GROUNDWATER STRESS DUE TO IRRIGATION IN SEMI ARID AND ARID REGIONS: IS DAIRYING A BOON OR A BANE?

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Abstract

One of the most remarkable impacts of India's growing economy is the demand for dairy products. However, the impact of this trend on the country's land and water resources has not been analyzed. India is the largest producer of milk in the world. A recent research in north Gujarat, which is known for intensive dairy farming, has shown that dairying is the most water-inefficient production systems, taking lion's share of the groundwater resources in the region. This has made many scholars argue that dairying in semi arid regions could lead to increased use of water in agriculture with direct impact on groundwater resources in such regions. However, distinction between commercial dairy farming, and dairying which complements crop production, and their implications for water intensity, is hardly every made.

The paper makes two major arguments. The first argument is that the water-intensity of dairying in semi arid and arid regions is largely determined by the nature of dairy farming, i.e., whether crops supplement milk production or dairying is intensive (high number of cattle supported per unit area of land). In the first situation, dairying would he highly water-efficient. In the second situation, it would be water-intensive. The second argument is that the trade offs in maximizing agriculture water productivity for a region as a whole would he different in the two situations. In intensive dairy farming areas, route to reduce groundwater stress would be through reducing milk production, and increasing the contribution of high-valued crops to overall farm income. Thus, there is a trade off between increased farming risk, and reduced cash flows and regional food security. This can be minimized by making dairy production more water efficient.

In areas where cereal production complements dairying, limited opportunities exist in enhancing agricultural water productivity if food security and employment generation are not concerns. Opportunities to raise milk production in such regions from the current levels, without making it water-intensive, are extremely limited. Water-intensive dairying would result in further depletion of groundwater in such areas. Further analysis shows that dairy production in humid and sub-humid areas would be highly water-efficient, as demonstrated in the case of Kerala. Nevertheless, intensive dairy farming would require more arable land or land which can be used for grazing.

1. INTRODUCTION

India is the largest producer of milk in the world. The country's milk production had gone up from 22.51 million ton in 1970-71 to 80.81 million ton during 2000-01 with per capita milk availability increasing from 115.3 gm/day to 238.06 gm/day during the period. Both semi arid and arid regions and sub-humid 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. This is different from other countries where demand for meat products increase with growing income levels. The milk consumption in India increased by 20% during 1990-2005 in per capita terms (von Braun, 2007). According to a recent projections, 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

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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 systems, consuming a large share of the groundwater resources in the region (Singh, 2004; Kumar, 2007). This has made many scholars argue that dairying in semi arid regions could lead to 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 every 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 two regions, if socio-economic 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 commercial basis, where intensively irrigated fodder crops like water-intensive alfalfa is fed to animals along with byproducts of cereal crops like wheat, bajra and sorghum. The other region is south western Punjab where cereals form a major chunk of the irrigated field crops, and dairying is taken up as a supplementary activity in which byproducts of crops are fed to animals.

2. THE CONTEXT

In water scarce regions, particularly arid and semi arid regions, heavy withdrawal of groundwater for irrigation has 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 cost of groundwater abstraction and increasing inequity in access to water are some of the socio-economic consequences. 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.
Recent research 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[2]. Against this in Punjab, the rice-wheat system of production is supposed to deplete Punjab's groundwater resources.
The natural course for agronomists and water resource managers to reduce water stress 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 groundwater managers is to reduce the area under cultivation of paddy and wheat that take a lot of water in the form of evapo-transpiration. Another suggestion is to delay the transplanting of paddy saplings during kharif to make use of the rains.

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

[2] In case of cash crops, castor offered highest net water productivity (Rs.7.21/m^3) and cotton the lowest (Rs.0.68/m^3). 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 m^3, respectively. In case of milk production, net water productivity for buffalo milk was Rs.0.19 per m^3 of water whereas the net water productivity for crossbred cow was Rs.0.17 per m^3 (see Kumar, 2007).

But this approach has serious limitations in most situations. Firstly, 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 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 farming system rather than field. Secondly, it ignores the effect of such changes on local food security and livelihoods. For example, large scale replacement of low water efficient cereal crop by a highly water efficient cash crops by farmers in a region might result in reduction in water use. But, it can cause local food insecurity, and affect domestic nutritional security of farm households.

3. WHAT DETERMINES WATER INTENSITY OF MILK PRODUCTION?

The water intensity of milk production is inversely related to its water productivity. High water intensity means low water productivity. Water productivity in milk production is analyzed using the concept of "embedded water", i.e., the amount of water depleted by the crops through evapo-transpiration that are used as animal feed and fodder. 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:

$$\sigma_{dairy,} = \frac{Q_{MP}}{\Delta_{milk}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (1)$$

Where Q_{MP} 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:

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

Where, Q_{cf} , Q_{df} and Q_{gf} are the average weights of cattle feed, dry fodder and green fodder used for feeding 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 ($Q_{MP\,j}$), 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/m^3. So, when farmers just depend on these crop residues for feeding animals, water productivity will be high. But, intensive dairying would force farmers to grow fodder crops for the 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 crop during its growth (evapo-transpiration), 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 groundwater system or surface flows for crop and milk production, it would be appropriate to consider the productivity of applied (irrigation) water. But, as precipitation also contributes to yield of many crops grown during monsoon, it is important to estimate the marginal yield due to irrigation, by segregating the rainfall contribution of the yield from 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 monsoon[3]. This would make marginal productivity of irrigation water equal to total productivity of irrigation water (Equation 3).

Irrigation water productivity in crop production σ_{crop} (kg/m^3) $= \dfrac{Y_{crop}}{\Delta_{crop}}$ ………. (3)

Y_{crop} and Δ_{crop} are the crop yield (kg/ha) and volume of water applied per hactare of irrigated area (m^3/ha) respectively.

Nevertheless, such assumptions would induce significant errors in estimation of water productivity for kharif crops that are grown in humid and sub-humid 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 byproducts are inputed in Equation (2) mentioned above to arrive at the value of Δ_{milk}. For byproducts of crops that are used for dairy production as inputs, the total irrigation 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 animal life cycle.

$$\theta_{dairy} = \frac{NR_{dairy}}{\Delta_{dairy}} \quad \text{………………..} \ (4)$$

4. AVERAGE PHYSICAL PRODUCTIVITY OF WATER IN MILK PRODUCTION IN TWO SEMI ARID REGIONS

The physical productivity of water in milk production was estimated using the standard formula (for details see Kumar (2007) or Singh (2004)) for 2 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 animal's entire life cycle; and the physical productivity of water for different types of green and dry fodder (kg/m^3). 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 cost of production 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. Further, the difference in economic productivity is much higher than that in physical productivity. The high physical productivity of

[3] 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.

water in milk production in case of western Punjab is 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 reduces the amount of embedded water. Whereas in the case of north Gujarat, alfalfa, a highly water intensive irrigated green fodder, was used commonly as feed for cattle.

Table 1: Milk Yield, and Physical and Economic Productivity of Water in Milk Production in two Semi Arid Regions

Variables	Punjab			North Gujarat		
	Buffalo	Cross bred Cow	Indigenous Cow	Buffalo	Cross bred Cow	Indigenous Cow
Average Milk Yield (lt/day)	3.25	4.46	2.98	3.12	5.33	N. A
Water Productivity (WP) (lt/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)

The difference in feeding pattern can be seen from Table 2. 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. Further, the quantum of cattle feed used for dairy animals in north Gujarat is much higher that that for 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 mainly comes from water. In north Gujarat, pumping depths are much higher than in Punjab. This results in very high capital and variable cost of irrigation owing to expensive deep tube wells, high capacity pump sets, and very high electricity charges.

Table 2: Comparison of Daily Average Feed & 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(lt/day)	Buffalo	55.8	59.10
	Indigenous Cow	52.6	Nil
	Crossbred Cow	60.2	49.10

Kumar, et al., (forthcoming) and Singh, (2004)

5. TRADE OFFS BETWEEN ENHANCING FIELD-LEVEL WATER PRODUCTIVITY AND REGIONAL WATER PRODUCTIVITY

5.1 The North Gujarat Case

While a standard approach to improve water productivity in agriculture to reduce the stress on groundwater would be 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, which gives stable income and regular cash flow to the farmers. It 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 reducing stress on groundwater, farm economy in four talukas of Banaskantha district in north Gujarat were simulated using linear programming. The results from 2 different optimization models, minimization and maximization, 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 introducing cumin or lemon. This would not affect the initial level of net farm income nor compromise on the food security of the region's population. However, while doing this, the milk production would fall sharply. This is because milk production was supported by irrigation of high water intensive crops, and any effort to cut down groundwater use meant reducing milk production.

With the introduction of water saving technologies (WSTs) for field crops including alfalfa, the extent of reduction possible in groundwater use was high (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% even if milk production in the region is 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. Enhancing regional water productivity and cutting down groundwater use for farming have li
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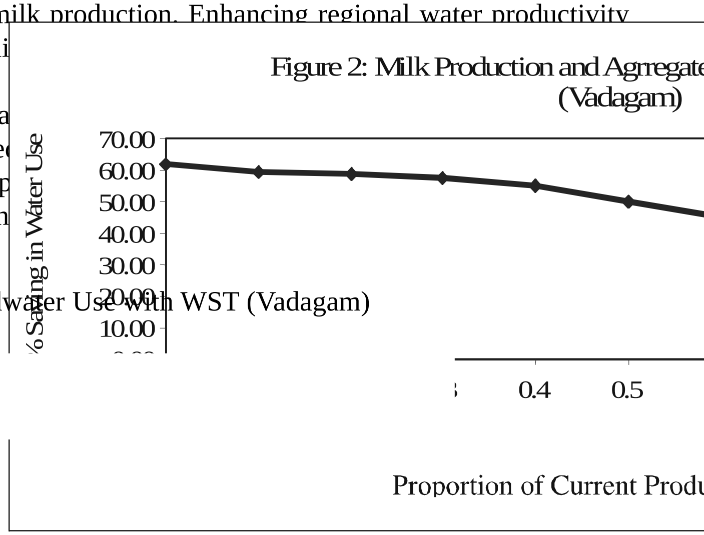


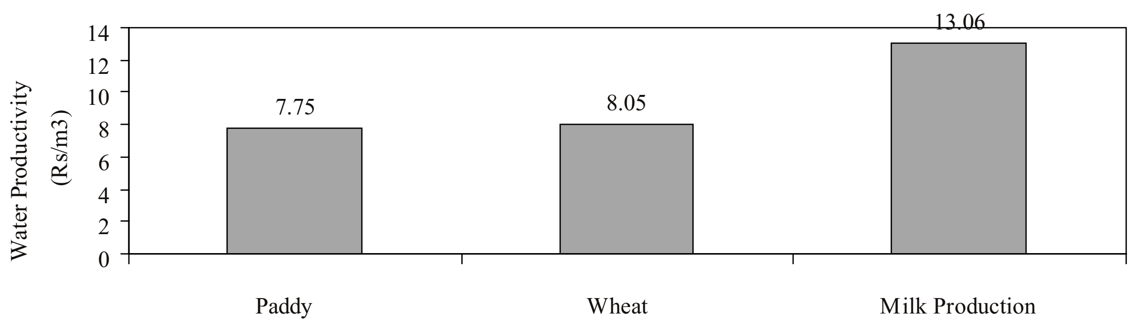
Figure 1: Milk Production and Agrregate Groundwater Use with WST (Vadagam)

5.2 The Punjab Case

Now, let us examine farming system interactions in western Punjab. Punjab's rice-wheat system of farming has been under criticism for the low resource use efficiency, low water use productivity and groundwater over-draft. It is established that many fruit crops have higher water productivity (Rs/m^3) than conventional cereals such as wheat and paddy in arid areas. For instance, pomegranate grown in north Gujarat gives a net return of nearly 40,000 Rs/acre (i.e., USD 900/acre) of land against Rs.8000/acre (i.e., USD 180/acre) in case of wheat. WP is approximately Rs.100/m^3 for pomegranate (with an estimated annual water application of 90 mm) against Rs.4.46/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. Some farmers in this region have already started shifting to high valued cash crops.

However, there is a limit to the number of farmers who can take up such crops due to the volatile nature of the market for most of these crops, the perishable nature of these crops, the high risk involved in their production[4] and the need to manage fodder for animals. In addition, investments for these crops are very high, demanding the ability to take risk. It may also be 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 suggests that the net water productivity in rupee terms is enhanced when byproducts 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 inWestern Punjab



The equation presented in the earlier section explains this phenomenon. Unlike in the case of north Gujarat where dairying is intensive, farmers in Punjab practice it as a complementary activity to crop production, and 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 byproducts is very high.

There are potential trade off exists between maximizing field level water productivity through crop shifts and maximizing water productivity at the farming system level. It is possible to enhance both field and farm level water productivity simultaneously by introducing high valued crops such as vegetables and fruits, if those crops have higher water productivity values than dairy production[5]. However, in both the cases, the risk involved in farming might increase. The reason is highly volatile nature of vegetable prices; and the high chances of drastic increase in fodder prices or fodder scarcity, in the event of a drought. It is found that while the normal price of dry fodder such as wheat hay and paddy straw is Rs. 1/kilo, it goes up to Rs. 4/kilo during drought years.

[4] The markets for fast perishing vegetables are often very volatile, and price varies across and within seasons. The problem of price fluctuation is also applicable to cotton grown in western Punjab, which has high water productivity.

[5] 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.

At the regional level, attempts to adopt water efficient crops or crop-dairy based farming to enhance agricultural water productivity might face several socio-economic 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 are food deficit, including eastern India (Amarasinghe et al., 2004; Kumar, Gulati and Cummings, 2007). 20% of country's wheat production, and 10% of its rice production comes from Punjab; it contributes 57% and 34% respectively to the central pool of grains for public distribution (Kumar, Gulati and Cummings, 2007).

Labour absorption capacity of irrigated agriculture and market prices of fruits are other considerations. Paddy is labour intensive, and a large chunk of the migrant labourers 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 labour days[6] during the peak kharif season. The total percentage of farm labour contributed by migrant labourers during peak season was reported to be 35% as per the Economic Survey of Punjab 1999-00 (GoI, 2001). Based on these figures, we estimate that the total number of labour days contributed to paddy fields by migrant labourers in Punjab was 55.75 million.

Replacing paddy by cash crops would mean reduction in farm employment opportunities. On the other hand, the lack of availability of labour and fodder would be constraints for 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 loosing revenue unless sufficient processing mechanisms are established. Hence, the number of farmers who can adopt such crops is extremely limited.

5.3 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, because of the difference in their farming systems. In 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. Import of fodder from neighbouring regions of is not an option. Situation in eastern India appears bleak, as these regions are net importers of food grains, and have very little arable land. While Haryana is an agriculturally prosperous region, dairying is also quite intensive in this region.

Introduction of cash crops in the farming system of north Gujarat would have adverse impact on the stability of farm income and cash flow to farm households. However, there would be no impact on self sufficiency in cereals. On the contrary, in western Punjab, there will be adverse impacts on regional food security, employment and risks in farming. In spite of the differences between the two regions, integrating socio-economic concerns such as food security, reducing risk in farming, improving livelihood opportunities through agriculture and improving water productivity in agriculture to save water for environment are 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 regions are also 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 can be achieved in dairying. Such complementarity comes due to large area under crop production in per capita terms, with the result that the available crop residues are sufficient to feed the livestock. Hence, it does not exert any additional pressure on local water resources.

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[6] This is based on the primary data which show that a hectare of paddy creates Rs. 5000 worth of farm labour in Punjab. This is exclusive of the machinery employed in ploughing and harvesting. With a labour charge at the rate of Rs.80/day, the number of labour days/ha of irrigated paddy is estimated to be 61 (source: primary data from Punjab).

Other opportunities for reducing pressure on groundwater through water productivity improvement in agriculture are extremely limited if the region contributes significantly to national food security and rural employment. In addition, there are limits to intensifying dairy production in such regions. The reason is that if dairying were intensive, with fodder crops grown specially instead of using 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.

6. CAN DAIRYING THRIVE IN WATER RICH REGIONS OF INDIA?

There are regions in India, which are under humid and sub-humid 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 evapo-transpiration. Such regions also indulge in dairy farming. These regions have a lot of naturally grown grasses which 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 the consumptive use of water by fodder crops would be very less, but most of the 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.

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
Green Fodder	16.00	15.59	12.17
Local green grass	13.37	14.05	11.59
Maize	2.64	1.54	0.58
Dry Fodder	11.75	11.39	10.63
Paddy Straw	11.75	11.39	10.63
Concentrate	3.37	3.34	2.59
Balanced cattle feed	1.57	1.73	1.12
Cotton seed cake	0.38	0.44	0.25
Wheat Bran	0.43	0.66	0.28
Rice Bran	0.99	0.51	0.94
Drinking Water (m^3.)	0.034	0.029	0.023

Source: Rajesh and Tirkey (2005)

This has a big impact on the irrigation water used for green fodder fed to cattle. It was found to be in the range of 40 - 160 lt/day/animal (Table 4). As a result, the effective water productivity in milk production (physical) was higher as compared to the semi arid north Gujarat. The study estimated effective irrigation water productivity in milk production to be 0.50lt/m^3, 0.74lt/m^3 and 0.51 lt/m^3, respectively, for buffalo, cross-bred 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 chunk of the water used up in milk production is the embedded water in cattle feed. It was 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.

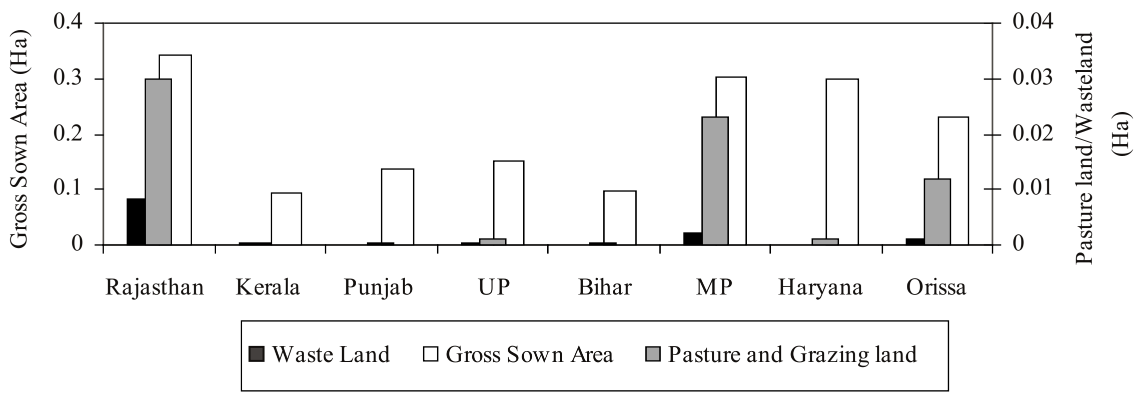
Further, the cost of producing fodder was found to be negligible, when compared to that of cattle feed. It worked out to be 10.6%, 8.9% and 13% of the total input cost, for buffalo, cross-bred cow and indigenous cow, respectively. The water productivity in economic terms was also relatively higher when compared to north Gujarat. The estimated effective irrigation water productivity was Rs. 1.0/m^3, Rs. 1.88/m^3 and Rs. 1.55/ m^3 or buffalo, cross-bred cow, and indigenous cow, respectively in Kerala (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. While per capita land availability is high in semi arid regions, it is extremely low in humid and sub-humid 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. It is clear that 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. It is 0.30 ha in Haryana against only 0.094 ha in Kerala (Figure 3).

Table 4: Total Water Use and Water Productivity in Milk Production, Palakkad, Kerala

Particulars	Kerala		
	Buffalo	Crossbred Cow	Indigenous Cow
Green fodder (m^3)	0.16	0.10	0.04
Dry Fodder (m^3)	4.73	4.59	4.28
Concentrate (m^3)	4.67	4.06	3.87
Drinking Water (m^3)	0.034	0.029	0.023
Total Water used (m^3)	9.60	8.77	8.21
Milk Production (Litre/day)	2.46	3.49	2.36
Irrigation Water Productivity (IWP) (litre/m^3)	0.26	0.40	0.29
Effective IWP in Milk Production (litre/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)

Figure 3: Per Capita Land Availability under Different Classes in Selected States of India



7. SUMMARY OF FINDINGS

Within the same agro climate, the nature of dairy farming determines the water intensity of milk production. It is low water intensive in regions where cereal production compliments 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 level of production. This makes dairy production highly water-intensive as demonstrated by north Gujarat. In sub-humid 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 (which is naturally available), and residues from crop production.

In semi arid and arid areas with intensive dairy farming, replacement of dairy farming by highly water-efficient orchards and cash crops would be the way to enhance water productivity in agriculture, and reducing the stress on groundwater without adverse consequences for 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 fodder crops and crops whose byproducts 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 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 crops which have water productivity higher than that in dairying. The reason is dairying, which cereal production sustains, yields much higher water productivity than cereals alone. Again, the scope for introducing crops, which are more water-efficient than dairying (like orchards) have constraints of regional food security and labour absorption in agriculture.

8. CONCLUSIONS

Dairying is emerging as a major economic activity in rural areas of India, given the growing demand for milk and other dairy products, 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 puts on local groundwater 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 locality produced. Analysis presented in this paper suggests that the water intensity of dairy farming could be remarkably different between regions of same agro climate, depending on the intensity of dairying vis-à-vis the number of dairy animals supported by the available cultivated land.

The most desirable situation is one in which crops compliment dairy farming. Such situation is possible when number of cattle per unit of cultivated land is relatively low. This ensures greater quantities of dry fodder 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 that have extra arable land that can be brought under cultivation. This is not applicable to Punjab, which already has high cropping intensity. Large scale import of dry and green fodder would be difficult. But, sub-humid and humid regions in India are not able to produce surplus fodder that can be exported to these regions.

Intensification of dairy farming is undesirable for semi arid regions, which depend on locally grown irrigated fodder crops, other than those obtained as by products of crop as this implies water-intensive milk production. Dairy intensification is an option where 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 conserve groundwater without affecting the socio-economic conditions of the communities which depend on it. This is in view of the fact that demand for dairy products is increasing exponentially in India, and the country cannot afford to allow decline in milk production. The options include: improving water productivity of crops, included those used in milk production, through the use of micro-irrigation; and replacement of existing low valued crops by 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.

While sub-humid and humid regions offer great potential to produce milk without depleting local water resources, they have limited land availability. Unfortunately, such regions in India have much less cropped area (gross sown area), 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. But, this will not be ecologically sustainable, and would eventually result in depletion of local water resources. In such regions, efforts should be made to make it more water-efficient through use of micro irrigation systems for the crops, including water-intensive forage crops. While ecologically sustainable dairy farming is possible in sub-humid and humid areas, there are major constraints to boosting milk production from such regions.

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