JOURNAL OF RECENT ADVANCES IN APPLIED SCIENCES (JRAAS) 27:24-30, 2012
ISSN 0970 1990, ST CODE 08 ,www.jraas.org. E MAIL: mhcdr@rediff.com

VIRTUAL WATER TRADE THROUGH FOOD AND VEGETABLE CROPS IN EASTERN UTTAR PRADESH, INDIA

RAVI PRAKASH SINGH[i], H. P. SINGH[ii] AND O. P. SINGH[iii]
Department of Agricultural Economics, I. Ag. Sc., Banaras Hindu University, Varanasi, India
[1]Research Scholar , [2]Professor, [3]Assistant Professor,

ABSTRACT

Amount of water present in cereals, milk and livestock in terms of the amount of water, one of the factors of production, used to produce it. Several researchers argued in similar lines that water scarce regions can achieve high water use efficiency at the global level by importing products that have high virtual water embedded in it and exporting products that have very low water content embedded. The present study was an attempt to estimate the virtual water trade through food and vegetable crops in eastern Uttar Pradesh, India. The study was based on the primary data and it was collected through personal interview. The result suggests that the farmers are exporting higher volume of virtual water from vegetables as compared to foodgrain. In case of Mirzapur district, total irrigation water used at farm level during the year was estimated to be 1274.04 m^3. Out of this, share of virtual water was 86.83 per cent, whereas in case of Varanasi district, it was 89.94 per cent. The higher virtual water trade in Varanasi district was due to the exporting water intensive crops like paddy and sugarcane.

KEY WORDS: water, cereals, milk and livestock

INTRODUCTION

The concept of virtual water was introduced in early 90's by Prof. Tony Allan to indicate the amount of water made available in the global system through agricultural commodity trade. Prof. Allan interpreted the amount of water present in cereals, milk and livestock in terms of the amount of water, one of the factors of production, used to produce it. The concept of virtual water was first introduced by him in water management discourses as a powerful economic tool to ameliorate water scarcity problems of national economics (Allan, 1997). Later on several researchers argued in similar lines that water scarce regions can achieve high water use efficiency at the global level by importing products that have high virtual water embedded in it and exporting products that have very low water content embedded (Warner 2003; Hoekstra and Hung 2002; Chapagain and Hoekstra 2003).

The argument that food import is a strong indicator of level of water deficit that economies face; that all economies around the world which face acute water scarcity problems can and should meet their water demand for food through serial imports from water-rich countries; and that virtual water trade can be used as an economic system to achieve water securities has become dominant in the discussions on ways of facing global water challenges (Allan, 1997: pp 4; Warner 2003: pp 127). This has almost become a truism because of the fact that some of the largest virtual water importing countries, the Middle East and North Africa, face serious water deficits and some of the virtual water exporting countries water rich.

Past researchers found that the virtual water is moving out from the water abundant region to water scarce region (Allan, 1997; Warner 2003; Hoekstra and Hung 2002; Chapagain and Hoekstra 2003). The study conducted by the Kumar and Singh (2005) argued that physical water availability is not a necessary condition for virtual water export, arable land is one of the important factor for virtual water export. This is because of two reasons: First, when access to arable land increases, the ability to utilize available blue water for irrigation increases. Second, increasing access to arable land improves the access to water held in the soil profile as "free good", a factor not taken into account in assessing water availability. Hence, many of the humid, water-rich countries will not be in a position to produce surplus food and feed the water scarce nations; and virtual water

often flows out of water-poor, land rich countries to land-poor water-rich countries. Singh *et al*. (2004a and 2004b) study the virtual water trade through dairy products and found that the virtual water exporting region is absolute water scarce region and water abundant regions are importing virtual water in the form of milk and milk products. The main objective of present study was to estimate the virtual water trade through food and vegetable crops grown in eastern Uttar Pradesh.

METHODOLOGY

Data Collection The study was based on the primary data and it was collected by using pre-tested schedule. There are 15 districts which come under the Eastern U.P. Out of these, Mirzapur and Varanasi districts have been selected purposively where maximum area was irrigated using ground water. In both the districts, most of the farmers were allocating maximum area under food and vegetable crops. A list of all the 12 blocks of Mirzapur district and 08 blocks of Varanasi district was prepared and one block namely Sikhar in Mirzapur and Pindra in Varanasi district were selected randomly. A list of all the villages of selected blocks, Sikhar in Mirzapur and Pindra in Varanasi (consisting of 112 and 98 villages respectively) was obtained and from this list two villages from each blocks were selected randomly. A list of all the farmers from each selected village was prepared separately, who grew food and vegetable crops on their farm. In each case 10 per cent of the farmers were selected randomly for the present study. In total 100 farmers were selected randomly, viz., 50 farmers from each block. The primary data included various inputs used for crop production in terms of quantity and value, crop output (main and by-products), number of irrigation given to crops, number of hours required to irrigate per unit area, pump discharge rate, farm harvest prices of different crops grown by sample farmers. Secondary data were collected from the district, block and Tehsil head quarters, Government Publications, Agriculture Census Report etc. from the respective department's web site.

ANALYTICAL PROCEDURE

Water Use for Crop Production Generally, farmers were growing crops under irrigated and rainfed condition and major source of irrigation water was ground water. For the quantification of ground water which was used by the farmers for growing irrigated food grain and vegetable crops, it was needed to find out pump discharge rate and total hours of irrigation water used for a particular crop. We used following equation (Singh, 2004; Kumar, 2007) for quantification of irrigation water:

$$\theta_{Crop} = I_n * H_{pi} * Pd_{(m^3/Hour)} \quad \text{... [1]}$$

Where,

θ_{crop} = Total water used for crop production (m^3);

I_n = Number of irrigation given to particular crop during the crop period;

H_{pi} = hours of pump run to provide one irrigation to crop;

$Pd_{(m^3/hour)}$ = Pump discharge rate measured as m^3/hour.

Water Allocation between Main and By-Product

Most of the foodgrains are having joint product i.e. main product (grain) and by-product (straw). This makes it difficult to estimate water used for production of main and by-product. For example; farmers are generally growing wheat for grain production, but they also get wheat straw, which is the by-product. In such a situation, the difficulties in allocation of total water used to produce the crop between wheat grain and wheat straw. Dhondyal (1987) suggested that the ratio that exists in the income of main product and by-product should also be the ratio for apportionment of their cost of production. Therefore, we allocated water according to the ratio of the value of main and by-product of the crops.

Physical Water Productivity

The physical water productivity (Kg/m^3) for a given crop was estimated using the data on crop yield and the estimated volume of water applied (using equation [1]) by all the sample farmers growing that crop. The physical water productivity of crops is estimated through following equation:

$$WP_{crop} = \frac{Q_{crop}}{\theta_{crop}} \quad \text{... [2]}$$

Where,

WP_{crop} = physical water Productivity of crops (Kg/m^3);

$Q_{crop(amin)}$ = the average yield of main product of crop (Kg);

θ_{crop} = the total volume of irrigation water used for crop production (m^3).

Net Combined Physical and Economic Water Productivity The net combined physical and economic water productivity (Rs./m^3) was estimated using data on net returns from crop production (Rs./ha.) and estimated volume of irrigation water (m^3) used. For the estimation of net income from particular crop, the data on inputs were obtained from each crop for all the farmers from primary survey. This included cost of seed, labour, fertilizer, pesticides and insecticides, irrigation cost, ploughing, cost of harvesting and threshing etc.

For estimation of net combined physical and economic water productivity (Rs/m^3) main and by-product of the crop and farm harvest prices were used. The combined physical and economic water productivity for crop production WP_{crop} (Rs/m^3) was estimated through following equation (Singh, 2004; Kumar, 2007):

$$NI_{crop} = (Q_{crop} * P_{FH}) - T_{input\ cost} \quad \text{... [3]}$$

Where,

NI_{crop} = Net income received from a particular crop (Rs);

Q_{crop} = Crop production per unit area (quintal);

*P_{FH} = farm harvest price of particular crop (Rs per quintal);

$T_{(input\ cost)}$ = Total input cost used for production of particular crop on per unit area (Rs).

$$WP_{crop} = \frac{NI_{crop}}{\theta_{crop}} \quad \text{... [4]}$$

Where,

WP_{crop} = Net combined physical and economic water productivity (Rs/m^3);

NI_{crop} = the net income received from a particular crop (Rs);

θ_{crop} = Total irrigation water used for particular crop production (m^3).

Estimation of Virtual Water Trade Through Crops

As we know that virtual water is the volume of water used for crop production and it is made available for other people or place we considered only those parts of the produce, which was marketed/sold outside of the village. For the estimation of virtual water trade, the following mathematical function was used:

$$VWT = WP_{crop} * Q_{sold} \quad \text{... [5]}$$

Where,

VWT = Total virtual water trade through crops measured in m^3;

WP_{crop} = Physical water productivity of crops measured in Kg/m^3;

Q_{sold} = Quantity of crops traded outside the village measured in Kg.

RESULT AND DISCUSSION

Allocation of Irrigation Water between Main Product and By-product

The crops grown during the kharif season in Mirzapur district by the sample farmers were maize, bajara and groundnut, whereas crops gown during rabi season were wheat, pea, chilli and tomato (Table 1). There was no crop grown by the sample farmers during summer season. Out of these crops, only maize, bajara and wheat crop had by-product and it was used to feed livestock or other purposes. Therefore, we allocated total volume of irrigation water among the main and by product and for rest of the crop total volume of irrigation water devoted for the main product. The allocation of volume of water was done on the basis of market value of main and by-product.

The crops grown by sample farmers in Varanasi district during kharif season were maize and paddy. While the crops grown during rabi season in Varanasi district were wheat, tomato, potato, mustard cauliflower and gram. In summer season, while tomato, Sponge gourd , cucumber, sugarcane, pumpkin and okra were grown by the sample farmers during summer season in Varanasi district. Most of the crops grown by sample farmers of the district having no by-product or very less quantity of by-product. These crops include tomato, potato, mustard, cauliflower, gram, Sponge gourd , cucumber, pumpkin and okra. For these crops total volume of irrigation water allocated for the production of main product, while rest of the crops having by-product. Therefore, we allocated total volume of irrigation water between main and by-product based on the market price of main and by-product.

Irrigation Water use, Crop Yield and Physical Water productivity

The irrigation water use, crop production and physical water productivity is presented in Table 2. There is no definite trend of irrigation water use and the crop yield of various crops in the Mirzapur district. This is due to the fact that the requirement of water uses varied from crop to crop. However the physical water productivity was very high in case of tomato (15.06 kg/m^3) followed by pea, wheat and chilli in rabi season. In kharif season physical water productivity is high in the case of maize (5.43 kg/m^3) crop followed by bajra and groundnut in the Mirzapur district (Table 2). In case of Varanasi district mainly two crops were grown during kharif season. The physical water productivity is high in case of maize crop (4.94 kg/m^3) followed by paddy. In rabi season the physical water productivity is high in case of potato followed by tomato, cauliflower, gram, mustard and wheat. In summer season the physical water productivity is very high in case of sugarcane followed by tomato, pumpkin, Sponge gourd , cucumber and okra.

Table 1: Irrigation water allocation between Main product and By-product

S. No.	Name of the crop	Mirzapur			Varanasi		
		Irrigation water use (m^3)	Irrigation water used for (m^3)		Irrigation water use (m^3)	Irrigation water used for (m^3)	
			Main product	By-product		Main product	By-product
		Kharif					
1.	Maize	588.51	573.74	14.77	685.80	675.17	10.63
2.	Bajra	513.36	491.48	21.88	-	-	-
3.	Groundnut	553.86	553.86	-	-	-	-
4.	Paddy	-	-	-	1644.50	1600.38	44.13
		Rabi					
5.	Wheat	2255.92	1919.06	336.85	2047.31	1778.58	268.73
6.	Pea	939.40	939.40	-	-	-	-
7.	Chilli	3041.20	3041.20	-	-	-	-
8.	Tomato	1026.00	1026.00	-	2430.00	2430.00	-
9.	Potato	-	-	-	2031.28	2031.28	-
10.	Mustard	-	-	-	910.04	857.78	52.26
11.	Cauliflower	-	-	-	2433.38	2433.38	-
12.	Gram	-	-	-	501.19	482.42	18.77
		Summer					
13.	Tomato	-	-	-	2570.33	2570.33	-
14.	Sponge gourd	-	-	-	2783.81	2783.81	-
15.	Cucumber	-	-	-	2849.06	2849.06	-
16.	Sugarcane	-	-	-	3649.58	3649.58	-
17.	Pumpkin	-	-	-	2431.51	2431.51	-
18.	Okra	-	-	-	2509.31	2509.31	-

Virtual Water Trade Through Crops

The virtual water is the embedded water with crops and when crops are traded from surplus area/farm to deficit area or consumer, indirectly embedded water also traded. In most of the crops, very small quantity of water retained by the farmers for their own consumption and other uses like seed, wage paid to the farmers in the form of kind and larger portion of their produce is sold out in the market. In this section we tried to estimate the virtual water trade in through crops in both the study area by the sample farmers i.e. Mirzapur and Varanasi. For the estimation of virtual water trade we collected information regarding the total crop produce, quantity of produce retained by the farmers for their own requirement including consumption and quantity sold into the market.

The crop-wise virtual water trade through different crops in the study area is presented in Table 3. The crops grown during the kharif season by the sample farmers in Mirzapur district were maize bajra and groundnut. Out of this, highest virtual water traded through the crops was maize (504.33 m^3) followed by

Table 2: Irrigation water use, crop production and physical water productivity

S. No.	Name of the crop	Mirzapur			Varanasi		
		Irrigation water use (m^3)	Crop yield (kg)	Physical water productivity (kg / m^3)	Irrigation water use (m^3)	Crop yield (kg)	Physical water productivity (kg / m^3)
				***Kharif* season**			
1.	Maize	573.74	2938.95	5.43	675.17	2955.47	4.94
2.	Bajra	491.48	2168.59	4.42	-	-	-
3.	Groundnut	553.86	2142.86	3.99	-	-	-
4.	Paddy	-	-	-	1600.38	4245.00	2.75
				***Rabi* season**			
5.	Wheat	1919.06	4046.25	2.12	1778.58	3221.25	1.86
6.	Pea	939.40	4842.99	5.58	-	-	-
7.	Chilli	3041.20	6365.85	2.11	-	-	-
8.	Tomato	1026.00	15437.50	15.06	2430.00	15,500.00	6.76
9.	Potato	-	-	-	2031.28	16437.50	8.20
10.	Mustard	-	-	-	857.78	1504.46	1.98
11.	Cauliflower	-	-	-	2433.38	15000.00	6.24
12.	Gram	-	-	-	482.42	1875.00	3.97
				***Summer* season**			
13.	Tomato	-	-	-	2570.33	15229.84	6.08
14.	Sponge gourd	-	-	-	2783.81	11833.33	4.27
15.	Cucumber	-	-	-	2849.06	9500.00	3.35
16.	Sugarcane	-	-	-	3649.58	302678.57	82.93
17.	Pumpkin	-	-	-	2431.15	13230.00	5.63
18.	Okra	-	-	-	2509.31	8156.25	3.34

groundnut (490.16 m^3) and lowest from the bajra with 475.13 m^3. Crop grown by the sample farmers during kharif season was maize and paddy in Varanasi district. The highest virtual water traded though paddy crop (1262.64 m^3) and lowest from the maize with 540.36 m^3 (Table 3). The maize crop was grown by the sample farmers in both the study area and the highest virtual water traded by the sample farmers in Varanasi district as compared to Mirzapur district. It is so because farmers of Varanasi district are using higher volume of water as compared to Mirzapur district. Resulting, the water productivity for maize crop was higher for Mirzapur district as compared to Varanasi district. Therefore, virtual water trade through maize crop in Varanasi district was higher as compared to Mirzapur district.

The crops grown by the sample farmers in Mirzapur district were wheat, pea, chilli and tomato. Out of these crops, highest virtual water traded through chilli (504.33 m^3) and lowest from the pea with 709.77 m^3 (Table 3). The crops grown by sample farmers in Varanasi district were wheat, tomato, potato, mustard, cauliflower and gram. The highest virtual water traded by the sample farmers though cauliflower with 2306.31 m^3 and lowest from gram with 380.68 m^3. During the summer season sample farmers of Mirzapur district were not taking any crop due to non-availability of irrigation water and they also thinking that it would help in improvement of soil fertility. The crops grown by the sample farmers in Varanasi district during summer season was cash crops, viz., tomato, Sponge gourd , cucumber, sugarcane, pumpkin and okra. Out of these crops, the highest virtual water traded through cucumber (2664.06 m^3) and lowest from the okra with 2291.78 m^3 (Table 3).

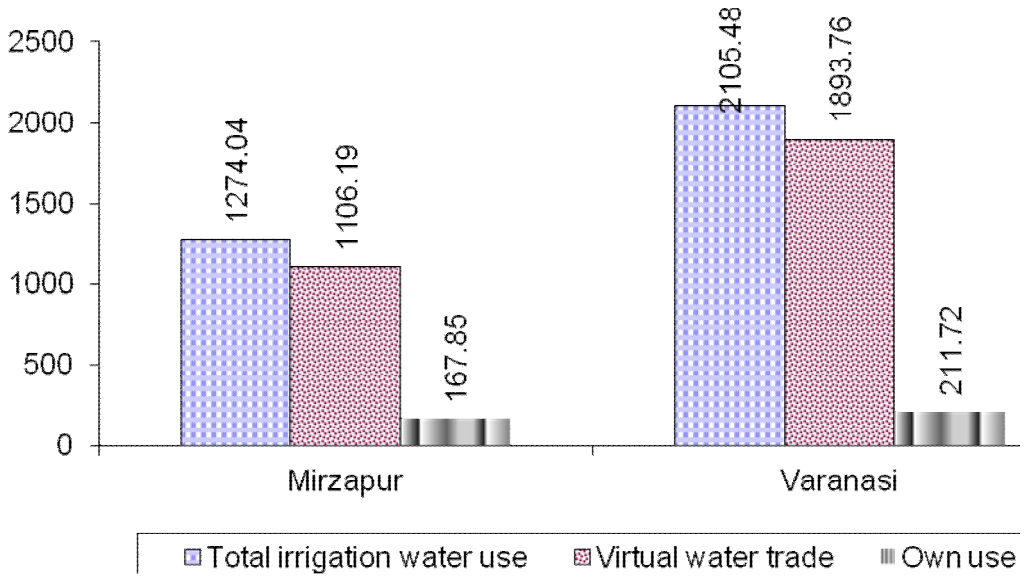
Virtual Water Trade Through Crops at Farm Level

In the above section (section 3.3) we discussed the virtual water traded by the sample farmers through the individual crops in both the study area i.e. Mirzapur and Varanasi district. In this section we discuss the virtual

Table 3: Virtual water trade through food and vegetable crops

S. No.	Name of the crop	Mirzapur			Varanasi		
		Irrigation water use (m^3)	Virtual water trade (m^3)	Own use (m^3)	Irrigation water use (m^3)	Virtual water trade (m^3)	Own use (m^3)
				Kharif season			
1.	Maize	588.51	504.33	84.18	685.80	540.36	145.44
2.	Bajra	513.36	475.13	38.23	-	-	-
3.	Groundnut	533.86	490.16	63.71	-	-	-
4.	Paddy	-	-	-	1644.50	1262.64	381.86
				Rabi season			
1.	Wheat	2255.92	1547.52	708.40	2047.31	1244.17	803.14
2.	Pea	939.40	709.77	229.63	-	-	-
3.	Chilli	3041.20	3005.59	35.62	-	-	-
4.	Tomato	1026.00	1010.83	15.17	2430.00	2229.36	200.64
5.	Potato	-	-	-	2031.28	1913.83	117.45
6.	Mustard	-	-	-	910.04	690.40	219.64
7.	Cauliflower	-	-	-	2433.38	2306.31	127.06
8.	Gram	-	-	-	501.19	380.68	120.51
				Summer season			
1.	Tomato	-	-	-	2570.33	2436.23	134.11
2.	Sponge gourd	-	-	-	2783.81	2613.12	170.69
3.	Cucumber	-	-	-	2849.06	2664.06	185.00
4.	Sugarcane	-	-	-	3649.58	3591.07	58.51
5.	Pumpkin	-	-	-	2431.15	2348.62	82.53
6.	Okra	-	-	-	2509.31	2291.78	217.53

Figure 1: Virtual Water Trade Through Food and Vegetable Crops at Farm Level



water traded at the farm level by the sample farmers in the study area. In case of Mirzapur district, total irrigation water used at the farm level for production of irrigated crops was 1274.04 m^3. Out of this, virtual water traded by the sample farmers was estimated to be

1106.19 m^3 and 167.85 m^3 water were used by the farmer for their own consumption. In case of Varanasi district, total irrigation water used by the sample farmer at the farm level was estimated to be 2105.48 m^3. Out of this virtual water move out from the village was estimated to be 1893.76 m^3 and remaining virtual water equivalent crop produce was used by the farmers for their own consumption (Figure 1)

SUMMARY AND CONCLUSION

In kharif season in both districts, the overall virtual water trade and own use was very high in case of paddy crop followed by maize, groundnut and bajra. In rabi season, the average virtual water trade was higher in case of chilli followed by cauliflower, potato, tomato, gram, mustard and wheat etc. In case of own use, it was very high in case of wheat followed by pea, mustard, gram, tomato, potato, cauliflower, and chilli in rabi season. In Varanasi district during summer season, the virtual water trade was higher in case of sugarcane followed by pumpkin, tomato, sponge gourd , cucumber and okra whereas in case of own use, it was higher in case of okra followed by cucumber, Sponge gourd , tomato, pumpkin and sugarcane. From the above discussion it is clear that farmers were exporting higher virtual water in the form of food and vegetable crops. The share of vegetable crops was higher in exporting virtual water as compared to food crops.

REFERENCE

1. Allan, J.A. (1997). Virtual water: A long term solution for water short Middle Eastern economies? Paper presented at the 1997 *British Association Festival of Science, University of Leeds*, September 9, 1997.
2. Chapagain A. K. and A. Y. Hoekstra (2003). Virtual water trade: A quantification of virtual water flows between nations in relation to international trade of livestock and livestock products, Virtual water trade, proceedings of the international expert meeting on virtual water trade, edited by Hoekstra, A.Y., *Value of water research report series* # 12.
3. Dhondyal, S P (1987), *Farm Management*, Friend Publications, Meerut, India, p 58.
4. Hoekstra, A.Y. and P.Q. Hung (2003), Virtual water trade : A quantification of virtual water flows between nations in relation to international crop trade, Virtual water trade, proceedings of the international expert meeting on virtual water trade, edited by Hoekstra, A.Y., *Value of Water Research Report Series # 12*.
5. http://www.fao.org/DOCREP/006/Y4525E/Y4525e04.htm#TopOfPage
6. Kumar, M. Dinesh and O. P. Singh (2005). Virtual Water in Global Food and Water Policy Making: Is There a Need for Rethinking, *Water Resource Management*, 19 (6) : 759-789.
7. Kumar, M. Dinesh with contribution from O. P. Singh (2007), "Groundwater Management in India: Physical, Institutional and Policy Alternatives". Sage Publications India Pvt. Ltd., New Delhi.
8. Singh, O. P. (2004). Water Productivity of Milk Production in North Gujarat, Western India, *Proceedings of the 2nd Asia Pacific Association of Hydrology and Water Resources (APHW) Conference*, Vol. 1: 442-449.
9. Singh, O. P., Amrita Sharma, Rahul Singh and Tushaar Shah (2004b). Virtual Water Trade in the Dairy Economy: Analyses of Irrigation Water Productivity in Dairy production in Gujarat, India, *Economic and Political Weekly*, 39 (31) : 3492-3497.
10. Singh, O.P., Amrita Sharma and Rabul Singh (2004a). Virtual Water Trade through Dairy Products : Analyses using Regional Estimates of Blue water Productivity of Milk Production in Gujarat India, Published in Abstract volume of *The 14th Stockholm Water Symposium,* Sweden: 177-178.
11. Warner, J. (2003). Virtual water- virtual benefits? Scarcity, distribution, security and conflict reconsidered, Virtual water trade, proceedings of the international expert meeting on virtual water trade, edited by Hoekstra, A.Y., *Value of Water* Research Report Series