

Water use efficiency in milk production under different groundwater regimes in southern Karnataka

MAHIN SHARIF and PK DIXIT*

**University of Agricultural Sciences, College of Sericulture
Chintamani 563125 Karnataka, India**

***National Dairy Research Institute, Southern Regional Station (ICAR)
Adugodi, Bangalore 560030 Karnataka, India**

Email for correspondence: sharif.mahin@gmail.com

ABSTRACT

The study comprised of computation of cost of milk production, cost of groundwater and water use efficiency (WUE) in milk production of different species of milch animals under different levels of groundwater regimes (safe, semi-critical, critical and overexploitation). The study was carried out in the Chamarajanagar and Mysore districts of Karnataka state which happen to represent both different groundwater regime and progressive dairy region. The study indicated noticeable variations in unit cost of groundwater extraction and it was highest in overexploited area (Rs 3.54/m³) followed by critical (Rs 1.91/m³), semi-critical (Rs 1.07/m³) and safe (Rs 0.80/m³) areas. Daily water depleted by the animals in the process of milk production was highest by crossbred cows (7.79 to 13.71 m³/day/animal) followed by buffaloes (4.89 to 12.07 m³/day/animal) and local cows (3.61 to 5.96 m³/day/animal). The study also revealed that economic efficiency of water use (net income per unit of water use) in milk production from crossbreds was positive and it was in the range of Rs 2.18 to 4.29/m³ and negative economic efficiency of water use was recorded in milk production from local cows (Rs 1.48 to 6.45/m³) and buffaloes (Rs 0.63 to 6.37/m³). Due to higher milk yield in crossbreds the higher WUE of (0.84 to 1.37l/m³) followed by local cows (0.51 to 0.81 l/m³) and buffaloes (0.38 to 0.87 l/m³). Depletion of direct water in the process of milk production was marginal in comparison with the water depleted to produce the feed and fodder of dairy animal and hence emphasis should be given to increase the WUE in production of feed and fodder.

Keywords: Groundwater exploitation; water use efficiency; milk production

INTRODUCTION

Water is one of the critical factors of animal production drawn from nature particularly pivotal role it plays in animal physiology and indirectly in the production of feed and fodder to sustain the animal

production system. The direct importance of water in milk production is well defined and tangible. But it was estimated by FAO that in the period from 2001 to 2007 on average 37 per cent of the cereals produced in the world were used for animal feed (Anon 2011) and it connotes the

importance of water and its indirect role in animal husbandry.

The recent developments in the geo-political and socio-economic conditions in terms of per capita income, food consumption pattern and complementary advances in animal production and processing technologies have been indicative of the march of animal husbandry from subsistence to commercial nature (Sharif et al 2013). As a sequel of it shifting focus on cultivated forage crops and concentrate feed against the greater reliance on agricultural by-products is being observed and the global production of animal products has almost doubled in the period from 1980 to 2004 (Anon 2005) and it is expected to get doubled in the period from 2000 to 2050 (Steinfeld et al 2006). In India also milk production was structurally shifted through its operation flood and it achieved the veritable position as the world's largest milk producing nation and it has been consistently maintaining the position since long.

Climate in India is characterised as arid and semi-arid and in these climates irrigation water (direct and indirect) is extensively used in raising farm animals. In India about 64 per cent of irrigated area relies on groundwater resources (Anon 2014). On the other hand groundwater table is falling continuously due to extensive use of irrigation water to grow high valued food as well as fodder crops and mismanagement of resources both at the

farm level and at the nodal policy making level and the property right of the groundwater is also not well defined. The consequences of overexploitation of the groundwater resources (not necessarily by dairying) are very complex in nature and disturb the balance of both ecological and socio-economic setup. These developments are affecting the livelihood of Indian farmers as dairying is closely interwoven with the livelihood support of populace and it utilizes low valued agricultural by-products and absorbs underemployed agricultural labour force which in turn provides nutrition and sustainable livelihood to rural masses.

Dairying is a water intensive activity. In north Gujarat the farmers produced 0.31 litre of buffalo milk and 0.49 litres of crossbred cow milk by using a m^3 of groundwater (Singh 2004). Similar studies carried out in different parts of Gujarat state showed that water productivity of buffaloes was 0.31 l/m^3 in south and central Gujarat and for crossbred cows it was 0.53 l/m^3 (Singh et al 2009).

It is becoming increasingly relevant to study the implications of farm animals on water resources. But little attention on the part of scientists or policy makers is given to understand the relationship between dairy production and groundwater use and efficient allocation of this scarce resource in the process of animal production in general and more so in milk production.

The present study was conducted in southern Karnataka (Mysore and Chamarajanagar districts) where groundwater is the major source of irrigation and the farmers cultivate high water intensive crops like sugarcane, banana and turmeric along with extensive dairying which in turn leads to over-draft of groundwater. Declining water table coupled with deepening of existing wells and digging of new wells aggravates overexploitation of groundwater and threatens the livelihood security of small and marginal farmers who cannot afford large investments for water abstraction (Sharif and Ashok 2011). Against this backdrop present study is an endeavour to peep into the groundwater use by the dairy farmers and economic efficiency of milk production across different animal breeds in different levels of groundwater exploitations.

MATERIAL and METHODS

Study Area and sampling: Watersheds of Karnataka state are categorised as over-exploited (ratio of extraction to recharge exceeding 100%), critical (ratio of extraction to recharge between 90 and 100%), semi-critical (ratio of extraction to recharge between 70 and 90%) and safe (ratio of extraction to recharge less than 70%) (Anon 2010).

The districts of Mysore and Chamarajanagar in southern Karnataka

were chosen for the study. These districts represented all the four levels of groundwater exploitation besides considerably contributed for the state's milk pool. From each level of groundwater exploitation sixty farmers were randomly selected and in total 240 dairy farmers were contacted for data collection pertaining to various inputs used in milk production for different milch species namely crossbred cows, buffaloes and local cows across the regions and seasons during 2012-13.

Data analysis

Cost of groundwater estimation: Cost of groundwater used in production of feed and fodder, servicing animal and their sheds, washing milking utensils and drinking water for animal etc was estimated as sum of amortized cost of well, amortized cost of pump sets, annual electricity cost and average repair cost of irrigation well, pump sets, electric repairs if any divided by the annual groundwater extracted.

Age of the irrigation well: The water yield life of irrigation well is an important factor used in estimation of amortization cost. It was worked out using Kaplan-Meier survival analysis. The Kaplan-Meier estimator of the survivorship function at time t is $\hat{S}(t) = \prod_{t_{(i)} \leq t} \frac{n_i - d_i}{n_i}$ with the convention that $\hat{S}(t) = 1$ if $t < t_{(1)}$. Using delta method, variance of the survivorship function is obtained as

$$\widehat{Var}(\hat{S}(t)) = (\hat{S}(t))^2 \sum_{t_i(t) < t} \frac{d_i}{n_i(n_i - d_i)}$$

The median survival time was used to work out the well drying rate and median time is the second quartile (50th percentile) . $\hat{t}_{50} = \min\{t: \hat{S}(t) \leq 0.50\}$ Log-rank test was used to test the significant difference between the survivorship functions obtained for different levels of groundwater exploitation.

Amortized cost of well and other annual cost of water extraction: The annual apportionments of initial investments made in construction of the well over its age is arrived by amortizing sum of costs incurred on diving, drilling, casing, pump, pump house, energising and GI pipes by using formula:

$$AC_{well} = \frac{[I_{well} * (1+i)^{AL}]}{(1+i)^{AL} - 1}$$

where AC_{well} = amortized cost of well, I_{well} = sum of all the initial investments made in construction of well, AL = average age of the irrigation well and i = interest rate.

Water extracted: Water abstracted per annum was worked out by:

Water abstracted (m³/annum) = Average number of days pumped per year x average number of hours pumped per day x yield of bore wells in litres per hour

Cost per unit of groundwater was calculated by taking the ratio of annual cost

of extraction to total volume of annual groundwater extracted.

Water allocation between main and by-product: In the case of milk production

most of the feed and fodder are by-products of crop production. For example farmers generally grow paddy for grain but paddy 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 paddy grain and paddy straw. Dhondyal (1987) suggests the ratio that exists in 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 main and by-product of crop.

Economics of milk production: Cost of milk production was arrived at by accounting for fixed costs and variable costs incurred by the farmers in milk production. The fixed costs enveloped primarily depreciation wrt milch animal, sheds and other fixed items and interest on fixed investments. The variable cost included expenditure incurred on various inputs namely green fodder, dry fodder, concentrates, labour and veterinary healthcare. In respect of feed, fodder and labour quantities utilised in milk production were ascertained and were multiplied by local market prices to arrive at the variable cost. The imputed value of dung was deducted from the gross cost to arrive at

net cost. The net cost was then divided by the average milk production per day for computing the cost of milk production. The net returns were computed by deducting net cost from the gross returns (quantity of milk produced per day multiplied by average price of milk procurement).

Total water used in milk production: The total water utilised in the production process had two components (i) water depleted within the production area (ii) water embedded in other inputs used in the production process. These are also often called as ‘internal’ and ‘external’ water footprints (Hoekstra 2003). The external water footprint is also called ‘virtual water’ (Allan 1998). The internal groundwater depletions when aggregated over all commodities produced such as fodder, rice, maize, sorghum and other crops and services (drinking and servicing of animals) that indicates the extent of groundwater depletion of available groundwater resources within the boundaries of study area. The virtual water was basically imported into the study area in the form of feeds and concentrates and this water is quantified using the relevant secondary data published in various similar works. Many of the other parameters for estimating the external water were not easy to collect. While it is acknowledged that these components had a role to play their estimation was beyond the scope of this study.

Water use efficiency in milk production:

It was estimated for buffaloes, crossbreds and local cows by taking ratio of average daily milk production to total water utilised in milk production process (it includes both embedded water in production of feed and fodder and direct groundwater).

RESULTS and DISCUSSION

Water used in production of feed and fodder:

Dairying in India is a subsidiary activity and by-products of the food crops (straw) are used to feed the animal for milk production. In the study area farmers had been growing four main food crops namely Punaji paddy, Ragi, Jowar and maize and their straw was being dried and stored as the dry fodder to feed the dairy animals. As the dry fodder is not sufficient to meet the cattle nutritional requirements and animals prefer to graze on the green fodder farmers also cultivated hybrid Napier (Co-3), fodder Jowar and maize. The groundwater used in cultivation of green fodder crops is easy to estimate. But in approximation of water consumed in production of dry fodder (by-product of crop) indirect approach was used as indicated in the methodology.

Irrespective of level of groundwater exploitation production of a kg of paddy straw consumed highest quantity of water (2.007 to 1.415 m³) than Ragi, Jowar and maize straw. In the case of production of green fodder, hybrid Napier grass exploited around 0.1 m³ of water and it was

comparatively higher than the water required to produce a kg of green fodder from Jowar and maize.

In the process of milk production farmers not only used the self-produced locally grown inputs but also used the inputs produced by other farmers in distant area. For instance in the study area most of the green and dry fodder was locally produced by the farmers. But most of the concentrates fed to the dairy animals were imported from other states or other regions within the state. Hence secondary data was used to estimate the water consumed in production of a unit of feed input and these figures were considered uniformly across levels of groundwater exploitation. Reddy (2012) reported that groundnut pod water productivity was 0.6 to 0.8 kg/m³ by considering average 0.8 kg/m³ of pod yield and 80 per cent cake yield it was worked out that production of a kg of groundnut cake required 1.562m³ of water. Similarly Sirohi et al (2013) documented that production of a kg of wheat bran required 0.530 m³ of water.

Cost of groundwater extraction: The competitive behaviour of the farmers in extraction of the groundwater resulted in decline in the average productive age of the well. This has led to metamorphosis of long-run overhead investments on the well to short-term investments. The marginal cost of groundwater extraction was zero as electricity charges were subsidised for

irrigation pump sets up to 10 HP irrigation motors for which Karnataka state government was supplying free electricity. The productive age of the well in overexploited area (7.00 years) was lowest followed by critical, semi-critical and safe area (Table 2). The higher investments on digging due to high depth water table and recurring investments on digging of new bore wells coupled with the lowest productive age and water yield resulted in the highest annual cost of water extraction and unit cost of groundwater in the overexploited area (Rs 23047.96/annum and Rs 3.54/m³) as against critical (Rs 15047.93/annum and Rs 1.91/m³), semi-critical (Rs 9218.05/annum and Rs 1.07/m³) and safe (Rs 8153.47/annum and Rs 0.80/m³) area.

Water use efficiency in milk production from crossbreds: Data on water depleted to meet the daily feed and fodder requirements for milk production from crossbred cows and water use efficiency are presented in Table 3. Across the levels of groundwater exploitation embedded water in the form of dry fodder was higher than the green fodder and concentrates. Average daily embedded water consumed by a crossbred cow in the form of dry fodder was highest in safe (8.32m³) followed by semi-critical (7.10m³), critical (4.12m³) and overexploited (2.81m³) areas. Similarly in case of green fodder also highest embedded water was depleted in safe (1.67m³) area than semi-critical (1.58m³),

Water use efficiency in milk production

Table 1. Water utilized in production of a unit of feed and fodder (m³/kg)

Feed and fodder	Safe	Semi-critical	Critical	Overexploited
Dry Fodder				
Punji paddy straw*	2.003	2.070	1.842	1.415
Irrigated Ragi straw	0.298	0.287	0.244	0.236
Irrigated Jowar straw	0.362	0.276	0.202	0.205
Irrigated maize straw	0.171	0.200	0.164	0.170
Green Fodder				
Hybrid Napier	0.100	0.098	0.103	0.086
Fodder Jowar	0.078	0.073	0.050	0.046
Fodder maize	0.058	0.078	0.065	0.067
Concentrated Feed				
Wheat bran@	0.530	0.530	0.530	0.530
Groundnut cake@	1.562	1.562	1.562	1.562
Maize crushed	0.560	0.649	0.530	0.519

*Punji rice is mainly grown in southern districts of Karnataka state. Farmers sow seeds in May-June under rainfed condition (utilizing rain water) and in later stage groundwater irrigation is given to sustain the crop.

@Inputs imported to the study area.

Table 2. Unit Cost of groundwater

Particulars	Safe	Semi-critical	Critical	Overexploited
Median age of the well (years)	18.00	15.00	10.00	7.00
Amortized cost of well (Rs)	7667.47	8818.05	14597.93	22567.96
Annual average repair cost (Rs)	486.00	400.00	450.00	480.00
Annual cost of water extraction (Rs)	8153.47	9218.05	15047.93	23047.96
Annual water extracted (m ³)	10156.72	8636.13	7885.65	6507.63
Unit cost of groundwater (Rs/m ³)	0.80	1.07	1.91	3.54

Source: Survey data

critical (1.47m³) and overexploited (1.19m³) areas. In estimation of average daily embedded water in concentrated feeds constant water productivity was considered

for wheat bran (0.530m³/kg) and groundnut cake (1.562m³/kg). Hence average daily water depleted in the form of concentrates is more or less equal in all the levels of

groundwater exploitations and it is around 3.5m^3 . As a result total embedded water depleted in safe area was higher than the semi-critical, critical and overexploited areas.

Even though milk yield was relatively lower in the water scarce areas water use efficiency was highest in overexploited (1.37 l/m^3) and critical (1.19 l/m^3) areas than the safe (0.88 l/m^3) and semi-critical (0.84 l/m^3) areas. This was mainly due to carryover effect of higher groundwater use efficiency in production of dry and green fodder in water scarce areas. Despite of higher water use efficiency of milk production in water scarce areas they incurred higher costs on water due to the higher unit cost of groundwater and this lowered the net income realised per unit of water use in water scarce areas (in overexploited Rs $2.18/\text{m}^3$ and in critical Rs $3.55/\text{m}^3$) than the water sufficient areas (in semi-critical Rs $3.48/\text{m}^3$ and in safe Rs $4.29/\text{m}^3$).

Water use efficiency in milk production from local-cows: Milk production from local cows also depleted highest quantity of average daily water per animal in the form of dry fodder than the green fodder and concentrates. In local cow's milk production daily water depleted per animal in the form of green and dry fodder in groundwater sufficient area was higher than the groundwater scarce area. Production of daily requirement of

concentrated feeds for local cows depleted water to the tune of 1.05 m^3 to 1.51 m^3 . Interestingly embedded water depleted/day/animal in the form of concentrated feeds was lower in water sufficient area (1.05 m^3 in safe and 1.12 m^3 in semi-critical) than the water scarce area (1.51 m^3 in critical and 1.42 m^3 in overexploited areas). This was due to the fact that local cows in the water sufficient areas were offered to feed relatively lower concentrated feeds than in water scarce area. Total daily water depleted in milk production from a local cow was highest in safe ($5.96\text{ m}^3/\text{animal}$) followed by semi-critical ($5.58\text{ m}^3/\text{animal}$), critical ($4.99\text{ m}^3/\text{animal}$) and overexploited ($3.61\text{ m}^3/\text{animal}$) areas (Table 4).

As a result of higher unit cost of water in groundwater scarce area cost of total water was highest in groundwater scarce areas (Rs $8.50/\text{day/animal}$ in overexploited and Rs $7.06/\text{day/animal}$ in critical) than the water sufficient areas (Rs $4.95/\text{day/animal}$ in semi-critical and Rs $4.06/\text{day/animal}$ in safe). Hence net loss realised per m^3 water was also highest in overexploited (Rs $6.45/\text{day}$) and critical (Rs $5.36/\text{day}$) area than the semi-critical (Rs $2.97/\text{day}$) and safe (Rs $1.48/\text{day}$) areas. But the water productivity of milk in local cow was highest in overexploited (0.81 l/m^3) areas followed by critical (0.56 l/m^3), semi-critical (0.53 l/m^3) and safe (0.52 l/m^3) areas.

Water use efficiency in milk production

Table 3. Efficiency of water-use in crossbred cow milk production

Particulars	S	SC	C	OE
EW in green fodder (m ³ /day/animal)	1.67	1.58	1.47	1.19
EW in dry fodder (m ³ /day/animal)	8.32	7.10	4.12	2.81
EW in concentrated feed (m ³ /day/animal)	3.58	3.86	3.84	3.68
Direct water consumed by animal (m ³ /day/animal)	0.05	0.05	0.05	0.04
Water used for servicing animals, shed etc (m ³ /day/animal)	0.09	0.08	0.07	0.07
Total water used in milk production (m ³ /day/animal) (A + B + C + D + E)	13.71	12.67	9.55	7.79
Cost of groundwater (Rs/day/animal) [#]	8.51	10.02	11.91	16.38
Net cost of milk production (Rs /day/animal)	192.96	197.40	209.34	206.94
Net cost +groundwater cost (Rs /day/animal) (G+H)	201.47	207.42	221.25	223.32
Milk production (l/day)	11.57	11.18	11.34	10.68
Cost of milk production (including groundwater cost) (Rs/l) (I/J)	17.41	18.55	19.51	20.91
Price of milk (Rs/l)	22.50	22.50	22.50	22.50
Gross returns (Rs/day/animal) (L*J)	260.33	251.55	255.15	240.30
Net income over cost of milk production including cost of groundwater (Rs /day/animal) (M-I)	58.86	44.13	33.90	16.98
Net income per unit of water use (Rs/m ³) (N/F)	4.29	3.48	3.55	2.18
Milk production per unit of water (l/m ³) (J/F)	0.84	0.88	1.19	1.37

EW= Embedded water, # in calculation of groundwater cost water consumed for the production of wheat bran and groundnut cake was excluded as these feeds were imported to the study area, S= safe, SC= semi-critical, C= critical, OE= overexploited

Table 4. Efficiency of water use in local cow milk production

Particulars	S	SC	C	OE
EW in green fodder (m ³ /day/animal)	0.67	0.62	0.50	0.44
EW in dry fodder (m ³ /day/animal)	4.12	3.73	2.88	1.65
EW in concentrated feed (m ³ /day/animal)	1.05	1.12	1.51	1.42
Direct water consumed by animal (m ³ /day/animal)	0.04	0.05	0.05	0.05
Water used for servicing animals, shed etc (m ³ /day/animal)	0.08	0.07	0.06	0.06
Total water used in milk production (m ³ /day/animal) (A + B + C + D + E)	5.96	5.58	4.99	3.61
Cost of groundwater (Rs/day/animal) [#]	4.06	4.95	7.06	8.50
Net cost of milk production (Rs/day/animal)	74.51	78.21	83.02	80.47
Net cost + groundwater cost (Rs/day/animal) (G+H)	78.57	83.16	90.08	88.98
Milk production (l/day)	3.10	2.96	2.81	2.92
Cost of milk production (including groundwater cost) (Rs/l) (I/J)	25.34	28.09	32.01	30.49
Price of milk (Rs/l)	22.50	22.50	22.50	22.50
Gross returns (Rs/day/animal) (L*J)	69.75	66.61	63.31	65.66
Net income over cost of milk production including cost of groundwater (Rs/day/animal) (M-I)	-8.82	-16.55	-26.77	-23.32
Net income per unit of water use (Rs/m ³) (N/F)	-1.48	-2.97	-5.36	-6.45
Milk production per unit of water (l/m ³) (J/F)	0.52	0.53	0.56	0.81

EW= Embedded water, # in calculation of groundwater cost water consumed for the production wheat bran and groundnut cake was excluded as these feeds are imported to the study area, S= safe, SC= semi-critical, C= critical, OE= overexploited

Water use efficiency in milk production from buffaloes:

From Table 5 it can be observed that total water depleted to produce the daily requirement of feed and fodder per buffalo was highest in safe (12.07 m^3) area than the semi-critical (10.86 m^3), critical (8.11 m^3) and overexploited (4.89 m^3) areas. Hence water productivity of buffaloes milk was highest in overexploited (0.87 l/m^3) areas followed by critical (0.53 l/m^3), semi-critical (0.40 l/m^3) and safe (0.38 l/m^3) areas. But the net loss realised per m^3 of water use in milk production from buffaloes was highest in groundwater scarce areas (Rs 6.37/day/animal in overexploited and Rs 3.39/day/animal in critical areas) than the groundwater sufficient (Rs 1.23/day/animal in semi-critical and Rs 0.63/day/animal in safe areas).

Inter-breed comparisons of water use efficiency and economic efficiency of water use in milk production revealed that daily total water depleted by an animal in the process of milk production was highest in crossbred cows (7.79 to $13.71 \text{ m}^3/\text{day}/\text{animal}$) followed by buffaloes (4.89 to $12.07 \text{ m}^3/\text{day}/\text{animal}$) and local cows (3.61 to $5.96 \text{ m}^3/\text{day}/\text{animal}$). The same trend was observed in cost of groundwater use with higher cost in crossbreds (Rs 8.51 to 16.38/day/animal) than the buffaloes (Rs 9.06 to 14.69/day/animal) and local cows (Rs 4.06 to 8.50/day/animal). Milk production from crossbreds was only an economically profitable activity and daily

net income realised per unit of water use was in the range of Rs 2.18 to $4.29/\text{m}^3$. Milk production from buffaloes and local cows was a loss making activity and daily net loss incurred per unit of water use was marginally higher in local cows (Rs 1.48 to $6.45/\text{m}^3$) than the buffaloes (Rs 0.63 to $6.37/\text{m}^3$). Water use efficiency of milk production was highest for crossbreds (0.84 to 1.37 l/m^3) followed by local cows (0.51 to 0.81 l/m^3) and buffaloes (0.38 to 0.87 l/m^3)

CONCLUSION

In the study area groundwater was the prime source of irrigation for production of most of the required feed and fodder and dairying was a subsidiary activity which utilised largely crop by-products and crops (green fodder and inputs for concentrated feed) in the process of milk production. Animals were relatively consuming less of direct water (both servicing and drinking) but indirect consumption of water was in the form of feed and fodder was very high. Hence increasing water use efficiency in crop production would increase the water use efficiency in milk production. The water use efficiencies in crossbred were higher than the buffaloes and local cows. Interestingly farmers in the water scarce areas (overexploited and critical) were more efficient than the farmers of water sufficient areas (safe and semi-critical) in utilization of groundwater.

Table 5. Efficiency of water use in buffaloes milk production

Particulars	S	SC	C	OE
EW in green fodder (m ³ /day/animal)	0.57	0.58	0.39	0.35
EW in dry fodder (m ³ /day/animal)	10.53	9.10	6.75	3.59
EW in concentrated feed (m ³ /day/animal)	0.89	1.10	0.91	0.87
Direct water consumed by animal (m ³ /day/animal)	0.04	0.04	0.05	0.05
Water used for servicing animals, shed etc (m ³ /day/animal)	0.03	0.03	0.03	0.03
Total water used in milk production (m ³ /day/animal) (A + B + C + D + E)	12.07	10.86	8.11	4.89
Cost of groundwater (Rs/day/animal) [#]	9.06	10.61	14.00	14.69
Net cost of milk production (Rs/day/animal)	100.46	101.19	110.69	112.77
Net cost + groundwater cost ((Rs/day/animal) (G + H)	109.52	111.81	124.69	127.46
Milk production (l/day)	4.53	4.37	4.32	4.28
Cost of milk production (including groundwater cost) ((Rs/l) (I/J)	24.18	25.56	28.86	29.78
Price of milk (Rs/l)	22.50	22.50	22.50	22.50
Gross returns ((Rs/day/animal) (L*J)	101.93	98.44	97.20	96.30
Net income over cost of milk production including cost of groundwater (Rs/day/animal) (M-I)	-7.59	-13.37	-27.49	-31.16
Net income per unit of water use (Rs/m ³) (N/F)	-0.63	-1.23	-3.39	-6.37
Milk production per unit of water (l/m ³) (J/F)	0.38	0.40	0.53	0.87

EW= Embedded water, # in calculation of groundwater cost water consumed for the production wheat bran and groundnut cake was excluded as these feeds are imported to the study area, S= safe, SC= semi-critical, C= critical, OE= overexploited

The dairy farmers are needed to be motivated and given some incentives to take initiatives in efficient use of groundwater by adopting efficient irrigation technologies like drip, sprinkler etc. In overexploited and critical areas to reduce the gap between recharge and extraction efforts should be made through peoples' participation for construction of water harvesting structures and desilting of the existing tanks so that groundwater supply could be augmented through recharge. Creating awareness about the importance of groundwater in dairying and its effective utilization through media, trainings and demonstrations for sustainable growth of dairying activity might reduce the pressure on groundwater.

REFERENCES

- Allan JA 1998. Virtual water a strategic resource: global solutions to regional deficits. *Groundwater* **36**(4): 545-546.
- Anonymous 2005. Livestock policy brief 02. <ftp://ftp.fao.org/docrep/fao/010/a0261e/a0261e00.pdf> (accessed 12 Jan 2014).
- Anonymous 2010. Dynamic groundwater resources of Karnataka, March 2009. Department of Mines and Geology, GoK and Central Groundwater Board, SW Region, 155p.
- Anonymous 2011. Food balance sheets. FAOSTAT, FAO, Rome, Italy, <http://faostat.fao.org>. (accessed 12 Jan 2014).
- Anonymous 2014. Global Map of Irrigation Areas. <http://www.fao.org/nr/water/aquastat/irrigationmap/ind/index.stm> (accessed 14 May 2014)
- Dhondyal SP 1987. Farm management. Friend Publications, Meerut, UP, India, pp 58-59.
- Hoekstra AY 2003. Virtual water trade. Proceedings, International Expert Meeting on Virtual Water Trade, Delft, 12-13 December 2002, the Netherlands.
- Reddy SR 2012. Agronomy of field crops. Kalyani Publishers, New Delhi, India.
- Sharif Mahin and Ashok KR 2011. Impact of groundwater over-draft on farm income and efficiency in crop production. *Agricultural Economics Research Review* **24**(2): 291-300.
- Sharif Mahin, Dixit PK, Krishnadas M and Sivaram M 2013. Understanding water productivity in milk production: some economic and ecological reflections. Compendium, Model Training Course on Management Strategies for Sustainable Livestock Production, NDRI, 18-25 Nov 2013, pp 114-117.
- Singh OP 2004. Water productivity of milk production in north Gujarat, western India. International Water Management Institute, India Project Office, Anand, Gujarat, India.
- Singh OP, Kumar M Dinesh 2009. Impact of dairy farming on agricultural water productivity and irrigation water use. IWMI publications, <http://publications.iwmi.org/pdf/H042638.pdf> (accessed in Oct 2013).
- Sirohi Smita, Pandey Divya, Vir Singh, Sohan, Bansod, Shradha and Upadhyay RC 2013. Water footprint of cattle and buffalo milk production. National Training Book of Climate Resilient Livestock and Production System, pp 213.
- Steinfeld H, Gerber P, Wassenar T, Castel V, Rosales M and de Haan C 2006. Livestocks's long shadow: environmental issues and options, FAO, Viale Dele Terme di Caracalla, Rome, Italy.

Received: 3.12.2014

Accepted: 27.1.2015