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Virtual irrigation water use in milk production: Results from water abundant regions of India

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Abstract
Dairy farming along with crop production is very common practice in India. Due to introduction of water intensive feed and fodder along with commercialisation of dairy farming, the milk production from dairy animals is one of the water intensive activities. Present study was an attempt to study the virtual water use in milk production in water abundant regions of Uttar Pradesh and Bihar. The study was based on the primary and secondary data. Primary data was collected through personal interview. Results suggests that over a period of time crossbred cow population water increasing whereas buffalo and indigenous cow was showing declining trend. The milk production in the country was growing with a compound growth rate of 4.80 per cent per annum during 1950-51 to 2017-18. Per litre milk production from buffalo, crossbred cow and indigenous cow requires 2207, 1559 and 2020 litre of embedded water respectively in eastern Uttar Pradesh, whereas in case of south Bihar plain it was 2622, 1956 and 2856 litre respectively.

Keywords: dairy farming; agronomic water productivity; net economic water productivity; virtual water

1. Introduction
Livestock rearing along with crop production is as old as farming system. Conventionally, farmers keep dairy animals based on the freely available crop by-products and family labour and farmers convert these into food, fuel and animal farm power. This age-old practice has rapidly transformed due to commercialisation of Indian dairy sector. Livestock plays an important role in socio-economic development of the rural population and it also contributes to Indian economy. Agricultural and allied sector is playing an important role in the Indian economy. As per population census 2011, nearly 54.6 per cent of total population of the country is engaged in agriculture and allied activities. The Gross Value Added (GVA) by all the sectors of India at current price was Rs 138415.91 billion during 2016-17. Out of this, share of agriculture and allied sector was accounting for 17.95 per cent (Rs 24840.05 billion) of GVA during 2016-17. The livestock sector contribute about 4.26 per cent (Rs 6399.12 billion) of India's GVA at current price during 2016-17 and 25.76 per cent to agriculture and allied GVA at current price during same period of time (GOI, 2018).
The growth of dairy sector in the country was chiefly attributed to the Operation Flood Programme and other dairy development programmes which was implemented by the central and state government. The Operation Flood Programme is considered as the largest dairy development programme in the world (Singh and Pundir, 2003) [6]. Dairy sector has emerged as an important source of income and employment generating activity for small and marginal farmers. The major factors influencing the growth of dairy sector are assured milk marketing facility through village dairy cooperatives, attractive price of milk, availability of balance cattle feed and veterinary facilities including artificial insemination and fast growing demand of milk and milk products.
After advent of "Green Revolution" technologies in mid-sixty leads enormously demand for groundwater for irrigated crop production. The negative consequences of heavy groundwater withdrawal were declining groundwater table in many parts of the country. To cope-up with this situation, farmers of water scarce regions are shifting from crop production to dairy production (Singh *et al.*, 2004) [8]. The success of "White Revolution" in the different parts of the country has added the burden on already stress groundwater resources (Singh, 2004) [8]. Past researchers reported that dairy farming is one of the water intensive livelihood activities in rural area, because it is based on the irrigated feed and fodder inputs which is used for milk production (Singh, 2004; Singh *et al*., 2004) [8, 9].

Dairy farming involves not only direct consumptive water (drinking water), but also embedded water in the form of green fodder, dry fodder and concentrates. The diary animal requires only 70-80 litres of drinking water per day per animal whereas lactating dairy animal requires some more water to produce the milk with very small fluctuation with seasons to season (Singh *et al*., 2004) [8]. But it is only the tip of iceberg so far as water use in dairy farming is concerned. Singh *et al.* (2004) [9], found that average daily water used by the buffalo, crossbred cow and indigenous cow in Gujarat was 8.53 m^3, 8.65 m^3 and 6.92 m^3 respectively and the share of drinking water being less than one per cent, while embedded water accounts for the rest (Singh *et al.*, 2004; Singh *et al*. 2014) [8, 10]. Chapagain and Hoekstra (2003) [1] studied the water intensity of milk production in India and they found that on average one litre of milk production requires about 2749 litres of water at aggregate level in India. The actual impact of dairy farming on water resources would depend on where all the milk is produced, and the nature of dairy farming (Singh and Kumar, 2009) [7]. Looking the milk production and water nexus, present study was an attempt to study the water use and water productivity of milk production in Eastern Uttar Pradesh and South Bihar Plain.

2. Research Methodology

2.1 Sampling Procedure

Present study was based on the primary and secondary data. Primary data was collected through personal interview using pre-tested schedule. Varanasi and Mirzapur district from eastern Uttar Pradesh was purposively selected for primary data collection. From each district one village was selected. From each selected village, 60 dairy farmers were selected for primary data collection (Table 1).

Table 1: Sample size

Name of the state	Name of the region	Name of the district	Name of village	Number of respondents
Uttar Pradesh	Eastern Uttar Pradesh	Varanasi	Raja Talab	60
		Mirzapur	Pahari	60
Bihar	South Bihar Plain	Patna	Baluan	60
			Hathiyakand	60
Total	02	03	04	240

Patna district from south Bihar plain was purposively selected. From the Patna district two villages viz, Baluan and Hathiyakund were selected. From each selected villages, 60 dairy farmers were selected for primary data collection. Total sample size from both the state was 240 (Table 1). The primary data include: types and quantity of feeds and fodders fed to livestock in different stages of livestock, life cycle of the animal, milk production, price of milk, cost of feed and fodder, irrigation charges, irrigation water charges etc. were collected.

2.2 Analytical Procedure

Dairy farmers are using green fodder, dry fodder (mostly by-products) and concentrates to feed dairy animals. Dairy farmers are using both green (rainfall) and blue water (irrigation water) for production of feed and fodder. Normally, feeds and fodders grown during kharif season are utilising both blue and green water, whereas during rabi and summer season, it is largely depends on irrigation water. The present study confined to consider only blue water use in dairy farming.

2.2.1 Water Use for Crop Production

Farmers grow a variety of crops as a strategy to cope-up with water scarcity. Through this, they sustain farming and dairy production, thereby livelihoods. The following method was employed to quantify irrigation water use for crop production.

$$\theta_{Crop} = I_N * H_{PI} * P_D \quad \ldots\ldots (1)$$

Where: θ_{Crop} is total water used for crop production (m^3); I_N is number of irrigation given to particular crop; H_{PI} is total hours of pump running for one irrigation; and P_D is pump discharge rate (m^3/hours)

2.2.2 Milk Water Productivity

The physical productivity of water in milk production for livestock WP_{Milk} (litres/m^3) can be defined as:

$$WP_{Milk} = \frac{Q_{MP}}{\theta_{milk}}$$

Where, Q_{MP} is the average daily milk output by one unit of livestock category over the entire lifecycle (litres/animal/day). θ_{Milk} is the total volume of water used per animal per day, including the water embedded in feed and fodder inputs, used in dairying for an animal in a day, worked out for the entire animal lifecycle (m^3/animal/day). It was estimated as (Singh, 2004; Kumar and Singh, 2007) [8, 5]:

$$\theta_{milk} = \frac{Q_{cf}}{WP_{cf}} + \frac{Q_{df}}{WP_{df}} + \frac{Q_{gf}}{WP_{gf}} + \theta_{DW}$$

Where Q_{cf}, Q_{df} and Q_{gf} are the average quantities of cattle feed, dry fodder and green fodder used for feeding a livestock unit per day (kg/animal/day); WP_{cf}, WP_{df} and WP_{gf} are the physical productivities (kg/m^3) of cattle feed, dry fodder and green fodder, respectively; θ_{DW} is the daily drinking water consumption by livestock (m^3/day). It is the average volume of water required by a dairy animal per day over its entire life cycle, including the water embedded in feed and fodder.

Q_{cf}, Q_{gf}, Q_{df} and θ_{DW} for a given category of livestock was estimated for the entire animal life cycle from the following: [i] weighted average of the average daily figures of these inputs for each season for animals in different stages of the life cycle, viz., calving, lactation stage, dry stage; and [ii] the time period in each stage of animal life cycle for that category of livestock.

Since all the farmers in the sample may not have animals that represent all the different stages of the life cycle in a particular category of livestock at a given point of time, the average values of inputs worked out for the sample farmers would be used as value of above mentioned variables. Likewise, the average values of physical productivity of water

in green fodder and dry fodder would be used for estimation. Q_{MP} (litre/animal/day) was estimated from: i] the weighted average of average daily figures of milk yield for different seasons; and ii] the ratio of time period in lactation and the average life span of the animal in that category.

WP_{gf} and WP_{df} was estimated by taking their respective quantities and the volume of water required for growing that crop. In the case of by-products of crops used as fodder, the water used for growing that crop was allocated among the main product and by-product in proportion to the prices of the respective produces in the market (Dhondyal, 1987; Singh, 2004) [2, 9].

The net return of milk production, NR_{milk} (Rs/animal/day) was estimated using values of Q_{MP}, the price of milk (Rs/litre) and the cost of production of the average amount of cattle inputs required in a day (Rs/animal/day) estimated for the entire animal life cycle as proposed by Singh (2004) [8] and Kumar and Singh (2007) [5]. It is important to mention here that with import of green or dry fodder in a farm, the cost of fodder input could also go up. This in turn would affect net water productivity in dairying WP_{Milk} (Rs/m^3). It can be estimated as (Singh, 2004; Kumar and Singh, 2007):

$$WP_{dairy} = \frac{NR_{milk}}{\Delta_{milk}} \quad \text{..... (3)}$$

In the case of purchase of inputs, the market price was used. In case the inputs are from farmers' own fields, the actual cost of production was estimated. In the case of farmers using crop by-products for dairying, the total cost of production of the given crop was allocated among the main product and by-product on the basis of the potential revenues that could be earned from their sale in the market. The quantity of inputs (feed and dry and green fodder) and milk outputs would be worked out for the entire animal life cycle and not on the basis of the actual use of inputs and milk yield at the point under consideration.

3. Result and Discussion

3.1 Livestock Population in India

Total crossbred animals in the country were 33.06 million in 2007 and it was increased to the level of 39.73 million by the year 2012 (Table 2). Out of this, share of male crossbred was 20.69 per cent in 2007 which was decreased to level of 15.03 per cent by the year 2012 registering the 12.73 per cent decline in the male population during the same period of time. In case of crossbred cow, total female population in the country was 26.22 million (79.31 per cent) in 2007 and it was increased to 33.76 million (84.97 per cent) by the year 2012. The growth of crossbred cow was found to be 28.77 per cent during same period of time. Total indigenous animals in the country was 166.01 million in 2007 and it was shrink to the level of 151.17 million by 2012 showing a decline of 8.94 per cent during the same period of time. Out of total population of indigenous animals in the country, the share of male animal was 46.25 per cent in 2007 and it was decline to the level of 40.98 per cent by 2012 registering a decline of 19.32 per cent during the same period of time. In 2007, total indigenous cow in the country was 89.24 million and it was declined to 89.22 million in 2012 showing a decline of 0.01 per cent during the same period of time.

Table 2: Species-wise dairy animal in India (Number in million)

Species	2007		2012		% change over 2007
	Number	Per cent	Number	Per cent	
I. Total crossbred	33.06	100.00	39.73	100.00	20.18
1. Total male	6.84	20.69	5.97	15.03	-12.73
2. Total female	26.22	79.31	33.76	84.97	28.77
II. Total indigenous	166.01	100.00	151.17	100.00	-8.94
1. Total male	76.78	46.25	61.95	40.98	-19.32
2. Total female	89.24	53.76	89.22	59.02	-0.01
III. Total buffalo	105.34	100.00	108.70	100.00	3.19
1. Total male	19.60	18.61	16.10	14.81	-17.83
2. Total female	85.75	81.40	92.60	85.19	7.99

GOI (2014)

In case of buffalo, total population in the country was 105.34 million and it was increased to 108.70 million in 2012 with a growth of 3.19 per cent during the same period of time. Out of this share of male buffalo was 18.61 per cent in 2007 and it was decline to 14.81 per cent by the year 2012. Total female buffalo population in the country was 85.75 million in 2007 and it was increased to 92.60 million by the year 2012 registering a growth of 7.99 per cent during the same period of time.

From the above discussion it is clear that the dairy farmers were gradually shifting from indigenous animal to crossbred animal and buffalo. Traditionally farmers were keeping indigenous cow to get bullock power. Due to farm mechanisation, the significance of bullock labour was reduced. Therefore, farmers were gradually shifting from indigenous animal to crossbred animals and buffalo in the country.

3.2 Milk production in India

In 1050-51, total milk production in India was 17 million tonnes and it was increased to the level of 175.35 million tonnes by the year 2017-18 (Figure 1). The growth trend analysis for milk production suggests that it was growing with a compound growth rate of 4.80 per cent per annum during same period of time. The per capita per day milk availability in India was 130 gram in 1950-51 and it was increased to the level of 355 gram by the year 2016-17. The growth trend analysis for per capita milk availability suggests that it was growing with a compound growth rate of 2.40 per cent per annum respectively.

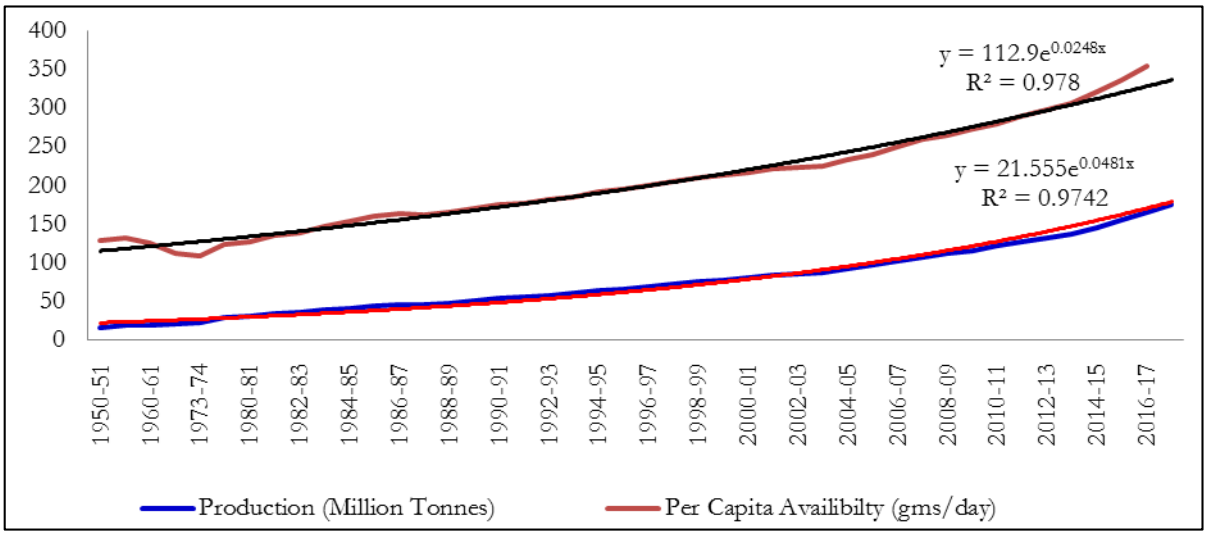

Fig 1: Milk production and per capita availability of milk in India

3.2 Feed and fodder use

After considering the different stages of life cycle of the dairy animal, we estimated the feed and fodder fed to dairy animals and same is presented in Table 3. In case of eastern Uttar Pradesh, the major green fodder fed to dairy animals in the study area was maize, *barseem* and MP *Chari*, whereas wheat *bhusa* was major dry fodder. In case of concentrates, barley flour and mustard cake was fed to dairy animals. In case of south Bihar plain, maize and barseem was main green fodder fed to dairy animals. Wheat bhusa and paddy straw was the main dry fodder used to feed dairy animals. Mustard cake and wheat bran was used as concentrate to feed dairy animals in south Bihar plain.

The dairy farmers were feeding larger quantity of green fodder followed by dry fodder and concentrates, whereas in case of south Bihar plain, larger share comes from dry fodder followed by green fodder and concentrates. The share of green fodder to total feed and fodder was ranging between 51 to 54 per cent, whereas share of dry fodder was 42 to 45 per cent and share of concentrates was four to five per cent. In case of south Bihar plain, the share of green fodder was ranging between 38 per cent to 41 per cent, whereas the share of dry fodder was 53 per cent to 57 per cent. The share of concentrates was five to six per cent.

Table 3: Average feed and fodder fed to dairy animal (kg/day/animal)

Name of Feed and Fodder	Eastern Uttar Pradesh			South Bihar Plain		
	Buffalo	CB Cow	Ind. Cow	Buffalo	CB Cow	Ind. Cow
A. Green fodder	16.65	18.85	14.47	11.03	11.05	8.13
1. Maize	5.70	6.63	5.43	0.30	0.33	0.45
2. Barseem	6.91	8.25	6.14	6.43	6.09	4.38
3. MP chari	4.05	3.96	2.89	-	-	-
4. Masuriya	-	-	-	4.30	4.63	3.29
B. Dry fodder	12.80	15.47	12.79	14.23	15.11	12.30
1. Wheat bhusa	12.80	15.47	12.79	9.44	8.09	7.37
2. Paddy straw				4.79	7.02	4.93
C. Concentrate	1.24	1.66	1.25	1.66	1.73	1.07
1. Barley flour	0.58	0.78	0.60	-	-	-
2. Mustard cake	0.66	0.88	0.65	0.51	0.73	0.54
3. Wheat bran	-	-	-	1.15	1.01	0.53

3.3 Milk production and milk price

Based on the life cycle of the dairy animals, milk production (per day per animal) was estimated for all dairy animals. In case of eastern Uttar Pradesh, highest daily milk production comes from the crossbred cow (2.90 litres) followed by indigenous cow (1.86 litres) and lowest from buffalo (1.80 litres). In case of south Bihar plain, highest daily milk production was observed for crossbred cow (2.73 litres) followed by buffalo (1.98 litres) and lowest for indigenous cow (1.56 litres).

Per litre average milk price received by dairy farmers was Rs 30, Rs 26 and Rs 28 for buffalo, crossbred cow and indigenous cow respectively in eastern Uttar Pradesh, whereas in case of south Bihar plain, it was Rs 30, Rs 28 and Rs 29 for buffalo, crossbred cow and indigenous cow respectively.

3.4 Water use for milk production

Based on the life cycle of animals and daily feeding pattern, embedded irrigation water for feed and fodder was estimated and it was present in Table 4. In case of eastern Uttar Pradesh, total water used for buffalo, crossbred cow and indigenous cow was found to be 3.98, 4.50 and 3.72 m^3 per day per animal respectively. Out of this, share of embedded water used by buffalo in the form of green fodder, dry fodder, concentrate and drinking water was 46.48, 27.89, 23.87 and 1.76 per cent respectively, whereas in case of crossbred cow it was 43.56, 29.78, 25.11 and 1.56 per cent respectively. In case of indigenous cow, the embedded water comes from green fodder, dry fodder, concentrate and drinking water was found to be 43.28, 30.38, 24.73 and 1.61 per cent respectively.

In case of south Bihar Plain, total water used for milk

production from buffalo, crossbred cow and indigenous cow was estimated to be 5.53, 5.59 and 4.58 m^3 per day per animal (Table 4). Out of total water used for milk production, the share of embedded water comes from green fodder, dry fodder, concentrate and drinking water for buffalo was found to be 28.65, 26.92, 43.08 and 1.54 per cent respectively, whereas in case of crossbred cow it was 26.22, 28.09, 44.38 and 1.31 per cent respectively. In case of indigenous cow, the share of embedded water comes from green fodder, dry fodder, concentrate and drinking water was found to 31.16, 27.91, 39.30 and 1.63 per cent respectively.

From above discussion it is clear that direct water consumed by dairy animals was less than two per cent and rest of water comes from feed and fodder.

Table 4: Irrigation water equivalent feed and fodder use (m^3/day/animal)

Name of Feed and Fodder	Eastern Uttar Pradesh			South Bihar Plain		
	Buffalo	CB Cow	Ind. Cow	Buffalo	CB Cow	Ind. Cow
A. Green fodder	1.85	1.96	1.61	1.49	1.40	1.34
1. Maize	0.48	0.52	0.46	0.14	0.14	0.16
2. Barseem	0.70	0.79	0.65	0.72	0.64	0.56
3. MP chari	0.68	0.65	0.51	-	-	-
4. Masuriya	-	-	-	0.64	0.62	0.63
B. Dry fodder	1.11	1.34	1.13	1.72	1.75	1.48
1. Wheat bhusa	1.11	1.34	1.13	1.21	1.05	0.96
2. Paddy straw	-	-	-	0.51	0.70	0.52
C. Concentrate	0.95	1.13	0.92	2.24	2.37	1.69
1. Barley flour	0.27	0.32	0.29	-	-	-
2. Mustard cake	0.68	0.81	0.63	1.06	0.95	0.74
3. Wheat bran	-	-	-	1.18	1.42	0.96
D. Drinking water (m^3)	0.068	0.070	0.064	0.075	0.073	0.066
Total water use (m^3)	3.98	4.50	3.72	5.53	5.59	4.58

3.5 Milk water productivity

On the basis of life cycle of the dairy animals, the agronomic and net economic water productivity was estimated. In eastern Uttar Pradesh, per day net income received by dairy farmers from buffalo, crossbred cow and indigenous cow was Rs 5.50, Rs 15.50 and Rs 3.38 respectively (Table 5).

Table 5: Physical and net economic milk water productivity (Per day/animal)

Particulars	Eastern Uttar Pradesh			South Bihar Plain		
	Buffalo	CB Cow	Ind. Cow	Buffalo	CB Cow	Ind. Cow
a. Green fodder (m^3)	1.85	1.96	1.61	1.49	1.40	1.34
b. Dry fodder (m^3)	1.11	1.34	1.13	1.40	1.50	1.20
c. Concentrate (m^3)	0.95	1.13	0.92	2.24	2.37	1.69
d. Drinking water (m^3)	0.07	0.07	0.06	0.08	0.07	0.07
e. Total water use (m^3)	3.98	4.50	3.72	5.20	5.34	4.30
f. Milk production (Lt.)	1.80	2.90	1.86	1.98	2.73	1.56
g. Price of milk (Rs/Lt)	30.00	26.00	28.00	30.00	28.00	29.00
h. Cost of feed and fodder (Rs)	49.33	60.59	49.51	48.98	46.73	40.08
i. Gross income (Rs)	54.83	76.09	52.89	60.01	76.97	45.74
j. Net income (Rs)	5.50	15.50	3.38	11.03	30.23	5.66
k. Physical milk water productivity (Lt/m^3)	0.46	0.65	0.50	0.38	0.51	0.37
l. Net economic milk water productivity (Rs/m^3)	1.47	3.47	0.93	2.15	5.62	1.32
m. Total water required for one litre milk production (Lts.)	2207	1559	2020	2622	1956	2856

The physical milk water productivity was found to be 0.46 litre/m^3, 0.65 litre/m^3 and 0.50 litre/m^3 for buffalo, crossbred cow and indigenous cow respectively. The net economic water productivity of milk production from buffalo, crossbred cow and buffalo was found to be Rs 1.47/m^3, Rs 3.47/m^3 and Rs 0.93/m^3 respectively.

In case of south Bihar plain, per day net income received by dairy farmers from buffalo, crossbred cow and indigenous cow was Rs 11.03, Rs 30.23 and Rs 5.66 respectively. The physical milk water productivity was found to be 0.38 litre/m^3, 0.51 litre/m^3 and 0.37 litre/m^3 for buffalo, crossbred cow and indigenous cow respectively. The net economic water productivity of milk production from buffalo, crossbred cow and buffalo was found to be Rs 2.15/m^3, Rs 5.62/m^3 and Rs 1.32/m^3 respectively (Table 5).

From above discussion it is clear that milk production from crossbred cow was more water efficient followed by buffalo and indigenous cow.

4. Summery and Conclusions

The demand for milk and milk products growing very fast in India due to fast growing population and increasing purchasing power of population. To respond the demand of milk and milk products, milk production is also increasing in many regions of the country. Many past researchers reported that dairy farming is one of the water intensive livelihood activities in the rural area (Chapagain and Hoekstra, 2003; Singh, 2004; Singh *et al*., 2004; Kumar and Singh, 2007; Singh and Kumar, 2009) [1, 8, 9, 5, 7].

The survey of species-wise livestock census, suggests that the population of crossbred cow in the country is increasing, whereas population of indigenous cow in the country is declining during 2007 to 2012. The milk production and per capita milk availability in the country is growth with a compound growth rate of 4.80 and 2.40 per cent per annum respectively. Based on the life cycle of the dairy animals, milk production from crossbred cow was found to be more water

efficient followed by buffalo and indigenous cow. Therefore, dairy farmers should keep crossbred cow for milk production which lead to increase milk production in the country and reduce the use of irrigation water for milk production. Dairy farmers should grow water efficient fodder to feed dairy animals.

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