

Impact of Dairy Farming on Agricultural Water Productivity and Irrigation Water Use

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Introduction

India is the largest producer of milk in the world. The country's milk production had gone up from 22.51 million tonnes in 1970-71 to 80.81 million tonnes during 2000-01 with per capita milk availability increasing from 115.3 gm/day to 238.06 gm/day during the aforesaid period. Both semi-arid and arid regions and subhumid and humid regions have contributed to this growth (Singh and Pundir 2003). This achievement was possible with the gradual replacement of traditional breeds of livestock by high yielding ones (Pandey 1995). One of the most remarkable impacts of India's economic growth is on the demand for dairy products, unlike what has been found elsewhere in that the demand for meat products increase with growing income levels. In India, consumption of milk increased by 20 % in per capita terms during 1990-2005 (von Braun 2007). According to a recent projection, the consumption of milk products in India, which currently stands at nearly 185 gm/person/day, is likely to grow at a rate of 0.7 % per annum to reach 236 gm/person/day during 2000-2025 (Amarasinghe et al. 2007), further increasing the demand for increased production.

But, the likely impact of this trend on the country's land and water resources has not been analyzed. A recent research in North Gujarat, which is known for intensive dairy farming, has shown that dairying is the most water-inefficient production system, taking a lion's share of the precious groundwater resources in the region (Singh 2004; Kumar 2007). This has made many scholars argue that dairying in semi-arid regions could lead to an increased use of water in agriculture with direct impact on groundwater resources in such regions. But, the distinction between commercial dairy farming, which is intensive, and the one which complements crop production, and their implications for water intensity in dairy production, is hardly ever made.

The actual impact of dairy farming on water resources would depend on where all the milk is produced, and the nature of dairy farming. In this article, we provide comparative analysis of water productivity in crops and dairying in the two semi-arid regions, viz., North Gujarat and Punjab, and demonstrate how the opportunity for reducing groundwater depletion through enhancing water productivity of crops differs between the two regions, if socioeconomic concerns have to be integrated in regional water allocation decisions. The first region selected for the purpose is semi-arid North Gujarat, where farmers had taken up intensive dairy farming on a

commercial basis, where intensively irrigated fodder crops like water-intensive alfalfa is fed to animals along with by-products of cereal crops like wheat, bajra and sorghum. The other region is south-western Punjab where cereals form a major portion of the irrigated field crops, and dairying is taken up as a supplementary activity in which by-products of crops are fed to animals.

The Context

In water-scarce regions, particularly in arid and semi-arid regions, heavy withdrawal of groundwater for irrigation is having several undesirable consequences. Demand management in agriculture is a standard approach to water management suggested for such regions (Kumar 2007). One important element of this approach works on water productivity of individual crops (as cited in Kumar 2007). Water productivity in agriculture refers to the biomass output or net income returns per unit volume of water applied or consumed for crop production.¹ It suggests replacement of cereal crops, which are economically less efficient in water use, with cash crops, which are economically more efficient in water use.

Semi-arid North Gujarat is one region in India where heavy withdrawal of groundwater for agriculture is causing secular decline in groundwater levels and scarcity of water for irrigation and drinking. Enormous increase in the cost of groundwater abstraction and increasing inequity in access to water are some of the socioeconomic consequences there. Throughout most of semi-arid Punjab, heavy withdrawal of groundwater is causing depletion, with negative economic and environmental consequences. With the demand for milk and dairy products growing in India, milk production is also increasing in many areas. More importantly, dairying is emerging as a major livelihood option in rural areas of semi-arid and arid regions facing water stress like North Gujarat, Kolar District in Karnataka and Alwar District in Rajasthan. One reason for farmers' preference for dairying as a livelihood option is the ability to manage the inputs such as feed and fodder through imports during scarcity.

Research conducted in North Gujarat had shown that dairying is highly water intensive, with estimated values of net water productivity in economic terms remaining far less than that of several conventional field crops. In case of cash crops, castor offered the highest net water productivity (Rs.7.21/m³) and cotton the lowest (Rs.0.68/m³). In case of food grains, highest net water productivity was found for kharif bajra and lowest for wheat crop with Rs.4.82 and 1.08 per m³, respectively. In case of milk production, net water productivity for buffalo milk was Rs.0.19 per m³ of water, whereas the net water productivity for crossbred cow was Rs.0.17 per m³ (see Figure 1 based on Kumar 2007). Against this, in Punjab, the rice-wheat system of production is supposed to deplete its groundwater resources.

The natural course for agronomists and water resource managers to save irrigation water in regions such as North Gujarat is to replace dairy crops by some of the highly water-efficient fruit crops and vegetables. Whereas in Punjab, the suggestion often made by water resource scientists and water managers is to reduce the area under cultivation of paddy and wheat that take a lot of water in the form of evapotranspiration. Another suggestion was to delay the transplanting of paddy saplings during kharif to make use of the rains (Hira and Khera 2000).

¹ While the first one is called physical productivity, the second one is called water productivity in economic terms.

But this approach has serious limitations in most situations. First, it ignores the linkages between different components within the farming system, which are often integrated. For instance, reduced cultivation of low water-efficient cereals and fodder could affect dry fodder availability, which could directly have an impact on dairying, a major source of income for millions of farmers. There is a need to recognize the fact that farmers allocate their water over the entire farm and not to individual crops. Unless we know about the comparative water productivity in dairying, decisions on changing crop compositions that help reduce water stress cannot be made. As a result, the unit of analysis of water productivity should be the farming system rather than the field. Second, it ignores the effect of such changes on local food security and livelihoods. For example, large-scale replacements of low, water-efficient cereal crop by a highly water -efficient cash crops by farmers in a region, might result in reduction of water use, but, it can also cause local food insecurity, and affect domestic nutritional security of farm households.

What Determines Water Intensity of Milk Production?

The water intensity of milk production is inversely related to its water productivity. Low water productivity means high water intensity. Water productivity in milk production is analyzed using the concept of ‘embedded water’, i.e., the amount of water depleted by the crops that are used as animal feed and fodder through evapotranspiration. The reason for this is that direct water consumption by cattle is low, whereas growing fodder and feed cereals need large quantities of water. The functional relationship between water productivity in milk production, and cattle inputs and outputs can be expressed as:

$$\sigma_{dairy, j} = \frac{Q_{MP}}{\Delta_{milk}} \dots\dots\dots (1)$$

Where Q_{MPj} is the average daily milk yield of a livestock over the entire life cycle. Δ_{milk} is the total volume of water, including the water embedded in feed and fodder inputs, used by an animal in a day. Both are worked out for the entire animal life cycle. Δ_{milk} is estimated as:

$$\Delta_{milk} = \frac{Q_{cf}}{\sigma_{cf}} + \frac{Q_{df}}{\sigma_{df}} + \frac{Q_{gf}}{\sigma_{gf}} + \Delta_{drink} \dots\dots\dots (2)$$

Where, Q_{cf} , Q_{df} and Q_{gf} are the average weights of cattle feed, dry fodder and green fodder used for feeding a livestock; σ_{cf} , σ_{df} and σ_{gf} are water productivity values (kg/m^3) of cattle feed, dry fodder and green fodder, respectively; Δ_{drink} is the daily drinking water consumption by livestock.

If water productivity of green fodder like fodder jowar, fodder bajra, and maize is high, then quantum of water used for dairying (Δ_{milk}) would be low. This can raise milk water productivity. If, on the other hand, the milk yield of the animal is high (Q_{MP}), then again, water productivity of milk production would be high. Similarly, if the amount of feed and fodder which an animal requires to be productive is low, then again milk water productivity will be high. Again, the feeding pattern would determine the amount of water needed. Wheat hay and

paddy straw have high water productivity in kg/m³. So, when farmers depend merely on these crop residues for feeding animals, water productivity will be high. But, intensive dairying would force farmers to grow fodder crops for this purpose, as crop residues won't be enough. Alfalfa, used as green fodder, is highly water-intensive.

The water productivity in crop production can be estimated in relation to the total water consumed by a crop during its growth (evapotranspiration), or the total irrigation water applied for crop production or the total effective water applied, which includes the irrigation dosage and effective rainfall. Since we are concerned with the depletion of water resources available from the groundwater system or surface flows for crop and milk production, it would be appropriate to consider the productivity of applied (irrigation) water. But, as the precipitation also contributes to the yield of many crops grown during the monsoon, it is important to estimate the marginal yield due to irrigation by segregating the rainfall contribution of the yield from the total yield. This has to be used in the denominator for estimating irrigation water productivity. However, for semi-arid and arid areas, the yield contribution of soil moisture from precipitation can be treated as negligible for most crops grown during the monsoon.² This would make marginal productivity of irrigation water equal to total productivity of irrigation water (Equation 3).

$$\text{Irrigation water productivity in crop production } \sigma_{crop} \text{ (kg/m}^3\text{)} = \frac{Y_{crop}}{\Delta_{crop}} \dots\dots\dots (3)$$

Nevertheless, such assumptions would induce significant errors in estimation of water productivity for kharif crops that are grown in humid and subhumid conditions. Hence, for such areas, the marginal productivity of irrigation water is estimated by running regression between yield and irrigation water dosage. The beta coefficient of regression equation gives the marginal productivity of irrigation water.

The estimated values of physical water productivity for crops and by-products are imputed in Equation (2) mentioned above to arrive at the value of Δ_{milk} . For by-products of crops that are used for dairy production as inputs, the total irrigation of water applied and cost of production of the crop are allocated between main product and by-products in proportion to the revenue generated from them, as suggested by Dhondyal (1987).

Water productivity in milk production in economic terms (θ_{dairy}) is estimated by taking the ratio of net return from milk production (NR_{dairy}) and the total volume of embedded water, and direct water use in milk production (Δ_{dairy}). Here again, the net returns are average values, estimated for the entire animal life cycle, taking into consideration the average milk yield worked out for the entire animal life cycle, the market price of milk and the cost of production of milk worked out for the animal life cycle.

$$\theta_{dairy} = \frac{NR_{dairy}}{\Delta_{dairy}} \dots\dots\dots (4)$$

² Needless to say, for winter and summer crops, such assumption would be quite reasonable and would not result in errors in estimation as residual soil moisture for growing crops would be negligible.

Average Physical Productivity of Water in Milk Production in Two Semi-arid Regions

The physical productivity of water in milk production was estimated for two types of livestock in North Gujarat and three types of livestock in western Punjab. The input data used for this were average daily milk yield, the average daily quantities of dry and green fodder and cattle feed for the livestock (kg), the daily drinking water use by the livestock (m^3), all estimated for the entire animal life cycle and the physical productivity of water for different types of green and dry fodder (kg/m^3) estimated using the standard formula (for details see Kumar (2007) or Singh (2004)). Subsequently, the water productivity in milk production in economic terms was estimated using the average net return from milk production using the gross return and average production cost of milk.

The results are presented in Table 1. It shows that the physical productivity of water for both buffalo and cross bred cow is much higher in western Punjab, when compared to North Gujarat. Furthermore, the difference in economic productivity is much higher than that in physical productivity. In the case of western Punjab; the high physical productivity of water in milk production could be attributed to the lower volume of embedded water in the inputs used for cattle owing to higher physical productivity of both green and dry fodder. In the case of western Punjab, it was found that only green fodder, such as winter *jowar* (fodder) and kharif *bajra* (fodder), and dry fodder available from residues of paddy (hay) and wheat (straw), were used. Since paddy and wheat have very high yields in the region, the physical productivity of dry fodder is very high. The cumulative effect of both these factors is the lower amount of embedded water. Whereas in the case of North Gujarat, alfalfa, a highly water-intensive irrigated green fodder, was found to be most common.

Table 1. Milk yield and physical and economic productivity of water in milk production in two semi-arid regions.

Variables	Punjab			North Gujarat		
	Buffalo	Crossbred Cow	Indigenous Cow	Buffalo	Crossbred Cow	Indigenous Cow
Average Milk Yield (liter/day)	3.25	4.46	2.98	3.12	5.33	N. A
Water Productivity (WP) (liter/ m^3)	1.79	2.53	3.68	0.31	0.49	N.A
WP in Milk Production (Rs/ m^3)	7.06	17.44	16.41	0.190	0.17	N. A

Source: Based on Singh (2004) and Kumar et al. (forthcoming)

Note: N.A. denotes not applicable

The difference in feeding pattern can be seen from Table 2 below. Though the amount of green and dry fodder quantities are less in the case of North Gujarat, alfalfa (figures in brackets) accounts for nearly 70 % of the green fodder for both buffalo and cross-bred cow. Furthermore, the quantum of cattle feed used for dairy animals in North Gujarat is much higher

Table 2. Comparison of daily average feed and fodder consumption per milch animal in western Punjab and North Gujarat.

Feed/Fodder	Animal Type	Bathinda (Western Punjab)	Mehsana (North Gujarat)
Green Fodder (Kg/day)	Buffalo	19.46	12.98 (9.25)
	Indigenous Cow	12.92	Nil
	Crossbred Cow	14.41	12.96 (9.07)
Dry Fodder (Kg/day)	Buffalo	7.94	5.48
	Indigenous Cow	5.07	Nil
	Crossbred Cow	4.33	6.44
Concentrate (Kg/day)	Buffalo	2.28	5.21
	Indigenous Cow	1.2	Nil
	Crossbred Cow	1.4	5.36
Drinking Water (Liters/day)	Buffalo	55.8	59.10
	Indigenous Cow	52.6	Nil
	Crossbred Cow	60.2	49.10

Source: Kumar et al. (forthcoming) and Singh (2004)

than that of western Punjab. The much higher water productivity in economic terms was due to: i) lower cost of production of milk, owing to the lower cost of production of cattle inputs such as dry and green fodder, resulting in much higher net returns; and, ii] the lower volume of embedded water in cattle feed and fodder. The difference in cost of inputs is mainly seen in irrigation water. In North Gujarat, pumping depths are much higher than that of Punjab. This results in very high capital and variable cost of irrigation owing to expensive deep tubewells, high capacity pump sets, and very high electricity charges.

Trade Offs between Enhancing Field-level Water Productivity and Regional Water Productivity

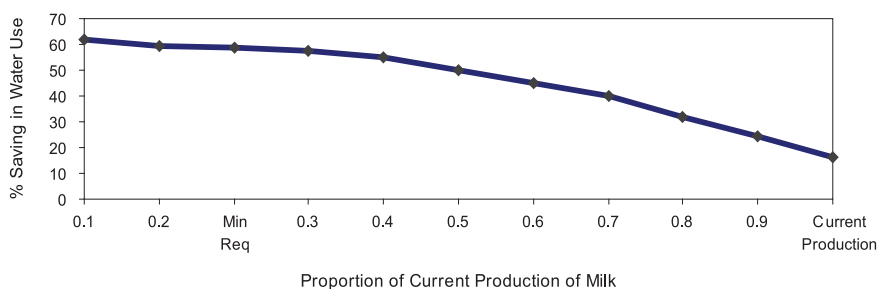
The North Gujarat Case

A standard approach to improve water productivity in agriculture (in order to save groundwater used in irrigation) would be the replacement of low water-efficient crops by those which are highly water-efficient. For North Gujarat, this would mean replacement of dairying by highly water-efficient crops such as orchards and cash crops like cumin. But, this would result in lower production of milk, the commodity which gives a stable income and regular cash flow for the farmers. Hence, it is a difficult option. Also, unlike in the case of agricultural crops, it is much easier for farmers to maneuver the inputs such as dry fodder and green fodder in his farm, though at the regional level it might be difficult for the farmers in the entire region to import fodder. Now, at the regional level, replacement of dairying by cash crops and orchards would have significant impact on the region's milk production, which not only sustain its rural economy, but also produces surplus for export to other deficit regions.

In order to analyze the opportunities and constraints for improving regional water productivity in agriculture and to save irrigation water, farm economy in four talukas (sub-regions) of Banaskantha District in North Gujarat were simulated using linear programming. The results from two different optimization models, minimization and maximization models, for all the four talukas were more or less similar. Results from Vadgam taluka of Banaskantha District of North Gujarat showed that the volume of groundwater used for agriculture can be reduced to an extent of 49.5 % through the introduction of cumin or lemon. This would not affect the initial level of net farm income or compromise the food security needs of the region's population. However, while doing this, the milk production would undergo a sharp fall. This is because milk production was relatively more water intensive, and any effort to cut down groundwater use meant reducing milk production and substituting it with crops that are highly water productive.

With the introduction of water-saving technologies (WSTs) for field crops including alfalfa, the extent of reduction possible in groundwater use was higher (60.1 %), with lower extent of reduction in milk production. The net farm output would not be adversely affected by this. Further analysis showed that using WSTs, the groundwater use could be brought down by 17.5 %, if milk production in the region is to be maintained at the previous level. As Figure 1 (source: Kumar 2007) shows, the extent of reduction possible in groundwater use reduces with reduced willingness to compromise on milk production. This means that, the amount of leverage available for enhancing regional water productivity and cutting down groundwater use for farming becomes limited, if the income from dairy production as a percentage of the total farm income has to be high.

Figure 1. Milk production and aggregate groundwater use with WST (Vadagam).



The adoption of orchard crops and drip irrigation systems involves risk taking by farmers. This is due to the need for finding markets in the first case, and the capital intensive nature of the system in the second case. Hence, the small and marginal farmers would show great resistance to adopting such systems. Thus, there is a trade off between enhancing water productivity of the farming system through crop and technology selection and reducing farming risks.

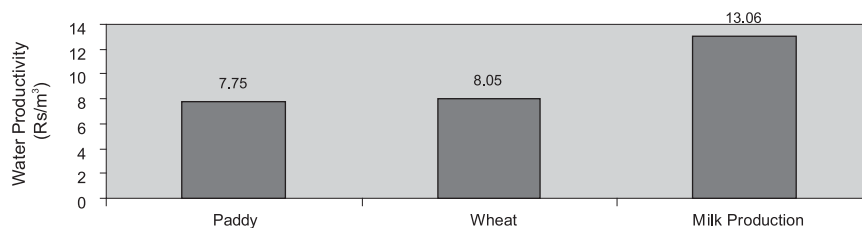
The Punjab Case

Let us examine the farming system interactions in western Punjab. Punjab's rice-wheat system of farming has been under criticism for causing low efficiency in resource use, low productivity of water use (Singh and Kalra 2002) and the problems of groundwater overdraft. It is established

that many fruit crops have higher water productivity (Rs/m^3) than the conventional cereals such as wheat and paddy in arid areas. For instance, pomegranate grown in North Gujarat gives a net return of nearly Rs 40,000 per acre (i.e., USD900/acre) of land against Rs.8,000 per acre (i.e., USD180/acre) in the case of wheat. The WP is approximately $\text{Rs}.100/\text{m}^3$ for pomegranate (with an estimated annual water application of 90 mm) against $\text{Rs}.4.46/\text{m}^3$ for wheat. Also, there are crops such as potato, tomatoes, cumin, cotton and groundnut which are more water-efficient than rice and wheat, which can be grown in Punjab. Farmers from this region have already started shifting to high-valued cash crops in a moderate way.

But, there are limits to the number of farmers who can take up such crops due to the volatile nature of the market for most of these crops, their perishable nature and the high risk involved in producing them.³ Also, the investments for crops are very high, demanding risk-taking ability. But, the extent to which farmers can allocate water to economically efficient crops would perhaps be limited by the need to manage fodder for animals. It may also get limited by the poor market support for orchard crops. Many farmers in Punjab and other semi-arid parts of India, manage crops and dairy farming together. Recent analyses from western Punjab seem to suggest that the overall net water productivity in rupee terms gets enhanced when the by-products of cereal crops are used for dairy production (see Figure 2). Water productivity in dairying was found to be higher than that of wheat and paddy (Kumar et al. forthcoming).

Figure 2. Water productivity in crops and milk production in western Punjab.



The equation presented in the earlier section explains this phenomenon. Unlike in the case of North Gujarat where dairying is very intensive, farmers in Punjab practice it as a complementary activity to crop production, where animal feeding depend mostly on crop residues such as wheat hay and paddy straw. They also do not grow highly water-intensive fodder crops like alfalfa. Water productivity (in kg/m^3 of water) for these by-products is very high.

This means that potential trade off exists between maximizing field level water productivity through crop shifts and maximizing water productivity at the level of the farming system. The possibility exists for simultaneously enhancing both field and farm level water productivity through the introduction of high-valued crops such as vegetables and fruits if those crops

³ The markets for fast perishing vegetables are often very volatile, and prices vary across and within seasons. The problem of price fluctuations is also applicable to cotton grown in western Punjab, which has high water productivity.

have water productivity values higher than those in dairy production.⁴ However, in both cases, the risk involved in farming might increase. The reasons for this risk factor are the highly volatile nature of vegetable prices and the high chances of drastic price increases, or fodder scarcity, in the event of a drought. It has been found that while the normal price of dry fodder such as wheat hay and paddy straw is Rs. 1 per kilo, it goes up to Rs. 4 per kilo during the drought years.

Now, at the regional level, attempts to adopt water-efficient crops or crop-dairy based farming to enhance agricultural water productivity might face several socioeconomic constraints. National food security is an important consideration when one thinks about crop choices. Punjab produces surplus wheat and rice and supplies them to many other parts of India, which have food deficits, including eastern India (Amarasinghe et al. 2007; Kumar et al. 2007). Twenty percent of the country's wheat production, and ten percent of its rice production comes from Punjab; it contributes 57 percent and 34 percent, respectively to the central pool of grains for public distribution (Kumar et al. 2007).

Labor absorption capacity of irrigated agriculture and market prices of fruits are other considerations. Paddy is labor intensive, and a high percentage of migrant laborers from Bihar work in the paddy fields of Punjab. As per our estimates, 2.614 million ha of irrigated paddy in Punjab (as per 2005 estimates) creates 159 million labor days during the peak kharif season. The total percentage of farm labor contributed by migrant laborers during peak season was reported to be 35 % as per the Economic Survey of Punjab 1999-2000. Based on these figures, we have estimated that the total number of labor days contributed by migrant laborers to paddy fields in Punjab to be 55.75 million (Kumar and van Dam, Paper 6 of this book).

Replacing paddy by cash crops would mean a reduction in farm employment opportunities. On the other hand, the lack of availability of labor and fodder would constrain intensive dairy farming to maximize farming system water productivity at the regional level, though some farmers might be able to adopt the system. Large-scale production of fruits might lead to price crashes on the market, and farmers losing revenue unless sufficient processing mechanisms are established. Hence, the number of farmers who can adopt such crops is extremely limited.

The Contrasts between North Gujarat and Punjab

Comparison of North Gujarat and western Punjab shows that even under similar climates, the routes to enhance water productivity and impacts of such initiatives on the farmers at the household level and on the socioeconomic system would be different, depending on the nature of the farming system. In the case of North Gujarat, water productivity improvement calls for replacing dairy farming with cash crops, and use of micro-irrigation systems for conventional crops. In Punjab, paddy-wheat system needs to be replaced by crops with higher water productivity than that in livestock farming, and dairying needs to be continued with imported fodder. Again, the possibility for import of fodder from the neighboring region of eastern India appears bleak, as these regions are net importers of food grains and have very little arable land. Haryana, while being an agriculturally prosperous region practices intensive dairying as well.

⁴ Otherwise, if the water productivity values of newly introduced crops is not higher than that of dairying, but higher than that of cereals, then fodder will have to be imported to practice dairying.

Introduction of cash crops in the farming system of North Gujarat would have adverse impacts on the stability of farm income and cash flow to farm households, though not on self-sufficiency in cereals. On the contrary, in the case of western Punjab, adverse impacts will be manifest in regional food security, employment and risks in farming. What appears is that in spite of the differences, integrating socioeconomic concerns such as food security, reducing risk in farming, and improving livelihood opportunities through agriculture; the opportunities for improving water productivity in agriculture to save water for the environment is extremely limited.

Now there are many semi-arid and arid regions in India, where dairying is emerging as a major source of livelihood in rural areas. They include western Rajasthan and peninsular and central India. These are also regions which are facing problems of groundwater over-draft. It is difficult to conclude that in semi-arid and arid regions, dairying would lead to further depletion of groundwater on the basis of the North Gujarat experience. In composite farming systems like the one in western Punjab, where dairying compliments cereal production, reasonably high levels of water productivity could be achieved in dairying. Such complementarity is due to the large area under crop production in per capita terms and the available crop residues being sufficient to feed livestock. Hence, it does not exert any additional pressure on local water resources.

Nevertheless, other opportunities for reducing pressure on groundwater through water productivity improvement in agriculture would be extremely limited if the region contributes significantly to national food security, rural employment etc. Also, there are limits to intensifying dairy production in such regions. The reason is that if dairying is made intensive, with fodder crops grown specially instead of being managed from crop residues, it would become water-intensive. In that way, it can induce additional pressure on local groundwater resources. But there are some ways to reduce the pressure on groundwater. They could include: enhancing water productivity of individual crops, including those used for dairying through micro-irrigation, which will also make milk production less water-intensive.

Can Dairying Thrive in Water-rich Regions of India?

There are large areas in India which are falling under humid and subhumid climatic conditions, including Kerala, north-east, the western and eastern Ghat regions and the Sub-Himalayan region. These regions have high rainfall and humidity, and low evaporation and evapotranspiration. Such regions also indulge in dairy farming. These regions have a lot of naturally grown grass that provide nutritious fodder for livestock. They also get dry fodder from residues of crops, particularly paddy. The advantage of such regions is that not only would the consumptive use of water by fodder crops be less, but most of such water needs would be directly met from precipitation. This is evident from a study conducted in Palakkad District of Kerala. It shows that green grass accounts for 84 to 95 % of the total green fodder fed to livestock.

This has a big impact on the irrigation water used for green fodder that is fed to cattle. It was found to be in the range of 40 to 160 liters per day per animal (Table 4). As a result, the effective water productivity in milk production (physical) was higher than that in the semi-arid North Gujarat. The study estimated effective irrigation water productivity in milk production to be 0.50 liter/m³, 0.74 liter/m³ and 0.51 liter/m³, respectively, for buffalo, crossbred cow and indigenous cow (Table 4). As Table 4 shows, though the actual irrigation water productivity in milk production is much lower than these figures, a significant part of the water used up in milk

Table 3. Average feed and fodder fed to livestock in Palakkad, Kerala (kg/day/animal).

Name of Feed and Fodder	Average Daily Input (kg) for		
	Buffalo	Crossbred Cow	Indigenous Cow
A. Green Fodder	16.00	15.59	12.17
1. Local Green Grass	13.37	14.05	11.59
6. Maize	2.64	1.54	0.58
B. Dry Fodder	11.75	11.39	10.63
1. Paddy Straw	11.75	11.39	10.63
C. Concentrate	3.37	3.34	2.59
1. Balanced Cattle Feed	1.57	1.73	1.12
2. Cotton Seed Cake	0.38	0.44	0.25
7. Wheat Bran	0.43	0.66	0.28
8. Rice Bran	0.99	0.51	0.94
D. Drinking Water (Lt.)	0.034	0.029	0.023

Source: Rajesh and Tirkey (2005)

Table 4. Total water use and water productivity in milk production, Palakkad, Kerala.

Particulars	Kerala		
	Buffalo	Crossbred Cow	Indigenous Cow
1. Green Fodder (m ³)	0.16	0.10	0.04
2. Dry Fodder (m ³)	4.73	4.59	4.28
3. Concentrate (m ³)	4.67	4.06	3.87
4. Drinking Water (m ³)	0.034	0.029	0.023
5. Total Water Used (m ³)	9.60	8.77	8.21
Milk Production (Liter/day)	2.46	3.49	2.36
Irrigation Water Productivity (IWP) (liter/m ³)	0.26	0.40	0.29
Effective IWP in Milk Production (liter/m ³)	0.50	0.74	0.51
IWP in Milk Production (Rs/m ³)	0.51	0.90	0.74
Effective IWP in Milk Production (Rs/m ³)	1.00	1.88	1.55

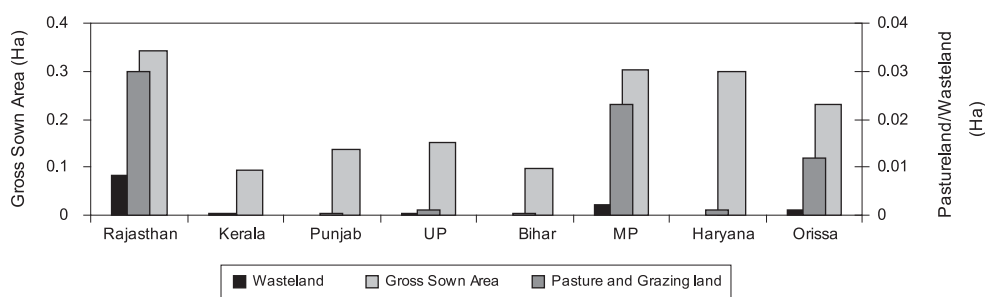
Source: Rakesh and Tirkey (2005)

production is the water embedded in the cattle feed. It was found to be 48.7 %, 46.2 % and 47.1 % of the total water used for milk production, for buffalo, cross bred cow and indigenous cow, respectively (see Table 3). Since local water resources are not used for their production, and are available from imports, they are not considered while estimating water productivity.

Furthermore, the cost of production of fodder was found to be negligible, when compared to that of cattle feed. It worked out to be 10.6 %, 8.9 % and 13 % of the total input cost, for buffalo, cross-bred cow and indigenous cow, respectively. The water productivity in economic terms was also relatively higher when compared to North Gujarat. The estimated effective

irrigation water productivity was Rs.1.0/m³, Rs.1.88/m³ and Rs.1.55/m³ for buffalo, cross -bred cow and indigenous cow, respectively (see Table 4)—(Rajesh and Tirkey 2005). Groundwater depletion due to agricultural withdrawal is not a problem in these regions. But, the amount of land available for dairy farming is a major constraint for increasing dairy production in the region. While per capita land availability is high in semi-arid regions, it is extremely low in humid and subhumid regions. The data on per capita gross sown area, per capita pasture land and per capita wasteland in eight major Indian states are given in Figure 3. The per capita land available in common lands (wasteland and pasture land) and cultivated area in semi-arid to arid Rajasthan is 0.454 ha and it is 0.30 ha in Haryana. Against these, the figure is only 0.094 ha in Kerala (see Figure 3).

Figure 3. Per capita land availability under different classes in selected states of India.



Summary of Findings

Water intensity of milk production is determined by the nature of dairy farming and not by climate alone. It is low water-intensive in regions where cereal production complements low levels of dairy production, which minimizes the amount of irrigated green fodder used. The case of Punjab demonstrates this. When dairying is practiced intensively, production of irrigated green fodder becomes compulsory to sustain such high levels of inputs required to maintain high levels of production. This makes dairy production highly water-intensive as demonstrated by the North Gujarat case. In subhumid regions like Kerala, milk production is highly water-efficient, and it induces no pressure on local water resources as it is sustained largely by green grass that is naturally available and residues from crop production.

In semi-arid and arid areas where intensive dairy farming is practiced, replacement of dairy farming by highly water-efficient orchards and cash crops would be the major route to enhance water productivity in agriculture and also save some of the water used in agriculture, without adverse consequences for the economic prospects of farming. But, concerns of ensuring stable farm income and cereal security would limit our ability to shift from dairy farming to highly water-efficient crops. The best way to improve agricultural water productivity without adverse effects on farm income, food security and resilience of farming would be to make dairy production more water-efficient through efficient irrigation technologies for all crops that are amenable to the technology, including those having by-products, which are used as dairy inputs.

There are other semi-arid and arid regions like Punjab, which produce surplus cereals for food deficit regions. Rice-wheat system of production accounts for a major portion of the irrigation water used, and is mainly responsible for groundwater over-draft in this region. Since this region is not a major contributor to India's 'milk bank', decline in milk production in this region won't pose any major challenge to the country's nutritional security. But, any attempt to replace wheat and paddy should consider such crops which have higher water productivity than that in dairying. The reason is dairying, which cereal production sustains, yields much higher water productivity than those cereals themselves. Again, the scope for introducing crops which are more water-efficient than dairying, like orchards, would be constrained by concerns of regional food security and labor absorption in agriculture.

Conclusions

Dairying is emerging as a major economic activity in rural India. One reason for the increasing preference among farmers for dairying over other crops is the growing demand for milk and other dairy products, the relatively stable market and the ability of farmers to manage the inputs for dairying through feed and fodder imports in the face of water scarcity. In semi-arid and arid areas, the pressure dairying can put on water resources would depend on the levels of water productivity achieved in dairying, the intensity of dairying and what portion of the animal feed and fodder are produced in the locality. As analyses presented in this paper suggest, the water intensity of dairy farming could be remarkably different between regions of the same agro climate, depending on the intensity of dairying vis-à-vis the number of dairy animals that have to be supported by the available cultivated land.

The most desirable situation is one in which crops compliment dairy farming. Such a situation is possible when the number of cattle per unit of cultivated land is relatively low. This ensures that greater quantities of dry fodder are available from crop residues. In such situations, overall water productivity of the farming system would be reasonably higher. There are no easy ways to increase milk production in such regions without making it water-intensive, but that would cause further depletion of groundwater reserves in those regions. Again, such options are applicable to areas, which have extra arable land that can be brought under cultivation. However, this is not applicable to Punjab which already has high cropping intensity. The difficult option would be to engage in large-scale import of dry and green fodder, but subhumid and humid regions in India are not able to produce surplus fodder that can be exported to these regions.

The most undesirable situation for semi-arid regions is the intensification of dairy farming that depends on irrigated fodder crops locally, other than those obtained from agricultural crops as this would mean high water-intensiveness of milk production. Such a situation is possible when the per capita arable land is very low. In such cases, the opportunities for improving regional water productivity, which do not adversely affect milk production, need to be explored. The idea is to save some water for the environment without affecting the socioeconomic conditions of the communities who depend on it. This is in view of the fact that demand for dairy products is still increasing in India, and the country cannot afford to allow a decline in milk production. The options include: a) improving water productivity of crops, including those used in milk production, through the use of micro-irrigation; and b)

replacement of existing low valued crops with high-valued orchard crops. For achieving these, promoting drips through subsidies could be one step, particularly for those fodder crops which fetch lower market value. The other step would be creating good marketing and processing facilities for fruits.

The subhumid and humid regions offer great potential to produce milk without depleting local water resources. The biggest constraint in such areas, however, is making milk production more intensive in spite of limited land availability. Unfortunately, such regions in India have much less crop land, pasture land and wasteland, which can supply biomass for dairy production. In a nutshell, intensive dairy farming is likely to pick up in semi-arid and arid areas, which have sufficient arable land. Such intensity, however, won't be ecologically sustainable and, as such, would eventually result in the depletion of local water resources. In such regions, efforts should be made to make it more water-efficient through the use of micro-irrigation systems for the crops, including water-intensive forage crops. While ecologically sustainable dairy farming is possible in subhumid and humid areas, there are major constraints to boosting milk production in those regions.

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