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Yield Gap in Milk Production and its Determinants in East Khasi Hills of Meghalaya

Jabir Ahmed[1], Evans Kemboi[2], Ram Singh[1] and S. M. Feroze[3@]

ABSTRACT

This study analyzes the yield gap in milk production and the factors contributing to it in the East Khasi Hills district of Meghalaya, India. Using primary data from 82 randomly selected households across four villages, the study estimates the total yield gap (TYG) at 49.62 per cent. The yield gap is divided into two components: yield gap I (6.62 per cent) and yield gap II (43.10 per cent), indicating that yield gap II is the larger contributor to the overall gap. The yield gap is more pronounced among large-scale cattle holders (56 per cent) than smallholders (46.71 per cent). The study identifies several significant factors influencing the yield gap, such as dairy farming experience, distance to research stations, contact with extension personnel, price of concentrate feed, and human labor allocated for dairy activities. The analysis suggests that yield gap I can be reduced by adopting advanced technologies from research stations. In contrast, yield gap II can be minimized by encouraging farmers to implement practices followed by progressive farmers. The findings underscore the need for targeted interventions, such as increased farmer access to research-based technologies and better coordination between extension personnel and dairy farmers to enhance milk production efficiency.

Keywords: Yield gap, ANCOVA, milk production, East Khasi Hills

JEL codes: Q10, Q12

I

INTRODUCTION

Yield gap concepts in livestock productivity are newly adopted from an agronomic evaluation that compares observed yields with maximum potential yields under certain agro-climatic conditions for a particular area (Narwal 2019). Though yield gap analyses are not frequently applied to livestock production, Van der Ven *et al*. (2003) have validated that an identical set of "production ecological concepts" may also be used in livestock production. Yield gap analysis can be performed to evaluate the range of livestock or agricultural production feasible on a particular farm or area and identify limiting factors of production (Mayberry *et al.* 2017). According to Van der Linden *et al.* (2021), milk production practices differ due to biophysical, economic, and cultural aspects. Progressive producers are more likely to manage resources efficiently, which could help to select the practical intervention strategies from local production realities, viz., use of inputs, improving technical efficiency, and embracing

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[1]School of Social Sciences, College of Post Graduate Studies in Agricultural Sciences (CAU-Imphal), Umiam, Meghalaya-793103; [2]Department of Agricultural Economics, Banaras Hindu University, Varanasi-221005; [3]Division of Agribusiness Management, ICAR-NAARM, Hyderabad-500030, Telangana.

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upgraded technology like a superior animal to reduce the yield gap currently observed (Bebe *et al.* 2018, Narwal 2019). Moreover, optimum stocking density should be checked to promote cow welfare and performance (Kemboi *et al.* 2021). Potential production refers to hypothetical situations when production is determined solely by the defining factors. Still, production realized on farms is a blend of "defining, limiting, and reducing conditions" where farmers may impact these parameters through various management techniques (Van der Linden *et al.* 2021). To attain maximum potential production, the animal should fully satisfy its nutritional needs regarding food and water, considering both quantity and quality and being disease-free (Van der Ven *et al*. 2003).

Most of the population in India's Northeastern (NE) region depends on farming for their livelihood. Dairy is a noteworthy component of a diversified farming system in the NE region, with the potential for poverty alleviation, nutritional security, and revenue generation (Feroze *et al*. 2010). Compared to other regions of India, the people of this region do not strongly prefer milk consumption. Still, the demand intensifies as the lifestyle changes and income increases (Feroze *et al.* 2017). Smallholder producers need to improve the output of milk production to meet growing household dietary demand and income generation while remaining competitive with large-scale farms (Mayberry *et al*. 2017), and they need to follow agricultural practices that are more effective and sustainable to boost the yields (Anderson *et al*. 2016).

Therefore, understanding the yield gap in milk production is of crucial concern. The focus should be on the supply side, as the demand side factors have not accomplished much to prompt milk production (Feroze *et al*. 2017). The crossbred animals were introduced to meet the demand for milk in the region; however, productivity (6.56 kg/day) stands low compared to the average of 7.95 kg/day for all of India. The typical milk yield for local cattle in Meghalaya is 0.78 kg/cow/day, far less than the average of 3.01 kg/cow/day (GoI 2019). Meghalaya's per capita availability of milk is 84 grams/day, significantly lower than in other parts of the country. East Khasi Hills (EKH) is one of the districts of Meghalaya in India, where no such study has been carried out to establish the cause of this low productivity. This investigation aims to explore this gap and identify the factors influencing a milk yield gap, which is crucial in setting up the foundation for taking the necessary steps to bridge the milk yield gap.

II

DATABASE AND METHODOLOGY

Study area and data collection

This study was conducted in the East Khasi Hills (EKH) district as it is the largest milk-producing district in Meghalaya, and the district has the second-highest population of exotic and crossbred cattle in the state. The EKH district covers an area of 2,748 square kilometers, located between latitudes 25°07” and 25°41” N and longitudes 91°21" and 92°09" E. The district has a population of 824,000, with a population density of 292 people per square kilometer. The literacy rate stands at 84.70 per cent, and the district has a sex ratio of 1011 females per 1,000 males (Census 2011). The district's climate varies from temperate in the plateau region to tropical and subtropical in the northern and southern areas, with annual rainfall ranging from 1,800 to 10,000 mm (Chakraborty and Saikia, 2022).

In the next stage, the Mylliem and Mawlai blocks were deliberately chosen due to their high cattle population. From the Mylliem block, Mawklot and Umlyngka villages were selected, and from the Mawlai block, Umjajew and Umthlong villages were chosen based on similar criteria. A complete listing of all households rearing cattle in these villages was conducted to prepare the sampling frame. The households were then categorized into small, medium, and large based on the number of standard animal units (Feroze et al., 2016) using the cumulative square root frequency method (Dalenius and Hodges, 1959). While a 10-15 per cent sample size is usually representative of the population, around 32 per cent of all cattle-rearing households, equating to 82 households, were selected to ensure an adequate sample size. The number of respondents from each category was determined using proportionate sampling to ensure appropriate representation from each group. Primary data on socio-economic variables, herd size, ownership of dairy assets, milk production, and institutional and technological access were collected from respondents using a well-structured and pre-tested interview schedule.

Data Analysis

An analytical tool developed by the International Rice Research Institute (IRRI) and modified by Gomez (1977) was utilized. Various scholars and researchers have used this technique to analyse similar objectives (Paul and Chandel 2010; Mayberry *et al*. 2017; Das *et al*. 2021; Kemboi *et al*. 2021). The general procedure as per the technique of the yield gap analysis is given below:

Total Yield Gap (TYG) = Yield Gap I + Yield Gap II …. (1)

Where,

Yield Gaps I (YG I) = Experiment Station Yield – Potential Farm Yield …. (2)

Yield Gap II (YG II) = Potential Farm Yield – Actual Farm Yield …. (3)

Different variables included in the yield gaps analysis of milk production for the EKH district were defined as follows: *Experimental Station Yield* (Y_r) **-** It is the wet average milk obtained from crossbred cattle on experiment stations in the region. Data was collected from a research station managed by the ICAR-Research Complex for the NEH region in Barapani. *Potential Farm Yield* (Y_p) **-** The milk yield level of households was arranged in descending order, and the wet average of the top ten per cent of the sample households was taken as Potential Farm Yield (Paul and Chandel 2010). This is the level of milk yield attained by the farmers of the same locality, and it sets the target for other farmers to achieve it if they also implement the same package of practices implemented by the progressive farmers. *Actual Farm Yield (Y_f)* - It was the wet average of the remaining 90.00 per cent of the households of the study area (Paul and Chandel, 2010), which could be augmented with little efforts made in the implementation of an improved package of practices and by eliminating technical and socio-economic constraints.

The yield gap percentage was calculated using the following formula:

Yield gap (%) = (yield gap/actual farm yield) x 100 (4)

It specifies the percentage change in actual farm yield (Y_f) that could be attained if all the constraints associated with the particular yield gap are eliminated.

The following ANCOVA model determined the factors contributing to the milk yield gap

$$Y = \beta_o + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 D_1 + \beta_8 D_2 + \beta_9 D_3 + \beta_{10} D_4 + \beta_{11} D_5 + \beta_{12} D_6 \quad (5)$$

Where Y = Yield gap (Potential farm yield-actual farm yield) (l), β_i = Parameters to be estimated (i= 0, 1, 2…, n), X_1 = Experience in dairy farming (years), X_2 = Distance from farmers' farm to research station (km), X_3 = Market access (km), X_4 = Price of concentrate (₹), X_5 = Quantity of concentrate/animal in-milk/day (kg), X_6 = Human days allocated/head of milch animal/day (hours), D_1 = Education of the household head (literate-1, otherwise-0), D_2 = Education of the person involved in dairy activities (literate-1, otherwise-0), D_3 = Economic status of dairy farmers (economically sound-1, otherwise-0), D_4 = Scientific cattle shed (yes-1, otherwise-0), D_5 = Contact with extension personnel (yes-1, otherwise-0), D_6 = Availability of green fodder in the surrounding (easily available-1, otherwise-0).

III

RESULTS AND DISCUSSION

Socio-Economic Profile of the Households

The socio-economic profile of the households is presented in Table 1. The average age of the household heads was 38.34 years, and the cattle rearers had 14 years of experience in dairy farming. The literacy rates of household heads and persons involved in dairy stood at 87.80 and 93.90 per cent, respectively. Most (51.20 per cent) of the cattle rearers resided in semi-*kaccha* houses, whereas 25.60 and 23.20 per cent of the respondents lived in the *pucca* and kaccha houses, respectively. About 42.70 per cent of cattle rearers possessed television, 36.60 per cent had a motorcycle, 14.60 per cent had four-wheelers, and a refrigerator was owned by 6.10 per cent of the respondents. Most farmers owned dairy assets like an animal shed (100.00 per cent) and a manger (79.30 per cent).

TABLE 1. SOCIO-ECONOMIC PROFILE OF THE HOUSEHOLDS

Particulars (1)	Unit (2)	Value (3)
Average age	Years	38.34
Experience in dairy farming	Years	14.00
Literacy rate of household head	%	87.80
Literacy rate of person involved in dairying	%	93.90
Housing structure	%	
Kaccha		23.20
Semi-*pucca*		51.20
Pucca		25.60
Household assets	%	
Power tiller		3.70
Motorcycle		36.60
Refrigerator		6.10
Television		42.70
Four wheeler		14.60
Others		4.90
Dairy capital assets	%	
Animal shed		100.00
Storage for feed and fodder		47.60
Manger		79.30

Composition of cattle owned by sample households

The ownership pattern of cattle is presented in Table 2. The sampled cattle rearers owned approximately 12.00 Standard Animal Unit (SAU). The average number of SAU was significantly higher for large farmers (23.11 SAU) in comparison to medium (13.69 SAU) and small farmers (6.25 SAU). Overall, the dominant category of the cow owned by the sample households was 'in milk and not pregnant' (5.64 SAU) in the study area, followed by 'in milk and pregnant' (4.18 SAU) and 'dry and pregnant' (3.32 SAU) type. This trend was also true for large farmers who owned 10.58 SAU of 'in milk and not pregnant,' 7.46 SAU of 'in milk and pregnant,' and 3.43 SAU of 'dry and pregnant' cows. In the case of medium and small farmers, possession of 'in milk and not pregnant' cows was also highest, but no difference in average number was found between 'in milk and pregnant' and 'dry and pregnant' types. Ownership of 'dry and not pregnant' cows was recorded as the highest in the case of medium-sized farmers.

TABLE 2. AVERAGE NUMBER OF CATTLE (IN SAU) OWNED BY THE SELECTED HOUSEHOLDS

Category of cow	Size of holding			
	Small	Medium	Large	Overall
In milk and not pregnant	3.23	5.90	10.58	5.64
In milk and pregnant	2.44	3.52	7.46	4.18
Dry and pregnant	2.44	3.61	3.42	3.32
Dry and not pregnant	0.00	1.71	0.00	1.71
Male <1 year	0.41	0.41	0.62	0.55
Female <1 year	1.34	2.28	3.78	2.17
Male>1 year	1.42	0.71	0.95	0.95
Female>1 year	1.37	1.76	2.64	1.86
Adult Male	0.00	1.48	1.48	1.48
Total	6.25	13.69	23.11	12.17

Note: SAU = Standard Animal Unit.

Yield Gap in Milk Production Across Different Categories of Farmers

The different milk yield levels and yield gaps are presented in Table 3. The milk yield was recorded at the experimental research station at 13.00 L/day, indicating the maximum possible yield in the study area. The yield level at the research station was relatively high since the cows were maintained scientifically and provided with all necessary resources, including technical inputs. The yield attained by the top 10 per cent (Potential Yield) of cattle rearers was 12.43 L/day, while the average yield realized by the remaining 90.00 per cent (actual yield) was 8.69 L/day. The estimated TYG present was 4.31 L/day/cow, which could be segregated into YG-I, *i.e.,* 0.57 L/day/cow, and YG-II, *i.e.,* 3.75 L/day/cow. Thus, YG-II was bigger than YG-I, which points out that environmental and physical factors were minor constraints. Paul and Chandel (2010), Kemboi *et al.* (2021), and Das *et al.* (2021) also documented that YG-II was greater than YG-I in their studies in Ri-Bhoi, West Khasi Hills district of Meghalaya and NE India, respectively. Advanced cattle rearers might have invested more in external feeds, manpower, veterinary services, and artificial insemination to increase milk yield (Bebe et al., 2018). High YG-II was caused by technical and socio-economic factors, which can be reduced by improved management practices, capacity building, and access to credit (Paul and Chandel, 2010). The TYG of 49.62 per cent could be segregated into YG-I (6.52 per cent) and YG-II (43.10 per cent). The percentage of YG-II was six times greater than YG-1, suggesting that 43.10 per cent of milk could be augmented by correcting the forces that contributed to YG-II as the YG-I stand difficult to exploit (Figure 1).

TABLE 3. YIELD GAP IN MILK PRODUCTION ACROSS DIFFERENT CATEGORIES OF FARMERS

Particulars	Size of holdings			
	Small	Medium	Large	Overall
(1)	(2)	(3)	(4)	(5)
1.Research station yield (L/day/animal)	13.00	13.00	13.00	13.00
2.Potential farm yield (L/day/animal)	12.63	12.44	10.71	12.43
3.Actual farm yield (L/day/animal)	8.86	8.62	8.33	8.69
4.YG-I (1-2)	0.38	0.56	2.29	0.57
5.YG-II (2-3)	3.76	3.83	2.37	3.75
6.Total yield gap (4 + 5)	4.14	4.38	4.67	4.31

The size-wise investigation reveals that small cattle rearers had the highest potential farm yield, followed by medium and large cattle rearers. This may be due to better management practices used by the progressive farmers, as the size of holdings was such that they could comfortably manage the cows on their farms. The YG-I for small, medium, and large cattle rearers was 0.38, 0.56, and 2.29 L/day/cow, respectively. The YG-II was noted to be highest in the medium size category (3.83 L/day/cow), followed by small (3.76 L/day/cow) and large farmers (2.37 L/day/cow). The YG-II was least in large cattle rearers since they owned sufficient resources and knowledge to rear animals; also, in the case of large herd size group of farmers, the actual and progressive cattle rearers followed almost similar management strategies, which made the YG-II lower. The TYG percentage stood highest for large farmers

(56.00 per cent) but the least for small cattle rearers (46.71 per cent). The maximum YG-I (27.51 per cent) was recorded in the case of large farmers, while the lowest percentage of YG-I was noticed in small farmers (4.23 per cent). The YG-II was highest for medium farmers (44.38 per cent), followed by small (42.48 per cent) and large (28.49 per cent) dairy farmers. Hence, it can be established that by correcting the reasons for YG-II, milk production can be increased by around 28.49, 44.38, and 42.48 per cent in large, medium, and small farmers, respectively, in the region (Figure 1).

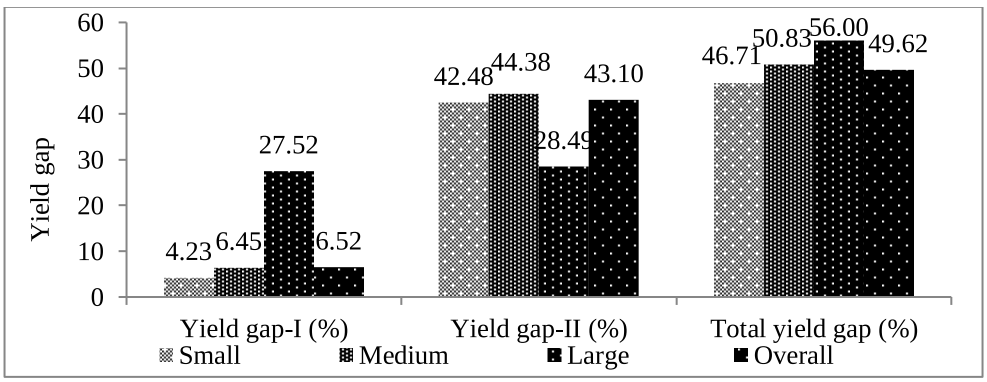

Figure 1**.** Percentage of yield gap across the category of farmers

Factors Affecting the Yield Gap in Milk Production

The calculated regression coefficients of the factors affecting the yield gap are presented in Table 4. One year of higher experience in dairy farming would reduce the yield gap by 0.19 L because experienced cattle rearers generally possess the knowledge for caring for dairy animals. Similar observations were made by Kemboi *et al.* (2021) and Das *et al.* (2021) in Ri-Bhoi and West Khasi Hills, respectively, who noted a negative and significant experience in dairy farming impact on the milk yield gap. In contrast, farmers maintaining contact with extension workers would decrease the yield gap by 0.21 L because they could acquire knowledge of better packages of practice and other improved technology from the extension workers. The regression coefficients for dairy experience and contact with extension personnel were negatively significant ($p<0.05$).

The effect of distance from the farmer's farm to the research station was positively significant ($p<0.01$), implying that the yield gap will be amplified by 0.266 L/day if the distance between the farmer's field and the research station increases by one km. The yield gap diminished up to 0.572 L by improving the human days allocated for dairy by one hour per day as the regression coefficient was negatively significant ($p<0.01$). This was consistent with the findings of Paul and Chandel (2010) and Feroze *et al.* (2019). However, Vishnoi *et al.* (2015) documented a negative impact of labour on milk yield but did not elaborate. The explanatory variables incorporated in the regression function explained nearly 66.00 per cent variation in the dependent variable, *i.e.*, yield gap.

TABLE 4. ESTIMATED COEFFICIENTS OF FACTORS AFFECTING YIELD GAP IN MILK PRODUCTION

Variables	Small			Medium			Large			Overall		
	B	SE	P	B	SE	P	B	SE	P	B	SE	P
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Constant	16.206	7.012	0.029	-8.802	15.900	0.587	-1.416	29.978	0.965	15.836	4.475	0.001
Experience in dairying	0.058	0.182	0.618	-0.327	0.042	0.179	-0.009	0.085	0.987	-0.190**	0.014	0.019
Education of the H. head	-	-	-	-0.029	1.106	0.908	0.479	1.658	0.421	0.092	0.379	0.278
Education of person involved in dairy	0.095	0.655	0.369	-0.164	1.976	0.498	-0.106	2.649	0.852	0.021	0.570	0.800
Economic status	0.150	0.367	0.202	0.171	0.987	0.493	0.187	1.437	0.707	0.043	0.280	0.582
Scientific cattle shed	-0.110	0.340	0.347	0.069	0.849	0.784	-0.445	1.540	0.490	-0.011	0.245	0.886
Distance from farmers farm to research station	0.396***	0.054	0.004	-	-	-	0.253	0.815	0.662	0.266***	0.141	0.001
Market access	-	-	-	0.122	0.486	0.649	-	-	-	-	-	-
Contactwith extension personn	-0.012	0.343	0.921	-0.440*	0.814	0.071	-	-	-	-0.211**	0.262	0.013
Price of concentrate	-0.258	0.288	0.058	0.292	0.589	0.263	0.019	1.175	0.981	-0.218**	0.179	0.011
Total quantity of concentrate	0.464***	0.171	0.001	0.098	0.318	0.718	0.470	0.550	0.381	0.114	0.131	0.181
Green fodder availability	-0.326***	0.689	0.006	-0.095	2.008	0.697	-0.037	1.585	0.936	-0.067	0.457	0.367
Human days allocated	-0.785***	0.095	0.000	-0.167	0.171	0.469	-0.104	0.886	0.867	-0.572***	0.133	0.000
R^2	0.763			0.386			0.577			0.663		
Dependent variable	Yield gap (L/day)											
No.ofobservations	37			29			16			82		

Note: ***, ** and * denote p< 0.01, p<0.05 and p<0.10, respectively, β = Regression coefficient, SE = Standard error, p = Probability value

For small cattle rearers, distance from the field to the research station, the quantity of concentrate per animal, availability of green fodder, and human days assigned to dairy activities were significant ($p<0.01$). About 76.30 per cent of the total variation in the exogenous variable was explained by the explanatory variables incorporated in the yield gap function for small farmers. The negative influence of extension personnel contact (β =-0.440*) was observed in the medium herd size category, implying that the yield gap might be reduced by up to 0.440 L/day by maintaining contact with extension personnel. In the large category, none of the explanatory variables was significant, which could be attributed to the small sample size. The independent variables included in the yield gap regression function described nearly 57.70 per cent of the total variation in the dependent variable in the case of large farmers (Table 4).

IV

CONCLUSIONS

This study concludes that a substantial difference in milk yield exists between the experiment station and the farmer's farm. Consequently, the percentage of the YG-II stood at approximately six times more than the YG-I. The extension agencies and research centers/institutes should take measures to demonstrate the positives of advanced technologies adopted at research stations to bridge the yield gap and encourage cattle rearers to use the technologies or practices adopted by progressive cattle rearers to minimize the YG-II. Moreover, increased coordination between extension personnel and cattle farmers is key to reducing the yield gap and improving animal care. Ongoing initiatives are needed to ensure a consistent supply of fodder to farmers; for instance, growing fodder and grass on community land and other wastelands may be a viable option.

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