The Implications of the "Virtual[i] Water Trade"[ii] and Virtual Environmental Degradation Trade for the São Francisco River Basin in Brazil[iii]

As Implicações do 'Comércio Virtual de Água' e de Degradação Ambiental para a Bacia Hidrogáfica do Rio São Francisco

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Abstract

Food production has an enormous impact on natural systems in both hydrological and ecological ways. In 2000, agriculture accounted for 67% of the total freshwater withdrawal in the world (UNEP, 2002). For the period of 1998-2002, that figure was 62% for Brazil (FAO, 2005). Water used in the production process of an agricultural or industrial good is 'virtual water' contained in the product. The 'virtual water' flow between nations is usually accompanied by a virtual environmental degradation current. Nations are exchanging surface and groundwater depletion, water pollution, soil erosion, and other negative externalities, which result from crop production. Such commerce involves trade-offs and unaccounted and unpaid environmental costs. Brazil has historically played the role of exporter of primary products, and consequently exports 'virtual water' to world food markets. The exportation of agricultural products causes a net transference of freshwater resources among regions and nations. I employ Hoekstra and Hung (2002)'s method to estimate the virtual water exported by the Rio São Francisco (SF) River Basin through grapes and mangos. What are the implications for semi-arid regions such as the Brazilian Northeast, which have chronically suffered from water shortage? What are other environmental consequences? This research analyzes the hydrological and ecological implications for local and regional systems resulting from selected primary sector activity taking into account virtual water transference and provides recommendations on more sustainable practices to reduce the loss of water and the environmental degradation of that river basin environment.

Keywords: Non-traditional agro-exports. 'Virtual water trade.' Virtual environmental degradation trade. Irrigation. Fruit production.

Resumo

A produção de alimentos causa impactos ao meio ambiente de forma hidrológica e ecológica. Em 2000, 67% da água doce retirada dos mananciais do planeta foram destinados à agricultura (UNEP, 2002). No período compreendido entre 1998 e 2002, o percentual foi de 62% para o Brasil (FAO, 2005). A água utilizada no processo de produção de um artigo agrícola ou industrial é denominada 'água virtual'. O fluxo de 'água virtual' entre as nações é usualmente acompanhado por uma corrente virtual de degradação ambiental. Países estão trocando depreciação de mananciais, poluição das águas, erosão dos solos e outras externalidades resultantes da produção agrícola. O comércio resulta em *trade-off* e custos ambientais não pagos. Historicamente, o Brasil tem sido um grande exportador de produtos primários, e conseqüentemente exporta 'água virtual' para o mercado mundial. A exportação de produtos agrícolas causa a transferência de água entre regiões e nações. Este artigo utiliza o método descrito em Hoekstra e Hung (2002) para estimar a quantidade de água exportada pela bacia hidrográfica do rio São Francisco, através do comércio internacional de uvas e mangas, e analisa as implicações para as regiões semiáridas, como o nordeste brasileiro, onde a água é um recurso escasso. O corrente artigo também investiga as implicações hidrológicas e ambientais para os ecossistemas locais e regionais procedentes do setor de produção agrícola, com ênfase na transferência de 'água virtual', e recomenda práticas mais sustentáveis que possam reduzir a perda de recursos hídricos, e a degradação ambiental da bacia hidrográfica do rio São Francisco.

Palavras-chave: Exportação de produtos agrícolas não tradicionais. 'Comércio virtual de água'. Comércio virtual de degradação ambiental. Irrigação. Fruticultura.

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1 Introduction

A hidden dynamic occurs when a country or region exports an agricultural product: water is lost and environmental degradation is usually gained. Still, world food supply and demand do not match spatially across the planet, and as a consequence, food consumed in one area is often not locally grown. In some cases, the supply comes from other regions within the same country or even from other nations. The spatial organization of the food market is also dictated by other variables, such as the preference of buyers and their ability to pay; and more importantly, by the price of the product, which plays a large role in the demand for food (Cardoso and Souza 2000). Indeed, upper middle-income consumers in First World countries have developed a taste for exotic fruits having a high income-elasticity of demand (The World Bank, 2004), such as mangos.

Food production affects the natural systems in both hydrological and ecological ways. In 2000, agriculture accounted for 67% of freshwater withdrawal in the world (UNEP, 2002). For the period of 1998-2002, in Brazil, water for agriculture accounted for 62% of the total water removed from freshwater systems (FAO, 2005). The management plan for the São Francisco River Basin, approved in 2004, revealed that 69% of water withdrawal in that watershed supplies the agricultural sector (CBHSF, 2004). Irrigated agriculture is increasingly practiced: irrigated areas in Brazil grew from 490,000Ha in 1961 to 2,890,000Ha in 1999 (FAO, 2006), presenting an average annual growth rate of 4.8% for a thirty-eight year period (Figure 1 below). In the São Francisco River Basin (SFRB), in 1960, 10,800Ha were irrigated. By 1999, that number was 333,000Ha (CODEVASF, n.d.), showing an average annual growth rate of 9.2% for the thirty-nine year period which is almost twice the national annual growth rate (Figure 2 below). Another way of documenting the above average growth of irrigation in the São Francisco Valley is to note that in the early 1960's, the irrigated area in the basin accounted for 2.2% (10,800/490,000) of the total irrigated area in Brazil, but in 1999, the ratio was 11.5% (333,000/2,890,000).

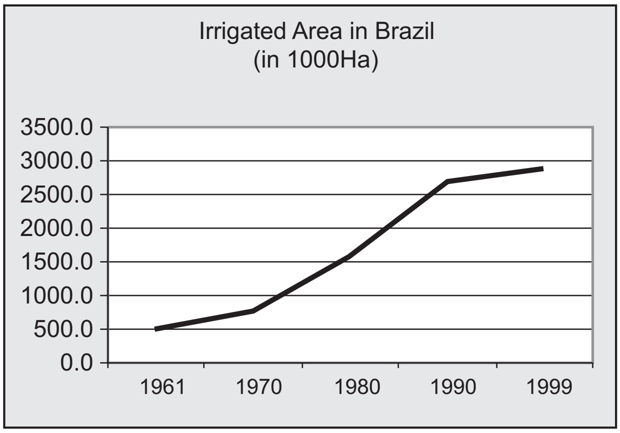


Figure 1: Irrigated Area (000Ha) in Brazil
Source: FAO, 2006
Note: Scales for Figure 1 and Figure 2 are different.

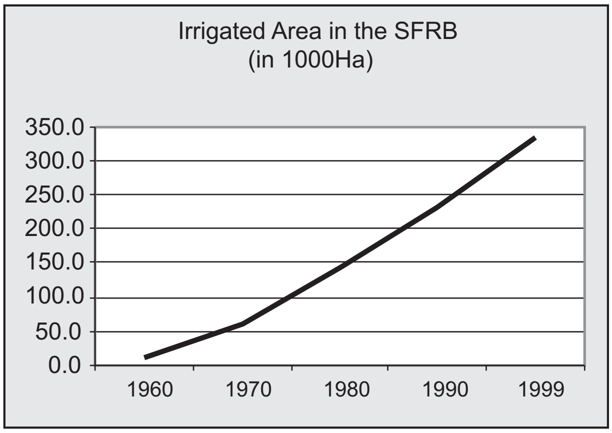


Figure 2: Irrigated Area (000Ha) in the SFRB
Source: CODEVASF, n.d.

"The water that is used in the production process of an agricultural or industrial product is called the 'virtual water' contained in the product" (Hoekstra and Hung, 2002, p.7). Tony Allan introduced the 'virtual water' concept in a seminar in 1993 (Allan, 2003; Hoekstra, n.d.; UNESCO-IHE, 2006). The 'virtual water,' and its amount of water that probably ended up being moved out of the basin (e.g., evaporated), can be described as a hidden productive cost paid by local systems. Depending on the source of the resource, such as in the case of nonrenewable aquifers (e.g., fossil water), the water could be lost by the local system forever.

It does not necessarily mean that after the productive process the 'virtual water' will be totally unavailable to local or regional systems as in the case of the real water contained in the crop exported. Some water goes away (e.g., run off to rivers and discharge into the sea), but some water stays. Local nature will recycle part of the 'virtual water' through the regional water cycle. Evapotranspiration from crops and land surfaces and subsequent precipitation, water runoff from surface and subsurface to local waterbodies, soil moisture and infiltration to local renewable aquifers, all might still make some of the resource available to local ecosystems.

As regards ecological considerations, the environmental degradation is extremely real. Agricultural practices result in the subtraction of nutrients from local and regional systems and soil depletion (FAO, 2004); as well as air, soil and water pollution from the addition of fertilizers and pesticides (Postel, 1993). For example, in the United States, the national water quality inventory, for 2000, showed that agriculture contributed with 48% of the river miles identified by USEPA as being polluted (EPA, 2003). Intensive agriculture is a major source of non-point pollution[d]. In Brazil, in a 2002 research (IBGE, 2005), based upon qualitative information provided by environmental managers for 5,560 Brazilian municipalities, 16.2% of that universe, 901 municipalities, have had water pollution resulting from agro-toxins and fertilizers use. The same study (IBGE, 2005) reported that 191(38%) out of 505 municipalities, which compose the SFRB, presented water pollution due to three major causes: domestic sewage discharge, solid residuals disposal and the use of agro-toxins and fertilizers.

As with irrigation, fertilizer consumption in Brazil has been increasing since late sixties (FAO, 2006) (Figure 3 below). It jumped from 270,004 Mt in 1961 to 7,682,000 in 2002 (FAO, 2006). In Brazil, a good correlation exists between state size of agriculture zone and the use of agro-toxins (IBGE, 2005). Fertilizers are used in intensive agriculture production, such as in fruit production poles in the Northeast of Brazil. If improperly used (e.g., in more than needed amounts), nutrients such as nitrogen percolate through the soil and contaminate groundwater (Mason, 2002). Excess of nitrate in the drinking water is detrimental for human health, for example, it is known to cause blue-baby syndrome (*methaemoglobinaemia*) in infants (Mason, 2002; CAST, 1992). Phosphorus is responsible for natural and cultural (anthropogenic) eutrophication. It stimulates algal growth and boom, and excessive macrophyte growth in surface freshwater systems (Mason, 2002; Esteves, 1998; Postel, 1993) and such primary production caused by the addition of nutrients and the subsequent process of its decomposition has multiple consequences: depletion of oxygen in waterbodies and the death of animal aquatic life; the impairment of human's uses of waterbodies, producing bad taste, odor and visual pollution; can lead to an increase in the cost of and need of water purification processes or restriction in drinking water consumption; human and environment diseases due to the boom of bacteria; and reduction of aesthetic values (Nascimento, 2003; Litke, 1999; Mason, 2002; CAST, 1992).

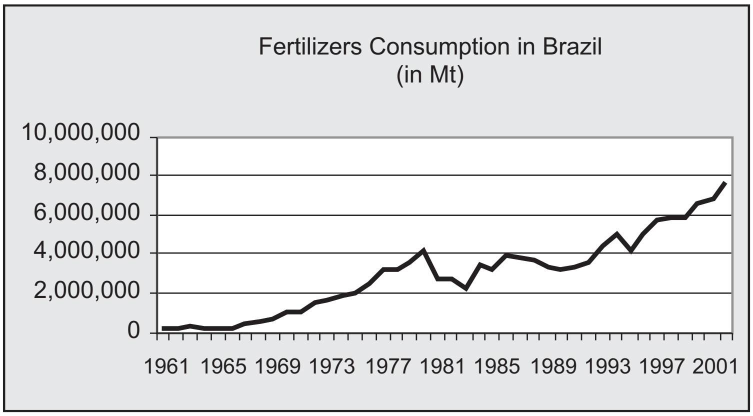


Figure 3: Fertilizers Consumption in Brazil in Mt
Source: FAO, 2006

Another environmental concern regarding the use of water for agricultural activity has to do with uses trade-off (or opportunity costs). Water withdrawn for agriculture might restrict and/or impair other uses, such as the maintenance of water to allow ecosystem life and for hydropower generation. Thus, due to mismanaging of water for irrigation, waterbodies are drying up in different parts of the world, as for example, the Aral Sea in Central Asia which is today a quarter of its original size (Jones, 2003; Small et al, 2001) and Rio Salitre in Brazil which used to be a permanent river. In addition, aquatic populations are becoming extinct, and the human population whose livelihood depend*s* on those resources are starving or/and dying.

In summary, "some countries support other countries in their water needs" (Hoekstra, n.d.,p.1), and nations are inadvertently or deliberately polluting themselves for others. Brazil has historically played the role of exporter of primary products, and consequently 'virtual water', and has engaged in virtual degradation flows to world food markets. During the colonial era, sugar was dominant, later followed by coffee and cocoa, and today, soybeans and oranges are among others major export items (FAO, 2006). For the period of 1995-1999, the nation occupied the tenth position in the world's rank of 'virtual water' exporter (Hoekstra and Hung, 2002) (Appendix 1). There is no doubt that the global water system and the human-environment are linked by 'virtual water trade' (Hoekstra, n.d.): grapes produced in the irrigated fields of the semi-arid region of the São Francisco River Basin, in Brazil, are consumed in countries of the First World such as the Netherlands. However, what is not recognized is that the Dutch are also consuming Brazilian water. This situation is illustrated by the case study below.

2 A Case Study: The Petrolina/Juazeiro Agro-industrial Pole

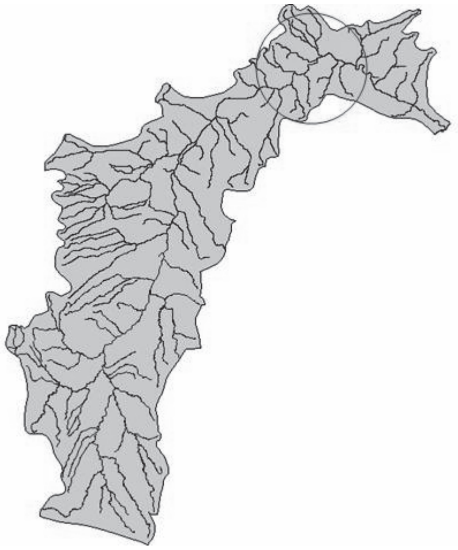
Fruit production is “nontraditional” agriculture (Collins, 1995), and its commerce is a growing economic activity in the world (Cardoso and Souza, 2000). World fruit production did not increase much for the period of 2000-2003, growing less than 1% per year, as compared to the 3.15% per year increase between the years of 1995 and 2000 (Kipe, 2004). Nonetheless, for the year 2003, fruit export was twice the size of that amount for1996, and 16% more than in 2000 (Kipe, 2004). As incomes in the world, especially the northern hemisphere have risen, households have up-scaled their eating habits and sought out “non-traditional foods” (other examples include sushi, French cheeses, etc.). But, in some regions of the world, such as in the SFRB, this type of products has been replacing the growth of traditional food products (e.g., corn, manioc) necessary to feed local populations.

Brazil is a major producer of fruit in the world, ranking in fourth position. In 1999, the nation produced 37,198,962.00 tons of fruits (excluding wine) out of the 459,299,131.00 tons of world production (FAO, 2006). But the country sent abroad only 12,288,295.10 tons of fruits (excluding wine) out of the 80,756,175.00 tons exported in the world (FAO, 2006). In 1999, Brazil had a small share (15%) of the international fruit market in relation to the size of the national production (Cardoso and Souza, 2000; Voth, 1999). Cardoso and Souza (2000) suggest that some reasons for that include: the specifications of national production do not fit with external demand (e.g., size of fruit and color); inadequate or expensive adequate packing (e.g., biodegradable, maintenance of fruit freshness); lack of marketing approach; and transportation issues. Also in some countries – such as United States and nations from Western Europe - to meet consumer requirements, environmentally friendly techniques and sanitary practices of production are a must (Cardoso and Souza, 2000). Nevertheless, the low participation in the global fruit market is a characteristic that Brazil is trying to overcome.

The Northeast, especially the Petrolina/Juazeiro agro-industrial pole located in the Sub-Middle zone of the São Francisco Basin in the states of Pernambuco and Bahia (Map 1 and Map 2 below)[e], has a large participation in the production of fruit in relation to the national outcome (Cardoso and Souza, 2000)[f]. Natural conditions, such as high average annual temperature (23ºC to 27 ºC) (Cardoso and Souza 2000, Voth 1999), high average of level of sunlight (*insolação média*) of about 2800 hours/year (EMBRAPA, n.d. a.), and low humidity, which doesn’t favor the development of plant’s diseases (CODEVASF, 1989b), along with economic characteristics, such as low prices of land and workforce, give to the Northeast advantages in relation to other regions of Brazil and even the world (Cardoso and Souza 2000).

Fruit production is labor intensive (Collins, 1995; Cavalcanti, 1996), requires skilled people and uses family members, as well as temporary and permanent workers (Collins, 1995). Technological innovations, such as machinery, have not yet being able to replace humans on labor such as pest monitoring, trimming and harvesting (Collins, 1993; Collins, 1995). A sexual division of labor exists in Brazilian fruit production and the workforce is unequally distributed across genders. In the case of grape production in the Petrolina/Juazeiro pole, the direct workforce is composed mostly by women[g] (Collins, 1995). In the case of mangos, men are preferred, and women participate of the final phase of the productive process, selecting and packing the fruit for export (Cavalcanti, 1996).

Mapa 1: São Francisco River Basin
Source: modified from www.codevasf.gov.br



Mapa 2: Petrolina/Juazeiro Pole (red circle)
Source: Created from ANA (n.d.) data

The pole is in a strategic location relative to important Northeastern state capitals: Recife 770 km, Salvador 520 km and Fortaleza 850 km (Silva et al, 2000); and ports (e.g., Salvador in Bahia, and Suape and Recife in Pernambuco State). Those above mentioned cities are closer to European and North American countries than are South and Southeast parts of Brazil (CODEVASF, 1989b). The pole is also on the longest navigable stretch of the São Francisco River (Silva et al, 2000), from Pirapora (Minas Gerais State) to Petrolina/Juazeiro, as well as is closer to a permanent source of water, the São Francisco River/Sobradinho Reservoir. The pole is formed by both public irrigation projects overseen and supported by a federal agency, the Companhia de Desenvolvimento dos Vales do São Francisco e Parnaíba – CODEVASF[h]; and also private enterprises (e.g., Agrovale).

"[T]he Sub-Middle is where most of the hydropower and irrigation expansion has taken place in SFRB" (Ioris, 2001, p.27). Large-scale irrigation in the Petrolina/Juazeiro agro-industrial pole started in late 1960s and early 1970s (Barros et al, 2004). Large public investments were made in the region during the 1970's (Silva et al, 2000). The construction of the Sobradinho Reservoir and dam for hydropower generation in the 1970s, led to flooding of towns and farms, but also brought local benefits. It made possible the existence of irrigation systems such as the construction of canals and pumping stations (Collins, 1993). One of the striking initial characteristics for the period of time between 1970s and 1985 was the replacement of traditional regional agricultural products (e.g., corn and manioc) by market oriented crops (e.g., tomatoes) (Silva et al 2000 citing Oliveira et al. 1991) and a decrease in the area of land devoted to extensive cattle-ranching activities (Collins, 1995;Silva et al, 2000). After 1985, the production of permanent fruit crops such as banana, grape and mango, became very important (Silva et al, 2000); as well as the production of industrial raw material, such as irrigated sugar-cane (Silva et al, 2000) used for example for sugar and ethanol production (Voth, 1999).

In late 80s, the Petrolina/Juazeiro pole accounted for almost half (49.1%) of the total irrigated area within the São Francisco River Basin, with private complexes surpassing public (governmental) projects (CODEVASF, 1989). In 2005, *the pole* comprised about 120,000 hectares of irrigated land (VALEXPORT, n.d.b.). Irrigation allowed agricultural production beyond the rainfed/dryland agriculture (*tradicional agricultura de sequeiro*) (Barros et al, 2004). The production was then less dependent on the variability of the semi-arid rain seasons. It permitted crop diversity, as well as spatial and temporal changes such as the location of the area of production and time of the growing season in relation to the year.

Fruit production is, today, the major activity of the Petrolina/Juazeiro pole (Barros et al, 2004). Grapes and mangos are the most important products *in natura* exported to supply the high-quality demand of other countries (Silva et al, 2000). Over half of the mango planted zones within the basin are within the Petrolina/Juazeiro Pole (Lopes et al 2004 citing CODEVASF 1999). Table 1 and Table 2 below show the magnitude of the valley's contribution to Brazil's export of grapes and mangos. In 2004, the Low Countries (Holland) (18.923.782 Kg), United Kingdom (4.907.710 Kg) and United States (1.397.270 Kg) were the nations which received the highest amount of grapes from Brazil, a total of about 88 % of Brazilian grapes sold abroad (VALEXPORT n.d.b citing SECEX/DATAFRUTA-IBRAF). For that same year, the Low Countries (Holland) (52.453.507 Kg), United States (27.395.827 Kg), Portugal (10.132.512 Kg) and United Kingdom (7.754.434 Kg) received about 88% of the mangos exported from Brazil (VALEXPORT n.d.b citing SECEX/DATAFRUTA-IBRAF).

Table1: Grapes Export by Brazil and Petrolina/Juazeiro Pole in Ton

Year	SFRB	BRAZIL	SFRB Participation in the Brazilian Total
1997	3.700	3.705	100%
1998	4.300	4.405	98%
1999	10.250	11.083	92%
2000	13.300	14.000	95%
2001	19.627	20.660	95%
2002	25.087	26.357	95%
2003	36.848	37.600	98%
2004	25.927	26.456	96%
2005	48.652	51.213	95%

Source: Modified from VALEXPORT (n.d.b, p.14) citing SECEX/DTIC/IBRAF

Table 2: Mangos Export by Brazil and Petrolina/Juazeiro Pole in Ton

Year	SFRB	BRAZIL	SFRB Participation in the Brazilian Total
1997	21.500	23.370	92%
1998	34.000	39.185	87%
1999	44.000	53.765	82%
2000	57.200	67.000	85%
2001	81.155	94.291	86%
2002	93.559	103.598	90%
2003	124.620	133.330	93%
2004	102.286	111.181	92%
2005	104.657	113.758	92%

Source: Modified from VALEXPORT (n.d.b, p.16) citing SECEX/DTIC/IBRAF

In the SF valley, "[g]rapes were first exported on the experimental basis in 1985", and commercially in 1987 (Collins, 1995, p.1105). Grapes replaced tomato plantations especially after 1989/1990 conflicts among tomatoes' producers and buyers (Collins, 1993). Mangos were first exported also in 1987 (VALEXPORT n.d.. a). Exports are carried out by individual farmers, by associations (e.g., VALEXPORT[i], BGMB[j]), and through export businesses (e.g., a French government company - Cacique) (Collins, 1993; Collins, 1995). Grapes produced in the valley have two major annual harvests (Collins, 1995). "The mangos of the São Francisco valley entered the European market precisely in the unsaturated October to January season filling a market niche. Now some producers already are able to obtain fruit almost all the year round applying new cultivation techniques" (Voth, 1999, p.9), which also implies more water being used in irrigation fields.

Mangos and grapes are perishable goods and require specific forms of preservation and transportation (Figure 4 below). After harvest, the fruits undergo several phases in 'packing houses'; as for example, they are selected, treated (e.g., submerged in hot water such as in the case of mangos), packaged and refrigerated (Correia et al, n.d.; Valexport, n.d.b.). Fruits from the SFRB region are mostly brought to ports by trucks in refrigerated containers, and then shipped by boat (França, 2000; Hirsch, 2005). Transatlantic shipment of fruit to Europe takes from 10 to 12 days (Voth, 1999). "Grapes are most often shipped by air, while melons, papaya, mangos and vegetables are shipped by boat in refrigerated containers" (Collins 1993:79). But, mangos were initially transported by air (Voth, 1999). The commerce also has been made possible due to the increase in the quality of air-transportation system of the region (Silva et al 2000), with the improvement of Petrolina Airport in 2004 (INFRAERO, n.d.). Today, the airport can receive large cargo aircrafts and has cold-storage facilities to preserve the quality of the fruits before transportation (Correia et al, n.d.). The same can't be said of aquatic and land transportation (Silva et al 2000). The São Francisco River Basin waterbodies have been loosing their navigability capabilities due to many causes, such as erosion of its banks, flow control for hydropower generation, and water withdrawal for irrigation purposes, the cumulative effects of which reduce water volume available and conditions to support navigation. In addition, the "navigable stretch" of the SFR, in which the Petrolina/Juazeiro region is located on, does not link the pole to coastal cities, and is not used for fruit export (França, 2000). Lack of road maintenance is a major problem in Brazil and in the SFRB (personal observations: July 2002, August 2004 and August 2006; França, 2000). Nonetheless, the reality of land transportation can change, in July 2006, a project to restore part of existing railroads and build a new one (*Transnordestina*) to link the countryside zones of the Northeast to coastal ports has been initiated (Folha de Pernambuco July 19, 2006).

Figure 4: Mangos from the São Francisco River Basin bought in France
Source: Picture by Marc Herold, January 2006, Marseille, France.

3. Hydro and Ecological Implications of 'Virtual Water' and Virtual Environmental Degradation Trade

'Virtual water trade' could replace the flow of real water among nations and regions, including inter-basin water transference projects (Hoekstra, 2002b) if the reason involving the matter was only the lack of the water resource and not issues such as food security, soil capabilities, and more narrowly economic considerations such as employment and economic growth. For example, North China, the 'bread basket' of that nation, receives water from the south of that nation through real inter-basin water transference projects; and sends the water back as virtual water through the sale of water-intensive crops to the South China (Ma et al, 2006). Nonetheless, reduced amount of food production in the South is due also to the pattern of land use, occupied by the construction of infrastructure and industries (Ma et al ,2006). In the case of the SFRB, the basin is already transferring water through a virtual inter-basin water transference project exporting crops to other watersheds and to the world. Could 'virtual water' trade also replace the controversial project (*Transposição*) of real inter-basin water transference from the SFR to other basins also in the Northeast of Brazil? When the project starts to work, the basin will then lose water in a real current, besides the already existing virtual flow losses.

'Virtual water trade' could also impact and redistribute food production in time and space. In that sense, some regions could be more capable and efficiently produce certain types of crops than others and in periods of the year different that is done today (Hoekstra, 2002b), such as off-season products (Voth, 1999). As already mentioned, the crops from the SFR valley fulfill a gap in Europe's fruit market. In the case of grains for example, food storage could be less difficult than water storage (Hoekstra, 2002b). Warehouses could replace water storage facilities.

The technical computation of 'virtual water trade' can use different perspectives. It can consider, for example, the water that is used in the time and place where the good was produced (producer perspective) (Hoekstra, 2002b). It can apply a user perspective, basing the calculations on the assumption that the virtual water is the amount that would be required for the production of the good by the importing country (Hoekstra, 2002b). Or it can also use both (Hoekstra, 2002b). Using the fruits of the SFRB and the Netherlands as examples, under the producer perspective, it would be better to grow the crops in the Netherlands because it is under a wetter climate, than in the arid northeast of Brazil, which demands more hydro resources. Crop production in arid regions, such as the SFRB requires more water than in humid and sub-humid climate. For example, "growing 1 kilogram of rice in a humid climate requires approximately 1 metric ton (Mt) of water, while growing the same kilogram of rice requires approximately 2 Mt of water in a dry climate" (SWS, 2003). Under a demand/user perspective, the Netherlands saved the amount of water that would be required to produce SFRB's fruits in that European country.

Hoekstra and Hung (2002) estimate how much water is used during the production of a crop, the 'virtual water,' in the producer country (producer perspective), and this is the process of calculation that will be exemplified here. This project will not assess how much water is really lost by local and regional systems during the productive process. Hoekstra and Hung (2002, p.13) calculated the specific water demand (SWD) per crop (c) in a country (n) dividing the crop water requirement (CWR) by crop yield (CY):

$$SWD[n,c] = \frac{CWR[n,c]}{CY[n,c]}$$

Note: Specific water demand is in cubic meters per ton.

Crop water requirement is based upon estimations for evapotranspiration for each crop for the growing period. FAO system (CropWat) and Hoekstra and Hung (2002) provide the estimated CWR in m^3/ha for different crops and countries. It is important to point out that, this is an average for the nation. The FAO website provides data on crops yield for Brazil. Specific water demands per crop and per country can be obtained in Hoekstra and Hung (2002). Using selected crops types, for 1999, for Brazil, as example, the specific water demanded for the production of grapes and mango for Brazil would be (Table 3 below):

Table 3: Specific Water Demand (in m^3/ton) for Grapes and Mango for 1999 for Brazil

Crops	Crop Water Requirement (CWR) in m^3/ha for 1999	Crop Yield (CY) in ton/ha for 1999	Specific Water Demand (SWD)=CWR/CY in m^3/ton for 1999
Grapes	7,640	15.8	485
Mango	13,810	7.4	1,878

Source of data: Hoekstra and Hung (2002)

In 1999, according to VALEXPORT (n.d.b, p14, 16) (Table 1 and Table 2 above) Brazil exported 11,083 tons of grapes and the SFRB 10,250 tons. For that same year, Brazil exported 53,765 tons of mango and the SFRB 44,000 tons. That means, for the total of only those two crops categories (Appendix 2), Brazil virtually exported 106,345,925 m^3 and the SFRB 87,603,250 m^3 of virtual water. Brazil is a country with periodic droughts (though of a regional nature). It is clear that SFRB is an area where the water is already in short supply and it is losing more water. Droughts in the Northeast are of two types: dry season which occurs every year for "7 to 9 months" and lack of or unequal distribution of rainfall during the 'supposed' rain season (José 1988). According to Ab'Sáber (1999), long periods of drought happen approximately each nine to twelve-years and less severe and extensive droughts happen annually. Others well known problems are that the semi-arid region of the northeast of Brazil losses a lot of water by evapotranspiration[k] (CEAS, 1971; Ab'Saber, 1999) and has water deficit (França, 2000). Petrolina/Juazeiro pole is also located in the *drought polygon* (*Polygono da Seca*), region where annual precipitation is an average of 750mm (Ab'Sáber, 1999).

According to the World Bank (2006), each dollar (2000 $) generated by the Brazilian agricultural sector for the period of 1987-2004 required one cubic meter of water (GDP/water use = 2000$ per cu. m). "[E]conomic returns to agriculture are relatively poor compared with those from industrial activity" (Allan 1993:14). A lot of water is lost, to gain little in economic terms (Allan, 1993). Nonetheless, high economic gain doesn't justify overexploitation and degradation of such vital resource, but it could hopefully be an incentive to use water more economically (Allan, 1993), not forgetting the necessary uses for activities for which it is difficult to assess economic values [e.g., environmental applications (Allan, 1993), such as to maintain the ecological discharge, necessary to support ecosystems functions].

If Brazil, in this case, the Petrolina/Juazeiro pole, is exporting increasing net amounts of water by 'virtual water trade', then in real terms, the exported monetary value of its water-rich agricultural crops would need to be adjusted downward. The price of the good doesn't accurately account for the depletion of the region's water resources. As noted in the citation below by Hoekstra and Hung (2002, p.9), 'virtual water' should be exported from water rich regions and countries to water poor places. In the SFRB the opposite is happening. The amount of water imported by a country throughout 'virtual water trade' adds to the nation's 'water footprint'[l] (Hoekstra and Hung, 2002). Then,

> A water-scarce country can thus aim at importing products that require a lot of water in their production (water-intensive products) and exporting products or services that require less water (water-extensive products). This is called import of virtual water (as opposed to import of real water, which is generally too expensive) and will relieve the pressure on the nation's own water resources. For water-abundant countries an argumentation can be made for export of virtual water. Import of water-intensive products by some nations and export of these products by others includes what is called 'virtual water trade' between nations (Hoekstra and Hung, 2002, p.9).

The loss of water is not the only problem to which the donor country might be subjected. The 'virtual water' trade between nations, when not sustainable, is usually accompanied by a virtual degradation flow. Countries are exchanging aquifer depletion, water pollution, soil erosion, and other negative externalities which result from the crop production. The commerce involves trade-offs and unaccounted and consequently unpaid environmental prices, especially because the product is exported at world market prices, and not at local ones which better reflect its real costs.

Agricultural production is responsible for innumerable environmental problems which exist in the Petrolina/Juazeiro area: there is a low level of conservation of public irrigated zones, which also affects the productivity of local systems (Silva et al, 2000); and irrigation, lack of or poor draining systems, and the high level of evaporation have caused a fast degree of salinization of soils (Cavalcanti, 1996; Silva et al, 2000). Indeed, "[i]n dry climates, evaporation of water near the soil surface leaves behind a layer of salt that also reduces crop yields and eventually; if the buildup becomes excessive, kills the crop" (Postel, 1993, p.58). Salts are added to the soil by irrigation water (Postel, 1993) and inadequate irrigation systems (e.g., aspersion) are also inefficient in relation to water loss (Silva et al, 2000).

The use of fertilizers and pesticides is another common problem (Silva et al, 2000). In the Northeast, nitrogen is highly used in irrigated fruit production to supply the demands of the international market (FAO, 2004). In late 1980s, "[t]he area surrounding Petrolina/Juazeiro … [had] the highest rates of use of fertilizers, irrigation and tractors in the Brazilian Northeast" (Collins, 1993, p.63). As noted in IBGE (2005) study, agro-toxins and fertilizers are known causes which impair the water resources of the São Francisco River Basin. Fertilization is necessary due to the natural characteristics of semi-arid soils: generally poor in N (Faria et al, 2000), deprived of organic matter (Faria et al, 2003), not deep and susceptible to erosion (EMBRAPA, n.d.a.). In the case of melons, scientific studies have demonstrated that, the use of nitrogen fertilization has improved fruit's characteristics, such as weight (Faria et al 2003 citing: Srinivas & Prabhakar 1984, Prabhakar et al. 1985, and Faria et al. 1994 and 2000).

4. Recommendations

Costs and benefits exist regarding the export of fruit (e.g., grapes and mangos) from the São Francisco River Basin. Negative production externalities and the opportunity cost of 'virtual water' traded are among the expenses. Monetary returns to selling enterprises and employment generation[m] are some of the benefits. Nonetheless, the two major issues that this article attempts to address are: how a water-scarce region is engaging in exporting water through virtual flows, which makes the zone even poorer in that resource; and the decreasing level of ecological sustainability of the river basin system. In this section, the article provides some recommendations to try to deal with those concerns:

4.1 Water Saving Techniques

Many forms of irrigation exist, such as basin, furrow, sprinkler (overhead) or small sprinkler, and drip or trickle irrigation (Manning, 1997; Collins, 1995; Postel, 1993). According to Manning (1997), regarding water conservation, sprinkler irrigation is advancement if compared with basin and furrow methods. In semi-arid regions, more water is applied; more of that resource will be lost caused by factors such as wind blow and evaporation due to high temperatures (Silva et al, 2000). Also, water needs to drain so that it does not evaporate leaving behind increasing salinity (Bouwer, 2002).

For the Petrolina/Juazeiro pole, in early 1990s, "[t]he main irrigation technologies in use in the region … [were] central pivot, aspersion and drip methods… Drip systems are by far the most common, even where not ideally suited to the crop" (Collins, 1993, p.63). Drip[n] irrigation under soil surface reduces the loss of water by evaporation (Otchet, 1999). According to CAST (1992, p.28), "[t]he optimum management strategy is to apply no more water than is necessary for full crop production and leaching of salts" "through the root zone to prevent harmful salt accumulation in the soil" (CAST, 1992, p.28), but in a water poor region a better solution would be to apply extra water after the irrigation season or let it to happen during the raining seasons, as suggests Manning (1997). Drip irrigation can be applied on or below soil surface, and close to crop's roots (Postel, 1993). Another alternative to reduce water withdrawal is to reuse the water that would leave the basin through runoff (Postel, 1993), by using soil conservation/water retention cultivation practices.

4.2. The Growth of Products Suitable for the Environment (dry-land agriculture)

The SFRB should produce crops that require less water. In our case, as Table 3 (above) exemplified, in 1999, the Specific Water Demand for mangos (1878 m^3/ton) was almost four times that number for grapes (485 m^3/ton). Should increased grapes production and export replace mangos? Taking also the social aspect into consideration, should export crops replace food for local populations (Voth, 1999)? Other problems of concern are the effects of new species on native ones and on the environment in general. Native species should be cultivated, but, producers are introducing new fruit species to supply the demand of foreign countries:

> "After 1985 a growing number of companies began to introduce Florida varieties of mango (Haden, Tommy Atkins, etc.) from the important production area in the State of São Paulo to the Northeast where a lot of native varieties were grown traditionally and sold to the markets in the Northeast and the Southeast of Brazil. The new varieties responding to foreign demand began to displace the native varieties also from the national market" (Voth, 1999, p.8).

4.3. Fertilizers and Pesticides Use and not Abuse

Producers from the Petrolina/Juazeiro pole have already been implementing approaches such as Fruit Integrated Production (*Produção Integrada de Frutas*) – FIP[o]. This alternative includes more environ-mentally friendly techniques which aim to meet international food market specifications, such as the efficient and effective use of fertilizers and agro-toxins, and mainly biological pest control (EMBRAPA n.d.a.; EMBRAPA n.d.b.; Lopes et al, 2004). FIP should be extended to other producers and crops. An important technique would be the use of fertigation, which means, fertilization through irrigation's water (Faria et al, 2000). It is known to be more efficient in relation the uptake of nutrients by plants (Faria et al 2000 citing Costa et al. 1986).

4.4. Diversification of Products

The conflict among tomatoes growers and buyers (Collins, 1993) has already showed some of the economic and social consequences resulting from the lack of diversification of crops in the pole, such as the dependence upon the price offered by few buyers in the market. The producers should diversify the crops planted also due to ecological considerations. Monocultures are more susceptible to diseases. A good example of that is the case of Bahia's cocoa industry destroyed in late 80s/early 90s by Witches' broom infection (Alves Filho, 2002; Griffith, 2004).

Conclusions

In summary, "virtual water trade" exists between nations and regions and is, most likely, unbalanced. In this project, only one side of the balance equation was analyzed. It would be interesting to look the entire agricultural/food balance in the Petrolina/Juazeiro pole region. The net transference among countries and regions can be measured, in water volume, as the input of water received through importation minus the output lost throughout exportation. In the future, if global climate change and other anthropogenic causes of freshwater shortage continue to affect and modify the global water cycle, "***water***-short ***countries*** can enhance their food security by importing ***water***-intensive food products"(Wichelns, 2004, p.50). As regards, Brazil, a drought-stricken country in regional terms, estimating the country's net balance of virtual water trade is of crucial importance, but to know the regional disparities related to the availability of freshwater resources is also a fundamental need. The Petrolina/Juazeiro pole, a water-short zone, is already transferring water in virtual way to other local, regional and international river basins. Attention should be paid to assure the sustainable use of the hydro resource, by reducing its real and virtual transference; as well as to diminish the environmental degradation, which stays within the basin.

The theory of comparative advantage in Economics argues that nations and regions should specialize in producing and then exporting goods (and services) in which they are more efficient producers. The São Francisco River region, in this specific case the Petrolina/Juazeiro pole, is exporting mangos and grapes which consume lots of the region's scarce but free water. If the real (or opportunity) cost of water were included in costs of production, the Basin's "comparative advantage" might look very differently, namely specializing in making water-saving products. In effect, fruit producers in the Basin are artificially prospering because of an unrealistic pricing system, reaping the private benefits and not paying the social and environmental costs.

Notes:

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[i] According to the Oxford English Dictionary [Online, accessed Aug 12, 2006], the term virtual means "so in essence or effect, although not formally or actually; admitting of being called by the name so far as the effect or result is concerned". In this paper's context, virtual means that the water that made the production possible is not obviously perceived, doesn't go together within the same package of the fruit exported, but it was demanded and removed from its sources and won't return to the local or regional water system in the same quantity and quality as it was withdrawn. Virtual environmental degradation means the local or regional ecological consequences generated during the process of production of a good exported.

[ii] 'Virtual Water Trade' as defined in Hoekstra and Hung (2002).

[iii] Paper presented by Lucigleide Nery Nascimento at VIII Brazilian Studies Association Conference – BRASA VIII, 2006, Nashville, Tennessee, United States

[iv] Non-point source (NPS) or diffuse pollution "originates over a broad area", "is caused by diffuse sources" (CAST, 1992, p.23), and "does not result from a discharge at a specific, single location (such as a single pipe) but generally results from land runoff, precipitation, atmospheric deposition, or percolation" (CAST, 1992, p.23 citing EPA, 1987).

[v] Petrolina/Juazeiro agro-industrial pole is centered in Petrolina/Juazeiro but also includes other cities such as Casa Nova, Curaçá and Sobradinho in Bahia State; and Santa Maria da Boa Vista, Orocó and Lagoa Grande in Pernambuco State (Damiani, 2003; França, 2000). The pole incorporates the Sub-Middle region of the São Francisco River Basin. Small-scale irrigated agriculture (e.g., onions and corn) started in the São Francisco River Basin in its riparian zones, in the 1950s, as a developmental policy (Damiani, 2003). But, the first irrigation public project, by CODEVASF, a pilot project, Bebedouto, started in 1960s growing subsistence crops, such as beans, corn and later on cotton (CODEVASF Staff, personal communication, Aug 4th 2006, Juazeiro). Today, the pole is composed by different irrigation zones, such as Mandacaru, Maniçoba, Tourão and Curaça in Bahia State; and Bebedouro, Nilo Coelho and Maria Teresa in Pernambuco State (Correia et al, n.d.).

[vi] "The waters of the São Francisco River are producing a new promised land in northeastern Brazil. Instead of milk and honey, one finds the sweetest and juiciest fruits ever grown in the country. The key to this agricultural success is irrigation, which, in a little more than a decade, has transformed Brazil's hot, arid sertão region into a verdant orchard. The controlled water flow makes fruit mature more quickly and allows for larger and more frequent harvests. In 1993, the region produced 80,000 tons of fruit, earning some $40 million for its 30 exporters. " (Nanne, 1994, p.44).

[vii] According to the nimble fingers argument, "[w]omen are considered not only to have naturally nimble fingers, but also to be naturally more docile and willing to accept tough work discipline, and naturally less inclined to join trade unions, than men; and to be naturally more suited to tedious, repetitious, monotonous work" (Elson and Pearson, 1981, p.93).

[vii] Since 1960s CODEVASF has been building irrigation projects' infrastructures, such as water canals and pumping systems (Damiani, 2003).

[viii] The VALEXPORT, created in 1988, has today about 55 members, which represent about 70% of the total amount of fruit produced in the São Francisco River Basin, and 80% of the amount exported (VALEXPORT, n.d.. b).

[IX] BGMB, Brazilian Grape Marketing Board or BGMA Association, was created in 1992 (Collins, 1995), composed by grapes producers to easier export through tools such as fixing the price and bulking export (Collins, 1995).

[XI] Evapotranspiration includes evaporation from plant and soil surfaces, and plant transpiration (Manning, 1997).

[XII] "The water footprint of an individual, business or nation is defined as the total volume of freshwater that is used to produce the foods and services consumed by the individual, business or nation. A water footprint is generally expressed in terms of the volume of water use per year" (Cardenas, 2006).

[XIII] Damiani (2003) recognized that irrigated crop production in Petrolina/Juazeiro pole has benefited both rural workers (i.e., year-round production and revenue) and farmers (e.g., employment opportunities, wage higher than Brazilian minimum wage and social security benefits).

[XIV] "Drip irrigation applies water through small emitters to the soil around individual plants or trees... A system of plastic pipes and hoses, operating at low pressure, delivers water to the emitters ... Water released from the emitters wets the surface and is draw down by capillary suction and gravity into the soil, where it becomes available for uptake by roots and eventual transpiration by the plant" (Manning, 1997, p.94).

[XV] FIP "has the objective of economically producing high quality fruits, obtained by ecologically safer methods, which minimize the collateral undesirable effects of the use of pesticides, increasing the environmental protection and improving human health" (Lopes et al, 2004, p.227).

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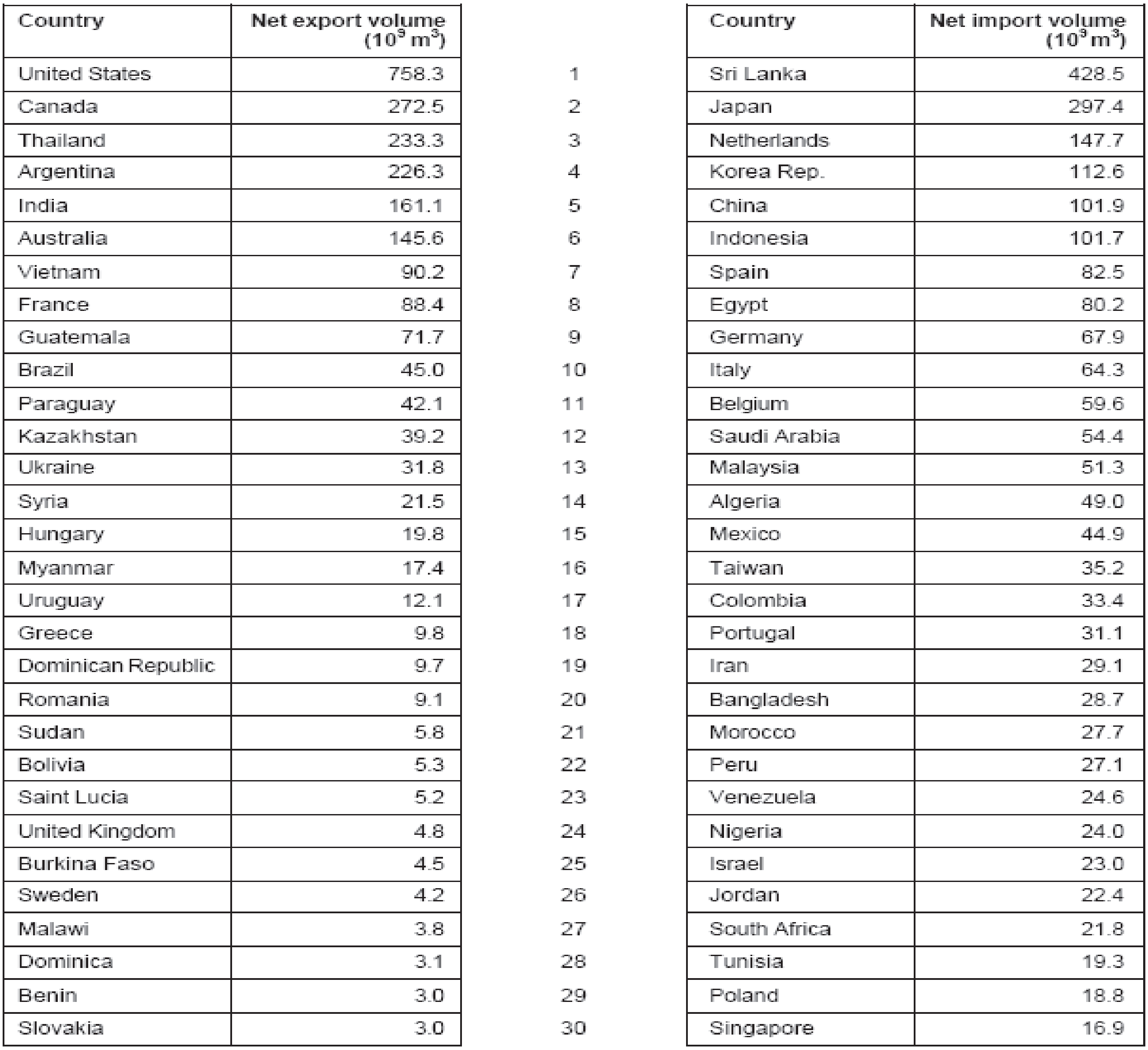
Appendix 1: "Top-30 of virtual water export countries and top-30 of virtual water import countries (over 1995-1999)"
Source: Hoekstra and Hung (2002, p.28).



Country	Net export volume (10^9 m^3)		Country	Net import volume (10^9 m^3)
United States	758.3	1	Sri Lanka	428.5
Canada	272.5	2	Japan	297.4
Thailand	233.3	3	Netherlands	147.7
Argentina	226.3	4	Korea Rep.	112.6
India	161.1	5	China	101.9
Australia	145.6	6	Indonesia	101.7
Vietnam	90.2	7	Spain	82.5
France	88.4	8	Egypt	80.2
Guatemala	71.7	9	Germany	67.9
Brazil	45.0	10	Italy	64.3
Paraguay	42.1	11	Belgium	59.6
Kazakhstan	39.2	12	Saudi Arabia	54.4
Ukraine	31.8	13	Malaysia	51.3
Syria	21.5	14	Algeria	49.0
Hungary	19.8	15	Mexico	44.9
Myanmar	17.4	16	Taiwan	35.2
Uruguay	12.1	17	Colombia	33.4
Greece	9.8	18	Portugal	31.1
Dominican Republic	9.7	19	Iran	29.1
Romania	9.1	20	Bangladesh	28.7
Sudan	5.8	21	Morocco	27.7
Bolivia	5.3	22	Peru	27.1
Saint Lucia	5.2	23	Venezuela	24.6
United Kingdom	4.8	24	Nigeria	24.0
Burkina Faso	4.5	25	Israel	23.0
Sweden	4.2	26	Jordan	22.4
Malawi	3.8	27	South Africa	21.8
Dominica	3.1	28	Tunisia	19.3
Benin	3.0	29	Poland	18.8
Slovakia	3.0	30	Singapore	16.9

Appendix 2: Virtual Water Exported for Mangos and Grapes in 1999.

Brazil		SFRB	
Mango	1,878*53,765	Mango	1878*44,000
Grapes	485 * 11,083	Grapes	485*10,250
Total: 106,345,925 m^3		Total: 87,603,250 m^3	

Source of data: Hoekstra and Hung (2002), VALEXPORT n.d.b.

Note: For the SFRB the calculations took into consideration the national average for water requirement. That number for the basin is probably superior due to the semi-arid climate.