Journal of Dairy Research

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Yield gap in milk production is considerable in Indian Himalayan state of Meghalaya

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Research Article

Cite this article: Kemboi E, Feroze SM, Singh R, Ahmed J and Tyngkan H (2021). Yield gap in milk production is considerable in Indian Himalayan state of Meghalaya. *Journal of Dairy Research* **88**, 121–127. https://doi.org/10.1017/S002202992100008X

Received: 2 July 2020
Revised: 17 November 2020
Accepted: 7 December 2020
First published online: 17 February 2021

Keywords:
Crossbred; milk production; Ri-Bhoi; yield gap

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Abstract

Yield gaps in milk production are here defined as the differentials between the actual yield obtained by the dairy farmer and the potential farm yield (production achieved by the top 10% of farmers: Gap 2) as well as the differential between this potential farm yield and the yield registered in the research stations (Gap 1). Assessment of yield gaps provides valuable information on potential production enhancement and drivers behind yield gaps. Milk production can be increased by narrowing the predominant large yield gaps in resource-poor smallholder farming system. Hence, this study assessed the milk yield gap and factors affecting the yield gap in Ri-Bhoi district of Meghalaya, a state located in the north-eastern Himalayan region of India. This research paper provides a scope for exploring the possibilities for improving dairy production in the state as well as contributing to literature through incorporating crucial determinants responsible for milk yield gap. A sample of 81 respondents was drawn purposely from two blocks of the district. The results indicated that the average number of cattle per household was 9.38 in standard animal units. The total yield gap was estimated at 6.20 l (91.06%) per day, composed of 0.80 l (11.76%) per day of yield gap I and 5.40 l (79.30%) per day of yield gap II. This demonstrates that the top performing farms were achieving a production level not dissimilar to that obtained on the research stations, but many were doing far less well. The size of cattle shed, dairy farming experience, concentrate price and human labour were the important determinants of the yield gap. Hence, encouraging the right stocking density of cattle, training on the preparations of home-made concentrates, access to cheap and quality concentrates, incorporating training and experience sharing on proper dairy management practices and use of technology could benefit the dairy farmers of the region.

Assessment of yield gap (YG) in livestock farming is increasingly attracting the attention of many agricultural researchers. YG is generally described as 'the difference between actual and potential yields for an agricultural product' where actual yield is the mean yield for a particular area while the potential yield is the greatest attainable average yield using best farming practices (Lobell *et al.*, 2009; Ittersum *et al.*, 2013; Mayberry *et al.*, 2017). Rising food demand with growth in global population and per head income will require a considerable increment of about 70% food production by 2050 (FAO, 2009; Lobell *et al.*, 2009). Dairy production augmentation by narrowing down the yield gap can greatly contribute towards this goal. The Indian dairy sector portrays an imperative performance in terms of the largest cattle population and milk producer in the world although the productivity is still sub-optimal when contrasted with other leading milk producing nations (Kumawat *et al.*, 2014). Nearly two-thirds value of the whole livestock sector is contributed by milk and its products and in addition the sector supports the majority of the rural households' livelihoods both through principal and subsidiary occupation (Mayberry *et al.*, 2017; Suthar *et al.* 2019). Milk production is estimated to reach 254.5 million metric tonnes by 2022 (GoI, 2018). Focus to increase productivity will be sustained through continued improvement of high-yielding crossbred dairy cows (Landes *et al.*, 2017), but at the same time this production target needs to be accomplished through a more productive and feasible farming system (Anderson *et al.*, 2016; Mayberry *et al.*, 2017). However, the livestock rearing scenario in the North East (NE) region of India, particularly the dairy sector is undeveloped in terms of various dairy development indices such as livestock dispensaries, stockmen centres, veterinary doctors or surgeons (Lalrinsangpuii *et al.*, 2016) when contrasted with other states of India. The majority of the local population are meat consumers but with an increase in per capita income, urbanization, changes in lifestyles and food habits the demand for milk in the region is rapidly growing, necessitating expansion in the dairy sector (Feroze *et al.*, 2010). The livestock sector constitutes part of mixed farming (animal and crop production) of Meghalaya (Feroze *et al.*, 2019). The milk production of the state remains below the median per capita availability in relation to that of all India (GoM, 2019). The crossbred cattle population in Ri-Bhoi district is considerably smaller than that of local cattle (Livestock Census, 2019) and the livestock sector is largely dominated by smallholder farmers under subsistence system (Kumar *et al*., 2007). Expanding milk productivity in this resource-poor smallholder farming system could be addressed through limiting the predominant large yield gaps (Anderson *et al*., 2016) especially in hill regions where livelihood options of producers are limited. Yield gap assessment is an important tool for recognizing 'the most limiting and reducing factors that determine the yields' (Cortez-Arriola *et al*., 2014). Therefore, exploring the possibilities available for improving the production of the dairy sector at the same time bridging the yield gap in the district is of prime concern. Earlier investigation concentrating on yield gap analysis has been carried out in various agro-climatic zones (Paul and Chandel, 2010; Ittersum *et al*., 2013; Henderson *et al*., 2016; Mayberry *et al.,* 2017; Horo and Chandel, 2019). A central flaw in earlier investigations is that they did not extensively incorporate other crucial determinants responsible for yield gap. The aim of this study was, therefore, to assess the milk yield gap and factors affecting the yield gap. We hypothesized that an identification of yield gap determinants would result in bridging the milk yield gap and overall improvement of the dairy sector in the region.

Materials and methods

Locale of the study

The present study was conducted in Ri-Bhoi district of Meghalaya. The district lies between North latitudes 25°15′ and 26°15′ and between East longitudes 91°45′ and 92°15′. The total area of the district is 2448 sq. km. and is sub-divided into four blocks with its headquarters located at Nongpoh. The population of Ri-Bhoi district as of 2011 has been estimated at 258 840 of which females comprises 1,26,309 and males 1,32,531 while the population density (per sq. km.) is 106 and average literacy is 75.67% (76.79% for male and 74.49% for female). The total number of villages in the district is 579 (Census, 2011). Ri-Bhoi district experiences different types of climate ranging from tropical climate in the areas bordering Assam to the temperate climate adjoining the East Khasi Hills District. The maximum rainfall is received in the months of June and July (Bhalerao *et al*., 2015).

Dairy farming scenario of the district

Ri-Bhoi district is home to 54 562 cattle which included 38 094 indigenous and 16 468 Crossbred (CB) cattle. Rib-Bhoi's share was 6.04% in total cattle population of Meghalaya with milk production of 23.83 thousand tonnes (GoM, 2018). The establishment of Regional Crossbred Breeding Stock Farm at Kyrdemkulai has had a noteworthy impact in supporting the improvement of cattle in the district while providing a platform to farmers on scientific methods of dairy management. During 2016–2017, there were eight stockmen centres, fifteen dispensaries, two aid centres and forty-three veterinary doctors/surgeons in the district (GoM, 2019).

Sampling design and data

Meghalaya was selected in the first stage since it has the highest cattle population and second highest milk production in the NE hill states. In the second stage, out of the eleven districts of Meghalaya, Ri-Bhoi district was selected as the district reporting the highest crossbred population and second-highest milk production in the state. In the third stage, two blocks *i.e.*, Umsning and Bhoirymbong were selected. Then, two villages from each block were chosen based on the highest cattle populations. In the last stage, a sampling frame was prepared through a complete enumeration of all households rearing cattle in all four selected villages, namely, Umtham, 5 Kilo, Nonsger and Pyllun. Then, 70% of the total households rearing cattle were selected randomly through proportionate sampling to get sufficient sample size for the study. Hence, a sample of 81 households was selected from two blocks of Ri-Bhoi district. The stratification of respondents into three groups was done through cumulative square root frequency method (Dalenius and Hodges, 1959) on the basis of the standard animal units (SAU) (Supplementary Tables S1 and S2). Primary data on socio-economic variables, herd size, production of milk *etc.,* were collected from the respondents using a well-structured, pre-tested schedule through interview during 2020.

Yield gap analysis

The analytical tool developed by the International Rice Research Institute (IRRI) and further modified by Gomez (1977) was used in the present study. The general procedure as per the technique of the yield gap analysis is given below:

$$\text{Total yield gap(TYG)} = \text{Yield Gap I(YGI)} + \text{Yield Gap II(YGII)} \quad (1)$$

where,

$$\text{YGI} = \text{Research Station Yield(Yr)} - \text{Potential Farm Yield (Yp)} \quad (2)$$

$$\text{YG II} = \text{Potential Farm Yield (Yp)} - \text{Actual Farm Yield (Yf)} \quad (3)$$

Research station yield (Yr) is the average milk yield obtained from cows on the research stations. The data was collected from ICAR-Research Complex for NEH Region, Barapani. It was assumed that this farm was being managed on scientific lines using latest technology and reflects the maximum possible level of milk yield that can be obtained from the cows in the region (Paul and Chandel, 2010). The potential farm yield (Yp) is the average yield realized by the top 10% of the sample households. The actual farm yield is the average yield realized by the remaining 90% of the household respondents which can be increased through adoption of improved management practices and by addressing the technical and socio-economic constraints.

The yield gap percentage was calculated using the following formula:

$$\text{Yield gap(\%)} = (\text{Yield gap/actual farm yield}) \times 100 \quad (4)$$

It signifies the percentage increase in actual farm yield that can be attained if all the constraints with the respective yield gap are addressed.

Determinants of milk yield gap

It was determined by ANCOVA model given below:

$$Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6 + \beta_7X_7 + \beta_8D_1 + \beta_9D_2 + \beta_{10}D_3 + \beta_{11}D_4 + \beta_{12}D_5 + \beta_{13}D_6 + \mu \quad (5)$$

Table 1. Average number of cattle (in SAU) owned by the selected households

Category of animals	Number of cattle in SAU			
	Small	Medium	Large	Overall
In milk and not pregnant SAU	2.78	5.13	8.69	4.61
In milk and pregnant SAU	1.90	3.53	5.42	3.42
Dry and pregnant SAU	2.20	2.50	5.56	3.30
Dry and not pregnant SAU	–	2.14	3.42	2.39
Pregnant heifer SAU	1.24	1.59	2.07	1.59
Male <1 SAU	0.41	0.62	1.00	0.71
Female <1 SAU	0.90	1.53	2.40	1.54
Male>1 SAU	–	0.85	2.13	1.42
Female>1 SAU	1.70	2.39	3.60	2.68
Male adult SAU	1.48	1.48	1.97	1.67
Total SAU	4.34	10.70	19.80	9.38

SAU, Standard animal unit.

where, Y = yield gap (potential farm yield-actual farm yield), β_i = parameters (i = 0, 1, 2…, 13), X_1 = experience in dairy farming (Years), X_2 = size of animal shed, X_3 = price of concentrate (₹), X_4 = quantity of concentrate (kg), X_5 = distance from farm to research station (km), X_6 = market access (km), X_7 = human days allocated/head of dairy animal/day (hours), D_1 = educational level of the family-head (literate-1, otherwise-0), D_2 = education level of the person who is involved in dairy activities (literate-1, otherwise-0), D_3 = economic status of dairy farmers (economically sound-1, otherwise-0), D_4 = contact with extension personnel (yes-1, no-0), D_5 = scientific cattle shed (yes-1, no-0), D_6 = vaccination (yes-1, no-0), and μ = error term (Supplementary Table S3).

Results and discussion

Cattle ownership by sample households

The average number of cattle per household, in standard animal units (SAU), was highest for in-milk and not pregnant cows (4.61) category, followed by in-milk and pregnant (3.42), dry and pregnant cattle (3.30). The result was higher as compared to that noted by Feroze *et al.* (2016). Generally, ownership of higher number of female cattle ensures continuous supply of income to the family through milk sale. On average, 3.30 SAU of dry and pregnant SAU were owned by the respondents and the number varied from 5.56 (large) to 2.20 (small) across all categories. Moreover, dry and not pregnant SAU were found in case of large (3.42) and medium (2.14) category only, none of the small category farmers kept them. The large category farmers with bigger herd size had the higher possibilities of owning a varied number of cattle both in-milk and dry and pregnant as contrasted with those of small category rearing one or two cows. Similar trends were depicted for the average total SAU (overall 9.38) across different categories of respondents though the variation between the three categories large (19.38), medium (10.70) and small (4.34) was quite distinctive (Table 1). Relatively small herd size was observed by Pathania and Sharma (2016) in Jaisinghpur tehsil and Meena *et al.* (2019) in Rajasthan as compared to the findings of the current study.

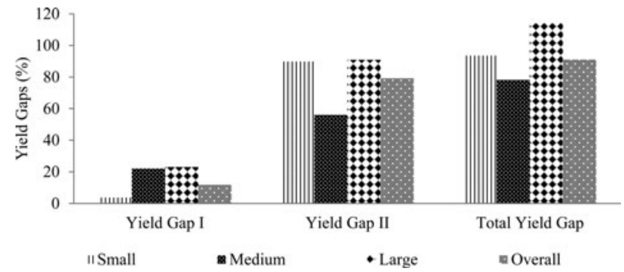

Fig. 1. Estimated yield gaps (%) across different herd size categories.

Table 2. Milk yield gaps across the herd size categories

Sl. No.	Particulars	Small	Medium	Large	Overall
1	Research station yield (l/d/animal)	13.00	13.00	13.00	13.00
2	Potential farm yield (l/d/animal)	12.75	11.39	11.6	12.2
3	Actual farm yield (l/d/animal)	6.71	7.30	6.07	6.80
4	Yield gap I (1–2)	0.25	1.61	1.40	0.80
5	Yield gap II (2–3)	6.04	4.09	5.53	5.40
6	Total yield gap (4 + 5)	6.29	5.70	6.93	6.20

Yield gap in milk production across different categories of respondent

Yield gap is the differential between the research station yield (Yr), potential farm yield (Yp) and actual farm yield (Yf). The average milk yield obtained in the research station was 13 l per day whereas the Yp and Yf were measured at 12.20 and 6.80 l/d, respectively. The total yield gap (TYG) estimated to be 6.20 l/d/cow in the investigation zone comprising of 0.8 l/d/cow of Yield Gap I (YGI) and 5.40 l/d/cow of Yield Gap II (YGII). The YG II was higher than the YG I; this might be feasible considering determinants such as environment, physical and non-transferable elements of technology are quite a challenge to be overcome by farmers except if carried out in research stations under control conditions. The overall percentage of TYG was 91.06% comprising of 11.76% of YGI and 79.30% of YGII (Fig. 1). The result identified in this current study was in line with the yield gap (%) increase outlined by Henderson *et al.* (2016) and Mayberry *et al.* (2017) in Sub-Saharan Africa and India respectively.

According to Paul and Chandel (2010) in north-eastern and Horo and Chandel (2019) in Jharkhand the overall TYG was lower (81.60 and 42.74% respectively) to the findings of the present study. If all the factors or constraints linked to production process are addressed, milk productivity will improve by about 79.30% (Fig. 1). Category-wise (large, medium and small herd category) the yield gap data are given in Table 2. The estimation of yield gap revealed highest percentage of the TYG (114.04%) for large category of herds, followed by small (93.60%) and medium (78.16%) category (Fig. 1). A similar trend was observed for YGII. The reason behind the noteworthy TYG level for large category might be inadequate management practices in dairying. If all the households utilize the prescribed management practices it may increase the milk yields by about 90.99, 89.88 and 56.08%

Table 3. Descriptive statistics and collinearity test for milk yield gap variables across different categories

Category	Variables	Descriptive Statistics			VIF
		Mean	SE	Variance	
	Experience in dairy farming	9.95	1.35	67.44	1.77
	Estimated animal shed size	43.19	3.06	345.66	1.74
	Price of concentrate	26.68	0.34	4.27	2.66
	Total quantity of concentrate	4.00	0.28	2.90	2.47
	Distance to research station	5.65	0.35	4.46	2.01
	Market access	11.03	0.60	13.36	9.08
Small	Human days allocated for dairy	18.84	0.93	31.81	9.83
(*n* = 37)	Education of the household head	0.68	0.08	0.23	2.68
	Education of person involved in dairy	0.71	0.08	0.21	1.90
	Economic status of the farmer	0.14	0.06	0.12	1.60
	Contact with extension personnel	0.38	0.08	0.24	2.05
	Scientific cattle shed	0.32	0.08	0.23	1.79
	Vaccination	0.92	0.05	0.08	1.94
	Experience in dairy farming	17.47	1.94	113.29	4.42
	Estimated animal shed size	83.17	6.23	1166.07	1.97
	Price of concentrate	26.29	0.34	3.43	1.95
	Total quantity of concentrate	4.55	0.28	2.39	2.28
	Distance to research station	7.22	0.30	2.72	1.58
	Market access	9.77	0.68	13.91	6.39
Medium	Human days allocated for dairy	17.03	0.98	28.72	6.92
(*n* = 30)	Education of the household head	0.73	0.08	0.20	2.81
	Education of person involved in dairy	0.82	0.07	0.15	2.15
	Economic status of the farmer	0.37	0.09	0.24	2.03
	Contact with extension personnel	0.37	0.09	0.24	3.10
	Scientific cattle shed	0.50	0.09	0.26	2.38
	Vaccination	0.93	0.05	0.06	1.95
	Experience in dairy farming	16.64	3.49	170.09	2.044
	Estimated animal shed size	107.43	18.36	4717.19	55.15
	Price of concentrate	25.54	0.46	3.00	50.85
	Total quantity of concentrate	4.11	0.50	3.55	5.12
	Distance to research station	10.57	1.41	27.96	–
	Market access	9.00	1.16	18.92	3.143
Large	Human days allocated for dairy	16.21	1.48	30.64	3.93
(*n* = 14)	Education of the household head	0.86	0.10	0.13	1.675
	Education of person involved in dairy	1.00	0.00	0.00	–
	Economic status of the farmer	0.5	0.14	0.27	3.223
	Contact with extension personnel	0.57	0.14	0.26	112.8
	Scientific cattle shed	0.71	0.13	0.22	42.77
	Vaccination	0.64	0.13	0.25	2.911
	Experience in dairy farming	13.89	1.18	112.38	1.30
	Estimated animal shed size	67.99	4.99	2017.06	1.71

(*Continued*)

https://doi.org/10.1017/S002202992100008X Published online by Cambridge University Press

Table 3. (*Continued.*)

Category	Variables	Descriptive Statistics			VIF
		Mean	SE	Variance	
	Price of concentrate	26.33	0.22	3.81	1.84
	Total quantity of concentrate	4.23	0.19	2.81	1.63
	Distance to research station	17.72	0.62	30.86	7.15
	Market access	10.21	0.43	14.77	6.71
Overall	Human days allocated for dairy	7.08	0.36	10.62	1.81
($n = 81$)	Education of the household head	0.73	0.05	0.20	2.00
	Education of person involved in dairy	0.80	0.05	0.16	1.60
	Economic status of the farmer	0.28	0.05	0.21	1.40
	Contact with extension personnel	0.46	0.06	0.25	1.46
	Scientific cattle shed	0.41	0.05	0.24	1.46
	Vaccination	0.93	0.03	0.07	1.37

SE, Standard error; VIF, Variance inflation factor.

in case of large, small and medium categories of farmers, respectively (Fig. 1).

Descriptive statistics of explanatory variables used in ANCOVA model

The respondents were quite experienced in dairy farming with, on average, 13.89 years experience (Table 3). The average cattle shed size was 67.99 m^2 but it varied widely with change in number of cows possessed. The prevailing price of concentrate in nearby market was Rs26.33/kg. The distance from dairy farm to research station and market were approximately 17.72 and 10.21 km, respectively. The variables were subjected to multicollinearity test using the variance inflation factor (VIF). The variance inflation factors for all the variables in overall category were satisfying the rule of thumb rule that 'VIF less than 10' implying absence of multicollinearity (Table 3).

Estimated coefficients for factors affecting milk yield gap across categories

The *R*-Squared (R^2) of the ANCOVA model was 0.651 which implied that all the exogenous variables entered in the model described around 65% variation in yield gap. Among all the predictor variables, experience in dairy farming, size of animal shed, price of concentrate and human labour allotted for dairy were found to significantly influence the total milk yield gap (Table 4). The coefficient of experience in dairy farming by household producer had a negative and significant ($P < 0.05$) influence on milk yield gap in the region. A one-year increase in farmer's experience in dairy farming will bridge yield gap of milk production by 0.048L. Farmers acquire knowledge, skills and capabilities as they specialize in the dairy enterprise, enabling them to expand the milk production. A similar observation was reported by Sultana *et al.* (2016) and Jafor (2019) in Bangladesh and Assam respectively, who recognized positive determination between dairy experience and increase in milk production. The size of animal shed of a cow had a negative and significant ($P < 0.01$) effect on aggregate milk yield gap. The yield gap will reduce by up to 0.46 l by allocating more space to each animal. Space allowance and good housing condition may play a key role in maximizing welfare which in turn may facilitate incremental milk production. Similar findings were reported in Ireland (Graves, 1989) and Norway (Naess *et al.*, 2011) who reported higher milk production linked to increased free space allocation.

The effect of concentrate price in milk yield gap was found to be significantly positive ($P < 0.01$). A one-Rupee increase in concentrate price will enlarge the yield gap by an estimated 0.25 l. When the price increases the farmer may be forced to buy less concentrate which in turn will directly affect milk production. The human labour allocated to the dairy was shown to have a significant impact on yield gap ($P < 0.01$). Additional human labour (1 h/d) will reduce the yield gap by around 0.34 l. The more time allotted for different dairy operations such as feeding the animal, health care, cleaning both animal and animal shed the more chances of general improvement in animal welfare thus increasing milk production. Human labour was mainly sourced from the family whereas several other dairy inputs including the collection of green fodder came from outside the farm. Additional hired labour can play a role in reducing the yield gap in milk.

Similarly, Paul and Chandel (2010) also reported a positive relation between human labour and milk yield in N-E states because larger dairy inputs were drawn from outside the farms. This result is also supported by Feroze *et al.* (2019) and Jafor (2019), who noted a positive association between labour and milk production in Meghalaya and Assam, respectively.

In conclusion, the study found that the yield gap present in the study area was very high. Bridging this yield gap will require a combined effort from various stakeholders *viz.,* farmers, input providers and government agencies for comprehensive dairy sector advancement. The animal shed size, dairying experience, concentrate price and human labour were the prime determinants of yield gap in milk. The producers need awareness pertaining to importance of finding the most appropriate stocking density (adequate space per cow) for enhancing the productivity and welfare of cows. Training on home-made concentrates to supplement what is sourced from outside can aid in increasing milk

https://doi.org/10.1017/S002202992100008X Published online by Cambridge University Press

https://doi.org/10.1017/S002202992100008X Published online by Cambridge University Press

Table 4. Estimated coefficients for factors affecting milk yield gap across categories

	Small			Medium			Large			Overall		
Variable	β	SE	*P*-value	β	SE	*P*-value	*B*	SE	*P*-value	β	SE	*P*-value
Constant	11.313***	2.922	0.002	5.652	3.621	0.141	0.812	0.821	0.427	0.664	3.877	0.865
Experience in dairy farming	−0.332	0.776	0.161	−0.176	0.037	0.675	0.369	0.498	0.533	−0.048**	0.022	0.033
Size of animal Shed	−0.351*	0.599	0.079	−0.653**	0.008	0.024	–	–	–	−0.462***	0.261	0.000
Price of concentrate	−0.83	0.855	0.348	−0.066	0.151	0.825	–	–	–	0.252*	0.147	0.092
Total quantity of concentrate	−0.782	0.462	0.111	0.226	0.282	0.445	−0.331	0.266	0.674	0.211	0.147	0.157
Distance to research station	–	–	–	−0.377	1.085	0.724	–	–	–	0.577	1.406	0.264
Market access	−0.348	0.91	0.193	0.527	0.261	0.622	0.2	0.08	0.642	−0.28	0.323	0.390
Human days allocated for dairy	−0.286	0.364	0.207	−0.203	0.139	0.424	0.029	0.5	0.954	−0.341***	0.282	0.001
Education of the household head	−0.089	1.706	0.747	0.096	0.683	0.775	0.772	0.809	0.205	0.459	0.592	0.441
Education of person involved in dairy	0.027	1.392	0.902	−0.123	0.705	0.677	–	–	–	−0.786	0.575	0.177
Economic status of the farmer	−0.023	1.965	0.911	0.416	0.537	0.161	−0.878	0.696	0.189	−0.104	0.476	0.828
Contact with extension personnel	−0.279	1.208	0.174	−0.112	0.561	0.714	–	–	–	−0.266	0.447	0.554
Scientific cattle Shed	0.13	1.298	0.545	−0.073	0.679	0.838	–	–	–	−0.51	0.45	0.262
Vaccination	0.081	2.106	0.663	0.139	0.97	0.611	−0.018	0.953	0.977	0.977	0.757	0.202
R^2	0.633			0.469			0.866			0.651		
No. of observation	37			30			14			81		
Dependent variable: yield gap (l/d/animal)												

Note: ***, ** and * indicate $P < 0.01$, $P < 0.05$ and $P < 0.10$, respectively.

productivity. The government can also play a vital function in this direction by ensuring farmers get cheap and quality animal feed concentrates in the hilly regions to benefit the marginal and small dairy farmers. Incorporating training and experience sharing on proper dairy rearing practices, use of technology such as milking machine can help the farmers. If these practices can be followed, it can minimize the yield gap in the dairy sector.

Supplementary material. The supplementary material for this article can be found at https://doi.org/10.1017/S002202992100008X.

Acknowledgement. The first author would like to thank the third India Africa Summit Forum, Government of India for awarding him full scholarship for the Masters Programme at the College of Post Graduate Studies in Agricultural Sciences (Central Agricultural University-Imphal) Umiam, Meghalaya. The authors also thank the reviewers for their comments in improving the paper.

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