How much water do we really use? A case study of the city state of Singapore

D. Vanham

ABSTRACT

The observed and predicted increase in urban population in the world is creating and will further create severe stress on existing water infrastructures and available water resources. Singapore’s population has increased from about 1 million people in the 1950s to almost 5 million currently. The city state has invested massively in a sustainable water supply system, and is regarded by many as a role model for future cities with respect to this topic. Solutions like water reuse, desalination and water demand management have already been implemented. However, city dwellers use much more additional water in the form of virtual water. Their actual water footprint is much higher than only domestic water. Water required for the generation of agricultural and industrial products are imported to cities, and can put a heavy burden on water resources in surrounding and even distant (rural) regions. The city state provides a unique opportunity to analyse virtual water consumption for a city, as required statistical data are available through the national Department of Statistics. For other cities such detailed data are rarely available. Mostly these data are only provided on a national level. This analysis provides a quantification of the actual water use of a future city. The paper describes whether the consumption of agricultural products (in the sense of water for food) is also sustainable in Singapore. The agricultural products that contribute largely to the total water footprint of Singapore – wheat, rice, livestock products and cotton– are analysed and discussed in detail.

A sustainable city of the future should account for its impacts beyond its borders. Whether the world can provide for the water and food for an increasing population highly depends on consumption patterns within future cities.

Key words | cities of the future, Singapore, sustainability, virtual water, water for food, water footprint

INTRODUCTION

By 2050 the world population is expected to increase from currently about 6.5 billion to between 8 (low growth) and 10.5 (high growth) billion people (UN 2011). The relative percentage of urban and rural population will respectively increase and decrease. Typically urban dwellers have a different – more water intensive – consumption behaviour as people in rural areas. Cities throughout the world with their increasing populations are affecting river basins by importing blue water for industrial products and blue (irrigation) and green (rainfed) water for food production (Vanham 2010). On the other hand farmland is disappearing as a result of the shortage of water, climate change, soil desolation and urbanization. Whether the world has enough water resources to provide a growing population with water, food and commodities in a sustainable way, is a key question.

This paper discusses the sustainability of the virtual water import related to the trade in agricultural (crop and livestock) and industrial products in the city state of Singapore. The direct blue water supply and consumption (water used directly from rivers and aquifers for drinking, washing, …) of the city state is compared with the net virtual water.
water consumption through agricultural products (crops and livestock products) as well as industrial products. Particular agricultural products that contribute largely to the total net virtual water consumption of the city state are discussed in detail: wheat, rice, livestock products (meat and eggs) and cotton. The virtual water associated with the consumption of these products is calculated by means of statistical data (data on consumption of main food products in Singapore from FAOSTAT and other sources) and data from the literature (virtual water content of these products). In this way the direct and virtual water consumption behaviour of the Singaporean citizen is quantified and discussed.

Singapore is by many regarded as a role model with respect to its water supply system for future cities (Tortajada 2006). The city state has invested and still is investing massively in a sustainable self-sufficient water supply system, aiming to be independent of current water import from Malaysia. Sustainable water use in this paper is defined as the use of water that supports the ability of human society to endure and flourish into the indefinite future without undermining the integrity of the hydrological cycle or the ecological systems that depend on it; a definition stated by Gleick (1998). Singapore’s Public Utilities Board (PUB) – which manages Singapore’s water supply, water catchment and used water – has won several prizes for the sustainable water management practices applied in the city state, e.g. the 2007 Stockholm Industry Water Award and the ‘Environmental Contribution of the Year’ at the Global Water Awards 2008. However, whether its virtual water consumption is sustainable is another question. The city state of Singapore provides a unique possibility to analyse virtual water consumption of a city, as its national Department of Statistics as well as other international institutions (e.g. the Food and Agricultural Organisation of the United Nations – FAO) provide for the required data to make this analysis. Basically these data are only available on the national level. A detailed virtual water analysis of other cities is normally not possible, although other similar examples include Hong Kong (Chau 1993; Chen 2001) or the small island of Mauritius (Ramjeawon 1994). This paper presents Singapore’s virtual water demands and their source regions, as well as the implications for these source regions for the most important products, like rice, wheat, cotton and livestock products.

The concept of virtual water – the amount of water used to produce a certain good – was first introduced by Allan (1998). He concluded that water conflicts in Middle Eastern countries – with their limited water resources – were limited as they import food grown with other countries’ water. Dutch scientist A. Hoekstra and colleagues developed the concept of water footprint. They calculated the virtual water in commodities (the ratio of the total volume of water used (m$^3$/yr) to the quantity of the production (ton/yr)) as a tool for water management and to give countries, companies, and individuals a clearer measure of their water footprint. Since then virtual water flows between countries and regions have been analysed by different authors, e.g., (Oki & Kanae 2004; Hoekstra & Hung 2005; Kumar & Singh 2005; Verma et al. 2009). The water footprint has three components: the green water footprint (volume of rainwater evaporated or incorporated into products), blue water footprint (volume of surface or groundwater evaporated, incorporated into product or returned to other catchments or the sea) and the grey water footprint (volume of water needed to dilute loads to such extend they reach certain water quality standards). Most studies on the calculation of water footprints of products have taken the two evaporative components only (i.e. green and blue water footprint), excluding the grey water footprint. In (Hoekstra & Chapagain 2007) the grey water footprint is included.

**METHODOLOGY**

The methodology of this paper is a combination of a literature review and statistical data analysis. An overview on used data sources is given in Table 1. Data on direct blue water supply and consumption in Singapore are obtained from PUB and the Singapore Department of Statistics, through their websites (PUB 2009; Singapore Department of Statistics 2010) and publications (Singapore Department of Statistics 2009). As reference year 2008 was chosen, as this year presented the most recent data at the time of writing of this paper.

An actual virtual water flow or water footprint analysis by means of modelling/calculation (which is the common procedure) is not made. Singapore’s net virtual
water import values for crop, livestock and industrial products are obtained from the publication (Hoekstra & Chapagain 2007). The latter is the only literature source where these data are provided. The reference period for these values is 1997–2001 (one average value for this period). Per capita consumption of main food products is analysed based on yearly data from 1997–2008 obtained from different sources (Table 2). The period 1997–2008 was chosen as it includes 1997–2001 as in (Hoekstra & Chapagain 2007) as well as the years up to the most recent data. For detailed descriptions on the net virtual water import of the important products wheat, rice and cotton, net import statistics (in tonnes) from (FAOSTAT 2010) as well as data on the virtual water content (m$^3$/tonne) and specified literature on rice (Chapagain & Hoekstra 2010) and cotton (Chapagain et al. 2006) were used. To analyse how much these products contribute to the total net virtual water import for crop products during 1997–2001 (Hoekstra & Chapagain 2007), the year 2001 was chosen for the analysis (wheat and cotton). For rice a different period is presented (2000–2004) as a specific publication (Chapagain & Hoekstra 2010) is available. It is clear that the use of different reference periods is a simplification which can include different values. But generally the per capita consumption of the different main agricultural products did not fluctuate excessively during the last decade (see Figure 3), which makes this methodology acceptable.

### Table 1 | Data sources used within the paper

<table>
<thead>
<tr>
<th>Data</th>
<th>Period</th>
<th>Data source</th>
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<tbody>
<tr>
<td>Water supply and consumption data</td>
<td>2008</td>
<td>(PUB 2009; Singapore Department of Statistics 2009, 2010)</td>
</tr>
<tr>
<td>Net virtual water import for crop, livestock and industrial products</td>
<td>1997–2001 average value</td>
<td>(Hoekstra &amp; Chapagain 2007)</td>
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<tr>
<td>Per capita consumption of main food products</td>
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<tr>
<td>Net import of agricultural products to Singapore (with indicating exporting country), and resulting net virtual water import</td>
<td></td>
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<tr>
<td>Wheat</td>
<td>2001</td>
<td>(FAOSTAT 2010) for import product, additionally (Hoekstra &amp; Chapagain 2007) for virtual water content of product</td>
</tr>
<tr>
<td>Cotton</td>
<td>1997–2001 average value</td>
<td>(Chapagain et al. 2006) for virtual water import</td>
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### Table 2 | Total and per capita real water use and virtual water import

<table>
<thead>
<tr>
<th></th>
<th>Total $(10^6 \text{m}^3/\text{yr})$</th>
<th>Per capita (l/person/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total water supply 2008</td>
<td>550</td>
<td>311</td>
</tr>
<tr>
<td>Domestic water use 2008</td>
<td>271</td>
<td>153</td>
</tr>
<tr>
<td>Total net virtual water import 1997–2001</td>
<td>11,781</td>
<td>8,069</td>
</tr>
<tr>
<td>Net virtual water import 1997–2001 related to crop products</td>
<td>2,386</td>
<td>1,634</td>
</tr>
<tr>
<td>Net virtual water import 1997–2001 related to livestock products</td>
<td>1,461</td>
<td>1,000</td>
</tr>
<tr>
<td>Net virtual water import 1997–2001 related to industrial products</td>
<td>7,934</td>
<td>5,435</td>
</tr>
</tbody>
</table>
WATER SUPPLY SYSTEM AND VIRTUAL WATER FLOWS OF SINGAPORE

Singapore’s population increased five fold during the last 6 decades (Figure 1), and its population was estimated at 4.84 million (6,814 persons per km²) in 2008 (Singapore Department of Statistics 2009). Massive investments were made in a sustainable water supply system, with water provided by the Four National Taps: water from local catchments, imported water from Malaysia, NEWater (brand name of recycled wastewater) and desalinated water. The total yearly water supply in 2008 was 550 million m³ (Figure 2, Table 2). Of this amount about half (271 million m³ or 1531 per capita per day) is for domestic purposes. The remaining water is used by the commercial and industrial sector (non-domestic use and industrial water). Singapore aims at being self-sufficient in its water supply by effective measures like water recycling (NEWater), desalinization, water conservation and the promotion of the use of water-efficient household appliances and water saving devices (water demand management measures). Currently water is still imported from Malaysia (about 40% of water supply). Water from local catchments accounts for about 20%, NEWater about 30% and desalinated water about 10% of water supply. By 2060, PUB plans to increase the current NEWater capacity so that NEWater can meet 50% of future water demand (PUB 2009). PUB also intends to ramp up desalination capacity so that desalinated water will meet at least 30% of Singapore’s water demand in the long term. The remaining 20% will come from local catchments, making Singapore 100% self-sufficient.

However, of a land area of 710.2 km², about 1% is used for agricultural purposes. The city is by no means self-sufficient in its food production. Also its industrial activities do not self provide the city with the goods it consumes. At
the beginning of this century (1997–2001), Singapore already imported more than 20 times the amount of its current direct blue water supply (550 million m³) as virtual water (11,781 million m³) (Figure 2, Table 2). It indirectly uses water from—partly (severely) water stressed—river basins throughout the world. For crop products 2,586 million m³ of virtual water (about 1,700 l per capita per day) was net imported, for livestock products 1,461 million m³ (about 1,000 l per capita per day) and for industrial products 7,934 million m³ (5,434 l per capita per day). This total net virtual water import equals more than 8,000 l per capita per day, a huge amount compared to the domestic water requirement of 153 l per capita per day.

VIRTUAL WATER CONSUMPTION IN SINGAPORE

Agricultural products: crops and livestock products

Per capita yearly consumption in Singapore of the main food products for the period 1997–2008 is shown in Figure 3. As in most Asian countries the diet is dominated by rice and vegetables. Chicken is the main source of animal proteins, followed by fish and pork. The last years the consumption of fish is steadily decreasing, and in 2007 and 2008 more pork was consumed than fish. The total yearly per capita consumption of meat kept constant between about 60 and 70 kg. This is much higher than the world average—35.7 kg in 1995 and 41.2 kg in 2005— but less than most other developed countries (FAO 2009).

The virtual water content of agricultural products has been calculated by (Hoekstra & Chapagain 2007). It has to be stressed that these values are not absolute values, but fluctuating ones according to its source region and production methods. In general, livestock products have a higher virtual water content than crop products. This is because a live animal consumes a large amount of feed crops, drinking water, and service water in its lifetime before its meat, eggs or milk is consumed. Therefore, a daily vegetarian diet with adequate calories intake requires about 2,000 l per person, whereas a livestock products based diet requires up to 5,000 l per person (Renault & Wallender 2000). With increasing income, generally a diet shift towards more animal proteins is observed (Keyzer et al. 2005). A healthy diet is by different authors defined as a daily intake of 3,000 kcal per person with a 20% animal protein share (SIWI et al. 2005; Rockström et al. 2007; Rost et al. 2009). In Singapore the daily per capita consumption of rice (384 kcal/100g) and wheat (375 kcal/100g) contributed during the last decade about 40 to 50% of this recommended value. On a world average the animal protein share is already higher (26% in 1995 and 28% in 2005) (FAO 2009) than the recommended 20%. The average animal protein share in developed countries was 48% in 2005. For Singapore this value was about 50%. Global average virtual water contents of some main agricultural products are (in m³/ton or l/kg) (Hoekstra & Chapagain 2007): 3,400 for white rice; 1,300 for wheat; 3,900 for chicken meat; 4,850 for pork; 15,500 for beef.

The total net import of wheat to Singapore in the year 2001 was 146,803 tonnes (import 160,086; export 13,283 tonnes) (Figure 4). Additionally the total net import of flour from wheat to Singapore in the year 2001 was 69,225 tonnes (import 110,907; export 41,682 tonnes). The per capita consumption in that year of wheat was 35 kg and of flour of wheat 17 kg. Of the total wheat import (160,086 tonnes) almost 100% originated from only three countries: Australia, the USA and Canada. By far the largest amount (60%) originated from Australia. This total wheat import (without flour of wheat) represents a virtual water import of 214 million m³. A disproportionally large virtual water

![Figure 3](https://iwaponline.com/ws/article-pdf/11/2/219/416467/219.pdf)
amount comes from Australia (154 million m³ for 96,763 tonnes) as compared with the USA (42 million m³ for 49,325 tonnes). For about double the amount of wheat imported, about four times as much virtual water is imported. This is due to the fact that the virtual water content of wheat in Australia is on average 1,588 m³ per ton (or l per kg) whereas in the USA this is 849 m³ per ton. In other words, it requires two times as much water on average in Australia compared to the USA to produce the same amount of wheat, due to differences in climate (crop water requirement for the period 1997–2001 in mm/growing period: 309 for Australia and 237 for the USA) and production techniques and natural settings (wheat yield in ton/ha: 1.9 for Australia and 2.8 for the USA (Hoekstra & Chapagain 2007)). There are of course regional differences within the countries themselves. For the production of Australian wheat for Singapore a projected area of about 50,000 ha per year was required, in the USA about 18,000 ha. The net virtual water flow for wheat thus shows that primarily Australian water resources are imported. Australia however has experienced successive droughts the last decade and water in the Murray-Darling basin has been depleted due to agriculture.

The net yearly virtual water import related to rice to Singapore was 614 million m³ for the period 2000 to 2004 (Chapagain & Hoekstra 2010). About 200 million m³ of this amount originates from irrigated agriculture (blue water). Most of the rice imported to Singapore during this period originates from Thailand (number six of the world’s largest rice producing countries during the period 2000–2004) (Figure 5), a country where the virtual water content for rice is high (1,617 m³ per ton or l per kg) (Chapagain & Hoekstra 2010). Additionally, the percolation per unit of paddy rice produced in Thailand is 1,253 m³ per ton. The average yield in this country is 2.7 ton per ha, which is comparable with the second largest rice producing country in

Figure 4 | Largest net virtual water flows for wheat (for the year 2001) to Singapore (not including the imports as flour). The areas in grey display the agricultural areas in the world (both rainfed and irrigated). Data source: (FAOSTAT 2010).

Figure 5 | Most important contributors to the total rice import (in tonnes) to Singapore. Data source (FAOSTAT 2010).
the world (India, 2.9 ton per ha) but much less than the first producing country (China, 6.2 ton per ha). Roughly 1/100th of the total yearly rice production in Thailand was imported by Singapore to feed its total population with rice. As much of the rice cultivation in Thailand is done during the rainy season, the share of green water is substantial. For Pakistan e.g., on the other hand, the share of blue water in its rice production is dominant. Wheat and rice account for about 35–40% of the total net virtual water imports for 1997–2001 related to crop products (2,386 million m³/yr) in Singapore.

Of a total net virtual water import related to livestock products of 1,461 million m³ per year (Figure 2), meat consumption (60–70 kg, predominately chicken and pork) in Singapore represents about 1,000 million m³ (about 70%). About 150 million m³ per year relate to the consumption of eggs (with approx. 300 eggs per capita per year consumed (AVA 2010)) and about 100 million m³ per year relate to the consumption of milk (with about 20 l per capita per year consumed (FAO 2009)). In East and South-East Asian countries per capita milk consumption is only about 1/10th as compared with European countries.

**Industrial products**

There are numerous categories of industrial products with a diverse range of production methods, and detailed standardized national statistics related to the production and consumption of industrial products are hard to find (Hoekstra & Chapagain 2007). The value of net virtual water import for Singapore as displayed in Figure 2, has been calculated by means of an average virtual water content per dollar added value in the industrial sector (m³/US$) (the ratio of the industrial water withdrawal in Singapore to the total added value of the industrial sector (US$/yr)). This is of course a simplification. The global average virtual water content of industrial products is 80 l per US$/yr. In the USA, industrial products take nearly 100 l/US$. In Germany and the Netherlands this value is about 50 l/US$. Industrial products from Japan, Australia and Canada take only 10–15 l/US$. In 2008 the added value of industrial production in Singapore was about 48 billion US$ (Singapore Department of Statistics 2010), of which 25% comes from the industry ‘electronic products and components’. The commercial and industrial sector use is about 200 million m³/yr (Figure 2), resulting in a virtual water content of industrial products of about 3 l/US$ for Singapore. This is a high water productive value. However, the imports of industrial products with much higher virtual water contents from different countries results in a net virtual water import of 7,934 million m³/yr. This high value can partly be explained by the import of construction material (steel, glass…) for the booming construction activities in the city state. A detailed analysis of which industrial products contain how much water is not part of this paper.

One product of which the water footprint is discussed is cotton, due to its high value. Cotton is a crop product, but it can also be partly seen as an industrial product (when it has been processed to e.g. clothing). The water footprint related to the consumption of cotton products in Singapore is 1,974 million m³/yr for the period 1997–2001 (Chapagain et al. 2006). This value presents the internal consumption of cotton in all its forms within the production process. Processed cotton products for export have already been subtracted from this value. Cotton has a very high virtual water content—the global average is 8,200 m³/ton for cotton lint. The global average water footprint for cotton products is 43 m³/yr per capita. An average US citizen has a cotton products related water footprint of 135 m³/yr. For the city state of Singapore this value is about 450–500 m³/yr (or 450,000–500,000 l/yr). Average global virtual water contents of selected cotton-based consumer products are 10,850 l for a pair of jeans, 9,750 l for a single bed sheet, 2,720 l for a t-shirt or 810 l for a diaper (Chapagain et al. 2006). This high value can be related to a typical urban consumption behaviour in a developed country. For this reason the city state of Singapore presents a unique example, as (virtual) water consumption related to cotton products in a highly developed city proves to be enormous. This is also due to the fact that large fractions of its cotton products are imported from India, a country where the virtual water content of cotton is very high (i.e. 8,662 m³/ton for seed cotton or 20,217 m³/ton for lint cotton).

**VIRTUAL WATER AND RESPONSIBLE CONSUMPTION**

Different authors analysed virtual water flows or virtual water transfers between countries and also regions. Some authors,
e.g., (Oki & Kanae 2004; Hoekstra & Chapagain 2007), indicate the management of virtual water flows or virtual water trade as a tool to address national and regional water scarcity. Indeed, there are opportunities for trading agricultural products from water abundant and highly productive areas to water-short areas. The concept states that water rich countries should produce and export water intensive commodities to water scarce countries, thereby enabling the water scarce countries to divert their precious water resources to alternative, higher value uses. Like the example of Middle Eastern countries (Allan 1998) as discussed in the introduction. This paper e.g., showed that the wheat import to Singapore from Australia requires much more water per unit of wheat (due to its lower productivity) than the import from the USA. A first estimate of the global water saving resulting from international trade between countries with differences in water productivity was made by (Oki & Kanae 2004). They considered international trade in five major crops (rice, wheat, maize, barley and soybean) and three types of meat (chicken, pork, beef) in the year 2000. They estimated that the countries exporting these commodities used 683 billion m$^3$ of water for producing them. The importing countries would have required 1,138 billion m$^3$ of water to produce the same volume of commodities within their own borders. This implies a global saving of 455 billion m$^3$ of water as a result of food trade. This study has however some technical limitations (Hoekstra & Chapagain 2007). (Hoekstra & Chapagain 2007) calculated a global water saving by trade in agricultural products of 350 billion m$^3$, which equals 5% of global water use in agriculture. In other words, physically seen it is attractive and recommendable to import products from water-efficient regions to water deficient and water-inefficient regions, and also to prefer the import from water-efficient regions over the import from water-inefficient regions.

However, there are some downsides of virtual water trade as a solution to water scarcity (Hoekstra & Chapagain 2007; Warner & Johnson 2007; Verma et al. 2009). Factors which need to be included with respect to this topic are, amongst others:

- **The availability of crop land.**
- **The risk of moving away from food self-sufficiency.**

Related to this the need to generate sufficient foreign exchange to import food which otherwise would be produced domestically and the risk of reduced access of food for the poor.

- **The livelihood of farmers and people working in the agricultural sector.** Thereby economic decline and worsening of land management in rural areas, as well as a related risk of increased urbanisation.

Still, virtual water is an important topic that can help inform public policy. If it were ever extended to consumer labelling, it could significantly increase consumer awareness and change buying and consumption behaviour. Labelling will however give no indication on local environmental, economic and local impacts. Labelling could however be extended with local water availability information (e.g. availability per capita), i.e., a water impact assessment can draw some conclusions about sustainability of water usage. The example of Singapore showed that for certain commodities consumed by the urban dwellers of the city state, more awareness is advisable due to their significant virtual water content. An example is cotton and its derived products. But also livestock products: the animal protein (meat, eggs, milk, fish) share of the Singaporean diet is definitely higher than recommended (20%) for a healthy diet of 3,000 kcal, as discussed before. The total net virtual water import related to livestock consumption equals 1,461 million m$^3$ per year. A reduction in the consumption of animal products would definitely imply less virtual water consumed and imported.

**CONCLUSIONS**

Singapore provides the unique possibility to analyse the virtual water consumption of a modern city, as the data required for such an analysis are generally only available at the national level. Despite Singapore’s achievements in developing towards self-sufficiency in domestic water consumption, it still imports water via food and industrial products (this net import equals about 20 times the amount of its current total blue water supply). In other words, Singapore indirectly relies on overseas water resources.

In this paper some of the major products related to net virtual water import to the city state are discussed. Important crop products include wheat and rice, which account for about 35–40% of the total net virtual water imports for
1997–2001 related to crop products (2,386 million m³/yr). Meat consumption (predominately chicken and pork) represents about 1,000 million m³ (about 70%) of a total net virtual water import related to livestock products of 1,461 million m³ per year. The animal protein share of the Singaporean diet is definitely higher than recommended (20%) for a healthy diet of 3,000 kcal. Huge imports relate to cotton and its derived products, resulting in a cotton products related water footprint of 450–500 m³/yr per capita. The global average is 43 m³/yr per capita. This high value can be related to typical urban consumption behaviour in a developed country. In 2008 the per capita domestic water use was 153 l/day and the total per capita blue water use was 311 l/day. These amounts are very small compared with the net per capita virtual water import (1997–2001) related to crop products (1,634 l/day), livestock products (1,000 l/day) and industrial products (5,435 l/day). The daily per capita domestic use of 153 l accounts for only 1/17th of the daily per capita virtual water import related to agricultural products (2,634 l) and for only 1/53th of the total daily per capita virtual water import (8,069 l).

In other words, although the water supply system of Singapore is regarded by many as a role model for future cities, the virtual water consumption of the average citizen within the city state is not sustainable. The concept of virtual water is an important topic for which awareness needs to be created, in order to influence public policy and increase consumer awareness to change buying and consumption behaviour.

The total world urban population as well as its relative proportion to total population will increase substantially in future. The consumption behaviour of the modern city dweller will therefore be determining whether future global food production will be sustainable or not. Sustainable food production requires the limitation of cropland expansion, the maintenance of ecological flows, the preservation of existing forests and ecosystems as well as addressing rural and urban poverty. The analysis of the real and virtual water use of Singapore is important within the framework of this global challenge. The efforts the city state made and still makes to invest in a sustainable urban water supply sector are very important and should be transferred to other cities. Global food production also needs to invest in sustainable practices, like e.g., discussed in (Vanham 2010). But consumption behaviour also has a determining influence. As responsible global citizens, every individual's commitment counts towards protecting common global environmental resources, particularly water.

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