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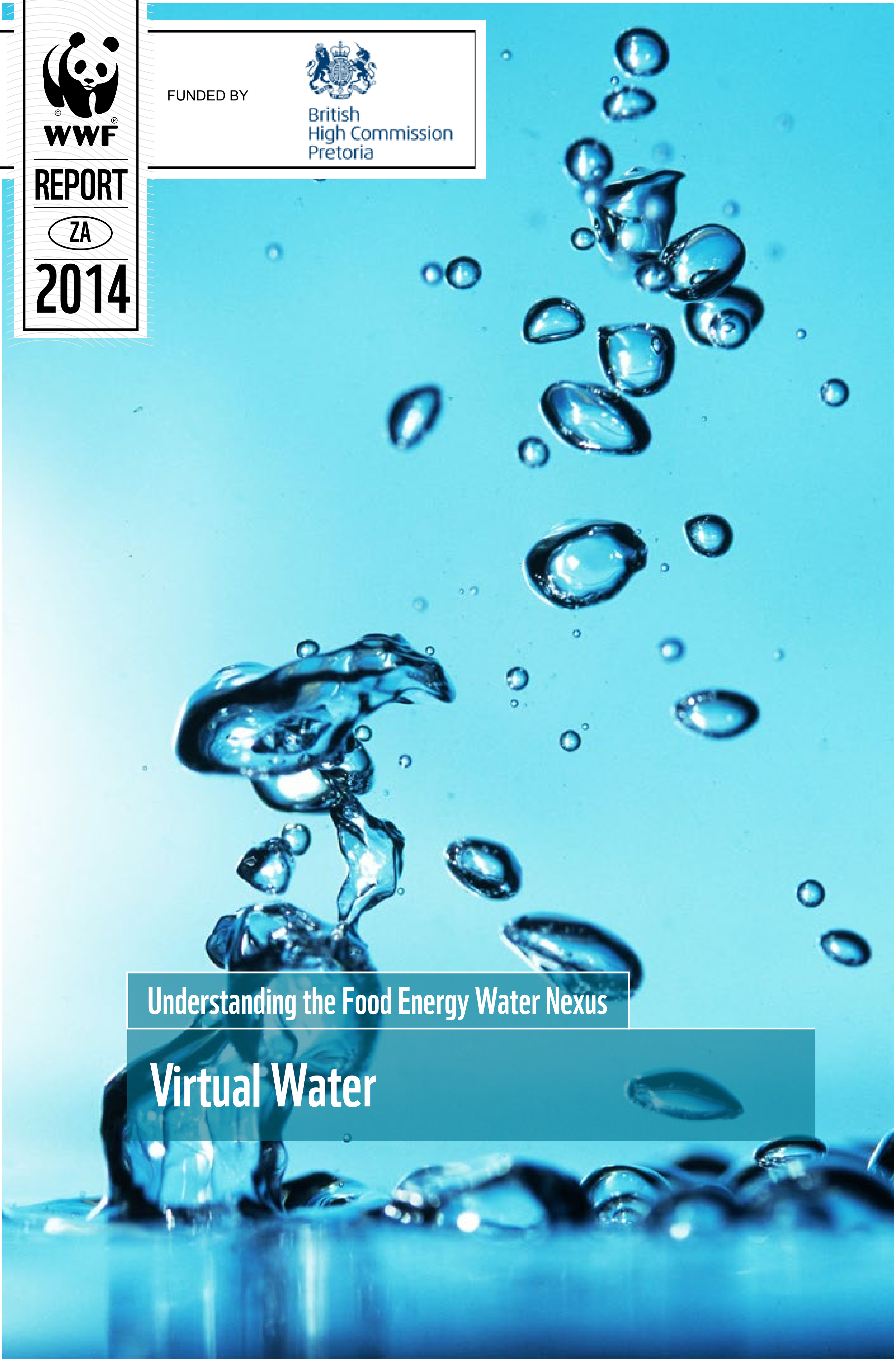

Understanding the Food Energy Water Nexus

Virtual Water

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ABOUT THIS STUDY

Food, water and energy security form the basis of a self-sufficient economy, but as a water-scarce country with little arable land and a dependence on oil imports, South Africa's economy is testing the limits of its resource constraints. WWF believes that a possible crisis in any of the three systems will directly affect the other two and that such a crisis may be imminent as the era of inexpensive food draws to a close.

WWF received funding from the British High Commission to establish a research programme exploring the complex relationship between food, water and energy systems from the perspective of a sustainable and secure future for the country. This paper is one of nine papers in the Food Energy Water Nexus Study.

PAPERS IN THIS STUDY

1. *Climate change, the Food Energy Water Nexus and food security in South Africa:* Suzanne Carter and Manisha Gulati
2. *Developing an understanding of the energy implications of wasted food and waste disposal:* Philippa Notten, Tjasa Bole-Rentel and Natasha Rambaran
3. *Energy as an input in the food value chain:* Kyle Mason-Jones, Philippa Notten and Natasha Rambaran
4. *Food inflation and financial flows:* David Hampton and Kate Weinberg
5. *The importance of water quality to the food industry in South Africa:* Paul Oberholster and Anna-Maria Botha
6. *The agricultural sector as a biofuels producer in South Africa:* Alan Brent
7. *Virtual water:* James Dabrowski
8. *Water as an input into the food value chain:* Hannah Baleta and Guy Pegram
9. *Water, energy and food: A Review of integrated planning in South Africa:* Sumayya Goga and Guy Pegram

ABOUT WWF

The World Wide Fund for Nature is one of the World's largest and most respected independent conservation organisations, with almost five million supporters and a global network active in over 100 countries. WWF's mission is to stop the degradation of the Earth's natural environment and to build a future in which humans live in harmony with nature, by conserving the world's biological diversity, ensuring that the use of renewable natural resources is sustainable, and promoting the reduction of pollution and wasteful consumption.

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ABSTRACT

South Africa is a water-scarce country. It is the 29th driest of 193 countries and had an estimated 1 110 m^3 of water per capita in 2005 (UNESCO-WWAP 2006). Moreover, its rainfall varies dramatically from season to season and the limited available water is distributed unevenly across the country. This poses several challenges for food production and food security. Some responses to this problem that are fast gaining ground are those of crop choices and virtual water. The term "virtual water" has been used previously to describe the volume of water embodied in food crops that are traded internationally. In recent years, the concept has been used to describe a situation in which water-scarce countries attempt to mitigate water-shortage problems by importing food from other countries instead of growing water-intensive food crops. Importing virtual water embedded in traded food can alleviate water stress and even achieve food security. Water trade can store water in its virtual-water form, enabling food storage to play a potential role in solving food problems while promoting the sustainability of water resources.

KEY WORDS

Virtual water, green and blue water, embodied water, embedded water, water scarcity, social adaptive capacity

CONTENTS

1. VIRTUAL WATER

Virtual water has been defined as "the water embodied in food crops that are traded internationally" (Allan 1998). It encourages a country to view agricultural crops in terms of the amount of water required to produce those crops. This can lead to improved trade policies to ensure that (a) food security and (b) scarce water resources are used to their maximum social and economic benefit. The concept of virtual-water trading advocates the idea that water-scarce countries should increasingly meet their food requirements by importing crops from water-rich countries (Horlemann & Neubert 2007), thereby saving the amount of water that would have been required to produce the crop locally (WWC 2004). The most positive effect generated by virtual-water trade is the water savings that are generated in the countries that import agricultural products (Chapagain et al. 2006). This makes water available for other beneficial uses.

The virtual-water content of a crop is the volume of fresh water used to produce the crop, measured at the place where the product was actually produced (production-site definition). It refers to the sum of the water use in the various steps of the production chain. The virtual-water content of a product can also be defined as the volume of water that would have been required to produce the product at the place where the product is consumed (consumption-site definition) (Chapagain & Hoekstra 2004). Whichever definition is appropriate will depend on the context. The production-site-specific definition can be employed when a global, or at least multinational, perspective is taken and the net virtual-water flows between importing and exporting countries are important. This is useful when the primary interest is whether or not virtual-water trading contributes to global water savings.

On the other hand, from the point of view of a single country (a purely national perspective), the consumption-site-specific definition is more relevant. For a given country the amount of water it could theoretically save by importing the product is the amount that it would use to produce it. For a water-scarce country this is the critical issue. It is specifically this volume of water that allows the local opportunity costs to be estimated (Wichelns 2004). The adjective "virtual" refers to the fact that most of the water used to produce a product is not contained in the product.

The water footprint of a crop is a similar concept to virtual water: it accounts for the direct and indirect use of water in the production of a commodity such that water use is estimated across the entire production and supply chain.Thus the water footprint of a crop might include the amount of water required to grow a crop as well as any water used in processing and cleaning the crop prior to consumption. It may also include the quantity of water polluted in producing the crop, through fertiliser and pesticide inputs.

1.2 GREEN, BLUE AND GREY WATER

Crops are either produced under purely rain-fed conditions or under irrigation, therefore the source of water plays an important role in evaluating water savings and opportunity costs associated with virtual-water trading. The virtual-water content of a crop is often described in terms of green and blue water, which indicates the proportion of water derived from rainfall and irrigation respectively. Green water is defined as water available in soil that is derived directly from rainfall. The opportunity cost of using green water for crop production is relatively low as there is often very little economic or social value that can be derived for any use other than agriculture. The cost of harvesting rainwater for alternative use is often prohibitive on a large scale. It is therefore generally regarded that using green water for agricultural production is highly beneficial to a country. Furthermore, rain-fed agriculture does not contribute significantly towards water scarcity: it does not withdraw water from bodies of water such as rivers, dams and lakes.

Blue water is defined as water contained in rivers, dams, lakes and aquifers. Blue water typically has a far higher opportunity cost than green water, particularly in a country where water is scarce. Blue water can be used for many alternative uses, such as domestic drinking water, recreation and industry. Irrigated agriculture diverts blue-water resources to crops and therefore impacts directly on the water resource. Irrigated agriculture can therefore potentially have a significant impact on water scarcity.

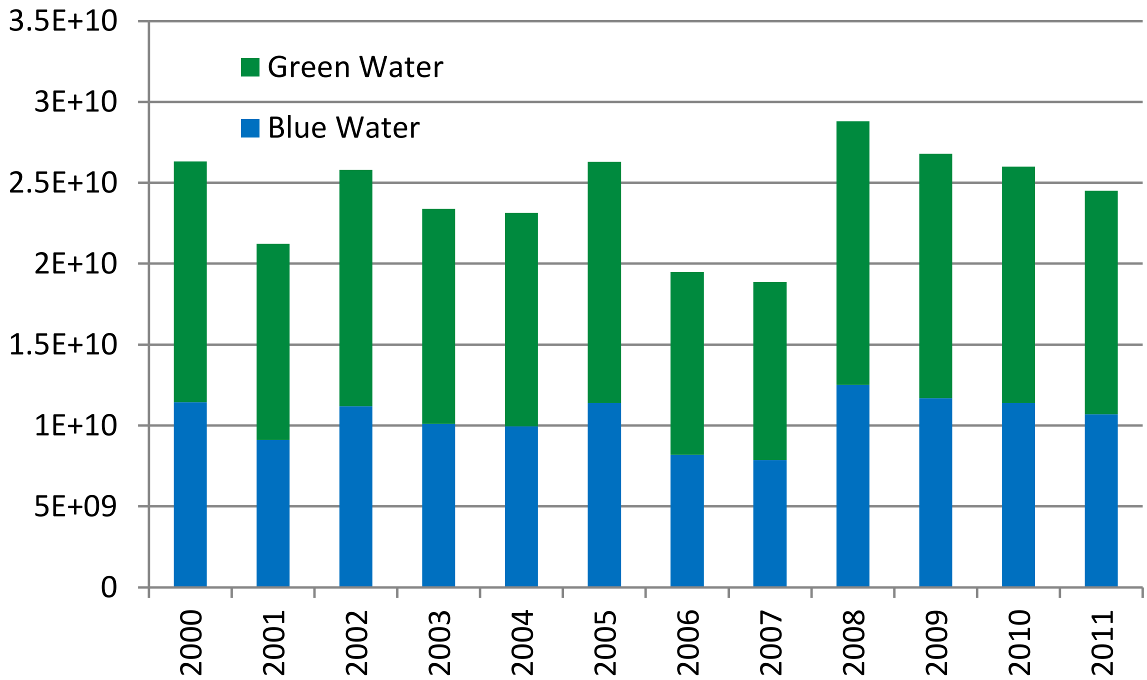
The Bottom Line: Within the context of South Africa, where irrigation accounts for approximately 60% of national water use, the blue-water content of a crop is key to analysing water savings related to the trade of agricultural products.

Recently, research on virtual water has expanded to define the grey-water content of a crop or product. The grey-water content of a process is an indicator of the degree of freshwater pollution that can be associated with a process and is defined as the volume of freshwater required to assimilate a pollutant load so as to meet existing water-quality standards. This is based on the premise that water of poor quality is unacceptable for certain uses and therefore makes that volume of water unusable. Within the context of agriculture, the grey-water content will consider the impact of fertilisers and pesticides on water quality.

2. VIRTUAL WATER IN SOUTH AFRICA

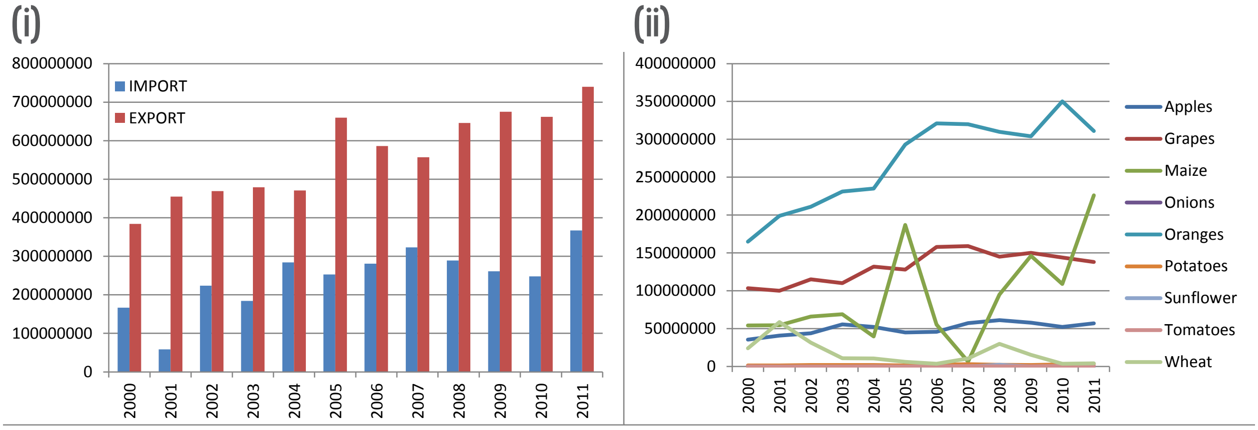
Water requirements to produce a crop can be estimated using models such as those used in irrigation scheduling. An estimate of the virtual-water content of the crop (m^3/tonne of crop produced) is given by expressing the total amount of water required to produce a crop (m^3) as a function of the yield of the crop (tonnes). The quantity of water that is virtually exported or imported into the country through trade of crops is estimated by analysing the import and export data. Analysis of the 10 most produced crops (in terms of tonnes produced per year) over the last 10 years shows that blue water forms a considerable proportion of total annual crop production, indicating a high dependency on irrigation.

Figure 1: Green and blue water use (m^3) associated with the 10 most-produced crops in South Africa



Analysis of trade data for these crops shows that South Africa is currently a net exporter of blue water (Figure 2 (i)), with oranges, grapes and maize accounting for high proportions of total annual exports (Figure 2 (ii)). Importation of blue water is considerably lower (roughly half of what is exported) indicating that South Africa is currently not reliant on virtual water. Furthermore, the export of blue water appears to be increasing over time.

Figure 2: Annual national blue-water import and export 2 (i) and blue-water export-associated high-production crops in South Africa 2 (ii)



Maize is one of the most exported crops from South Africa and thus accounts for a considerable proportion of virtual-water export. The majority of maize is exported to other Southern African Development Community (SADC) countries and, as seen in an analysis of virtual-water trade among the member countries (adopting the production-specific definition where the virtual-water content of maize in each trading country is used), results in a net saving of water (Dabrowski et al. 2009). This is because South Africa has the lowest total virtual-water content for maize production and exports high quantities of maize to countries that produce maize with a higher virtual-water content. Within the SADC context, this would appear to be an efficient use of water; an example that highlights the importance of considering green and blue contributions to virtual-water content.

A reanalysis of the SADC trade of maize, taking blue and green water into account, reveals a different picture: the blue-water content of maize production in the majority of SADC countries is very low because there is generally sufficient rainfall to meet the water requirements for maize. Due to the relatively lower rainfall in South Africa the blue-water content of maize is high. Consequently, as South Africa is the main exporter of maize, exporting to countries that have a lower blue-water content, this results in a net loss of blue water within the SADC trade, with the heaviest impact on one of the most water-scarce countries in the region.

3. VIRTUAL WATER IN CONTEXT

3.1 SUSTAINABLE DEVELOPMENT

The Policy on Resource Directed Management of Water Quality (DWAF 2006) describes six enabling principles of sustainable development:

- protection of water resources
- optimal water use
- equity between generations
- current equitable access
- environmental integration
- good governance.

The principle of optimal water use, or choosing the "best alternative use", is in turn enabled by a series of principles, one of which is virtual-water use. This puts virtual-water use explicitly in the context of sustainable development. The virtual-water concept provides one of a number of approaches to ensure that water is indeed used in the most appropriate way in the public interest. It is also entirely consistent with the principles of integrated water-resource management.

Protection of water resources is also an issue that may affect decisions relating to optimal water use. For example, the best alternative use for water in a particular area may be by the associated aquatic ecosystems, in so doing maintaining their integrity. A degree of "protection" from potential anthropogenic impacts may be required to achieve this. The virtual-water concept can therefore also be directly related to the protection of water resources.

3.2 SOCIO-ECONOMIC CONSIDERATIONS

3.2.1 FOOD SECURITY

As the Earth's natural resources come under ever-increasing stress it is important to identify ways in which scarce resources can be protected or used more efficiently. Water is unevenly distributed over the globe and many countries are water scarce. National food security is a vital goal for every country and agriculture is the largest single user of liquid freshwater worldwide (Qadir et al. 2003). These two reasons have inevitably been important contributors to the emphasis that has been placed on the virtual-water concept and crop production in the literature.

Food security has often been interpreted as requiring self-sufficiency in food production (WWC 2004). This creates a sense of national security by minimising reliance on other countries to satisfy food requirements. However, in an effort to achieve this, many countries have used water unsustainably and have literally run out of the resource (e.g. Israel, Libya and Jordan).

Food security can be defined as "access by all people at all times to enough food for an active, healthy life" (World Bank 1986) and can be met through importing the bulk of food requirements from other countries, provided that the country is capable of doing so. In this regard the "social adaptive capacity" of a country is vital to alleviate water scarcity and provide food security through virtual-water trading.

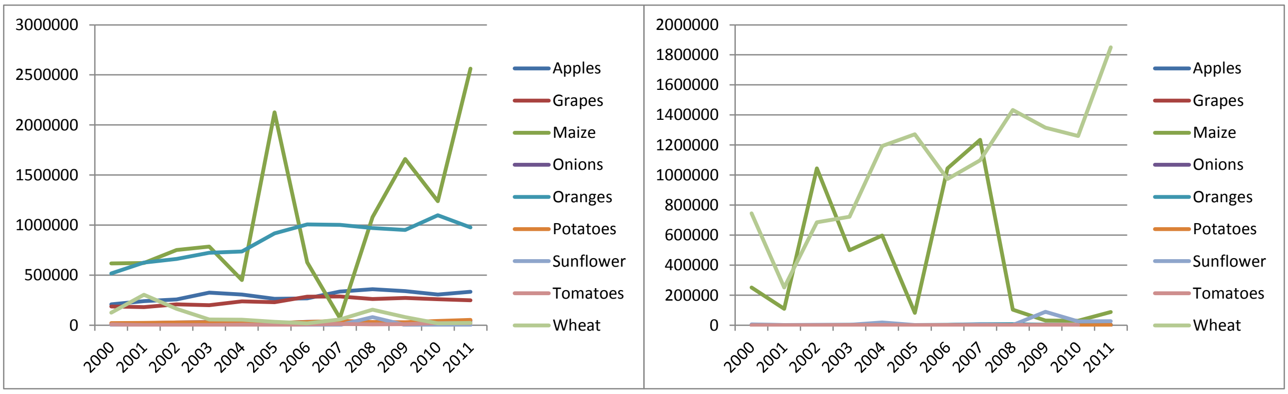
3.2.2 SOCIAL ADAPTIVE CAPACITY

A consideration of the virtual-water concept may ultimately lead to a change in policy to import more food. Indeed, this may be inevitable in those countries where water has become so scarce that local crop production is no longer viable. As obvious as this may sound, it can only be successful under certain conditions. Specifically, the country must have a social adaptive capacity (Earle 2001) that is the sum of second-order social, economic and political resources available to respond or adapt to the changes imposed by the policy. This social adaptive capacity would involve (a) less local crop production and (b) increased reliance on the importing countries and alternative productive use of the water to generate income to pay for imported food. Within an agricultural context this would imply that a country might increasingly export high-value commodities and, at the same time, increasingly import low-value commodities.

To some extent South Africa shows signs of exhibiting social adaptive capacity to meet its food requirements. For example, while oranges form the bulk of blue-water exports they are a high-value crop in comparison to wheat. Oranges have been increasingly exported over the last 10 years (Figure 3 (i)) while wheat has been increasingly imported over the same time period (Figure 3 (ii)). However, maize production and export to countries better suited to maize production continues to significantly increase the export of blue water from the country.

Figure 3: Export (i) and import (ii) of high-production crops produced in South Africa

(i) (ii)



The Bottom Line: Reducing local agricultural productivity to adapt to a virtual-water policy will result in a loss of income and jobs in the sector. To compensate for this, the country's economy needs to be sufficiently diversified. It needs to be able to break away from its dependence on the scarce resource and move from productive efficiency to allocative efficiency (Earle 2001). This is entirely consistent with the principle of optimal water use and is an important enabling principle of sustainable development in a water-scarce country like South Africa. Equivalently, opportunity costs for each potential water use must be identified and carefully considered so that water is used in a way that will generate the greatest income or socio-economic benefit.

It has been noted, accordingly, that "the import of virtual water via imported food and export of other commodities requiring less water will remain a valid concern for water-short nations seeking to maximise the value of their limited resources" (Qadir et al. 2003).

In the context of South Africa, mining is seen as an important contributor to development, economy and job creation. Policies could thus potentially see a shift to maximising the value of water through reduced agriculture and increased mining productivity. However, as in the case of the upper Olifants River catchment where coal mining is prolific, reliance on this sector could significantly impact on water quality (grey water, i.e. high salinity and generation of acid mine drainage in extreme cases). Any shift in saving blue water by importing crops through income generated by increased mining output needs to be weighed up against the impact of this policy on water quality (i.e. the grey-water footprint). The virtual-water and water-footprint concepts, therefore, emphasise that impacts on freshwater systems are ultimately linked to human consumption and that issues of pollution and water scarcity can be better understood by considering the production chain as a whole (i.e. water use in the mining industry is a function of water quantity and water quality).

The concept of virtual water only considers the crop and the water (and water quality) that it needs. However, as noted above, a number of socio-economic and political components must also be considered. As noted by Wichelns (2004): "The virtual water metaphor, while not a sufficient criterion for determining optimal strategies, still serves an important role in gaining the attention of public officials. Once that is accomplished, the discourse can be extended to include consideration of opportunity costs and comparative advantages, as strategies are determined and policies are selected." Specifically, policy makers are encouraged to evaluate the relative scarcity of key resources in the context of national goals (Wichelns 2001).

3.2.3 DANGERS OF THE COUNTRY-CENTRIC APPROACH

The danger of adopting the above consumption-site-specific definition for virtual water (Chapagain & Hoekstra 2004) is that this purely country-centric focus takes no direct account of the costs (being either direct or indirect) of production on the exporting country, such as on the environment. For example, the impact on water resources in the exporting country may not be a primary concern of the importing country. As noted by Chapagain et al. (2006), national policy makers are not usually interested in global or regional water savings but rather in the status of national water resources.

In reality, this is mitigated in at least two possible ways:

- High direct production costs would typically be passed on to the importing country. However, it would require the exporting country to take explicit account of environmental costs, such as water use. Many products are put on the world market at a price that does not properly include the cost of the water contained in the product (Hoekstra & Hung 2005). Addressing this may require some degree of economic sophistication in the exporting country. There still remains an urgent need to develop appropriate concepts and tools to do so (Hoekstra & Hung 2005).
- The importing country could adopt a responsible attitude to environmental impact in the exporting country by insisting on appropriate environmental management in the exporting country. This attitude is adopted by the European Union (EU), for example.

It is only in these ways that virtual-water trading can truly hope to lead to global water savings. However, it is evident from this analysis that importers could potentially benefit (either knowingly, because they have low environmental morals, or unknowingly) at the expense of less sophisticated exporters. Chapagain et al. (2006) have noted in respect of cotton that with the general lack of proper water-pricing mechanisms or other ways of transmitting production information, cotton consumers have little incentive to take responsibility for the impact on remote water systems.

4. FURTHER RESEARCH

Further research should be carried out on the natural, social, economic, environmental and political implications of using virtual-water trade as a national strategic instrument in water policy. This includes an analysis of the geo-political importance of virtual water, the opportunities and threats involved and the associated political processes underlying decision-making on application of this concept.

Furthermore, common, harmonised procedures of estimating virtual-water content and virtual-water accounting should be developed and disseminated, enabling accurate and unbiased estimates of virtual-water flows between countries. For example, a study by the Council for Scientific and Industrial Research (CSIR) published virtual-water content values for crops that were significantly lower than internationally published values (Dabrowski et al. 2008).

Significant progress has been made with the production of the Water Footprint Manual (Hoekstra et al. 2009) and blue-, green-and grey-water footprints have been developed for all countries worldwide. The validity of these values, however, needs to be verified through country-specific studies.

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