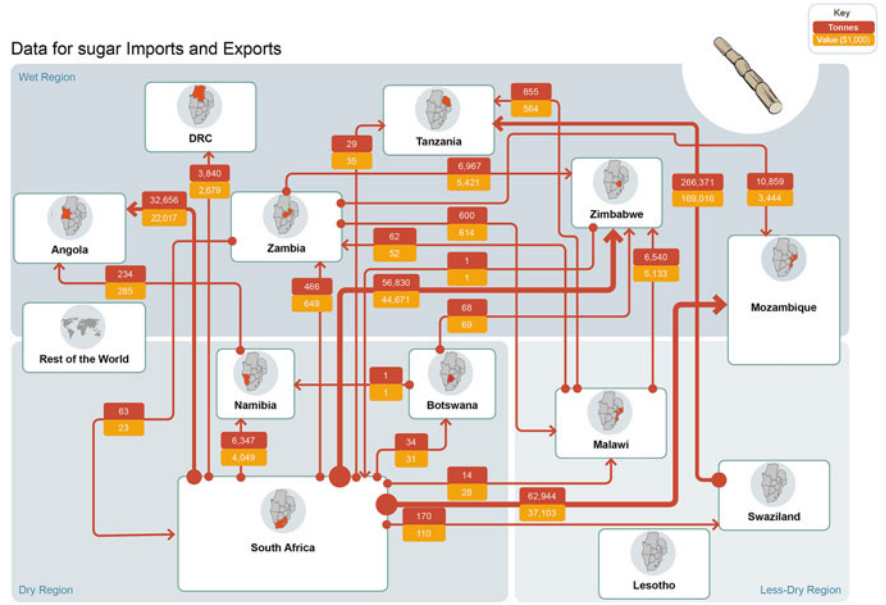


Fig. 8 Import and export of sugar within SADC, in terms of tonnages and respective values (Trade data with the rest of the world are not shown)

4.3 Examples of Lower-Tier Data

Lower-tier data relate to water footprints, which can be generated for trade patterns as a whole as shown in Fig. 2, or for individual products (or groups thereof). Figures 9, 10 and 11 show data on the blue and green water transfers between the SADC countries allied to the trade in maize, ground nuts and sugar. These graphics provide the key Virtual Water components to complement the data on tonnages and values shown in Figs. 6, 7 and 8.

Interesting patterns are revealed when the water footprint data are interrogated in detail. Examples of these are shown in Text Boxes 1 and 2, which address water productivity values of various types, and crop yields. As noted in Text Box 1, blue water productivity is generally quite low for sugar production in southern Africa, averaging US\$2.78/m³. Higher blue water productivity is noted for groundnuts (mean of US\$4.41/m³), with very much higher values for maize (averaging US \$177/m³). These figures reflect the reliance on blue water (and irrigation) for the crops involved. It is noted that while the data on water productivity are to some extent dependent on exactly where the crop is grown (and may be susceptible to the issues described previously in terms of the robustness of detailed water footprint information), average data have been used here.

When analysed on the basis of the full Virtual Water footprint, productivities average only US\$0.38/m³ for groundnuts, but somewhat higher for sugar

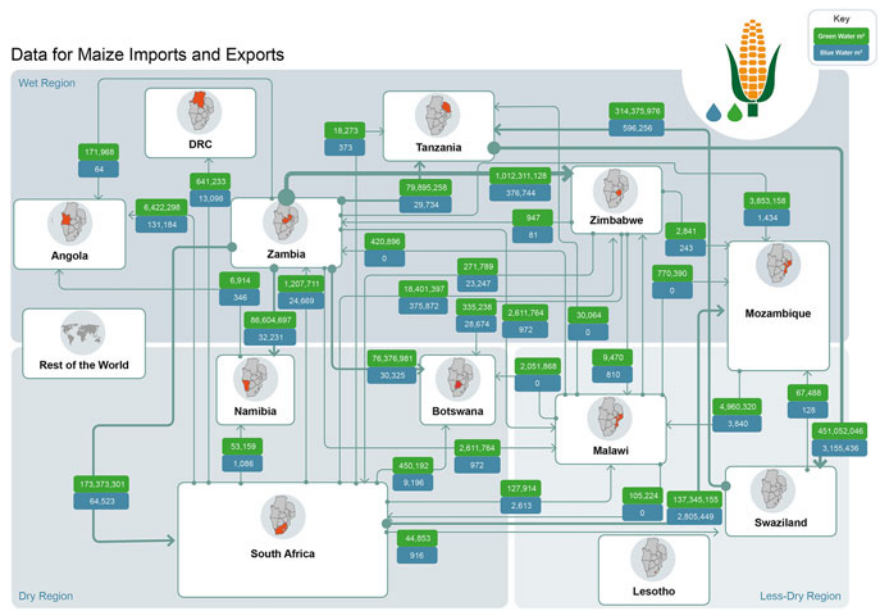


Fig. 9 Import and export of green and blue water in maize traded within SADC (Trade data with the rest of the world are not shown)

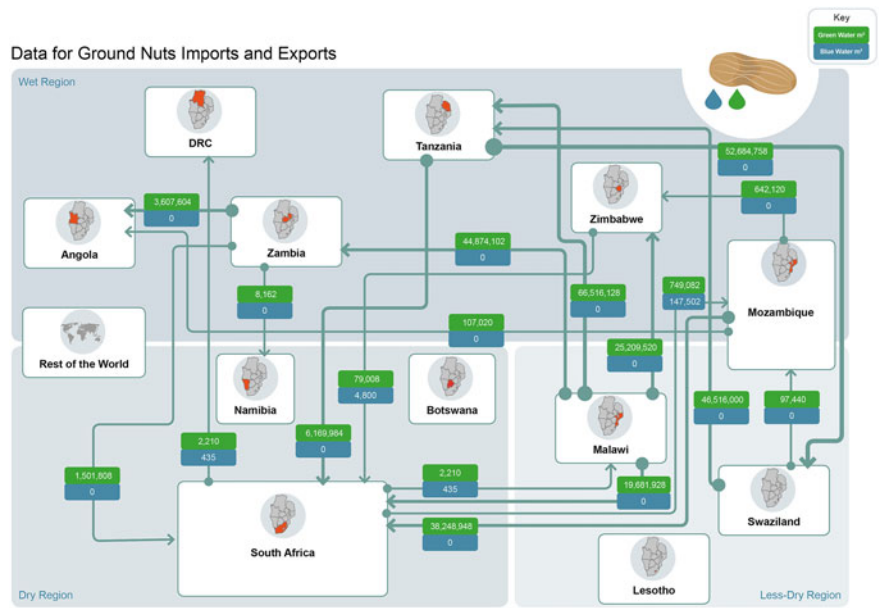


Fig. 10 Import and export of green and blue water in ground nuts traded within SADC (Trade data with the rest of the world are not shown)

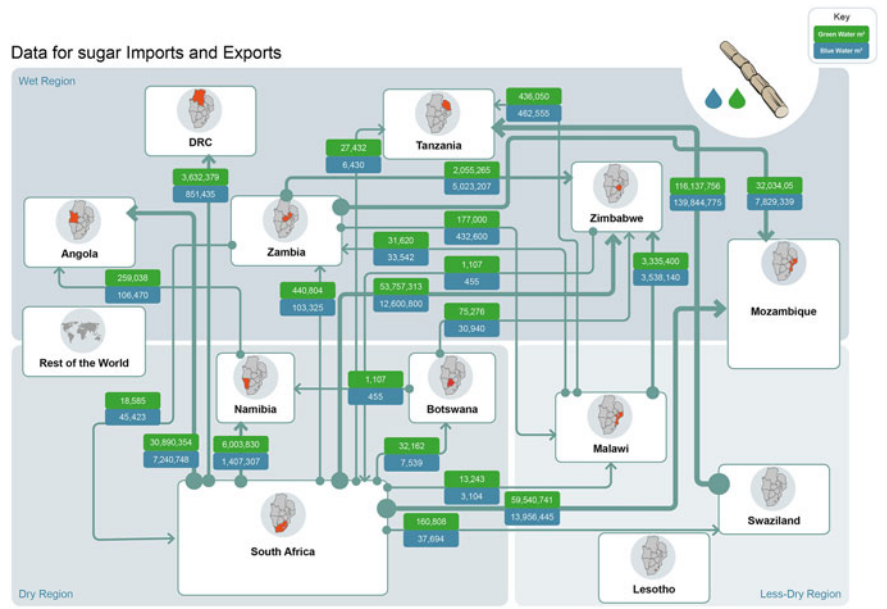


Fig. 11 Import and export of green and blue water in sugar traded within SADC (Trade data with the rest of the world are not shown)

(US\$0.69/m³) and considerably greater for maize (US\$1.28/m³). The most striking facet of the data relates to the very large differences between the water productivities calculated for specific sources/destinations of traded crops. It is clear from the relatively simple analysis completed to date that further focus on the patterns of crop production would materially affect both agricultural efficiency and economic returns, with potentially large effects on poverty in certain rural areas.

The second example provided here involves the production of sugar on a regional basis in both South Africa and Zimbabwe. In South Africa, sugar is grown primarily in KwaZulu Natal and Mpumalanga Provinces. Very considerable differences exist between these two locations in terms of the extent of irrigation of the crop, this being far greater in KwaZulu Natal (at 90 % of the total area devoted to sugar) than in Mpumalanga (only 14 % of the total area used for sugar production being irrigated). As expected, crop yields are lower for the non-irrigated product (56 tonnes/ha as an average in KwaZulu Natal), and rise considerably when irrigation is made available (89 tonnes/ha in Mpumalanga). In Zimbabwe, all sugar is grown in the Save River Basin, and this is all irrigated. The primary distinction relating to sugar production in this instance involves the average yields attained by subsistence farmers on small-holdings (34 tonnes/ha) and those achieved by commercial operations (76 tonnes/ha). Text Box 2 includes some initial analysis in this regard.

The examples cited above show that the data platform is of exceptional utility, and is capable of providing information at many levels of detail and specificity. It is important to note that the tool that has been created by the current work is not simply a cut-down version of the dataset published by Mekonnen and Hoekstra, but has been designed specifically for use in southern Africa to assist SADC in moving towards regional water and food security, creating a vision of water as a regional public good.

Text Box 1: An Example Concerning Virtual Water Transfers In Agricultural Products Traded Internationally in Southern Africa

‘Water productivity’ is considered by many commentators to be an important measure of the efficiency of agricultural activities. Generally measured as the financial return per volume of water used (US\$/m³), water productivity values as reported to date in the literature refer to a basis of blue water only. Where crops are grown with a heavy reliance on green water (and only limited blue water use), this increases the apparent water productivity.

The data platform was used to derive the standard water productivity values (based on blue water alone) and also for a new parameter, which could be termed the ‘Virtual Water productivity’. The latter values are based on all forms of water used to grow a primary crop: blue, green and grey water, in combination.

Three distinct types of crops were selected to create this example, and the resulting data are summarised as follows:

- Average (blue) water productivity values were US\$2.78/m³ for sugar; US\$4.41/m³ for groundnuts; and US\$177/m³ for maize.
- Mean values for the Virtual Water productivity were US\$0.38/m³ for groundnuts; US\$0.69/m³ for sugar; and US\$1.28/m³ for maize.

The water productivity data show the influence of the blue water/green water mix used for each crop, in a very clear fashion. Virtual Water productivity figures provide a much more coherent base to compare the financial output from each crop, but effectively value each form of water equally.

The data for these three crops traded in various fashions between the SADC countries show great differences from place to place (trade to trade) in both water productivity and Virtual Water productivity—the averages cited above masking very large variations. Such information is not usually used by farmers or by governmental authorities in reaching decisions on preferred crops to be produced in specific locations.

Should public or private entities incorporate considerations of Virtual Water (or at least, the distinct types of water) into their planning in terms of which crop to grow, where?

Are governmental bodies the most appropriate to lead in any such an intervention, or would private sector farming interests be better engaged?

How likely is it that the SADC countries would agree to grow 'thirsty crops' in the north of SADC, and 'less thirsty crops' in the more arid southern regions, with trade between these addressing local demand for all the various types of crops?

Text Box 2: The Production of Sugar in Southern Africa

Yields for the production of sugar in South Africa and Zimbabwe are shown below:

Location	Type of production	Yield (Tonnes/ha)
KwaZulu Natal (RSA)	Dry land (not irrigated)	56.0
	Irrigated	70.7
Mpumalanga (RSA)	Dry land (not irrigated)	63.6
	Irrigated	89.5
Zimbabwe	Subsistence (small-holdings)	34.0
Zimbabwe	Commercial	76.0

As would be anticipated, the yields increase perceptibly when irrigation is made available (in South Africa), although the uplift in yield provided by irrigation is not particularly great (26 % in KwaZulu Natal, and 41 % in Mpumalanga). In Zimbabwe, the key determinant of yields of sugar involves the distinction between those attained by subsistence farmers on small-holdings, and the much higher yields achieved by commercial operations.

What level of government intervention may be countenanced, to attempt to improve crop yields in such scenarios?

Is the irrigation of sugar (which has low water productivity in general) a rational use of blue water supplies in the water-stressed areas of southern Africa? Should blue water be allocated to higher-value crops in such water-stressed areas, and how might this be achieved?

What forms of intervention may be promoted to increase subsistence-level yields of crops? Should subsistence farmers be encouraged to grow crops with higher water productivities, and how might this be achieved?

In the course of the construction of the data platform, the team noted that certain types of data could be added to the data platform. These include the following:

- Data on the national production and consumption of agricultural products (as opposed to internationally traded products), which would be of interest when parties wish to interrogate the efficiency of the sector in particular countries and provinces. The production data can be associated with areas farmed, yields, and economic values;
- Detailed data on the specific trade patterns of the SADC nations with individual countries in the 'Rest of the World' category, on a product-by-product basis or more generic platform, as may be desired.

In terms of high levels of detail, a few products do not have assigned water footprints, as no data are available internationally in this regard. Further work could also be completed to superimpose more detailed estimates of animal size on the data platform, to better assess the Virtual Water component of livestock products. However, given that this type of additional work is likely to require substantial resources, it should only be pursued on an as-needed basis.

5 Virtual Water Transfers in Traded Electricity

5.1 Consumptive Water Use in the Generation of Electricity

As noted in a previous section, there is considerable variation in the methodologies used internationally to measure the consumptive use of water in the generation of electricity. Some authors cite data based simply on the evaporative losses involved

in the generation process, as this is generally by far the largest and most important component of overall net water use. By contrast, other authors attempt ‘life cycle analyses’ which extend to the source of the energy (and the process making this available), the equipment used, downstream transmission, etc. Such details are captured particularly clearly in a recent literature review by Meldrum et al. (2013).

The resources available to the current authors did not permit full life-cycle analyses of consumptive water use in the generation of electricity amongst all of the facilities in the continental SADC countries, and in any event these were not deemed to be required. Thus, CRIDF seeks to introduce the concepts of Virtual Water and the nexus into the general policy-related planning process within the region as a whole. While it is recognised that highly specific data on life cycle water use in certain scenarios might be of relevance in particular circumstances at a later time, the present report employs indicative data only, based on estimates of the evaporative losses of water in particular electricity generating technologies. Similarly, no attempt has been made to address the relatively minor sources of electricity within the continental SADC countries (wind, solar, etc.), and the focus here is on thermoelectric plants which dominate in the South of SADC, and hydropower facilities that are primarily located in the North of the region.

In thermoelectric power generation, the level of consumptive water use depends primarily on the selected method of cooling, with a significant difference being observed between once-through and recycling systems. By contrast, the consumptive use of water in the generation of electricity using hydropower varies greatly amongst distinct types of facilities, and also between specific plants of any one type.⁶ Run-of-the-river systems which do not involve large impoundments have low consumptive water use, while facilities including large dams and reservoirs exhibit a much higher consumptive use of water. This is due to a number of factors, including in particular the surface area of any impoundment; the rate of evaporative loss from the reservoir; and the efficiency of the turbines. In the USA, Torcellini et al. (2003) cited a range for hydropower plants from close to zero consumptive use for run-of-the-river systems, to more than 208 L/kWh—very much greater at the higher end of the range than the consumptive water use in thermoelectric plants (see below).⁷ The consumptive use of water by hydropower facilities in Africa can

⁶For generic data, see for example *Energy Demands on Water Resources. Report to Congress on the Interdependency of Energy and Water*. US Department of Energy, December 2006.

⁷It is notable that some of the water sources used to support thermoelectric power generation also involve impoundments, in some instances to increase assurance of supply. However, these are generally much smaller than those employed to generate hydropower, with minor evaporative losses—and they are also usually multi-use facilities, being employed in support of agricultural irrigation in particular. It is also arguable that the evaporation off the large hydropower-related impoundments such as Kariba and Cahora Bassa might not all be allocated to hydropower generation in isolation (where multiple use occurs), but in those cases the hydropower generation was the primary *raison d’être* for the construction of the dams. The analysis provided here is thus considered to be generically robust, and in any event the very large distinction between consumptive water use in the two forms of electricity generation would persist, even where additional (minor) factors are taken into account.

be far higher than that of similar plants in the USA, due to the higher evaporative loss in many locations in Africa (although these also vary considerably from site to site). Importantly, increased evaporative loss due to climate change induced higher temperatures could increase net water use in hydropower. Given the higher than average temperature increases expected in the SADC region, climate change could play an increasingly important role in SADC's energy future.

Table 2 provides a brief summary of the energy sector in each of the 12 SADC countries addressed in this chapter, and this highlights two key points of relevance to Virtual Water transfers. South Africa generates about 80 % of the electricity produced in southern Africa as a whole, and this equates to approximately 40 % of the generation of electricity in the entire continent. Amongst the CRIDF countries addressed here, the northern states rely heavily on hydropower for the generation of electricity (see Table 3), while South Africa presently utilises coal-fired thermo-electric generation for the great majority of its electrical supplies, as shown in Table 4.

Recent data from Eskom reveal a consumptive use of water of 1.37 L/kWh in the generation of South African electricity, as a nation-wide average. This nation-wide average for the consumptive use of water in electricity generation in South Africa is competitive by comparison to performance elsewhere, e.g. Torcellini et al. (2003) reported an average consumptive use of 1.4–1.9 L/kWh for thermoelectric power generation by a large range of such facilities in the USA. It is notable that the newer thermal plants in South Africa are more water-efficient, and the gradual introduction of dry cooling will reduce water consumption even further.

Amongst the major hydropower plants in SADC (see Table 3), certain facilities in the Zambezi River basin are of particular significance due to their reliance on large dams which impound reservoirs of very considerable surface area—with highly significant evaporative losses. Data from Beilfuss (2012) were used by the CRIDF project team to determine the consumptive uses of water at the three major hydropower sites in the Zambezi River basin.

These revealed the lowest use at Itzhi-Tezhi/Kafue Gorge (64 L/kWh); intermediate values at Cahora Bassa (296 L/kWh); and by far the highest consumptive use of water at Kariba (1040 L/kWh). The particularly high losses at Kariba reflect the relatively shallow reservoir with a large surface area, and this is also demonstrated by data for electricity generation per reservoir surface area (0.3 MW/km^2 at Kariba, as opposed to 1.4 MW/km^2 for Cahora Bassa). The total evaporative losses at the hydropower facilities in the Zambezi River basin equate to a consumptive use of about 11 % of the mean annual flow of the system as a whole, and this creates major changes not only to the total water flow in the basin but also to the seasonal pattern of flows.⁸

⁸It could be argued that the construction of major dams for generating hydropower has effects not only on evaporation rates upstream, but also those downstream, due to the resulting changes in river flow dynamics/cross-section, etc. Such effects are certainly relevant in terms of basin-level water management, but they have not been taken into account here (and are believed in most cases to be minor, compared to evaporative losses at the reservoir sites).

Table 2 Overview of the energy resources and electricity supplies in each of the continental SADC countries

Country	Energy resources	Electricity supplies
Angola	Considerable oil and gas resources (global #18 in reserves) in ongoing development, these entirely dominating the national economy. Primary energy use still dominated by biomass, followed by oil, hydropower and natural gas	Approximately 70 % of internal generation from hydropower (Cuanza, Catumbela, Cunene Rivers). Gas-fired production likely to increase. Only 30 % coverage of the population currently. Not yet fully integrated into the SAPP, but a connection to Namibia is being established
Botswana	No oil or gas reserves. Moderate coal resource, essentially all utilized within the country	Significant importer of electricity, mostly from South Africa
DRC	Significant oil reserves, with more likely to be discovered. A minor oil exporter currently. Some coal and significant hydropower at Inga in particular. The development of Grand Inga could completely alter the African balance of power generation	Only a moderate net exporter of electricity, mostly from the Inga projects. New Power Purchase Agreement with South Africa relating to Inga III. Massive future potential as an exporter of hydropower from Grand Inga
Lesotho	No oil, gas or coal reserves; reliant on national biomass and imported fossil fuels	Minor generation through hydropower, including the Lesotho Highlands Water Project. Minor net importer of electricity from South Africa
Malawi	Very minor oil production at present. No gas currently exploited, but attempts are ongoing to develop oil and gas under Lake Malawi/Nyasa (involving a dispute with Tanzania)	Essentially all electrical power generated in-country mostly through hydropower—with significant new hydropower plans, and no significant imports or exports
Mozambique	No significant oil reserves. Natural gas exploited from the onshore Pande and Temane fields mainly (80 %) used by South Africa, <i>via</i> the Sasol pipeline. Massive natural gas reserves found recently in the Rovuma basin offshore in the north. Significant coal reserves	Poor internal access to electricity (25 % of population). National grid backbone to be constructed. Cahora Bassa and other hydropower sources of key importance but coal and gas also used increasingly for generation. Significant exporter of electricity, likely to increase considerably over time. Imports energy from South Africa to support an aluminium smelter
Namibia	No oil or gas reserves exploited currently, but Kudu gas field offshore (shared with South Africa) under early development. Ruacana hydropower facility operating in the North and hydropower at Baynes on	Significant importer of electricity, mainly from South Africa and historically also from Zimbabwe (Hwange thermal station). New agreement with Aggreko for importation from Mozambique

(continued)

Table 2 (continued)

Country	Energy resources	Electricity supplies
	the Cunene River is planned (shared with Angola). Coal imported to supply ageing Van Eck facility in Windhoek. Plans for 500 MW coal-fired facility at Walvis Bay	(Ressano Garcia) sourced from natural gas
South Africa	By far the most dominant country in southern Africa in terms of energy development to date. Small internal reserves of oil and gas but some imports from Mozambique and Kudu/shale gas in the Karoo may change this in the future. Heavily reliant on coal currently (global #9 in coal reserves) but poor quality leads to very high <i>per capita</i> greenhouse gas emissions. Major synthetic fuels sector. Minor hydropower, mostly already constructed	Strong coverage of the population, being enhanced over time. By far the largest electricity generator in southern Africa, about 90 % from coal (minor nuclear, hydropower and gas). Plans to increase nuclear generation to diversify the energy mix remain under review. Recent exports have decreased as domestic demand has increased and growth of generation capacity slowed
Swaziland	No oil or gas reserves but moderate coal resources. Biomass dominates the energy use in-country	Minor net importer of electricity, mostly from South Africa
Tanzania	No proven oil reserves but significant gas, some of this shared with Malawi (under dispute) and also with Mozambique in the Rovuma Basin. Likely to export natural gas in the future. Moderate coal reserves, supplemented by importation. Heavy reliance on biomass for fuel	Low population coverage (15 %). Most electricity from hydropower (60 %), with the remainder from fossil fuels. Essentially self-sufficient for electricity. Recent link to the SAPP; Tanzania represents a link between the SAPP and the Eastern Africa Power Pool
Zambia	Minor oil production and no gas. Significant hydropower, Kariba being dominant. New hydropower being planned	Net minor exporter of electricity from hydropower sources. This may change given the rapid growth in national demand
Zimbabwe	Minor oil reserves and no gas but moderate coal resources. Thermal power plants are present, with some hydropower. Marked reliance on biomass in rural areas	Net importer of electricity, mainly from South Africa. Previous Power Purchase Agreement for export to Namibia has lapsed

Table 3 Examples of major existing hydropower facilities in the northern countries of SADC

Country	Hydropower site	Installed capacity (MW)	Date of construction	Comments
DRC	Inga I and II	351 and 1424	1972 and 1982	Major refurbishment needed
DRC	Inga III	4800	2016 on?	Being developed currently
Lesotho	Lesotho Highlands Water Project	110	1998	Phase II being considered at present
Mozambique	Cahora Bassa	2075	1974	Operation delayed until 1997
Namibia	Ruacana	330	1978	Fourth turbine added in mid-2012
Zambia/Zimbabwe	Kariba	1470	1959	Two separate power stations exist
Zambia	Kafue Gorge	990	1973	The Itezhi-Tezhi Dam regulates flows

Table 4 The generation of electricity by South Africa for the year 2012/2013

Source	GWh (net)	Percentage of total
Coal-fired stations	232,749	90.5
Nuclear power station	11,954	4.6
Purchase from independent power producers	3516	1.4
Pumped storage stations	3006	1.2
Wheeling (transmission)	2948	1.1
Gas turbine stations	1904	0.7
Hydroelectric stations	1077	0.4
Wind energy	1	<0.1
Totals	257,155	100

6 Trade in Electricity and Virtual Water Transfers

It is important to note that the international trade of electrical power in southern Africa varies substantially over time. This reflects short-term changes in the capabilities of utilities to generate power, coupled to fluctuations in power demand. Some such variations are challenging to predict, e.g. unexpected problems at generating stations can reduce the electrical power available in a broader geography and can have knock-on effects elsewhere, sometimes with major consequences involving wide-scale load-shedding. This is a particular problem in circumstances

where the reserve margin is low, as has been noted throughout almost all of SADC since late 2007—in large part because of the difficulties experienced in South Africa over recent years (reflecting the high proportion of SADC electricity that is generated in South Africa; see above).

These time-related variations in the international trade in electricity in southern Africa imply that any analysis of Virtual Water transfers in electrical supplies that are traded between the various countries should be considered as a general pattern, rather than in terms of absolute values which are in fact of relevance only to one particular time period. This is not especially problematic, however, as the key issue relating to Virtual Water transfers in the regional electricity network involves the very large difference in the consumptive use of water by facilities involving thermoelectric technology *versus* the larger hydropower plants.

Table 5 and Fig. 12 show an example of Virtual Water transfers in electricity traded internationally within southern Africa for the year 2012–2013, data on the trading pattern being derived from Eskom and from the SAPP Coordination Centre in Harare. Exports from South Africa to other countries occur in general through the SAPP transmission network and Eskom does not assign a specific source to any such trading, all electricity generated in-country being considered as a ‘common pool’. In this circumstance, the national estimate of consumptive use of water in South Africa for the generation of electricity (in 2012/2013) was utilised to calculate the volumes of Virtual Water transferred in each trade. Relatively small volumes of Virtual Water were involved, as South Africa exhibits a low consumptive use of water in its overall electricity generation portfolio (and most of the power generated is in any event used nationally, rather than being traded). The total transfer of Virtual Water in electricity traded externally by South Africa in 2012–2013 was 19.34 MCM, as compared to 331 MCM of water used consumptively for all of the power generation in-country (5.8 % traded; the remainder used nationally).

The cross-trade in electricity between South Africa and Mozambique involves a considerable differential in Virtual Water transfers. As shown in Table 5 and Fig. 12, the 8280 GWh traded from South Africa to Mozambique in 2012–2013 involved a transfer of 11.76 MCM of Virtual Water, whilst the 6540 GWh of

Table 5 Transfers of Virtual Water in internationally traded electricity in the year 2012/2013

From	To	GWh/year (net)	L/kWh	MCM/year VW	Comments
South Africa	Mozambique	8280	1.42	11.76	No specific source identified; generic consumptive use figure employed
	Botswana	2570	1.42	3.65	
	Namibia	1780	1.42	2.53	
	Swaziland	600	1.42	0.85	
	Zambia	250	1.42	0.35	
	Lesotho	140	1.42	0.20	
Mozambique	South Africa	6540	296	1936	From Cahora Bassa

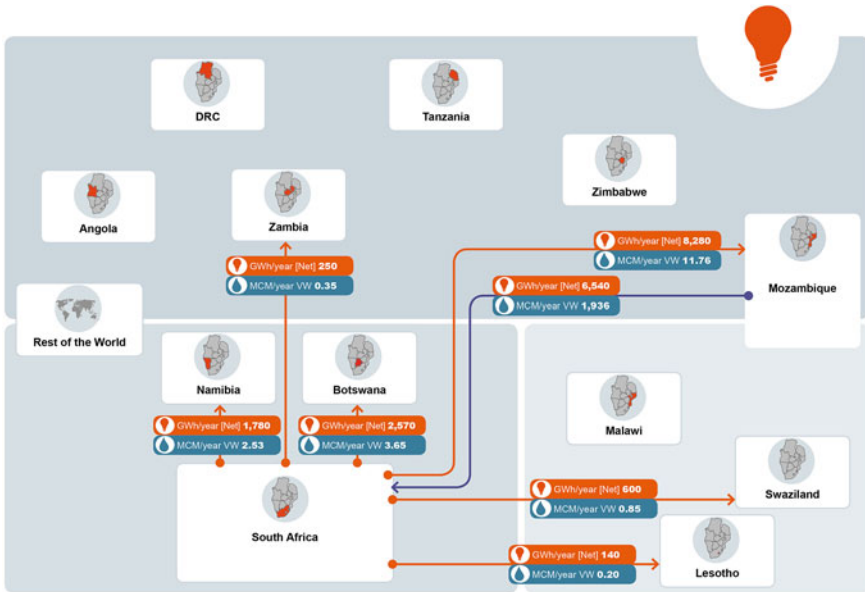


Fig. 12 The trade in electricity in 2012–2013 amongst the SADC countries

electricity derived from Cahora Bassa and traded to South Africa in the same time period implied a Virtual Water transfer of 1936 MCM.

This very large differential holds true, whether more sophisticated life-cycle analyses (or estimates of downstream effects of hydropower dams) are included, or otherwise. The distinction reflects the very great differences in the consumptive use of water by the two power generation systems, but these need also to be considered against the background of the annually renewable water resources in each country, as a whole. Thus, the degree of constraint on the water supplies is of importance in determining preferred regional patterns of electricity generation in the future.

7 Initial Reflections on the Top-Level Data

The total volume of water utilised in generating electricity in South Africa is not insignificant, at 331 MCM/year in total in 2012/2013 (2.65 % of the total annual renewable water resource nationally, making Eskom the single largest user of water in the country). However, this is altogether dwarfed by the water volumes used in the large hydropower schemes in the northern SADC countries. As noted by Beilfuss (2012), the three biggest hydropower facilities in the Zambezi River basin have fundamentally altered the total mean annual flow of the river system and have very significantly changed the seasonal flow patterns. Thus, the evaporative losses at Kariba amount to 16 % of inflows at that point, on average; those at

Itezhi-Tezhi/Kafue Gorge account for 3 % of inflows; and the evaporative loss at Cahora Bassa equates to 6 % of inflows at that point in the system. In overall terms, some 11 % of the flow of the Zambezi River system is lost by evaporation at the various hydropower facilities along its length—amounting to more than 12 km³ of water annually, as an average. This represents by far the single largest use of water in the Zambezi River system, and rivals the blue water component of the Virtual Water volumes traded in the agricultural sector. Indeed, the Zambezi Basin IWRM Strategy recognises hydropower as the single largest water user in the Basin. (Mott-Macdonald 2008).

It is important to understand that this does not necessarily imply a preference for thermoelectric power over hydroelectric power (or *vice versa*) at any one part of the overall system within the continental SADC states. Thus, national preferences (relating to self-sufficiency/security of supply, costs, and other factors) are viewed differently by each country and the existing pattern of supply reflects this, at least to some degree. The 12 sovereign states thus face individual and collective decisions on their preferred future pattern of electricity generation and trading internationally. However, as is argued there are substantial water carbon and cost savings to be had in the conjunctive management of hydro and thermal-power.

Representatives of the SAPP have stated that electricity demand in southern Africa is increasing by more than 5 % annually (faster than the GDP growth in most of the countries), and this implies a doubling in the total demand for electricity every 14 years, amongst the continental SADC countries as a whole. In particular, very rapid increases in industrial demand for electricity between 2003 and 2007 caught ESKOM off guard. Major challenges exist in terms of satisfying the increasing demand:

- Large numbers of new generating facilities will be required. Some of these are already in construction (e.g. Inga III) or are planned (e.g. Batoka Gorge, Mphanda Nkuwa), with hydropower facilities again dominating in the northern SADC countries.⁹
- South Africa is continuing to consider its preferred energy mix, with possible increases in nuclear energy but the certainty of new coal-fired stations also being involved (the Kusile thermoelectric station having been selected to follow the finalisation of the Medupi facility), and the potential use of shale gas (although the latter remains highly controversial).
- Major new transmission systems are required, both to satisfy existing demand and to create a robust network for international trade in electricity. This is a particular focus of the SAPP, and some of the challenges that will be faced are highlighted in Chapter “[Electrical Power Planning in SADC and the Role of the Southern African Power Pool](#)”.

⁹It is notable that when these new facilities come online, some will affect the data for consumptive water use as shown here. This will occur as new plants are constructed downstream of existing facilities which already enjoy regulated flows from upstream reservoirs, and also when some of the existing facilities are expanded in relation to their electrical output.

For South Africa, the future is especially challenging due to tightening restrictions on water availability; the inexorable increase in demand for electricity; and the current reliance of some of the neighbouring countries on exports of electricity from South Africa. The high assurance of supply that is required for electricity generation implies that the use of blue water exerts particularly severe effects on other types of water utilisation or allocation in times of drought. Inter-sectoral competition for water already exists in many of South Africa's basins (and in some of the neighbouring countries also), and the high and increasing domestic/municipal demand for water is especially notable on a country-wide basis in South Africa. In addition, the atmospheric emissions from power generating facilities in South Africa are considerable and concerns exist over greenhouse gases and effects on climate change. The possibility of the development of shale gas resources in the Karoo—estimated by the US Energy Information Administration to amount to up to 485 trillion cubic feet—remains controversial in large part due to concerns over the environmental impacts of hydraulic fracturing ('fracking').

Other countries in southern Africa exhibit varying responses to the energy sector, and the satisfaction of their own national demand (see Table 2). For example, Namibia has long been reliant on imports of electricity from South Africa, but it is predicted that this will change in the future as major new supplies are developed within Namibia (a coal-fired power station near Walvis Bay; the Kudu gas reserve in Namibian waters offshore; and the Baynes hydropower site on the Kunene River). Botswana depends heavily on its national coal resources, and also on imports of electricity from South Africa. Tanzania, having suffered load-shedding due to low water levels serving its hydropower plants (which produce almost 40 % of the country's electricity needs) is focusing on expanding thermal energy production—and the newly discovered gas supplies in the Rovuma basin offshore offer considerable future potential in this regard. Nonetheless, there are still opportunities to develop hydropower in the wetter regions of Tanzania.

Other SADC countries have limited hydrocarbon reserves and continue to rely heavily on hydropower, with major facilities planned or under development at sites such as Batoka Gorge (Zambia/ Zimbabwe), Lower Kafue Gorge (Zambia), Mphanda Nkuwa (Mozambique), and Inga III (the DRC). Extensions to existing hydropower stations are also envisaged, substantially increasing the present electricity generation portfolio of SADC as a whole.

The Grand Inga development in the DRC would fundamentally alter the pattern of electricity production in Africa, given its massive potential (variously estimated as 39,000–42,000 MW). Several types of schemes have been considered, including run-of-the-river facilities and impoundments of various forms. Although the latter would be likely to imply a higher consumptive use of water, the Congo River flow is so massive, and the use of water in the DRC is so small at the present time (the Congo's low flows tend to equate with the Zambezi's peak flows) that Virtual Water transfers should not raise problems in that instance.

A second factor that could substantially change the future pattern of electricity production in southern Africa involves the very large gas reserves discovered recently in the offshore Rovuma Basin in northern Mozambique/south-eastern

Tanzania, referred to briefly in the text above. Current estimates suggest that this will exceed 100 trillion cubic feet and the world class resource offers very significant opportunities for electricity production (with relatively low consumptive water use and atmospheric emissions). No decisions have been made as yet as to the preferred use of the gas—although the export of liquefied natural gas to the Far East appears to be almost certain for a significant proportion of the resource.

It is also possible that South Africa will proceed with the exploitation of shale gas in the Karoo. However, this option involves the use of hydraulic fracturing ('fracking'), which remains highly controversial; potentially contaminative; and relatively water intensive. No analysis of the possible use of water in fracking procedures has been made during the current work, although this could be addressed at a later stage to provide important new information of relevance to eventual policy considerations.

The impacts of climate change on water availability are difficult to estimate. The World Bank estimated that climate change in the Zambezi River basin may reduce mean annual river flows predicted by 16 % in the upper section; 24–34 % in the middle reaches; and 13–14 % in the lower Zambezi (World Bank 2010). While most scientists now acknowledge that the precise changes to hydrological parameters that would accompany climate change are challenging to predict, any such alterations in flow patterns would be little short of catastrophic in relation to hydropower generation in the Zambezi basin.

Various alternatives are being considered in this regard, including the operation of hydropower plants as effective run-of-the-river facilities (at full reservoir levels), coordinated hydropower management (as opposed to unilateral management), and other possibilities.

Such considerations bring the importance of regional planning into the forefront of the debate. The rationale for the creation of the SAPP is instructive in this regard (Economic Consulting Associates 2009a, b). Prior to the SAPP being established, the early development of transmission systems between Botswana, Zambia and Zimbabwe was intended to reduce the reliance of the 'Frontline States' on imports of electricity from South Africa during apartheid. The dismantling of apartheid in the early 1990s brought new opportunities and in response to the 1991–92 drought which imposed severe limitations on hydropower production in the Zambezi River basin, South Africa was able to fill the gap through the existing transmission network. Other facilities brought into operation at a later time (e.g. Cahora Bassa) assisted in creating greater robustness within the regional electricity network. Nonetheless, the regional transmission network requires upgrading for the SAPP to reach its full capacity, and currently only a small portion of the demands for trades through the SAPP can be met (see Chapter "Electrical Power Planning in SADC and the Role of the Southern African Power Pool").

South Africa possessed two goals through this and the later period: initially to act as the power-house of southern Africa (and maybe even the continent as a whole); and later to be in a position to import relatively cheap hydropower from the northern SADC countries. For some eight years, a regional option of importing energy from the north at peak times, and reversing that process off peak allowed for

the optimisation of hydropower and thermal power—effectively storing energy behind the hydropower dams in the Zambezi for use at peak times. However, the long term operation has been compromised, primarily due to the rapid growth in electricity demands in the region, making little available for export. The bilateral trade in electricity that pre-dated the establishment of the SAPP continues to represent the great majority of the electricity trade in the region, the initial short-term electricity market (STEM) and the more recent day-ahead market (DAM) created under the SAPP representing only very small proportions of the electricity traded internationally.

In the present context, the southern countries within SADC face a complex challenge—the need to meet sovereign demands, while also receiving benefits from regional cooperation in electricity trading (and the water-related benefits that may accompany this). Thus:

- The demand for electricity is growing more rapidly than GDP in all of the countries involved, and commonly at a faster pace than the electricity generation/transmission infrastructure can be delivered.
- There is little scope for further hydropower generation in the southern countries, with the exception of the 600 MW Baynes facility to be shared by Namibia and Angola on the Kunene River, and the expansion of hydropower production through the Lesotho Highlands scheme.¹⁰
- A continued reliance on coal-fired power stations in SADC as a whole will exacerbate the emissions of greenhouse gases, which are already high on a *per capita* basis, in South Africa in particular.
- Concerns raised by the Fukushima event of 2011 and by previous incidents in the nuclear power industry have cast doubt on plans for enhanced nuclear power generation in South Africa.
- Only minor scope exists for the expansion of renewable electricity generation, e.g. from wind and solar sources, and the lead times for these systems may be longer than is typical in more developed economies.

The southern countries in SADC—which experience much greater water stress than those further north—need to finalise strategic decisions on their preferred approach to electricity generation in the future. The fundamental components of this decision relate to a choice between additional thermoelectric facilities which will maintain national supplies in South Africa at least, *versus* the importation of the relatively cheaper mix of hydropower and thermally-derived electricity from the northern SADC countries (the latter, accompanied by a concomitant reduction in national energy security for the southern states). The preferred degree of regional integration represents a significant issue in this regard, and some commentators have placed this goal to the forefront of the debate (African Development Bank 2011).

¹⁰The second phase of the Lesotho Highlands Water Project was officially commenced in late March 2014. This is reported to involve a total cost of R15.5 billion, and will involve the construction of the Polihali Dam and the Kopong pumped storage supplying a further 1200 MW of hydroelectric power to Lesotho.

South Africa has therefore largely pursued its own power plan, rather than the optimised regional plan.

Despite this, the water-related implications of regional integration in energy production have received little attention in SADC, to date. However, the connections within the water, food and energy Nexus are coming into greater focus in the international arena. The data reported here on the distinctions in consumptive water use between thermoelectric and hydropower facilities in southern Africa augment this debate, and support the focus on the Nexus (as opposed to simply addressing water availability in isolation).

The key issue in relation to Virtual Water transfers in electricity involves the massive distinction between the Virtual Water content of electrical supplies derived from thermoelectric facilities and those from hydropower stations relying on large impoundments. This matter is addressed in brief in Text Box 3, which raises questions as to the preferred mix of regional electrical supplies in the future.

Notwithstanding the complexity of comparing the precise water footprints of various sources of electricity, for the purposes of the current study, certain broad inferences can be made specifically with respect to building regional climate resilience, improving regional integration, and building regional energy security:

- Given the strategic nature of electricity and its role in sustaining and building national economies, the SADC States are unlikely to significantly erode their sovereign security in terms of their national supplies of electricity.
- There is considerable scope for increased hydropower production in the Zambezi River basin, and this may be the only viable source to create greater sovereign security for electricity supplies to Zambia and Zimbabwe.
- There are substantial opportunities for increased thermal generation based on supplies from offshore gas fields in Mozambique and Tanzania.
- Hydropower production in the hotter northern States, while generally supported by higher flows and water availability, is highly vulnerable to increased temperatures and evaporation, and hence to climate change.
- Thermal power production in the generally dry south, while gradually becoming more water-efficient, remains a significant user of water especially in drought periods, and makes South Africa a substantial source of carbon emissions.
- The conjunctive and coordinated trading of electricity supplies through the SAPP can bring greater regional water/energy security and economic benefits for the SADC States, and can also reduce the carbon footprint of the region as a whole.

Text Box 3: An example concerning Virtual Water transfers in electrical supplies in Southern Africa

South Africa faces specific problems in relation to electricity generation in the future:

- The national demand for electricity continues to grow rapidly, with no reduction forecast.
- The capacity for additional hydroelectric supplies within South Africa is minor.
- Other renewable sources (wind, solar) are very unlikely to contribute significantly to South Africa's demand, especially peak demand, in the shorter term.
- Concerns exist in relation to the development of further nuclear energy.
- A continued reliance by South Africa on coal-fired facilities will increase atmospheric emissions yet further, which is not preferred. Carbon capture technologies are not yet sufficiently developed to reduce effects on climate change.
- There are concerns regarding the availability of sufficiently high grade coal and the reliance on open cast mining which affects the suitability of coal in wet weather.
- The South African government is currently exploring shale gas and fracking but this will occur in one of the drier regions of the country and remains highly controversial.
- Fresh water demand will also rise if electricity generation within South Africa is to increase in the future. The water demand of Eskom is already significant, at 331 MCM/year.

In such a scenario, a case can be made for a regional approach to electricity generation and use, with South Africa importing some of its electricity from countries to the North, most rely heavily on hydropower (and have very significant water resources). The development of Grand Inga in the DRC is one obvious option.

An alternative possibility (which is not mutually exclusive) would involve an agreement with Mozambique for electricity supplies from natural gas reserves, to be developed off northern Mozambique/southern Tanzania. However, this will increase South Africa's reliance on external electricity, and hence requires a shift in thinking from sovereign to regional security. This can, however, reduce the demand for water in South Africa.

8 Economic Accounting of Water

Economic accounts for water were developed initially as a specific component of the overall System of Environmental-Economic Accounting (SEEA), with the United Nations Statistics Division taking a leading role (SEEA 2014). The parent system was described in the handbook on integrated environmental and economic accounting, which is commonly referred to as SEEA-2003 (UN et al. 2003). The accounting system as a whole is aligned with the System of National Accounts used by most nations to generate statistics of relevance to their economies (ibid).

Economic accounts for water (the SEEAW) are one of five sub-components of the SEEA, the others addressing energy, fisheries, land and ecosystems, and agriculture. The key documents of specific relevance to water are those from 2006 and 2012, the later version having been aligned to a revision of the System of National Accounts released in 2008 (ibid).

The SEEAW includes the following water-related parameters as components of its standard format:

- stocks and flows of water resources within the environment;
- pressures of the economy on the environment in terms of water abstraction, and emissions added to wastewater and released to the environment, or removed from wastewater;
- the supply of water, and the use of water as input in a production process and by households;
- the re-use of water within the economy;
- the costs of collection, purification, distribution and treatment of water, as well as the service charges paid by the users;
- the financing of these costs, that is, who is paying for the water supply and sanitation services;
- the payments of permits for access to abstract water, or to use it as sink for the discharge of wastewater; and
- the hydraulic stock in place, as well as investments in hydraulic infrastructure during the accounting period.

Quality accounts and the economic valuation of water represent additional components of the SEEAW which remain experimental in nature at the present time, and are subject to further development.

9 Relevant Studies to Date in SADC

The SADC Economic Accounting of Water Use Project was completed in late 2010 (SADC 2010). Pilot Water Account Reports were produced for four countries (Malawi, Mauritius, Namibia and Zambia), and also for two river basins (the

Maputo and the Orange-Senqu). The standard approach embodied by the SEEAW was utilised, hence aligning the data with the System of National Accounts.

In general terms, economic accounting for water provides a conceptual framework to analyse the contribution of water to the economy of a country, and also the impact of the economy on water resources. This allows conclusions to be reached on whether water is utilised in efficient, equitable and sustainable fashions within countries (or in other distinct geographical units). Importantly, only blue water is addressed (in all its forms, including groundwater) in the present economic accounting systems, and green water, grey water and Virtual Water are not taken into account by the current techniques. However, the linkage between the water-related data and the national accounting system provides a powerful indicator of the uses of blue water in support of the economy, and the effects of the economy on blue water resources. The accounting system can be used at various levels, from individual enterprises and establishments (defined by their International Standard Industrial Classification [ISIC] denoters), to industry types; and also at the household level and higher levels of domestic use. ISIC components of specific relevance to water use within SADC include the following:

- ISIC 1-3 Agriculture, forestry and fishing;
- ISIC 5-33, Mining and quarrying;
- ISIC 41-43 Manufacturing and construction;
- ISIC 35 Electricity, gas steam and air conditioning supply;
- ISIC 36 Water collection, treatment and supply;
- ISIC 37 Sewerage; and
- ISIC 38, 39, and 45-99 Service industries.

Within these rather broad categories, economic accounting of water can be utilised to demonstrate the contribution of blue water to various components of a national or regional economy. This represents a tool of some utility in relation to blue water (and Integrated Water Resource Management) in the specific and complements considerations of the other forms of water.

Key indicators that are derived by economic accounting of water include:

- water use intensity;
- water pollution intensity;
- water productivity (relating to Blue Water only; see elsewhere in this report);
- water losses in distribution;
- the per capita water storage; and
- the average water price and supply cost.

Examples of the results of the SADC project on economic accounting of water include the following:

- All of the SADC countries allocate the majority of the blue water in use to their agricultural sector, even though this sector provides low returns to the economy by comparison to the industrial or services sectors. The agricultural sector is,

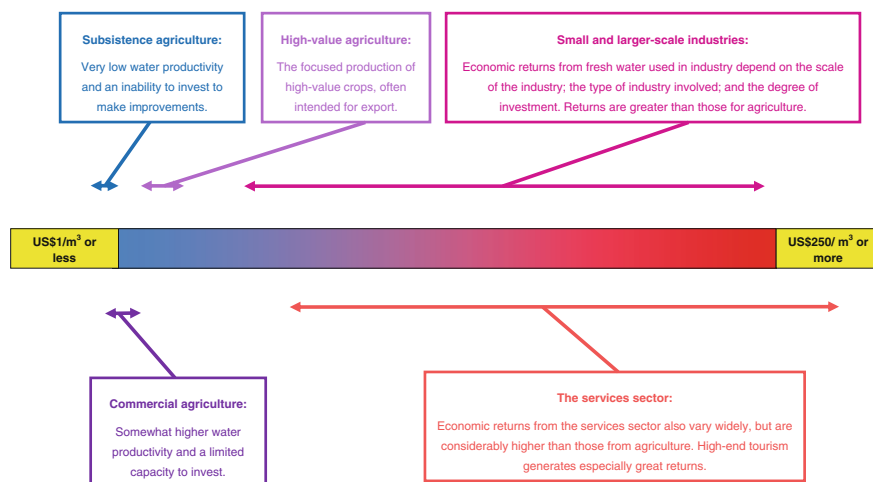


Fig. 13 Water productivity continuum, with comments on the three major sectors (Phillips 2012)

however, of particular importance for employment (e.g. 83 % of the total workforce in Malawi).

- In some countries, the sectoral comparison on returns to the economy is particularly marked. Thus, for example, a cubic metre of blue water in Mauritius provides US\$0.38 as a return from the agricultural sector, but US\$237 from the industrial sector. Such a pattern has been noted in other studies also (Phillips et al. 2011), as shown in Fig. 13.
- Certain countries suffer a major lost opportunity cost relating to blue water, due to poor levels of water supply and sanitation. The data for Malawi reveal that this equates to an astonishing 17 % of Gross Domestic Product (US\$456 million annually), compared to a SADC-wide average of 3.2 % annually.
- Namibia performs quite well by comparison to some of the other SADC countries, in part because it has been utilising water accounting techniques since the mid-1990s (and its legislation and Vision 2030 documentation recognise the value of this approach). However, returns to the economy from the agricultural sector in Namibia are low, reflecting the highly arid nature of the country.
- Zambia is relatively water-rich, but suffers from under-development of its blue water resources (and its industrial sector, which provides high returns from blue water use). Tourism is also a notable sub-sector in Zambia, and provides very high returns for blue water allocations.
- River basin-based studies are of considerable utility in revealing the economic effects of distinct Blue Water allocation strategies. Issues relating to benefit sharing and to the appropriate pricing of Blue Water resources are also highlighted in these investigations.
- While the fact that the current techniques are restricted entirely to blue water erodes the utility of economic accounting of water approaches, the data arising

from such studies are nevertheless of importance. The SADC investigation concluded that:

- The technique can be used with pertinent results at both national and river basin level, although certain indicators are somewhat challenging to derive at the river basin level.
- A variety of indicators can be generated during the process involved in economic accounting of water use (see below), and these are of importance for decision making and policy formulation at the national and regional levels.
- The capacity to compile water accounts represents a challenge to many SADC countries, but certain states (Botswana, Namibia, and South Africa) have experience in the techniques involved and have already recognised the policy relevance of the approach.
- The compilation of economic accounts for water is best approached through the establishment of national task teams, these involving a range of governmental entities and skill bases.
- The harmonisation of certain types of data collection within SADC would assist in the compilation of economic accounts of blue water use—including a reliance on the ISIC categories in terms of industrial groupings. In some instances, hydrological data are also inadequate, and groundwater remains especially poorly characterised to date in SADC.
- Wastewater-related data are inadequate, and the water quality aspects of the approach remain under-developed as a result.
- The SEEAW approach does not address livestock as an economic unit, but blue water allocations to livestock are important in SADC.
- Economic accounting of water also fails to address the demand for blue water allocation as an ‘environmental reserve’ or to provide base flow in river systems.

A combination of approaches involving economic accounting of water and the techniques relating to other forms of water shows particular promise for the future. The complementary nature of the various approaches addressed in the present report is of very considerable importance, and the use of all of the forms of analysis in combination will offer a highly nuanced view of water resource management in the future. This is especially important in water-stressed systems, where allocations account for most or all of the available blue water. However, in other circumstances—exemplified especially well by Malawi within SADC, but also by Zambia and perhaps Angola—it is clear that relatively minor changes to water policy could have far-reaching implications for food security, poverty alleviation, and climate resilience.

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