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Export and Import of Virtual Water from Different States of India Related to Food Grain Trade

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ABSTRACT: Virtual water refers to the water required in the production of goods or services. The adjective 'virtual' refers to the fact that most of the water used in the production is in the end not contained within the product. The virtual water concept has two types of practical use. First, virtual water can be seen as an alternative source of water and thus can be an instrument to achieve regional water security. Secondly, the virtual water content of a product tells something about the environmental impacts of consuming this product.

When goods and services are exchanged, so is the virtual water and this refers to virtual water trade. Many studies have estimated the virtual water trade between various countries. India is a country with large geographical area (3.29 Mkm^2) and the culturable area is 1.43 Mkm^2. The annual average precipitation is about 4000 km^3. There are large variations in climate and land productivity. There is large disparity among various states in production of food grains. Some of the states contribute food grain to the central pool and some withdraws food grain from the central pool. This paper quantifies the volume of virtual water export/import from/to various states of India to/from central pool related to trade of major food grains i.e. wheat, paddy and rice.

INTRODUCTION

Virtual water was defined at the beginning of the 1990s by Professor J.A. Allan as 'water embedded in commodities' (Allan, 1993). The amount of water consumed in the production process of an agriculture or industrial product is called the 'virtual water' contained in the product. This water is 'virtual' because it is not physically contained anymore in the product. The real water content of products is generally negligible if compared to the virtual water content. For example, to produce a kilogram of wheat in India, we need 1654 lt of water, whereas to produce 1 kg maize 1937 lt of water is required. Producing livestock products generally requires even more water per kg of product. One kg of cheese for instance requires about 5000–7000 lt of water (Chapagain and Hoekstra, 2003). A cup of coffee uses about 140 lt of water whereas tea requires only $1/8^{th}$ of that. About 3200 lt of water is required to produce a 32-megabyte computer chip of 2 grams (Williams *et al.*, 2002).

The virtual water concept has two types of practical use (Hoekstra, 2003). First, virtual water can be seen as an alternative source of water and thus can be an instrument to achieve regional water security. The concept is useful because it draws attention to the notion that serious local water shortages can be very effectively ameliorated by global processes. Virtual water trade can be an instrument in solving geopolitical problems and even prevent wars over water (Allan, 1993; 2003). Secondly, the virtual water content of a product tells something about the environmental impacts of consuming this product. The amount of water we drink each day, and use for washing, sanitation and other household tasks seem insignificant when compared to the amount of water we eat through our food.

Virtual water trade refers to the transfer of (virtual) water that takes place during trade of various goods and services. Some countries of the world do not have adequate water to meet their current and projected water needs while in some other countries, available water is much more compared to the demands. Further, in big countries, there are regions of surplus or deficient water availability. A possible approach to overcome this spatial mis-match between water availability and demands is to transport water from surplus regions to deficient regions. Due to the involvement of large distances and associated infrastructure and other costs, transportation of real water between water-rich and water-poor countries may be very difficult. Therefore, a viable option for water-scarce countries could be to import water-intensive products rather than produce them domestically. In the similar vein, water-rich countries

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could reap benefits from their abundant water resources by producing and exporting products that consume large quantities of water. Of course, in reality things are not so simple and additional questions of food security, energy security, employment, etc. enter in the picture.

Virtual water trade is becoming an important concept of water management on global as well as regional level, particularly in the region where water is scarce. Many studies (Chapagain and Hoekstra, 2004; Hoekstra and Hung, 2002; Renault, 2002; Oki *et al.*, 2003) have estimated the magnitude of virtual water trade between various countries. This paper quantifies the volume of virtual water export and import for various states of India related to trade of major food grains i.e. wheat, paddy and rice.

VIRTUAL WATER CONTENT

Virtual water content of a product is the quantity of water that is consumed to produce it. The quantity depends upon the technology and conditions of production. The virtual water content of various primary and processed crop products, livestock products and industrial products for different countries was estimated by Chapagain and Hoekstra (2004). The virtual water content of a crop in a country is calculated as the ratio of total water used for the production of crop to the total volume of crop produced in that country. Crop water use is assumed equal to the crop water requirement which is calculated by accumulation of data on daily crop evapotranspiration over the complete growing period. Crop water requirements for different crops have been calculated using the CROPWAT model of FAO. The virtual water content of an animal at the end of its life span is defined as the total volume of water that was used to grow and process its feed, to provide its drinking water, and to clean its housing and the like. The virtual water content of a processed product depends on the virtual water content of the primary crop or live animal from which it is derived. The virtual water content of the primary crop or live animal is distributed over the different products from that specific crop or animal. Virtual water content of industrial products is estimated on a country average basis by dividing the individual water withdrawn by a particular country with the value added from industrial sector for that country. Table 1 gives the virtual water content of selected crops and livestock products calculated for India. The average virtual water content of industrial products for India is estimated as 4.75 lt/Rs or 0.215 m^3/US$.

VIRTUAL WATER TRADE

The virtual water trade for India was estimated by various authors over the years (Hoekstra and Hung, 2002; Zimmer and Renault, 2003; Chapagain and Hoekstra, 2004). Kumar and Jain (2007) presented a review of virtual water content of various products estimated for India and gave the status of virtual water trade taking place from India. According to the latest estimate by Chapagain and Hoekstra (2004), India has exported 42.5 Gm^3/yr of virtual water with net export of 25.4 Gm^3/yr. Out of total export of 42.5 Gm^3/yr, crop trade contributed 76%, livestock 8% and industrial products 16%, whereas out of total import, 81% trade was related to crop, 2% to livestock and remaining 17% to industrial products. Soybean and Palm oil were the major crops for virtual water export and import, respectively. During the period 1997–2001, India was among the top 15 gross virtual water exporter and among top 10 net virtual water exporters. Chapagain *et al.* (2005) calculated virtual water flow from India related to export of cotton products as 25.66 Gm^3/yr which consists of 16.83 Gm^3 of green water, 5.75 Gm^3 of blue water and remaining 3.08 Gm^3 for dilution water. Dilution water is the volume of water required to dilute waste flows to such an extent that quality of the water remains below agreed water quality standards.

VIRTUAL WATER TRADE FROM DIFFERENT STATES OF INDIA RELATED TO FOOD GRAIN TRADE

The green revolution in India in mid 1960's resulted in quantum jump in food grain production from 51 Mt in 1950–51 to 203 Mt in 1998–99. But, there is large disparity among various states in production of food grain. Various central and state agencies purchase food grains from different states for central pool and sell these under Targeted Public Distribution System and under various welfare programmes in different states. Food Corporation of India (FCI) keeps record of purchase and sale of food grains for different states (FCI, 2003–04). Table 2 shows the sale and purchase of wheat, rice and paddy for different states of India for the year 2003–04. In some states, the purchase is more as compared to sale (+ve contribution of food grain to central pool) and in other states, it is reverse (–ve contribution). This table also gives the amount of purchase minus sale for all states. Out of the 23 states/regions listed in Table 2, only two states namely, Punjab and Haryana are net exporter of wheat to the central pool and all other states/regions are net

Table 1: Virtual Water (VW) Content of Crop and Livestock Products for India (1997–2001) (Chapagain and Hoekstra, 2004)

S. No.	Product	VW Content (m^3/ton)	S. No.	Product	VW Content (m^3/ton)
Crop and crop products					
1.	Almonds (in shell)	9769	31.	Mustard oil	4643
2.	Apples	1812	32.	Onions (Dry)	538
3.	Bananas	415	33.	Onions (Fresh)	214
4.	Barley	1966	34.	Oranges	364
5.	Beer	411	35.	Papaya	922
6.	Cabbage	180	36.	Pears	1287
7.	Carrots/turnip	192	37.	Peas (Dry)	3040
8.	Cashew Nuts	15340	38.	Peas (Green)	178
9.	Cauliflower	100	39.	Pepper	8333
10.	Cloves	61304	40.	Pineapples	305
11.	Coconut oil	3051	41.	Plums	1907
12.	Coconuts	2255	42.	Potatoes	213
13.	Coffee	12180	43.	Rice (husked)	3702
14.	Coffee (roasted)	14500	44.	Rice (Paddy)	2850
15.	Corinader seeds	949	45.	Soybeans	4124
16.	Cotton Lint	18694	46.	Spinach	144
17.	Cotton seed	8264	47.	Sugar (raw)	1301
18.	Dates	3030	48.	Sugar (refined)	1391
19.	Garlic	1268	49.	Sugar Cane	159
20.	Ginger	1556	50.	Sunflower seed	4304
21.	Grape wine	341	51.	Sunflower/safflower oil	8541
22.	Grapefruit	411	52.	Tea (Green)	1804
23.	Grapes	238	53.	Tea Black	7002
24.	Groundnut (in shell)	3420	54.	Tobacco	2627
25.	Groundnut oil	8875	55.	Tomatoes	302
26.	Jute	2823	56.	Turmeric	1556
27.	Lemons and Limes	611	57.	Urd/mung/gram beans	3078
28.	Maize	1937	58.	Walnuts (in shell)	11721
29.	Mangoes/Guavas	1525	59.	Watermelons	362
30.	Millet	3269	60.	Wheat	1654
Livestock and livestock products					
1.	Bovine	7386	9.	Horses/Ass/Mules	2849
2.	Buttermilk	2068	10.	Leather (Bovine)	17710
3.	Cheese	6793	11.	Milk (fat <1%)	1369
4.	Chicken meat	7736	12.	Milk (fat >1% & <6%)	1415
5.	Eggs (Birds)	7531	13.	Milk (fat >6%)	2547
6.	Fowls/Poultry	6024	14.	Milk powder	6368
7.	Goat meat	5187	15.	Sheep	3397
8.	Goats	3018	16.	Sheep meat	6692

importer of wheat. For Rice, Punjab, Haryana, Uttar Pradesh, Uttarakhand and Chhattisgarh are the net exporters and other states are net importers. Only 9 states namely Punjab, Haryana, Uttar Pradesh, Rajasthan, Andhra Pradesh, Madhya Pradesh, Bihar, Jharkhand and Orissa have made sale/purchase of paddy to/from central pool and only Uttar Pradesh was net importer.

The states having +ve contribution of food grains to central pool effectively export the virtual water whereas the states having –ve contribution are importers of the virtual water. The amount of virtual

water export/import is equal to the amount of food grain export/import multiplied by the virtual water content of the respective food grain. Taking the virtual water content of wheat, rice and paddy as 1654 m^3/ton, 3702 m^3/ton and 2850 m^3/ton (Table 1) respectively, Table 3 shows the amount of virtual water import and export from different states. Punjab, with an export of 12184 mm^3, is the biggest exporter of virtual water related to wheat, whereas Rajasthan is the biggest importer with an import of 4887 mm^3. For rice, Punjab is again the biggest exporter (22434 mm^3) and Tamil Nadu (11236 mm^3) is the biggest importer.

Considering all the three food grains, Punjab, Haryana, Uttar Pradesh, Uttarakhand and Chhattisgarh are the net exporters, with largest export from Punjab. Among the net importers, Tamil Nadu is at the top followed closely by neighboring state Karnataka. A graphical representation of net exporters and importers is shown in Figure 1.

The above calculations are made assuming that the virtual water content of the food grain considered in this paper are correct. The virtual water content of these food grains are taken from the report by Chapagain and Hoekstra (2004). In this report, the virtual water content of various crop and crop products is calculated considering the country's average climate data. Some of the data used is of the capital city of the country. So, only single value has been reported for whole of India. As the climate in India varies spatially, the virtual water content of various crops and crop products will also vary spatially i.e. the virtual water content may be different for different states. Another shortcoming is that the estimates of virtual water content of crops are based on crop water requirements, which leads to overestimates in those cases where actual water availability is lower than the crop water requirement. The calculations could be improved by first estimating the virtual water content of different food grains for different states of India considering the actual water use by crops, which however will require more specific data per crop.

Table 2: Purchase and Sale of Wheat, Rice and Paddy (tonnes) from Different States of India for the Year 2003–04 (FCI, 2003–04)

S.No.	Region/State	Wheat			Rice			Paddy		
		Purchase	Sale	Purchase-Sale	Purchase	Sale	Purchase-Sale	Purchase	Sale	Purchase-Sale
1.	Jammu & Kashmir	0	3,18,787	–3,18,787	0	4,51,846	–451,846	–	–	–
2.	Punjab	126,97,661	53,31,230	73,66,431	85,12,186	24,52,286	60,59,900	10,86,318	5,061	10,81,257
3.	Haryana	84,76,889	27,07,268	57,69,621	13,06,276	1,80,623	11,25,653	27,434	0	27,434
4.	Uttar Pradesh	95,217	157,04,04	–14,75,187	15,38,742	6,75,923	8,62,819	0	7	–7
5.	Uttarakhand	66,477	1,38,841	–72,364	1,67,277	1,06,688	60,589	–	–	–
6.	Delhi	12,118	4,81,690	–4,69,572	0	78,169	–78,169	–	–	–
7.	Rajasthan	2,58,727	32,13,315	–29,54,588	35,620	58,048	–22,428	13,227	0	13,227
8.	Himachal Pradesh	612	1,51,246	–1,50,634	3,450	1,79,237	–1,75,787	–	–	–
9.	Andhra Pradesh	0	85,472	–85,472	31,83,182	46,64,090	–14,80,908	55,676	0	55,676
10.	Tamil Nadu	0	1,59,465	–1,59,465	0	30,35,025	–30,35,025	–	–	–
11.	Karnataka	0	4,54,033	–4,54,033	73	28,81,441	–28,81,368	–	–	–
12.	Kerala	0	2,24,013	–2,24,013	0	7,78,371	–7,78,371	–	–	–
13.	Madhya Pradesh	30,383	19,06,722	–18,76,339	60,509	4,55,969	–3,95,460	55,805	0	55,805
14.	Chhattisgarh	0	1,83,976	–1,83,976	9,98,927	42,085	9,56,842	–	–	–
15.	Maharashtra	0	19,94,213	–19,94,213	2,27,013	11,24,224	–8,97,211	–	–	–
16.	Gujarat	0	8,80,641	–8,80,641	0	2,54,249	–2,54,249	–	–	–
17.	Assam	0	2,89,089	–2,89,089	17,037	13,84,362	–13,67,325	–	–	–
18.	N.E.F.	0	45,035	–45,035	0	4,20,488	–4,20,488	–	–	–
19.	N & M Region	0	78,674	–78,674	0	2,02,358	–2,02,358	–	–	–
20.	Bihar	1,343	10,01,497	–10,00,154	1,73,797	5,15,854	–3,42,057	1,09,422	650	1,08,772
21.	Jharkhand	0	3,48,407	–3,48,407	0	2,68,504	–2,68,504	1,703	0	1,703
22.	Orissa	0	2,92,907	–2,92,907	10,90,976	18,05,638	–7,14,662	21,007	0	21,007
23.	West Bengal	0	12,94,123	–12,94,123	5,62,667	12,41,728	–6,79,061	–	–	–

N.E.F.—North East Frontier N&M Region—Nagaland & Manipur Region

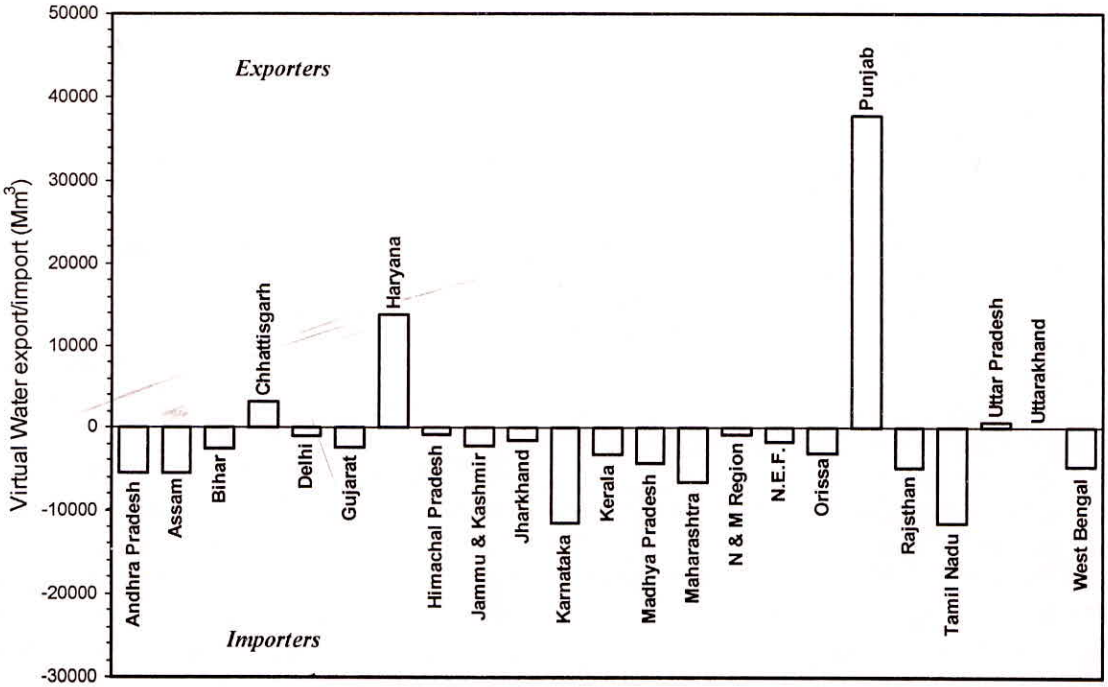

Fig. 1: States with net export/import of virtual water related to trade of food grains

Table 3: Virtual Water Export (+ve)/Import (–ve) Related to Purchase and Sale of Wheat, Rice and Paddy from Different States of India for the Year 2003–04

Sl. No.	*Region*	*Wheat (mm^3)*	*Rice (mm^3)*	*Paddy (mm^3)*	*Total (mm^3)*
1.	Jammu & Kashmir	–527.27	–1672.73	0	–2,200
2.	Punjab	12,184.08	22,433.75	3,081.58	37,699
3.	Haryana	9,542.95	4,167.17	78.19	13,788
4.	Uttar Pradesh	–2,439.96	3,194.16	–0.02	754
5.	Uttarakhand	–119.69	224.30	0	105
6.	Delhi	–776.67	–289.38	0	–1,066
7.	Rajasthan	–4,886.89	–83.03	37.70	–4,932
8.	Himachal Pradesh	–249.15	–650.76	0	–900
9.	Andhra Pradesh	–141.37	–5,482.32	158.68	–5,465
10.	Tamil Nadu	–263.76	–11,235.66	0	–11,499
11.	Karnataka	–750.97	–10,666.82	0	–11,418
12.	Kerala	–370.52	–2,881.53	0	–3,252
13.	Madhya Pradesh	–3,103.46	–1,463.99	159.04	–4,408
14.	Chhattisgarh	–304.30	3,542.23	0	3,238
15.	Maharashtra	–3,298.43	–3,321.48	0	–6,620
16.	Gujarat	–1,456.58	–941.23	0	–2,398
17.	Assam	–478.15	–5,061.84	0	–5,540
18.	N.E.F.	–74.49	–1,556.65	0	–1,631
19.	N & M Region	–130.13	–749.13	0	–879
20.	Bihar	–1,654.25	–1,266.30	310.00	–2,611
21.	Jharkhand	–576.27	–994.00	4.85	–1,565
22.	Orissa	–484.47	–2,645.68	59.87	–3,070
23.	West Bengal	–2,140.48	–2,513.88	0	–4,654

CONCLUSIONS

Virtual water trade is a new concept which is slowly gaining acceptance. At present, it is not much used in decision making. There are numerous examples of countries which are facing water shortage but still they are involved in production processes that consume large quantities of water. Within the countries also, there are regions of water deficit in which water guzzling crops are being produced. Nevertheless, this is a useful concept which is likely to gain importance and wide application in the future.

This paper reports the virtual water export/import from/to different states of India to/from central pool related to trade of major food grains. Punjab and Haryana are the two states which are net exporters of all the three food grains (wheat, paddy, rice) and so are net exporters of virtual water to central pool. Uttar Pradesh, Uttarakhand and Chhattisgarh are net exporters of Rice. All other states are net importers of virtual water through food grains. Punjab is the biggest exporter of virtual water related to wheat, whereas Rajasthan is the biggest importer. For rice, Punjab is again the biggest exporter and Tamil Nadu is the biggest importer. Considering the three food grains, Punjab, Haryana, Uttar Pradesh, Uttarakhand and Chhattisgarh are the net exporters. If the data on trade of good grains among different states is available, the virtual water trade between different states can also be estimated. It is of interest to note that some states are not willing to physically transfer water to the other states but are transferring large quantities of water in virtual form.

The study has some limitations. Data of only three food grains has been considered. Large quantity of virtual water being transported through vegetables, fruits and other food grains have not been considered. Moreover, transportation of food grains through means other than FCI has not been taken into account.

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