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Water Intensity of Milk Production : A Comparative Analysis from Waterscarce and Water Rich Regions of India

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Abstract

Livestock plays an important role in socio-economic development of the rural population and also contributes significantly to India's economy. Dairy farming is one of the water intensive livelihood activities in rural area because it consumes lot of embedded water in the form of feed and fodder. The overall objective of the present study was to estimate the irrigation water productivity of milk production in water rich and water scarce regions of India. The study shows that total irrigation water used to produce a litre of milk from buffalo, crossbred cow and indigenous cow is 3.27 m^3, 2.18 m^3 and 2.30 m^3 respectively in Gujarat, whereas, 5.49 m^3, 3.01 m^3 and 4.86 m^3 respectively in Punjab. In case of Kerala, total water used for producing a litre of milk from buffalo, crossbred cow, and indigenous cow is 3.90 m^3, 2.51 m^3 and 3.45 m^3 respectively. India has a vast bovine population dominated by unproductive/ low milk yielding animals and these animals are competing with the natural resources i.e. land and water. Further amplification of bovine population in the country would add additional burden on already over-exploited natural resources including water. The gradual replacing a part of water intensive milk producing animal with water efficient milk producing animal, would help not only reduce the population of the unproductive animals but also substantially ease the pressure on our precious irrigation water without compromising on milk production. It is imperative to use available natural grasses which are available in forest/grazing land as a fodder for dairy animals to cut down the irrigation water which is used for fodder production. Further more it is required to cultivate water efficient green fodder crops to cut down the blue water use for milk production.

Keywords: Irrigation water productivity, milk water productivity, effective water use, physical water productivity, combined physical and economic water productivity.

Livestock rearing along with crop production is as old as farming itself. Traditionally, farmers maintained livestock in relation to the freely available by-products of crops and availability of family labour. Thus, each household used to be a virtually independent production system without purchase of inputs of milk production and with modest marketable surplus. This age-old practice however has rapidly undergone a change in recent decades, because of massive commercialisation/industrialisation of Indian dairy sector. The demand of milk and milk products is increasing vary fast due to increase in purchasing power of the people and diversification of food basket. As per projection made by Amarasinghe *et al*. (2007) the per capita milk demand in rural and urban area would be 220 and 0.335 gram per day respectively in 2050 as compared to 160 and 224 gram per day for rural and urban respectively in 2000. As per demographic projection made by Mahmood and Kundu (2006), total population of India would be 1580 million by 2050. Out of this nearly 53 % (837.4 million) population will reside in urban area and remaining 47 % (742.6 million) would live in rural area. Total milk and milk product demand in India would be 161.83 million tonnes in 2050. Out of this share of rural and urban demand would be 59.54 and 102.29 million tonnes respectively.

Livestock plays an important role in socio-economic development of the rural population and also contributes to India's economy. The contribution of India's buffalo population to the world's total buffalo population is about 57.3 %, whereas the share of cattle population is 14.7 %. The share of Indian goats, sheep, and poultry population is 16.7 %, 6.8 % and 4.5 % of the world's total population respectively in 2010 (GOI, 2012).

During 1960s and early 1970s, India was a recipient of massive material support from the World Food Programme (WFP) and European Economic Community (EEC). After inception of "Operation Flood" programme; which was launched for overall development of India's diary sector, India has positioned itself as the world's leading milk producer. In 1950-51, total milk production of India was 17 million tonnes and it increased to 22 million tonnes in 1970-71 and it was further augmented to 121.80 million tonnes by 2010-11. Despite being the largest milk producer in the world, per capita milk availability in the country is one of the lowest in the world. Per capita milk availability in the country increased from 124 gm/day in 1950-51, to 281 gm/day in 2010-11. However, it is still below the world average of 285 gm/day/capita (Singh *et al*., 2004a).

The share of agriculture and allied sectors to the India's gross domestic product (GDP) was 15.28 % in 2010-11. Livestock sector is one of the fast growing sectors in rural India and it accounted for about 23.8 % of the India's agricultural GDP and about 3.64 % of country's total GDP in 2010-11. In 2010-11, the value generated from agriculture sector was 1416441 crores. Out of this share of livestock sector was 27.42 % (₹ 388370 crores) during the same period of time. The gross value of output from livestock sector has increased from ₹ 20856 crores in 1950-51 to ₹ 388370 crores in 2010-11. Out of the total value generated from the livestock sector, the share of milk and milk product has increased from about 55 % in 1950-51 to 67.52 % in 2010-11. The share of meat, egg and dung group to total value of output from livestock sector is 16.56 %, 3.89 %, and 6.71 % in 2010-11 (GOI, 2012).

Operation Flood Programme was the key driver of growth in dairy sector in India. Operation Flood Programme which was launched by the National Dairy Development Board (NDDB), Anand, in 1970 is considered as the largest dairy development programme in the world (Singh and Pundir, 2003). The major factors influencing the growth of dairy sector are assured milk marketing facility at doorsteps of the dairy farmers through village dairy cooperative society, remunerative price of milk, and availability of balance cattle feed and veterinary facilities including artificial insemination at farmers' door step. The dairy sector has also helped in generating employment opportunity of millions of rural youth those having less employment opportunity in rural area.

With the advent of "Green Revolution" technologies and water-intensive crops, the pressure on groundwater for irrigation has enormously increased in different parts of country as 60 % of the total net irrigated area in the country is irrigated by groundwater (Shah *et al*., 2006). The excessive withdrawal of groundwater for irrigation is leading in alarming drops in groundwater levels in many parts of the country (Kumar, 2002). Beside this, other negative consequences of overdraft of groundwater are groundwater contamination, salinity ingress in coastal area, higher concentration of fluoride and arsenic in groundwater etc.

To cope-up with physical water scarcity, farmers of water scarce regions are shifting from crop production to dairy production (Singh *et al.*, 2004a). Dairy farmers are growing water intensive fodder crops from the available irrigation water to sustain their dairy farming and regular flow of income from the sale of surplus milk. Dairy farming is one of the water intensive livelihood activities in rural areas, because it is based on the irrigated feed and fodder inputs which is used for milk production (Wigginton and Raine, 2000; Singh, 2004; Singh *et al*., 2004).

Dairy farming involves not only direct consumptive/drinking water used by dairy animals, but also used embedded/virtual water in the form of green fodder and dry fodder (by-products of cereal), and other crops residues that are fed to livestock. The dairy animal requires nearly 70-80 litres of drinking water per day per animal depending on the climatic condition and species whereas lactating bovine requires some more water to produce the milk (Singh *et al*., 2004a). But it is only the tip of iceberg so far as water use in dairy farming is concerned. Singh *et al.* (2004a) found that out of total water used for milk production from buffalo, crossbred cow and indigenous cow, the share of drinking water is less then 1 %, while embedded water accounts for the rest (Singh *et al.*, 2004a). Chapagain and Hoekstra (2003) studied the water intensity of milk production in India and they found that on an average one litre of milk production requires about 2.75 m^3 of water at aggregate level. The present study an attempt to analyse irrigation water used for milk production in water scarce and water rich regions of India.

Objectives

The overall objective of present study was to find the irrigation water used for milk production in water rich and water scarce region of the country i.e. Gujarat, Punjab and Kerala. The specific objectives of the present study are: [1] to analyse the water intensity of milk production from buffalo, crossbred cow and indigenous cow in water scarce and water abundant region; and [2] to analyses the physical and economic water productivity of milk production from buffalo, crossbred cow and indigenous cow.

Data and Methodology

Data Use

Primary data were collected and used to fulfil the objectives of the present study. The primary data was collected from three Indian states viz., Gujarat, Punjab, and Kerala. In Gujarat, we selected five districts i.e. Anand, Surat Banaskantha, Mehsana and Rajkot districts, Amritsar district from Punjab and Palakkad district from Kerala was selected for the study purpose. From each district we had selected two villages and from each village, we selected 30 farmers those are growing crops along with dairy

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farming. So, total sample size was 420 households from 14 villages of seven districts from three states of India.

Analytical Procedure

Feed and fodder which is grown by dairy farmers during kharif season utilise both blue water (irrigation water) and green water (rain water), whereas during rabi season, farmers are using groundwater for cultivation of feed and fodder crops. Farmers are also using natural grasses to feed dairy animals, which are available in forest, grazing/pasture land and agricultural field. Grosses are utilizing green water (rain water). Present study was confined to consider only irrigation water (blue water) used in dairy farming. To achieve the objectives, we did different types of analysis and made estimation and assumptions which are discussed under subsequent headings.

Water Use for Crop Production

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

$$\theta_{crop} = I_{Hr} * P_d \quad \text{...} \quad (1)$$

The physical crop water productivity is calculated as

$$WP_{crop} = {Cy}/{\theta_{crop}} \quad \text{...} \quad (2)$$

The combined physical and economic water productivity (Rs/m^3) for crop production is calculated as:

$$WP_{crop} = {NI_{crop}}/{\theta_{crop}} \quad \text{....................................} \quad (3)$$

Where: θ_{crop} is total water use for crop production (m^3); I_{Hr} is total hours of irrigation water used for crop production; P_d is pump discharge (m^3/hour); WP_{crop} is crop water productivity (₹/m^3 or Kg/m^3); Cy is crop production and NI_{crop} is net income from crop production (₹).

Water Allocation between Main and By-product

In milk production, most of the feed and fodder are by-products of crop. For example; farmers generally grow wheat for grain production. But wheat straw which is a by-product is used as fodder for cattle. In such a situation, the total water used to produce the crop should be allocated between wheat grain and wheat straw. Dhondyal (1987) argues that the ratio of the income of the main and by-product should also be the ratio in the apportionment of their cost of production. Therefore, water was allocated according to the ratio of the value of main and by-product of the crops.

Water Used for Milk Production

Total water used for milk production depends on two variables: (1) direct water used by livestock in the form of drinking water; and (2) water used for the production of green and dry fodder and concentrates. The water used by dairy animals per day is defined as:

$$\theta_{milk} = \frac{Q_{cf}}{WP_{cf}} + \frac{Q_{df}}{WP_{df}} + \frac{Q_{gf}}{WP_{gf}} + \theta_{DW}$$ …….…………. (3) (Singh, 2004; Kumar, 2007)

Where θ_{milk} is water used for milk production, Q_{cf}, Q_{df} and Q_{gf} are the average quantities of cattle feed, dry fodder and green fodder fed to livestock (kg/animal/day); WP_{cf},WP_{df} and WP_{gf} are the physical water productivities (kg/m^3) of cattle feed, dry and green fodder, respectively; θ_{DW} is the drinking water used 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 for a given category of livestock would be 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., growing stage, calving, lactation stage, dry stage; and [ii] the time period in each stage of animal life cycle for that category of livestock. The net return of milk production,(Rs/animal/day) would be estimated using values of, 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) and Kumar (2007). 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 (Rs/m^3). It can be estimated as: …………. (4) (Singh, 2004; Kumar, 2007)

Results and Discussion

Irrigation Water Productivity for Crop Production

Dairy farmers were growing different types of green and dry fodder to feed dairy animals. For dry fodder, farmers are using by-products of wheat, paddy, jowar, bajra, maize, etc. and these crops are grown by farmers for grain production. The dairy farmers are growing green fodders like alfalfa, barseem, jowar, pioneer jowar, elephant grass etc. to feed dairy animals. The physical water productivity (Kg/m^3) and net and gross physical and economic water productivity (Rs/m^3) of different crops grown by farmers is presented in Table 1. The higher physical water productivity of the crop indicate more efficient use of irrigation water through on farm water management or better farm management through better inputs management for crop production.

In Gujarat, dairy farmers are growing different types of green fodder. Farmers are obtaining higher physical water productivity (kg/m^3) for maize followed by the alfalfa and lowest for pioneer jowar. In case of Punjab, farmers are growing barseem as a green fodder and average physical water productivity is 1.87 kg/m^3. In case of Kerala, farmers are getting very high physical water productivity for maize (green fodder). It may be due to the high rainfall occurred in the study area and farmers are providing very less quantity of irrigation water for crop production.

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Table 1: Physical and Gross and Net Combined Physical and Economic Water Productivity of Crops

Name of the Crops	Gujarat				Punjab				Kerala			
	Economic water productivity (Rs/m^3)		Physical water Productivity (Kg/m^3)		Economic water productivity (Rs/m^3)		Physical water Productivity (Kg/m^3)		Economic water productivity (Rs/m^3)		Physical water Productivity (Kg/m^3)	
	Gross	Net	Main Prod.	By-prod.	Gross	Net	Main Prod.	By-prod.	Gross	Net	Main Prod.	By-prod.
A. Green Fodder												
1. *Mayo*	1.02	-	4.09	-	-	-	-	-	-	-	-	-
2. *Jariya*	3.18	-	5.29	-	-	-	-	-	-	-	-	-
3. Alfalfa	3.13	-	5.95	-	-	-	-	-	-	-	-	-
4. Maize	5.79	-	7.14	-	-	-	-	-	25.19	24.72	16.80	-
5. P. Jowar	1.80	-	2.38	-	-	-	-	-	-	-	-	-
6. Barseem	-	-	-	-	1.78	1.36	1.87	-	-	-	-	-
B. Cash Crops												
1. Sugarcane	2.22	0.13	3.63	5.23	-	-	-	-	-	-	-	-
2. Groundnut	32.40	11.71	2.17	14.08	-	-	-	-	-	-	-	-
3. Cotton	10.83	7.13	0.43	-	-	-	-	-	-	-	-	-
C. Food-rain Crops												
1. Bajra (K)	2.87	0.91	0.64	3.09	-	-	-	-	-	-	-	-
2. Bajra (S)	2.46	1.16	0.54	2.69	-	-	-	-	-	-	-	-
3. Paddy (K)	1.95	0.20	0.37	6.09	4.70	3.43	0.79	2.33	4.20	3.08	0.65	4.20
4. Paddy (R)	-	-	-	-	-	-	-	-	2.48	1.91	0.35	2.48
5. Wheat	5.04	2.54	0.73	5.81	5.38	3.84	0.87	2.68	-	-	-	-
6. Jowar (K)	9.12	4.78	1.12	4.30	-	-	-	-	-	-	-	-
7. Jowar (S)	2.98	1.38	0.40	1.50	-	-	-	-	-	-	-	-

K: Kharif; R: Rabi and S: Summer; Main Prod.: Main Production; By-prod: By-product

Source: Authors' own estimate based on primary data

As in water abundant regions, farmers are more concern with higher net income from per unit cropped area, whereas in case of water scarce region, farmers are more concern with getting higher income per unit of irrigation water use. The cropping pattern of the Punjab is the paddy–wheat system and farmers are allocating larger area under both crops, whereas in Kerala, cropping pattern is paddy–paddy system. The cropping pattern of Gujarat is mixed, in the water rich regions of Gujarat farmers are growing water intensive crops like paddy, sugarcane and wheat and farmers are allocating less area under green fodder cultivation in the region. In water scarce region of Gujarat, farmers are growing bajra, jowar and cotton. Farmers are allocating more area under green fodder production to sustain dairy farming as physical water availability for crop production is constraining factor for sustaining irrigated crop production.

Average Feed and Fodder Use

Dairy farmers are feeding different types of feed and fodder to livestock in different seasons. Farmers are also changing animals' feeding pattern in relation to different stages (lactating, dry, pregnant) of animals across the seasons. Generally farmers are providing green and dry fodder to all types of animals in all the stages of animal i.e. in-milk, dry and pregnant animals depending on the availability of fodder. During shortage of green fodder, farmers provide higher quantity of green fodder to in-milk and pregnant animal and less quantity to dry animal. Farmers provide concentrates only to lactating animals, advance stage of pregnant animal and some amount of concentrate to female calf. Dairy farmers do not provide any type of concentrate to dry animals. We estimated the average feed and fodder used for milk production from buffalo, crossbred cow and indigenous cow based on the lifecycle of the animals. The life cycle of the animals includes different stages: calf stage; maturing stage; pregnant stage; lactating stage; dry stage; and productive life of the animal. The length of different stages of animals is depend on the types of animal i.e. buffalo, crossbred cow and indigenous cow.

Based on the lifecycle of the dairy animal, the average daily feed and fodder fed to different livestock in different states are presented in Table 2. The dairy farmers are feeding highest quantity of feed and fodder to crossbred cow followed by buffalo and lowest for the indigenous cow in all the location of study area. In Gujarat, average daily drinking water supplied to buffalo, crossbred cow and indigenous cow is $0.044 m^3$, $0.038 m^3$ and $0.033 m^3$ per animal respectively, whereas, in Punjab it was $0.067 m^3$, $0.054 m^3$ and $0.031 m^3$ per day respectively. In Kerala, average daily drinking water given to buffalo, crossbred cow and indigenous cow is $0.034 m^3$, $0.029 m^3$ and $0.023 m^3$ per animal respectively.

Table 2: Average Feed and Fodder Fed to Livestock

Name of Feed and Fodder	Feed and Fodder (Kg/day/animal)								
	Gujarat			Punjab			Kerala		
	Buffalo	CB Cow	Ind. Cow	Buffalo	CB Cow	Ind. Cow	Buffalo	CB Cow	Ind. Cow
A. Green Fodder	15.94	14.76	12.72	16.75	16.32	12.36	16.00	15.59	12.17
B. Dry Fodder	15.08	15.35	11.02	13.55	14.44	14.94	11.75	11.39	10.63
C. Concentrate	2.78	3.93	2.40	2.07	1.84	2.58	3.37	3.34	2.59
D. Drinking Water (m^3)	0.044	0.038	0.033	0.067	0.054	0.031	0.034	0.029	0.023

CB Cow: Crossbred cow; Ind. Cow: Indigenous cow

Source: Author's own estimate based on the primary survey

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Average Milk Production

Based on the lifecycle of the dairy animal, we estimated average milk production per day per animal. The analysis suggests that average milk production per day per animal is highest for crossbred cow in all the states. Buffalo's milk production ranks second in Punjab and Kerala, whereas in Gujarat, it ranks third. The third rank goes to indigenous cow in Punjab and Kerala, whereas, in Gujarat, it ranks second place. In Gujarat, farmers are rearing high yielding species of indigenous cow know as "Gir", having genetic potential for high milk yield. In Gujarat, average daily milk production from buffalo, crossbred cow, and indigenous cow was 2.75, 4.0, 3.21 litres per animal respectively, whereas, in case of Punjab, it was 2.50, 4.45, and 2.79 respectively. In Kerala, average per day per animal milk production was 2.46, 3.49, and 2.36 litres for buffalo, crossbred cow, and indigenous cow respectively.

Water Use for Milk Production and Productivity

Based on the lifecycle of dairy animals we estimated water productivity of milk production in both term i.e. physical (litres/m^3) water productivity and combined physical and economic (₹/m^3) water productivity for different types of dairy animals in different states and it is presented in Table 3. We also estimated the effective net combined physical and economic water productivity of milk production. In case of Gujarat, total water used for milk production is highest for crossbred cow followed by buffalo and lowest for indigenous cow and the net combined physical and economic water productivity is highest for crossbred cow, followed by buffalo and lowest from indigenous cow, whereas in case of Punjab, net combined physical and economic water productivity is highest for crossbred cow followed by indigenous cow and lowest from buffalo. In case of Kerala, net combined physical and economic water productivity is highest net for crossbred cow followed by indigenous cow and lowest for buffalo.

It is clear from Table 3 that net physical and economic water productivity of milk production is very low as compared to most of the crops grown by the farmers (Table 1), but framers are still continuing dairy farming. As we know, that farmers are getting dry fodder almost free because they grow cereal crops and from that they get by-product which is used as a dry fodder. The dairy farmers are also able to reduce number of dairy animals during the scarcity of irrigation water and they can increase during the availability of irrigation water. But it is not possible in case of crop production. Now, we discuss the "effective net combined physical and economic water efficiency" of milk production. The "effective net combined physical and economic water productivity" of milk production, is worked out by deducted the water used for producing dry fodder from the total water used by dairy animal per day. In Gujarat, effective net combined physical and economic water productivity of milk production from the buffalo, crossbred cow and indigenous cow is ₹ 1.40/m^3, ₹ 1.66/m^3 and ₹ 1.98/m^3 respectively, whereas, in Punjab, it is ₹ 0.56/m^3, ₹ 1.32/m^3 and ₹ 0.66/m^3 respectively. In Kerala, the effective net combined physical and economic water productivity of milk production from buffalo, crossbred cow, and indigenous cow is ₹ 1.00/m^3, ₹ 1.88/m^3 and ₹ 1.55/m^3 respectively. For crossbred cow, the effective net combined physical and economic water productivity of milk production is highest in all the state. The total water used for a litre of milk production from buffalo, crossbred cow and indigenous cow is 3.27m^3, 2.18m^3 and 2.30m^3 respectively in Gujarat, whereas, in case of Punjab it is 5.49m^3, 3.01m^3 and 4.86m^3 respectively. In Kerala, the total water used for producing a litre of milk production from buffalo, crossbred cow and indigenous cow is 3.90m^3, 2.51m^3 and 3.45m^3 respectively.

Table 3: Physical and Combined Physical and Economic Milk Water Productivity

Particulars	Gujarat			Punjab			Kerala		
	Buff.	CB cow	Ind. cow	Buff.	CB cow	Ind. cow	Buff.	CB cow	Ind. Cow
1. Green fodder (m^3/day/animal)	4.03	3.97	2.59	6.62	6.29	5.00	0.16	0.10	0.04
2. Dry fodder (m^3/day/animal)	1.31	1.30	1.00	5.12	5.52	5.75	4.73	4.59	4.28
3. Concentrate (m^3/day/animal)	3.14	3.35	3.30	1.90	1.51	2.78	4.67	4.06	3.87
4. Drinking water (m^3/day/animal)	0.04	0.04	0.04	0.067	0.054	0.031	0.034	0.029	0.023
5. Total water used (m^3/day/animal)	8.53	8.65	6.92	13.70	13.37	13.56	9.60	8.77	8.21
6. Milk Production (Litre/day/animal)	2.75	4.00	3.21	2.50	4.45	2.79	2.46	3.49	2.36
7. Physical water productivity (Litre/m^3)	0.32	0.46	0.46	0.18	0.33	0.21	0.26	0.40	0.29
8. Gross combined physical and economic water productivity (Rs/m^3)	4.39	4.15	4.10	2.03	2.65	1.79	2.95	3.98	2.78
9. Net combined physical and economic water productivity (Rs/m^3)	0.38	0.39	0.13	0.35	0.78	0.38	0.51	0.90	0.74
10. Effective net combined physical and economic milk water productivity (Rs/m^3)	1.40	1.66	1.98	0.56	1.32	0.66	1.00	1.88	1.55
11. Water used for one litre milk production (m^3)	3.27	2.18	2.30	5.49	3.01	4.86	3.90	2.51	3.49

Note: Buff: Buffalo; CB Cow: Crossbred cow; Ind. Cow: Indigenous cow
Source: Author's own estimate based on primary data

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Conclusion

Livestock plays an important role in socio-economic development of the rural population and it also contributes to India's economy. Dairy farming is one of the water intensive livelihood activities in rural area because it consumes lot of embedded water in the form of feed and fodder. Total water used for a litre of milk production from buffalo, crossbred cow and indigenous cow is 3.27m^3, 2.18m^3 and 2.30m^3 respectively in Gujarat, whereas, in Punjab it was 5.49m^3, 3.01m^3 and 4.86m^3 respectively. In Kerala, the total water used for producing a litre of milk production from buffalo, crossbred cow, and indigenous cow is 3.90m^3, 2.51m^3 and 3.45m^3 respectively.

Intensification of bovine population for further increase in milk production in India will further increase burden of already over exploited natural resources including water. The strategy of replacing a part of the low yielding bovine population (water intensive milk production) with high milk yielding crossbred animals (water efficient milk production). This would not only reduce the population of the un-productive/high water intensive milk yielding animal which are competing for feed and fodder but also substantially ease the pressure on our prestigious irrigation water. To reduce the total irrigation water used for milk production, it is imperative to use natural biomass which is available free on grazing and pasture land as a fodder for dairy animals. Further more it is required to cultivate water efficient green fodder crops to cut down the irrigation water use for milk production.

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