Virtual Water Trade in Dairy Economy

Irrigation Water Productivity in Gujarat

During the past 50 years, Gujarat has led India's exemplary growth in dairy production by forging the world's best known cooperative movement. Thanks to the market access and production enhancement programmes run by cooperatives, dairying has emerged at the centre stage of rural livelihoods systems in arid and semi-arid regions. However, intensification of dairying has been accompanied by intensive use of water used in growing feed and fodder. This study estimates that dairying-based rural livelihoods systems are now threatening the limited water resources of arid and semi-arid areas, and their future in turn is threatened by the depletion of these resources. The paper analyses virtual water exports and imports by some of the leading dairy cooperatives of Gujarat.

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I Introduction

With the advent of green revolution technologies and water-intensive crops, the pressure on groundwater for irrigation has enormously increased in Gujarat [Bhatia 1992]. Secular decline in groundwater levels leading to increase in cost of water abstraction structures is depriving resource poor, small, and marginal farmers of direct access to groundwater. Those, whose wells have dried up, largely depend on water purchased from rich well owners often at prohibitive prices to sustain irrigated agriculture [Gass et al 1996; IRMA/UNICEF 2001]. To cope with the situation, farmers are shifting to low water-intensive crops having high economic value [Kumar 2000, Kumar forthcoming]. Farmers are also switching from crop production to dairy production given the short-term cash flow and stable income from it. The dairy industry has seen a major upswing after the inception of 'Operation Flood Programme' in India, which was launched by the National Dairy Development Board, Anand in 1970. India has emerged as the largest producer of milk in the world by attaining 81 million tonnes during 2001 [Singh and Pundir 2003]. Gujarat is one of the fore runners of dairy production in the country. But this changing trend has added to the burden on already stressed groundwater resources.

Dairy farming involves not only direct consumptive water use by cattle for milk production, but also embedded water in green fodder and byproducts of cereal crops and other cereals and crop residues that are fed to cattle. Dairy farmers in Gujarat are heavily dependent on import of dry fodder and feed, which points to growing trade in 'virtual water' [Allan 1993]. Virtual water is defined as the volume of water required to produce a commodity or service [Allan 1998; Hoekstra 1998]. It has also been called 'embedded water' [Hoekstra 1993]. The transfer of virtual water embedded in various commodities and services that are traded is becoming an important element of water management discussions at global as well as regional level, particularly in regions which experience water deficits for food production [Chapagain and Hoekstra 2003]. Chapagain and Hoekstra (2003) have developed a methodology to quantify the virtual water flows between nations through trading of livestock and livestock products. According to their estimates, global virtual water trade through crop and livestock products is estimated to be 940 km^3/year, equivalent to a quarter of India's annual precipitation. Livestock and livestock products accounted for 26 per cent of this trade.

A dairy animal requires only about 70 and 80 litres of water per day in the form of drinking water. Lactating dairy animal requires some more water to produce milk (2.5 litres drinking water per litre of milk production). A cow or a buffalo producing 10 litres of milk a day, then, would require about 100 litres of drinking water (Trivedi, personal communication, 2003). But this is only the tip of the iceberg so far as water use in dairy farming is concerned. Singh and Kishore (2003) found that average daily water used by buffalo and crossbred cow in Mehsana district of Gujarat was 10.18 m^3 and 10.51 m^3, respectively, with the share of drinking water being less then 1 per cent, while embedded water accounts for the rest.

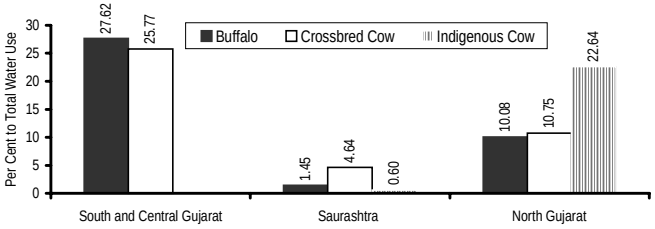
II Objectives and Methodology

The objectives of this paper are to: (i) quantify the total irrigation water used for crop and dairy production in different region of Gujarat, and disaggregate water use in dairy production for buffalo, crossbred cows and indigenous cows; (ii) estimate the irrigation water productivity of crop and dairy production both in agronomic and economic terms; and (iii) quantify the virtual water trade through trading of milk in different regions of Gujarat.

The study covered five district cooperative dairy cooperative unions falling in three distinct regions of Gujarat: (a) Anand and Surat districts dairy unions in south and central Gujarat; (b) Mehsana and Banaskantha districts dairy unions in north Gujarat; and (c) Rajkot district dairy union in Saurashtra region. Two villages were selected from each union and from each village a sample of 30 dairy farming households was surveyed.

Mehsana and Banaskantha fall in the north Gujarat region, which is 'absolutely water scarce' going by Malin Falkenmark's index of physical water scarcity [IRMA/UNICEF 2001]. Rajkot district falls in Saurashtra, which according to the same index

Figure 1: Imported Virtual Water Use in Milk Production (Per Animal/Day)



is a 'water scarce' region. Anand and Surat fall in south and central Gujarat, which is a 'water abundant' region (ibid).

The study considered both direct consumptive water use and embedded water use (irrigation water used for producing inputs of dairy production) to estimate total water used for dairy production. The estimates understate true water use because all calculations are done for irrigation water use; the use of rainfall and soil moisture is excluded. Throughout the paper then by 'water productivity', we mean 'irrigation water productivity'.

Table 1: Gross Cropped Area and Percentage Area under Fodder Crops

(Area in Ha)

Year	Name of the District				
	Kheda	Surat	Rajkot	Mehsana	Banaskantha
1975-76	29910	65938	23157	47882	143553
	[5.14]	[14.61]	[3.02]	[5.27]	[14.65]
1980-81	35551	66612	26260	55160	159117
	[5.94]	[15.53]	[3.24]	[6.25]	[16.51]
1985-86	26336	65459	16200	61556	152232
	[4.61]	[15.32]	[2.24]	[6.87]	[15.70]
1990-91	24863	57959	18734	95265	154291
	[4.09]	[12.77]	[2.31]	[11.02]	[14.69]
1995-96	24585	58401	64790	128134	211503
	[3.76]	[11.92]	[8.35]	[13.88]	[18.79]

Note: Figure in parenthesis represents percentage area under fodder crops.
Source: Government of Gujarat, undated.

The following formulation was employed to quantify irrigation water use for crop production and included all major crops grown in the respective regions.

Total water use (m^3) = Number of irrigation × Hours per irrigation × Pump discharge (m^3/hrs)

Water productivity for crop production is calculated as:

Crop water productivity (kg/m^3) = Crop output (kg)/Total water used (m^3)

The total water used for dairy production depends on two variables: (i) drinking water; and (ii) irrigation water used for the production of green and dry fodder and concentrates. The water used per day per animal is defined as:

Total water use (m^3/day/animal) = {Drinking water (m^3) + Green fodder (m^3) + Dry fodder (m^3) + Concentrate (m^3)}

Milk production per m^3 of water is calculated as:

Water productivity in milk production (litre/m^3) = Milk production (litre)/Water use (m^3)

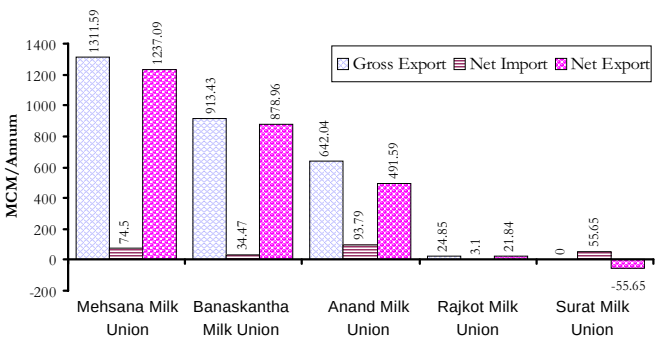
III
Results and Discussion

During 2000-01, total milk production in the state was 53.13 lakh metric tonnes and it accounted for 6.57 per cent of India's milk production. The per capita milk availability was 294 grams/day and is higher than the national average and also the nutritional requirement recommended by the Indian Council of Medical Research, i e, 250 grams/capita/day. Continuous and rapid growth in dairy production in Gujarat was achieved through increase in holding of improved cattle breed, increase in use of balanced cattle feed, and improved veterinary services. Another significant important input of dairy production was expansion of irrigated fodder crops. The contribution of irrigated area under fodder crops to gross cropped area is presented in Table 1. The contribution of irrigated area under fodder crops has declined in south and central Gujarat during 1975-76 to 1995-96, whereas significant increase in the area under fodders is observed in north

Table 2: Water Use for Major Crop Production and Water Allocation

Name of Crops	Average Depth of Watering (mm)								
	South and Central Gujarat			Saurashtra Region			North Gujarat Region		
	Main Product	Byproduct	Total	Main Product	Byproduct	Total	Main Product	Byproduct	Total
A Green Fodder									
1 Mayo	677.76	-	677.76	-	-	-	-	-	-
2 Jariya	1292.13	-	1292.13	-	-	-	-	-	-
3 Alfalfa	1080.19	-	1080.19	1320.45	-	1320.45	2079.10	-	2079.10
4 Maize	276.39	-	276.39	274.36	-	274.36	948.30	-	948.30
5 P Jowar	-	-	-	-	-	-	1067.50	-	1067.50
B Cash Crops									
1 Sugar cane	1789.40	180.29	1969.69	-	-	-	-		-
2 Tobacco	675.64	-	675.64	-	-	-	-	-	-
3 Groundnut	-	-	-	81.31	13.20	94.51	-	-	-
4 Cotton	-	-	-	370.65	-	370.65	1346.49	-	1346.49
5 Cumin	-	-	-	160.53	-	160.53	-	-	-
6 Castor	-	-	-	-	-	-	949.33	-	949.33
7 Sesamum	-	-	-	-	-	-	370.49	-	370.49
8 Mustard	-	-	-	-	-	-	622.45	-	622.45
9 Green gram	-	-	-	-	-	-	141.61	-	141.61
C Foodgrain Crops									
1 Bajara (K)	460.09	97.77	557.85	-	-	-	259.04	97.09	356.14
2 Bajara (S)	630.32	86.20	716.52	-	-	-	620.87	182.72	803.57
3 Paddy	1168.19	74.62	1242.81	-	-	-	-	-	-
4 Wheat	607.14	39.42	646.55	375.75	54.86	433.61	802.40	117.28	919.32
5 Guvar	-	-	-	-	-	-	76.47	20.39	96.86
6 Jowar (K)	-	-	-	-	-	-	138.92	118.41	303.89
7 Jowar (S)	-	-	-	-	-	-	510.03	416.11	926.14

Figure 2: Virtual Water Trade by the Milk Unions, Gujarat



Gujarat and Saurashtra region during the same period of time (Table 1).

Table 2 presents our survey data on the average depth of irrigation water applied by farmers to major crops and their allocation between main and byproduct. We allocated the total water used between main and byproduct according to the ratio of income from the main and byproducts [Dhondyal 1987]. Alfalfa is one of the important green fodders and is being grown by dairy farmers in all regions. Average depth of watering for alfalfa varied from 1,080 mm (in south and central Gujarat) to 2,079 mm (in north Gujarat). Dairy farmers are growing maize as a green fodder across the study area and its average depth of watering varied from 274 mm (Saurashtra region) to 948 mm (north Gujarat). Sugar cane and tobacco are important among cash crops which farmers in south and central Gujarat grow. Sugar cane is more water-intensive compared to tobacco (Table 2). In Saurashtra, highest water use occurs in cotton and the lowest in kharif groundnut. Among foodgrain crops, wheat is grown all over Gujarat and the depth of watering applied in it varied between 634 mm (in Saurashtra) and 919 mm (in north Gujarat).

Seasonwise average daily feed and fodder input to in-milk and dry animal and calf were estimated first using our survey data; using average daily feeding pattern, these values were imputed into the entire life cycle of the animal. Based on these, the daily inputs of dairy production were estimated. In south and central Gujarat, of average daily fodder fed to dairy animals, large share comes from the local grasses, whereas bulk of the dry fodder fed is paddy straw. In case of concentrate, larger portion comes through balanced cattle feed ('Amuldan/Sumuldan') (Table 3). In Saurashtra region, large share of greens comes from maize fodder (Table 3); while the most popular dry fodder in the region is groundnut straw. Balanced cattle feed ('Rajdan') and cottonseed cake are used as concentrates. Dairy farmers of Saurashtra breed the indigenous 'Gir cow', known for its endurance and relatively higher milk yield when compared to other non-descript cows. In north Gujarat region, alfalfa is a preferred green fodder (Table 3); bajra and jowar straw are the main sources of dry fodder. The concentrate is given in the form of balanced cattle feed ('Sagardan'/'Banasdan') and cottonseed cake (Table 3). Across the regions, almost the same quantum of green and dry fodder is fed to in-milk and dry animals. However, the concentrate is fed only to in-milk and pregnant cows and buffaloes in advanced pregnancy.

In south and central Gujarat, average daily milk production of buffalo and crossbred cow were estimated to be 1.87 litres and 2.90 litres per animal, respectively. Average daily milk production in Saurashtra region for buffalo, crossbred cow and indigenous cow are 4.72 litres/animal, 6.39 litres/animal and 4.08 litres/animal, respectively. For north Gujarat region, it is 3.82 litres/animal, 5.14 litres/animal, and 4.00 litres/animal for buffalo, crossbred cow, and indigenous cow, respectively.

With shorter inter-calving period, less time to arrive at first calving stage and longer period of lactation, the average daily milk production of crossbred cow is more than that of buffalo and indigenous cow. Interregional variation in productivity of crossbred cows is probably explained by the differences in relative importance of dairying in the livelihoods. In water abundant south and central Gujarat, crop production is the main source of livelihood but in water scarce north Gujarat and Saurashtra, dairy farming is the primary source of livelihood and crop production is secondary.

Table 4 presents the physical, net, and gross value productivity of major crops grown across the three regions of Gujarat. Physical productivity is crop yield per unit of irrigation water (kgs/m^3), whereas value productivity is the value of output per unit of irrigation water (Rs/m^3). The physical and gross value productivity of water in alfalfa was found to be the highest in south and central Gujarat and lowest in north Gujarat (Table 4). Dairy farmers grow maize as a green fodder across the study area and physical and value productivity of water in maize production was highest in Saurashtra region and lowest in north Gujarat (Table 4). In south and central Gujarat farmers grow sugar cane and tobacco, and gross value productivity of water in tobacco was found to be higher than that of sugar cane. In Saurashtra region, value productivity of irrigation water was the highest for kharif groundnut and lowest for cumin (Table 4). In north Gujarat, cotton,

Table 3: Average Feed and Fodder Fed to Livestock in Different Regions of Gujarat

(Kgs/day/animal)

Name of Feed and Fodder	South and Central Gujarat		Saurashtra Region			North Gujarat		
	Buffalo	Cow	Buffalo	CB Cow	Indigenous Cow	Buffalo	CB Cow	Indigenous Cow
A Green fodder	*13.77*	*12.90*	*14.04*	*13.39*	*12.84*	*20.01*	*18.00*	*13.60*
1 Local green grass	5.85	5.51	1.27	1.88	1.56	5.09	3.37	5.67
2 Sugar cane top	3.50	1.12	-	-	-	-	-	-
3 Mayo	1.51	0.91	-	-	-	-	-	-
4 Jariya	0.73	2.70	-	-	-	-	-	-
5 Alfalfa	0.72	1.34	3.09	3.80	3.39	8.22	7.68	4.67
6 Maize	0.68	0.39	8.78	6.82	7.51	1.44	1.68	0.59
7 Jowar	-	-	0.90	0.89	0.38	-	-	-
8 Pioneer jowar	-	-	-	-	-	3.32	3.53	2.68
9 Others	0.78	0.93	-	-	-	1.94	1.74	0.00
B Dry fodder	*5.96*	*5.35*	*11.17*	*11.74*	*9.04*	*6.38*	*5.74*	*5.29*
1 Paddy straw	2.84	2.32	-	-	-	0.45	0.37	0.18
2 Bajara straw	1.95	2.75	-	-	-	2.35	2.43	1.91
3 Wheat straw	0.50	0.19	-	-	-	0.60	0.56	0.20
4 Jowar straw	0.37	0.10	0.14	0.14	0.21	2.99	2.39	3.00
5 Groundnut straw	-	-	10.88	11.20	8.05	-	-	-
6 Local grass	-	-	0.14	0.40	0.78	-	-	-
C Concentrate	*2.04*	*2.10*	*3.23*	*4.29*	*3.18*	*2.15*	*2.30*	*1.29*
1 Balanced cattle feed (Amuldan/Sumuldan/ Sagardan/ Banasdan)	0.99	1.56	0.30	1.08	0.12	1.38	1.77	0.80
2 Cotton seed cake	0.51	0.23	2.90	3.21	3.06	0.11	0.07	0.16
3 Groundnut cake	-	-	0.03	0.00	0.00	-	-	-
4 Guvar	-	-	-	-	-	0.08	0.08	0.06
5 Maize	0.10	0.26	-	-	-	-	-	-
6 Others	0.44	0.05	-	-	-	0.58	0.38	0.27
D Drinking Water (Lts)	*38.59*	*31.96*	*40.77*	*33.62*	*27.87*	*52.14*	*48.59*	*37.54*

Source: Authors' own estimate based on primary survey data, 2003.

castor, and mustard are the main cash crops and net value productivity of water is the highest for green gram and lowest for sesamum (Table 4).

Among foodgrains, wheat is grown across all the three regions of Gujarat under study, and gross value product of water use in wheat is lowest in north Gujarat and highest in Saurashtra (Table 4). The net value product of water in paddy is estimated to be Rs 0.20/m^3. In north Gujarat region, farmers are growing bajra and jowar during both kharif and summer season. The net value product of water in kharif bajra and summer bajra are Rs 0.64/m^3 and Rs 0.62/m^3, respectively (Table 4).

Water Used in Dairy Production and Its Productivity

In this section, we present the estimates of the amount of embedded water in the feed and fodders of different types of cattle on the basis of irrigation water applied. Table 5 presents daily direct (drinking water) and indirect (water used for feed and fodder production) water consumed by different types of animals across the regions of Gujarat. The share of drinking water is less than 1 per cent of total water used by dairy animals.

In south and central Gujarat, embedded water use is the highest in the form of concentrate feeds, followed by green and dry fodder. The physical and net value productivity of water in milk production for crossbred cow is more than that for buffalo (Table 5). In Saurashtra region, daily water used for milk production, highest portion of embedded water comes from concentrate followed by green and dry fodder (Table 5). The physical product of water in milk production is highest for indigenous cow and lowest for buffalo, whereas net economic efficiency of milk production is highest for buffalo and lowest for indigenous cow (Table 5). In north Gujarat region, of the total water used for milk production, largest share comes in the form of green fodder followed by concentrate and dry fodder. The physical and net value productivity of water use in milk production is highest for crossbred cow and lowest for indigenous cow (Table 5).

Normally farmers do not consider those inputs which are already available with them either as byproducts of crop production or fodder produced in their farm. They consider only those inputs which are purchased from the market. Secondly, farmers do not consider the 'virtual water' which comes from outside of the region in form of cattle feed. For calculation of water productivity in dairy production, we considered water used for green fodder production, ingredients of concentrate which is produced within the region and drinking water. The water productivity in dairy production for the crossbred cow is higher than that of buffalo and the indigenous cow in south and central Gujarat and north Gujarat, whereas, in Saurashtra region it was highest for indigenous cow (Table 5). It is important to note that in Saurashtra region dairy farmers prefer the Gir breed of cow as it is more efficient in dairy production than the indigenous cow.

Alfalfa is a highly water-intensive crop, though the water requirement varies from region to region (Table 2). Out of the total green fodder, share of alfalfa for different types of animals varies across regions (Table 3). It is quite low in south and central Gujarat at 5 per cent to 10 per cent, whereas, in Saurashtra region, it is 22 per cent to 28 per cent and in north Gujarat region, it is as high as 34 per cent to 46 per cent. In north Gujarat, annual groundwater draft is about 1,528.8 million cubic metres (mcm)/annum. Out of this alfalfa, alone takes away about 13 per cent (198 mcm/annum) of the total water diverted for irrigation [IRMA/UNICEF 2001]. In north Gujarat, if we could cut down water application rate or increase irrigation water productivity of alfalfa, then it would help in making dairy production less water-intensive and will lead to substantial reduction in groundwater draft.

Kumar et al (2003) studied the performance of drip irrigation in alfalfa cultivation in Banaskantha district of north Gujarat region and found that it could save about 43 per cent irrigation water and increase the crop yield by 10 per cent. The dairy unions

Table 4: Gross and Net Physical and Value Product of Water in Production of Major Crops

Name of the Crops	South and Central Gujarat				Saurashtra Region				North Gujarat Region			
	Value Product (Rs/M^3)		Physical Product (Kg/M^3)		Value Product (Rs/M^3)		Physical Product (Kg/M^3)		Value Product (Rs/M^3)		Physical Product (Kg/M^3)	
	Gross	Net	Main Product	By-product	Gross	Net	Main Product	By-product	Gross	Net	Main Product	By-product
A Green fodder												
1 Mayo	1.02	-	4.09	-	-	-	-	-	-	-	-	-
2 Jariya	3.18	-	5.29	-	-	-	-	-	-	-	-	-
3 Alfalfa	5.01	-	9.10	-	3.21	-	6.43	-	1.16	-	2.32	-
4 Maize	3.40	-	6.39	-	12.90	-	12.90	-	1.06	-	2.12	-
5 P Jowar	-	-	-	-	-	-	-	-	1.80	-	2.38	-
B Cash crops												
1Sugar cane	2.22	0.13	3.63	5.23	-	-	-	-	-	-	-	-
2 Tobacco	13.34	10.26	0.53	-	-	-	-	-	-	-	-	-
3 Groundnut	-		-	-	32.40	11.71	2.17	14.08	-	-	-	-
4 Cotton	-		-	-	18.40	12.96	0.74	-	3.25	1.29	0.12	-
5 Cumin	-		-	-	24.61	16.74	0.41	-	-	-	-	-
6 Castor	-		-	-	-	-	-	-	4.41	2.60	0.31	-
7 Sesamum	-		-	-	-	-	-	-	2.92	0.96	0.12	-
8 Mustard	-		-	-	-	-	-	-	4.59	2.53	0.31	-
9 Green gram	-		-	-	-	-	-	-	7.12	3.30	0.47	-
C Foodgrain crops												
1 Bajara (K)	2.17	1.18	0.54	2.55	-	-	-	-	3.56	0.64	0.74	3.62
2 Bajara (S)	2.44	1.70	0.54	2.97	-	-	-	-	2.47	0.62	0.53	2.40
3 Paddy	1.95	0.20	0.37	6.09	-	-	-	-	-	-	-	-
4 Wheat	3.56	1.56	0.65	7.12	8.19	4.82	1.09	8.18	3.36	1.23	0.45	2.13
5 Guvar	-	-	-	-	-	-	-	-	5.89	0.40	0.79	2.95
6 Jowar (K)	-	-	-	-	-	-	-	-	9.12	4.78	1.12	4.30
7 Jowar (S)	-	-	-	-	-	-	-	-	2.98	1.38	0.40	1.50

of north Gujarat are major stakeholders in milk procurement and are constantly striving to increase their milk procurement from dairy farmers through promoting improved technologies for improving feed energy conversion efficient such as chaff-cutters and urea molasses block (UMB). Emerging research suggests that milk unions need to seriously consider programmes to motivate dairy farmers to adopt water-saving technologies, if necessary by providing credit and subsidy support to them. Doing this makes sense not only from the viewpoint of improving their business but also in terms of managing the precious groundwater resource which is so crucial for sustaining dairy industry in north Gujarat.

Virtual Water Used in Daily Feed Regimen of Cattle

In dairy production process, huge quantity of embedded water is traded in the form of dry fodder and concentrates. We have considered only the embedded water in the cattle feed which is traded between the regions of Gujarat and between the states. Figure 1 presents the contribution of imported virtual water used in milk production per day per animal across the regions of Gujarat with different types of animals. The virtual water consumed by different types of animals depends on the amount of cattle feed fed to them. Buffaloes consume larger amount of virtual water as compared to crossbred cow in south and central Gujarat. In Saurashtra region, it was the highest for crossbred cow as compared to buffalo and indigenous cow, whereas in north Gujarat indigenous cows consume more imported water than buffalo and crossbred cow (Figure 1).

In the methodology we have used, the virtual water content of milk is the total water used for milk production. Based on this notion, our study makes an attempt to quantify the annual virtual water trade that takes place by the dairy unions in the form of liquid milk export outside the district/region and the import of balanced cattle feed or inputs for producing balanced cattle feed from outside. For estimation of virtual water import and export, five-year averages of milk export and cattle feed inputs imports by the dairy union have been considered. We assumed that total raw milk procurement by union minus raw milk sold within the district was the net milk export outside the district. Then we derive,

Milk export by dairy union
= milk procurement – milk sale within the district
Net virtual water export
= Gross virtual water export (milk) – Net import of inputs of cattle feed

First of all we considered the ratio of milk of buffalo, crossbred cow, and indigenous cow into total milk procured by the district dairy union. On the basis of this, total water used to produce that quantity of milk was estimated by multiplying the water used for producing a litre of milk by dairy animals across the dairy unions.

As per our estimate, the Anand dairy union exports 642 mcm of embedded water every year in form of milk, while it imports 93.79 mcm/year embedded water in form of ingredients of balanced cattle feed. The net virtual water export by Anand milk union is about 491.59 mcm/annum (Figure 2). The Surat dairy union is a net importer as its total milk procurement is consumed within the district itself. The net virtual water import were 55.65 mcm/year in the form of cattle feed. Surat, which falls in a water abundant region of south Gujarat, imports virtual water through cattle feed imports. In the case of Rajkot dairy union, the gross virtual water export is about 24.85 mcm/year against virtual water import of 3.1 mcm/year in the form of cattle feed from Mehsana dairy union. The net virtual water export is about 21.84 mcm/year. The gross virtual water export by Mehsana dairy union is 1,311.49 mcm/year while it imports 74.5 mcm/year in the form of ingredients of cattle feed. The net virtual water export is 1,237.09 mcm/year. Similarly, the Banaskantha dairy union exports were 913.43 mcm/year of virtual water against an import of 34.47 mcm/year. The net virtual water export by the Banaskantha dairy

Table 5: Water Use in Dairy Production and Productivity of Animals
(Per Day/animal)

	South and Central Gujarat		Saurashtra Region			North Gujarat		
	Buffalo	CB Cow	Buffalo	CB Cow	Ind Cow	Buffalo	CB Cow	Ind Cow
1 Green fodder (M^3)	2.01	1.76	2.67	2.62	1.75	7.41	7.52	3.42
2 Dry fodder (M^3)	1.45	1.52	0.84	0.86	0.67	1.65	1.51	1.33
3 Concentrate (M^3)	2.51	2.20	4.22	5.31	4.27	2.70	2.54	2.33
4 Drinking water (M^3)	0.04	0.03	0.04	0.03	0.03	0.05	0.05	0.04
5 Total water used (M^3)	6.01	5.51	7.77	8.82	6.71	11.81	11.63	7.11
6 Milk production (litre/day)	1.87	2.90	3.82	5.14	4.00	2.56	3.95	2.42
7 Water productivity (litre/M^3)	0.31	0.53	0.49	0.58	0.60	0.22	0.34	0.34
8 Gross value product of water in dairy production (Rs/M^3)	3.99	4.34	6.43	5.34	5.13	2.74	2.76	3.07
9 Net Value product of water in dairy production (Rs/M^3)	0.60	0.70	0.32	0.17	0.14	0.23	0.30	0.12
10 Effective net value product of water in production (Rs/m^3)	1.57	2.18	3.65	1.39	1.74	1.39	1.32	2.18
11 Water used for one litre dairy production	3226	1887	2041	1724	1667	4546	2941	2941

Note: CB cow: crossbred cow; Ind. cow: Indigenous cow
Source: Authors' own estimate based on primary survey.

Table 6: Dairy Production and Water Used for Dairy Production during 1998-99

Name of the Region	Milk Production in '000 Tonnes – 1998-99				Water Used in Milk Production (BCM)			
	Indigenous Cow	Crossbred Cow	Buffalo	Total (Cow + Buffalo)	Indigenous Cow	Crossbred Cow	Buffalo	Total (Cow + Buffalo)
North Gujarat	358.99	127.99	1284.27	1771.25	1.056	0.377	5.925	7.357
South and central Gujarat	332.94	141.26	1041.96	1516.16	1.070	0.268	3.349	4.687
Saurashtra region	571.54	16.76	766.86	1355.17	0.960	0.029	1.560	2.549
Kachchh region	120.04	1.26	79.98	201.28	0.202	0.002	0.163	0.367
Total Gujarat	1383.51	287.27	3173.06	4843.84	3.288	0.676	10.996	14.960

Source: GOG. Undated.

union is 878.96 mcm/year (Figure 2). Thus, north Gujarat, which is the most water scarce region of the state, exports the maximum quantity of virtual water (2,116.05 mcm) through its dairy industries.

For the purpose of quantification of total water used by dairy farming in the state, we collected districtwise milk production by different types of animals for the year 1998-99 (GOG Undated). We have assumed that: (i) water used by different types of animals to produce one litre of milk in Kachchh region is similar to that in Saurashtra region; and (ii) in south and central Gujarat, indigenous cow consumes same amount of irrigation water as a buffalo of same region is consumes.

Total milk production of the state during 1998-99 was 4,843.84 thousand tonnes. Out of this, 28.54 per cent milk was produced by non-descript and indigenous cows, 5.93 per cent by crossbred cows, and 65.53 per cent from buffaloes. From our survey, we know the estimated total water used to produce a litre of milk from different types of dairy animals in different regions (Table 5). To quantify the total water used for milk during 1998-99, we multiplied total milk production by water used for a litre milk production. Based on the average figures of water intensity of milk production for different types of dairy animals in different regions, the total amount of milk produced from these regions and its composition, the irrigation water use for dairy farming was estimated. The estimated irrigation water use to produce 4,843.84 thousand tonnes of milk by different types of animals (buffaloes, crossbred cows, and indigenous cows) in the state is about 14.96 BCM (Table 6). It is important to point out that this estimate is based on the assumption that purely rain-fed milk production is insignificant in Gujarat.

Conclusion

Dairy farming is one of the important sources of livelihood in rural Gujarat. It is more pre-eminent in the regions facing physical scarcity of water due to the shortage of power supply and acute scarcity of irrigation water. In water abundant south and central Gujarat, crop production is still the main source of livelihood and milk production is of secondary importance.

Dairy farming is highly water-intensive, though the efficiency of water use varies across regions and also across animals. As Table 5 (row 11) shows, Gujarat uses 1,900-4,600 litres of irrigation water per litre of milk produced; this is much higher than 2,749 litres of total water use per litre of milk production at all-India level and the global average of 874 litres [Chapagain and Hoekstra 2003]. This suggests strong need to reduce the water intensity of dairy production in Gujarat.

Use of highly water-intensive irrigated green fodder makes dairy farming more water-intensive. In view of this, it becomes imperative to improve water use efficiency of irrigated fodder production in different regions of Gujarat.

Application of drip irrigation in alfalfa crop production, which is a highly water-intensive green fodder and largely grown green fodder in north Gujarat, would save irrigation water use by up to 43 per cent in north Gujarat. Therefore, it is critical to promote water saving technology at least in alfalfa in north Gujarat, but also in other water-stressed regions.

Water productivity of dairy production also varies across different types of livestock. Crossbred cows were found to have highest irrigation water productivity in all the three regions.

Virtual water trade through milk by the dairy union presents a counter-intuitive picture. Our estimates show that north Gujarat, which is 'absolute water scarce', is exporting a net volume of about 2,116.05 mcm of virtual water annually through dairy business. The virtual water import in the form of feed and fodder is one of the options to reduce the pressure on irrigation water in water scarce north Gujarat and Saurashtra region. These water scarce regions can reduce the pressure on their precious water resources by meeting their feed and fodder requirements through import from regions which have surplus biomass. EPW

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References

Allan, A J (1993): 'Fortunately There Are Substitutes for Water Otherwise our Hydro-political Futures would be Impossible', *Priorities for Water Resources Allocation and Management*, ODA, London, pp 13-36.

– (1998): 'Global Soil Water: A Long-Term Solution for Water-Short Middle Eastern Economies', *Proceeding of Water Workshop: Averting a Water Crisis in the Middle East – Make Water a Medium of Cooperation Rather than Conflict*, Green Cross International, March, Geneva.

Bhatia, B (1992): 'Lush Fields and Parched Throats: Political Economy of Groundwater in Gujarat', *Economic and Political Weekly*, XXVII (51-52): A 12-170.

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 A Y Hoekstra, Value of Water Research Report Series # 12.

Dhondyal, S P (1987): *Farm Management*, Friend Publications, Meerut, India, p 58.

Graham, G, M Dinesh Kumar and David Mc Donald (1996): 'Groundwater Degradation and its Socio-economic and Health Impacts: Practical and Policy Options for Mitigation', Draft Report of VIKSAT-Natural Resource Institute Collaborative Research Project.

Government of Gujarat (undated): *16th Survey Report on Estimates of Major Livestock Product (1998-99)*, Director of Animal Husbandry, Government of Gujarat. http://www.indiastat.com

– (undated): *'Season and Crop Report'*, Department of Economics and Statistics Division, Ministry of Agriculture, Government of Gujarat, Gandhinagar, various issues.

Hoekstra, AY (1993): 'Virtual Water: An Introduction, Virtual Water Trade', proceedings of the international expert meeting on virtual water trade, edited by A Y Hoekstra, Value of Water Research Report Series # 12.

– (1998): *Perspectives on Water: An Integrated Model-based Exploration of the Future*, International Books, Utrecht, the Netherlands. *http://web243.petrel.ch/GreenCrossPrograms/waterres/middleeast/allan.html*,

IRMA/UNICEF (2001): *White Paper on Water in Gujarat'*, report prepared for the government of Gujarat.

Kumar, M D (2000): 'Institutions for Efficient and Equitable Use of Groundwater: Irrigation Management Institutions and Water Markets in Gujarat, Western India', *Asia-Pacific Journal of Rural Development*, Vol X (1), July.

– (forthcoming): 'Impact of Electricity Prices and Volumetric Water Allocation on Energy and Groundwater Demand Management: Analysis from Western India', *Energy Policy*, in press.

Kumar, M D, Tushaar Shah, Maulik Bhatt and Madhu Kapadia (2003): 'Dripping Water to a Water Guzzler: Techno-economic Evaluation of Efficiency of Drip Irrigation in Alfalfa', paper presented at 3rd IWMI-Tata Annual Partners' Meet, International Water Management Institute, Anand.

Singh, O P and Avinash Kishore (2004): 'Water Productivity of Milk Production in North Gujarat, Western India', paper presented at 3rd IWMI-Tata Annual Partners' Meet, International Water Management Institute, Anand.

Singh, O P and R S Pundir (2003): 'Dairy Development in Uttar Pradesh during Operation Flood Programme', *The Maharashtra Co-operative Quarterly*, LXXXX (5), pp 38-50.