Measuring Efficiencies of Dairy Buffalo Farms in the Philippines Using Data Envelopment Analysis

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Abstract: This study aimed to measure the efficiency scores of 75 dairy buffalo farms in the province of Nueva Ecija, Central Luzon, Philippines, using an input-oriented, variable-return-to-scale Data Envelopment Analysis (DEA) model. The farmer-informants or decision-making units (DMUs) were categorized as smallholders, family modules, and semi-commercial in operations. Personal interviews using structured questionnaires were done to gather various information on the socio-economic and management practices of the DMUs. Output in the form of volume and value of milk produced and inputs such as quantities and costs of biologics, feeds, forage, and labor were also collected and evaluated among individual DMUs. The efficiency scores were computed using PIM-DEA software, which identified fully efficient DMUs lying on the frontier line (scores of 1.0) and those enveloped by it (inefficient DMUs with scores of less than 1.0). The overall mean Technical Efficiency (TE), Allocative Efficiency (AE), and Economic Efficiency (EE) scores among the DMUs were 0.80, 0.81, and 0.65, respectively. Most of the inefficient DMUs were in the smallholder category. In sum, smallholder DMUs classified under low and moderate TE clusters should reduce their inputs by 53.31% and 40.01%, respectively, to become fully efficient. Likewise, higher lambda values among efficient peer DMUs indicate the best practice frontiers that the inefficient peer DMUs can benchmark with. Extension and advisory services can help promote the best management practices of the frontiers to improve the TE, AE, and EE of the inefficient DMUs.

Keywords: Data envelopment analysis, decision-making unit, frontier, dairy buffalo.

INTRODUCTION

Since 1999, the Philippine Carabao Center (PCC), an agency attached to the Department of Agriculture, in partnership with local government units, organized farmer groups, and private entities, has led the implementation of village-based water buffalo dairying in various localities in the country. The province of Nueva Ecija (in central Luzon), in particular, was given the utmost attention in this respect, as it was declared the National Impact Zone (NIZ) for dairy buffalo production. The basic interventions in the NIZ include massive crossbreeding (upgrading) of native (swamp-type) water buffalos through artificial insemination (AI) and bull loan programs, entrustment of purebred dairy buffalos, community organization, social preparation, technical training, marketing assistance, and other extension support services. After almost 20 years, more than 1,000 farmers have already been engaged by the PCC in Nueva Ecija alone as partner cooperatives who are tending around 3,932 dairy buffalos as of 2018 [1].

Over the years, the PCC has endeavored to evaluate the efficiency of the farmers' dairy buffalo operations mostly through animal performance indicators such as calving rate, calving interval, milk production, and the like. Recently, the PCC has focused its evaluation on the profitability indicators, the foremost of which is the return on investment (ROI). These metrics are adequate to evaluate a single dimension of performance (i.e., either production or profitability). However, for a program (e.g., the PCC's dairy buffalo module) that provides or involves a multitude of services and resources (inputs) to clients that define or contribute to its success or outputs, such performance metrics or statistics may be simplistic, and problematic [2]. In other words, as implemented by its farmer clients, the PCC's dairy buffalo module is seen here as a situation where multiple outputs and inputs are involved, which are not readily analyzed using conventional techniques like profitability ratios [3].

In line with the above premises, this research offered a more inclusive or holistic approach to determining performance efficiencies of dairy buffalo farms in the NIZ by way of data envelopment analysis or DEA. Introduced by Charnes, Cooper, & Rhodes [4], DEA is described as a very powerful service management and benchmarking technique that locates the best ways to improve practices not visible to other techniques. This model compares service units considering all resources and services being provided and identifies the most efficient or best practice units. Through linear programming, it calculates the amount and type of cost and resource savings that can be

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achieved by making each inefficient unit as efficient as the most efficient. To put it simply, DEA allows for a simultaneous evaluation of heterogeneous contributing factors to compute the most efficient use of resources or inputs for a given set of performance metrics or outputs [5].

Measuring Efficiency

Traditional measures of performance are based on financial records and accounting, which have many disadvantages, such as the following: (a) they were designed for an environment of mature products and stable technologies [6]; (b) they are poorly designed to provide the information necessary to guide the direction of the organization in making long-term decision based on the ever-changing environment [7]; (c) cost-based accounting metrics are well over half-a-century old [8]; (d) inadequate in meeting the needs of the contemporary business environment [9]; (e) fail to consider the requirements of today's organization and strategy [10]; (f) cost accounting is still often dated and thus misleading in its information [11]; (g) performance is usually isolated to individual units, rather than holistically measured and interpreted [12]; (h) many managerial decisions are historically founded on concepts such as return on investment and payback period [13], which is often far removed from operational relevance, resulting in a failure to understand the implications on processes [14]; (i) the importance of the customer is often ignored or downplayed in financial decisions [15]; and (j) there is no distinction in the use of management accounting rules applied to different types of operational processes such as: service operations, manufacturing to high volumes or wide variety, mass customization, or other combinations [12].

This statement of measurement of efficiency has been the concern of researchers with an aim to investigate the efficiency levels of farmers engaged in agricultural activities. Based on the pioneering article of Farrell [5], several approaches to efficiency measurement have been developed. The most popular techniques used to measure farm efficiency are the DEA [4] and the Stochastic Frontier Analysis or SFA [16-17]. The former uses mathematical linear programming methods, whereas the latter uses econometric methods. The choice of which method to be used depends on the situation or has to be decided in every case. The quality of the data, the appropriateness of various functional forms, and the possibility of making behavioral assumptions heavily influence the relative suitability of DEA and SFA.

The main advantage of non-parametric DEA is that it does not require specification of the functional form of the production function. It simultaneously utilizes multiple outputs and multiple inputs, with each being stated in different units of measurement (i.e., X_1 could be in units of animal inventory, and X_2 could be in units of kilograms without requiring an a priori trade-off between the two). The DEA focuses on revealed best practice frontiers rather than on central-tendency properties or frontiers, and it generates a set of "peer" units with which a unit is compared. Also, it is the best method for determining the best allocation of a farm's scarce resources and the scale of operation.

DEA Applied to Dairy Operations

There has been quite a number of published literature on DEA as applied to dairy farms, but most of which are limited to dairy cattle [18-24], and only a few deal with dairy buffalos [25,26]. Except for [22], the main focus of their analysis was on technical efficiencies with emphasis on commercialized (i.e., minimum of 50 cows) dairy farms with expectedly high or more varied types of inputs or resources in their operations. Such conditions are not applicable to a country like the Philippines, where smallholders (one to five-cow level) dominate the large ruminant (cattle and buffalo) sector, and only a few engage in semi-commercial operations (maximum of 20-cow level). In the current study, various categories of dairy buffalo farms were considered ranging from smallholder to semi-commercial. This was the first time, at least in the Philippines, a DEA methodology was applied considering the said conditions.

The DEA considers three measures of efficiency: technical efficiency (TE) or the ability of a decision-making unit or DMU (dairy buffalo farmer in this study) to produce the largest possible quantity of output from a given level of inputs (output-oriented) or produce a given level of output with the smallest possible level of inputs (input-oriented); allocative efficiency (AE), which measures the ability of a technically efficient DMU to use inputs and produce outputs in optimal proportions given their respective prices; and economic efficiency (EE), which measures the overall performance and is calculated as EE= TE x AE [27,28]. If the farm is technically and allocatively efficient, it is said to be cost-effective. It is also possible for a DMU to exhibit either TE or AE without having EE [29].

The current study adopted a variable return to scale-input oriented DEA (VRS-IODEA) model, wherein every increase in input would not result in a proportional increase in output [30]. This is important because the farms are expected to operate at different scales of operation. The main advantage of this model was that the scale-inefficient farms would only be compared to efficient farms of similar size and characteristics.

It is better and more logical for a developing country like the Philippines to use an input-oriented DEA model so that scarce resources can be saved and these resources can be used more efficiently to produce the same output [31]. Also, the input-oriented model is more appropriate in the agricultural sector because the farmers have the most control over the number of inputs they are using rather than at the output level [32]. Figure **1** shows the process of how EE was derived using DEA.

The current study is the first to apply DEA to three types of dairy buffalo farms categorized according to the number of animals reared by the DMUs, i.e., smallholder (1-5 buffaloes), family module (6-10 buffaloes), and semi-commercial (11-20 buffaloes). Moreover, unlike most other previous studies on DEA that focused only on TE, the current study also established the AE and EE of the DMUs.

It is hypothesized that lower efficiencies are more common among smallholder farms owing to minimal inputs or resources in raising only a few animals, which are also projected to produce fewer outputs. Conversely, bigger farms with more resources or inputs to deploy are expected to produce more outputs and demonstrate more efficiencies in their operations.

In general, this research aimed to evaluate and analyze the efficiencies of dairy buffalo farms in Nueva Ecija (central Luzon in the Philippines) using DEA. Specifically, it aimed to (1) determine inputs and output in dairy buffalo production by selected farmer-informants (DMUs); (2) measure the TE, AE, and EE scores of the DMUs; (3) determine a potential adjustment in inputs among inefficient DMUs; (4) determine the "best practice frontier" for benchmarking among inefficient DMUs; and (5) recommend a solution for identified inefficiencies in dairy buffalo production by the DMUs.

MATERIALS AND METHODS

Study Area and Farm Classifications

This research was conducted in the province of Nueva Ecija (in Central Luzon, Philippines). Farmers who have been actively engaged in dairy buffalo

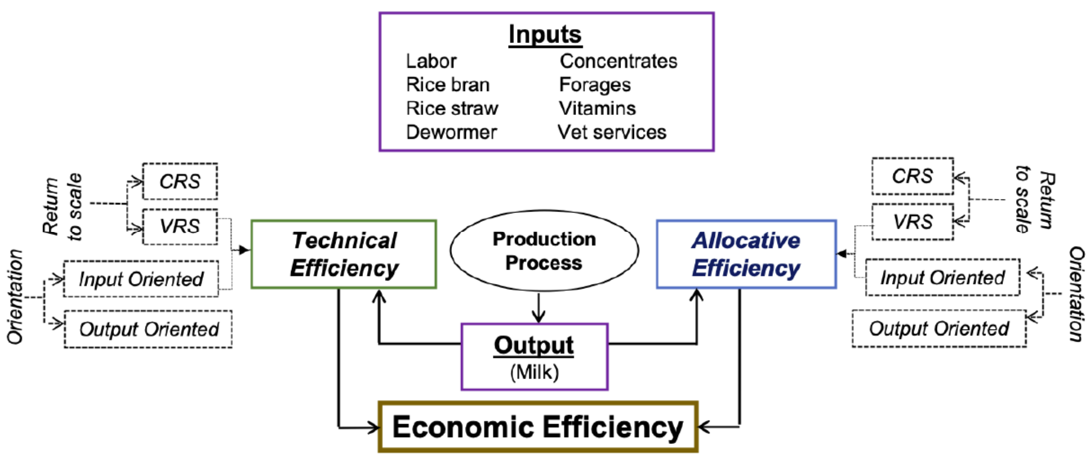

Figure 1: Conceptual framework for economic efficiency in dairy buffalo production using Data Envelopment Analysis.

Table 1: Classification of DMUs in Nueva Ecija, 2021

Classification	No. of Farms	No. of Cows
Smallholders (3-5 buffalos)	58	220
Family module (6-10 buffalos)	12	96
Semi-commercial (11-20 buffalos)	5	78
TOTAL	75	394

production for at least five years and with at least three buffalo cows (each has undergone at least one production cycle) were the population of interest (i.e., hereinafter referred to as DMUs). Table **1** shows how the DMUs were classified, along with the number of farms and the number of dairy buffalo cows per farm classification.

The farm classifications were consistent with the conditions set forth by the Philippine Statistics Authority Board [33] in classifying livestock farms. For dairy and large ruminants, smallholder farms are those that tend at most 5 cows, while semi-commercial farms tend 6-50 cows. Semi-commercial farms are those that were able to grow their herd size over the years or have invested in procuring a large number of buffalos (maximum of 20 buffalos in the current study). The study’s third category, i.e., family module farm, served as a middle ground and was internally created by the PCC, wherein 5 heads of female buffalos are awarded to a family (or a household) as part of its dairy buffalo entrustment program. It differed from the smallholder in that the PCC entrusted the latter with only one startup female buffalo.

Data Gathering and Analysis

Socio-Demographics, Management Practices, Input and Output Data

The study employed personal and individual interviews with the 75 DMUs to obtain primary data, which included socio-demographics, investments and assets in buffalo dairying, farm characteristics, animal inventory, adoption of technologies or improved management practices, and inputs and outputs in buffalo dairying. To augment the primary data, secondary data were also sourced from the actual farm records and field data previously gathered by the PCC.

Input data included those that directly affect milk production, such as labor (number of man-days and peso value of family and hired labor), feeds (kilogram and peso value of feed concentrates, rice bran, fresh forage, and rice straw), and biologics (mg or mL and peso value of vitamins and dewormer). Output data are in terms of liters and peso value of milk produced. The latter also represents the gross income from milk production per farm classification. Descriptive statistics such as frequency counts, averages, and percentages were used in presenting these data.

Mean Efficiency Scores

In this study, a production cycle is defined as the period from when the animal stopped milking from the previous calving until the end of the current calving's lactation period (dry-off). The input and output data were entered into and analyzed for mean TE and AE scores using the Performance Improvement Management Software Version 3 (PIM-DEA soft V3) under the VRS input-oriented model. Quantitative input (weight, volume, numbers) and output (weight or volume) data were entered in the TE model, while input and output peso values were entered in the AE model in the PIM-DEA software. Note that the mean EE scores were determined simply by multiplying the mean TE scores by the mean AE scores. The analysis covered one production cycle to gauge and compare the efficiencies of different DMUs.

Clustering of Efficiency Scores

The TE, AE, and EE-generated scores were spread over a wide range. Thus, they were subdivided into four classes or clusters, namely low, moderate, high, and full (or fully efficient). Clustering through class intervals (class width) helps organize the said efficiency scores data to facilitate their subsequent analysis. In determining the class interval, the lower limit (lowest efficiency score, i.e., 0.3782) was first subtracted from the upper limit (highest efficiency score, i.e., 1.0000), which gave a value of 0.6218. This was then divided by 3, which was the desired number of classes because the fourth class, or the "fully efficient" cluster (with an efficiency score of 1.0000), was already predetermined. The resulting interval value was 0.2072, which was added to each base score in the first three clusters (low, moderate, high) to establish their respective ranges of efficiency scores. For the “high” efficiency cluster, the value of 0.0001 was subtracted from 1.000 to serve as its upper limit. Below is the result of such clustering.

Efficiency Cluster	Efficiency Scores
Low	0.3782-0.5854
Moderate	0.5855-0.7927
High	0.7928-0.9999
Full	1.000

The number of cases or frequency counts per efficiency cluster for each DMU farm classification was then determined.

Production Possibility Set (PPS)

Using the PIM-DEA software, a sample PPS chart was developed for a visual assessment of how an available input can be used more efficiently by a DMU to produce a certain output level.

Actual Usage of Inputs and Potential Adjustments

For each cluster of efficiency per DMU farm classification, actual usage of inputs (biologics, feeds, forages, and labor) was recorded while the corresponding input adjustments (or targets) and gain or loss percentages were generated by the PIM-DEA software.

Benchmarking with Best Practice Frontier

Using the PIM-DEA software, lambda (λ) values or raw weights assigned to the peer DMUs were generated in a table. The DMUs that share zero lambda values are not peers, while those with lambda values greater than zero are considered peers, which indicates that inefficient DMUs have corresponding reference groups (efficient DMUs). Benchmarking inefficient DMUs with their efficient DMU peer or "best practice frontier" was done by locating in the table the inefficient and efficient DMUs that share the highest lambda value.

RESULTS AND DISCUSSION

Socio-Demographic Characteristics of Dairy Buffalo Farmers

Table **2** summarizes the socio-demographic profile of dairy buffalo keepers in Nueva Ecija. The majority (77%) of the DMUs were classified as smallholders who had 3-5 milking animals. The latter is taken care of by the head of the family for the reason that this endeavor is a very challenging task. Raising dairy buffalo is their main source of livelihood, wherein they earned as much as PHP 234,697.00 from milk production alone in the year 2021.

The amounts of investment and assets differ based on the size of the farm (Table **3**). On average, the DMUs invested in land, which had the highest cost share (64%), amounting to PHP 558,622.00, among other assets. It is followed by forage hauling equipment (23%), housing facilities (7%), and water sources (2%). Semi-commercial farms invested more in housing as

Table 2: Socio-Demographic Profile of Dairy Buffalo Owners (DMUs), Nueva Ecija, 2021

Particulars	Smallholder farms (58)	Family module (12)	Semi-commercial (5)	All (75)
Age (years)				
Mean	51	50	55	51
Range	29-73	42-60	43-74	29-74
Gender (%)				
Male	93	92	100	93
Female	7	8	0	7
Civil status (%)				
Single	3	0	0	3
Married	95	100	80	94
Widow	2	0	20	3
Household Size	5	5	3	5
Educational Attainment (%)				
Elementary	14	25	0	15
High School	50	8	20	41
Vocational	17	17	40	19
College	19	50	40	25
Years in school (mean)	10	11	13	11
Years of membership in an organization	13	12	13	13
Years of experience in dairying	12	14	12	13
Sources of income (PHP)				
Rice production	66,502	84,500	130,000	73,615
Dairying	157,816	366,332	810,586	234,697
Vegetable production	25,492	79,250	82,000	37,861
Others	13,929	0	100,000	17,534

Table 3: Amount of Investment and Assets (in PHP) in Dairy Buffalo Farming, Nueva Ecija, 2021

Particulars	Smallholder farms (58)	Family module (12)	Semi-commercial (5)	All (75)
Land	553,069	517,500	762,500	558,622
Forage hauling equipment	165,217	217,200	273,700	196,375
Housing	42,828	89,583	272,500	62,824
Water source	15,700	23,142	71,600	20,617
Forage chopper and grass cutter	5,919	9,717	12,500	6,965
Power sprayer	1,126	7,542	4,200	2,257
Other assets	10,754	55,823	94,717	23,736
TOTAL	794,613	920,507	1,491,717	871,396

Table 4: Characteristics of Dairy Buffalo Farms, Nueva Ecija, 2021

Farm Characteristics	Smallholder farms (58)	Family module (12)	Semi-commercial (5)	All (75)
Source of forage (%)				
Communal	5	0	0	4
Own forage area	7	33	0	11
Both	88	67	100	85
Other particulars				
Housing (m^2)	96	131	246	111
Forage area (m^2)	1,613	2,871	6,240	2,123
Distance to PCC (km)	15.2	13.2	20.8	15.2
No. of years in dairying	12	14	12	13

Table 5: Total Current Animal Inventory of Dairy Buffalo Farms, Nueva Ecija, 2021

Buffalo Category	Smallholder farms (58)	Family module (12)	Semi-commercial (5)	All (75)
Senior bull	12	4	6	22
Junior bull	16	4	6	26
Cow	220	96	78	394
Heifer	116	46	43	205
Female calf	75	45	12	132
Male calf	50	17	31	98
TOTAL	489	212	176	877

compared to other assets. It indicates that they value the health of their stocks for the latter to reach maximum productivity. Tables **4** and **5** show the farm characteristics and animal inventory summary.

Management Practices in Dairy Buffalo Production

Although the management of dairy buffalo faces many challenges, the DMUs continuously take care of their animals as part of their agricultural activities, which gives them a good source of income. Since they have been involved in the business for 13 years, they have learned and applied new knowledge gained from training, seminars, field visits, and techno-demos. Most of them adopted recording systems, feeding technology, hygienic milking practices, artificial insemination (AI), and animal health practices (Table **6**).

Table 6: Percentage of Dairy Buffalo Farms who Adopted Technologies or Improved Management Practices, Nueva Ecija, 2021

Technology	Smallholder farms (58)	Family module (12)	Semi-commercial (5)	All (75)
Housing	98	100	100	99
Recording system				
Breeding	98	100	100	99
Milk production	98	100	80	97
Animal Health	97	100	100	97
Income	64	83	60	67
Calf management				
Early weaning (after birth)	3	8	20	5
Feeding with milk replacer	5	8	0	5
Feeding technology				
Improve forage	97	100	100	97
Concentrates	95	92	100	95
Legumes supplementation	66	58	100	67
Mineral supplementation	62	83	60	65
Silage	43	75	100	52
Complete confinement	21	67	40	29
Hygienic milking				
Cleaning the udder	100	100	100	100
Foremilk stripping	100	100	100	100
Dipping teats in iodine solution	98	100	100	99
Milk cooling	43	92	40	51
Breeding (AI technology)	97	92	100	96
Animal Health				
Deworming	100	100	100	100
Vitamins	100	100	100	100

Inputs Used, Costs, and Milk Production

Maximizing the use of labor, feeding nutritious and improved forages, and giving enough feeds for dairy buffalo are some important aspects of becoming successful in dairying. In dairy buffalo management, the inputs used and costs differ according to farm size, the intensity of inputs used, and milk production. Labor, forages, and feeds costs accounted for the major inputs share at 34%, 28%, and 23%, respectively. The average cost of production for five heads of dairy buffaloes was PHP 295,510.00.

The labor inputs showed that the family module had lesser use of man-days per animal with a value of PHP 14,218.00 compared to PHP 21,294.00 and PHP 21,674.00 for smallholder and semi-commercial, respectively (Table **7**). Labors include gathering forages, feeding and water, cleaning and maintaining housing, bathing, pasturing, and milking. The family module also recorded a high cost of inputs in terms of forages per animal, amounting to PH P17,833.00.

The average milk produced was 6,283 liters per lactation per farm at an average price of PHP 61.91 per liter (Table **8**). Semi-commercial farms sold their milk production at a higher price (PHP 68.65 per liter) compared to other farms. Overall, an average gross sale of PHP 388,981.00 per farm or PHP 77,796.00 per animal per lactation cycle was recorded.

Efficiency Analysis

Measurement of Efficiency

A VRS input-oriented model for DEA shows that larger farms have higher mean efficiency scores than

Table 7: Average Inputs Used and Costs per Farm in Raising Buffalo Cows, Nueva Ecija, 2021

Inputs	Smallholder Farms (58)		Family module (12)		Semi-commercial (5)		All (75)	
	Per farm	Per animal	Per farm	Per animal	Per farm	Per animal	Per farm	Per animal
Dewormer								
Quantity (mg or ml)	811	203	1,665	208	2,856	220	1,020	204
Value (PHP)	2,053	513	4,496	562	6,518	501	2,584	517
Vitamins								
Quantity (mg or ml)	106	27	200	25	385	30	138	28
Value (PHP)	678	170	1,474	184	2,871	221	937	187
Feeds								
Quantity (kg)	2,226	557	5,403	675	11,641	895	3,590	718
Value (PHP)	43,489	10,872	103,354	12,919	215,270	16,559	68,836	13,767
Rice bran								
Quantity (kg)	2,101	525	4,886	611	5,713	439	3,333	667
Value (PHP)	15,078	3,770	38,083	4,760	42,870	3,298	23,511	4,702
Forages								
Quantity (kg)	92,173	23,043	213,993	26,749	323,132	24,856	131,490	26,298
Value (PHP)	61,448	15,362	142,662	17,833	215,421	16,571	83,831	16,766
Rice straw								
Quantity (kg)	12,517	3,129	37,535	4,692	101,379	7,798	22,634	4,527
Value (PHP)	8,887	2,222	26,650	3,331	71,979	5,537	16,070	3,214
Labor								
No. of man-days	516	129	694	87	1,395	107	588	118
Value (PHP)	85,176	21,294	113,742	14,218	281,767	21,674	99,741	19,948
TOTAL COST (PHP)	216,809	54,202	430,461	53,808	836,696	64,361	295,510	59,102

Table 8: Gross Income from Milk Production per Farm Classification, Nueva Ecija, 2021

Particular	Smallholder farms (58)		Family module (12)		Semi-commercial (5)		All (75)	
	Per farm	Per animal	Per farm	Per animal	Per farm	Per animal	Per farm	Per animal
Milk production (li)	4,377	1,094	10,353	1,294	18,866	1,451	6,283	1,257
Price (PHP/li)	59.66	59.66	61.43	61.43	68.65	68.65	61.91	61.91
Income (PHP)	261,132	65,283	635,985	79,498	1,295,151	99,627	388,981	77,796

smaller ones (Figure **2**). This may be possible because larger farms maximize their resources in producing output and also due to low overhead costs. This finding is consistent with the works of Uzmay, Koyubenbe & Armagan [19], which noted that efficiency scores increased as the farm size expanded. In summary, the mean TE and AE for the 75 farms were 0.80 and 0.81, respectively. These results indicate that the output of the farms could be increased by 20% if the operation were to be technically efficient or by 19% if AE was assumed. The mean EE is 0.65, indicating that the farms could still produce 35% more milk for a given level of inputs.

The mean TE score of 0.80 was lower compared to the recent study by Topuz & Karabulut [26] on dairy buffalos, which showed a mean TE score of 0.95 with the VRS assumption. Also, in comparison, previous DEA studies in dairy cattle farms showed varying results in mean TE scores using the VRS model at

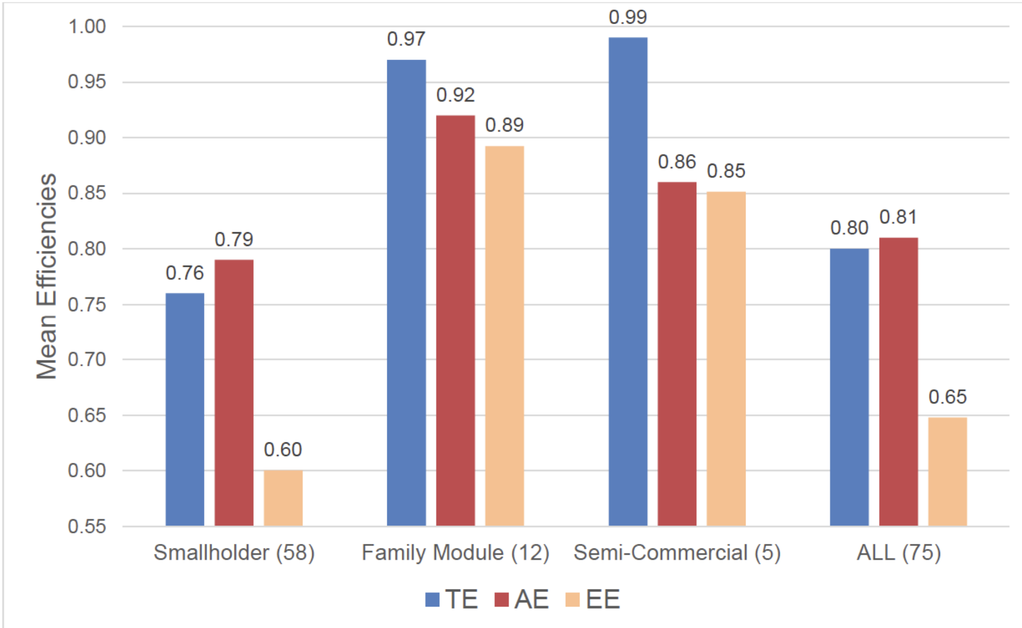

Figure 2: Mean TE, AE, and EE scores of dairy buffalo farms in Nueva Ecija.

0.328 [18], 0.923 [19], 0.954 [20], 0.771 [22], 0.78 [23], and 0.650 [24]. But in summary, all these results imply that many dairy farms are operating below full efficiency.

Figure **3** presents the number of cases per cluster of efficiencies for each dairy buffalo farm classification in Nueva Ecija. Of the 58 smallholder DMUs, 31 (53.44%) belong to a low cluster of EE, while only 2 (3.44%) were categorized under full EE. For the 12 family-module DMUs, 6 (50%) belong to the moderate EE cluster, while 3 (25%) belong to the full EE cluster. Meanwhile, all 5 semi-commercial DMUs belong to either high or full EE clusters. In summary, only 7 out of the 75 DMUs, or 9.33%, belong to the full EE cluster with scores of 1.0.

Production Possibility Set (PPS)

All DMUs that lie on the production frontier (or border) line in the PPS are considered fully efficient, while the rest are inefficient (i.e., they are enveloped by the borderline) and show how far they are from the frontier. Results reveal that most farms used their

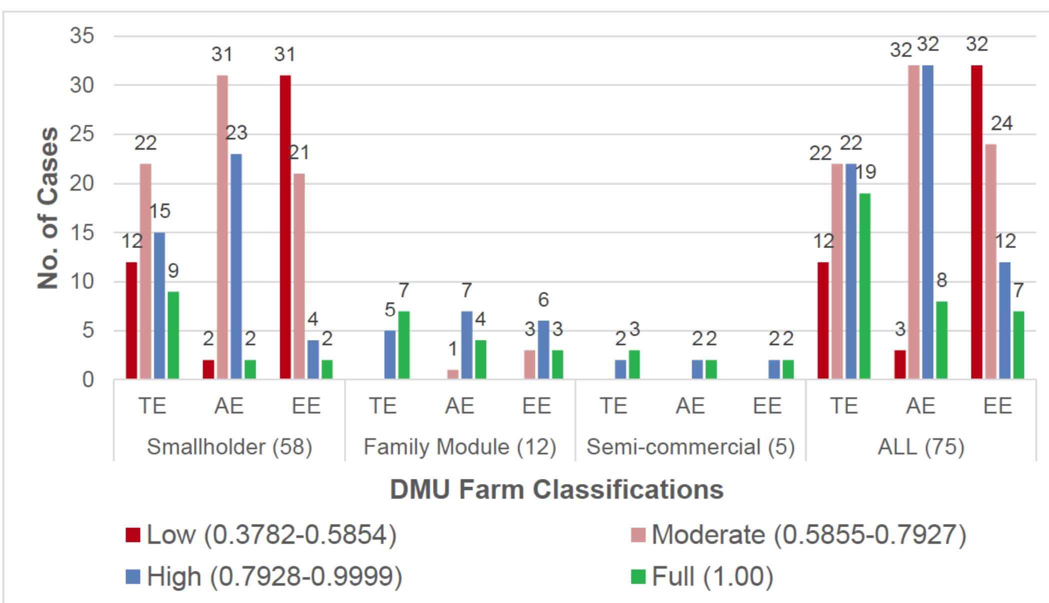

Figure 3: Number of cases per efficiency cluster for each dairy buffalo farm classification in Nueva Ecija.

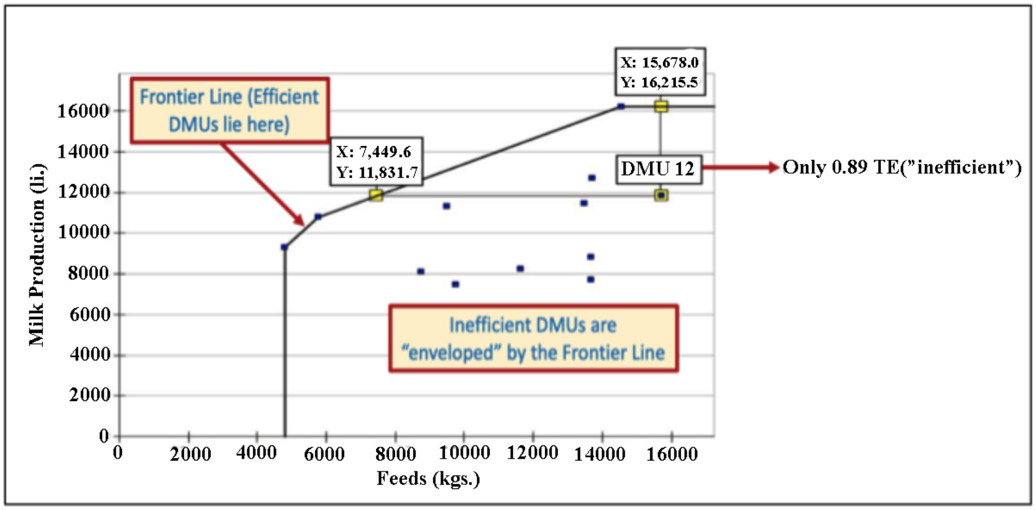

Figure 4: A PPS Chart Showing the Input-Output of an Inefficient DMU in Nueva Ecija.

resources below the frontier line, indicating that there were substantial inefficiencies among the dairy buffalo farms in using their resources. To improve their efficiencies, inefficient DMUs need to adjust or recalibrate the number of resources they are using or change their management practices.

Figure **4** provides an illustration of how such observation looks like using DMU 12 (one of the family module farms) as an example. In the PPS chart, DMU 12 was inefficient, with only 0.89 or 89% TE. It has produced a total output of 11,831 liters of milk in one production cycle. Using an input-oriented DEA, it should have fed only 7,449.6 kg of feeds (as one of the inputs) for its 10 lactating buffaloes instead of the actual 15,678 kg of feeds to attain full efficiency, all other variables held constant. Conversely, for an output-oriented DEA, at the level of 15,678 kg of feeds offered to the dairy buffaloes, the same farm should have produced a total of 16,215.5 liters of milk in one production cycle if it were to operate at full efficiency. The same analysis can be applied to the other DMUs.

Mean Actual Usage and Potential Adjustments

Tables **9a-c** present summary statistics of actual usage and potential adjustments (targets) of inputs used in raising dairy buffalo per farm for each TE cluster. Inefficient farms employed the wrong input mix, given the prices. Better management practices by their peers can be adopted in order to reduce the level of inputs to the target values while achieving the same level of output.

For the smallholder farms, the low-efficient farms' average milk production was 3,990.75 liters in one production cycle for four lactating animals. Inputs, e.g., biologics, commercial feeds, forages, and labor were costly. For them to become efficient, they have to reduce their input usage by 53.31% without sacrificing the amount of milk collected from the animals. On the other hand, moderately efficient farms have to reduce their inputs by 40.01% to attain efficiency without affecting milk production. Supplementation of commercial feeds under this category used more than half of the rations (53.28%), amounting to 5,595.39 kg valued at PHP 63,891.00. There is a potential for this group to attain full efficiency if they manage and reallocate the use of inputs effectively. Highly efficient farms operate at a range of 0.80 mean TE, which is considered to be within the fully TE farms range. This group needs only 19.43%, 14.73%, and 24.03% reduction across inputs for smallholders, family modules, and semi-commercial farms, respectively, to become fully efficient. Further analysis revealed that fully efficient farms under the smallholder category have the lowest actual usage of resources such as biologics, feeds, forages, and labor, which produced about 5,485.35 liters of milk for four lactating buffalo cows. Though the average milk production for low-efficient farms was 3,990.75 liters, it was observed that this group had the lowest usage of resources if target inputs were attained (reallocated).

Peer DMUs and Benchmarking with Best Practice Frontier

Tables **10 a-c** present the lambda (λ) values (raw weights) assigned to the peer DMUs in the DEA model. All inefficient DMUs were listed vertically in the first column of the table, while all efficient DMUs were listed horizontally at the top of the table. To illustrate, in the colored row under smallholder farms, DMU 4, which

Table 9a: Actual, Targets and Percentage Gain/Loss in One Production Cycle, Nueva Ecija, 2021

TE Cluster	Smallholder Farms												
	Biologics (ml)			Feeds (kg)			Forages (kg)			Labor (man-days)			Mean Gain/loss (%)
	Actual	Target	Gain/loss (%)	Actual	Target	Gain/loss (%)	Actual	Target	Gain/loss (%)	Actual	Target	Gain/loss (%)	
Low	1,188.42	530.82	-54.66	4,365.80	1,831.73	-55.28	140,133.76	64,796.49	-52.64	690.21	336.72	-50.66	-53.31
Moderate	926.68	564.68	-38.38	5,595.39	2,315.56	-53.28	102,933.93	64,106.83	-35.22	522.36	340.05	-33.18	-40.01
High	829.93	627.55	-22.40	3,467.76	2,375.20	-22.04	91,364.90	73,626.58	-18.62	421.26	336.88	-14.64	-19.43
Fully efficient	677.89	677.89	0.00	2,604.83	2,604.83	0.00	83,932.06	83,932.06	0.00	424.42	424.42	0.00	0.00
Mean	917.21	591.50	-31.66	4,326.69	2,275.77	-37.35	104,689.73	69,787.85	-29.07	515.74	351.63	-26.85	-31.23

Table 9b: Actual, Targets and Percentage Gain/Loss in One Production Cycle, Nueva Ecija, 2021

TE Cluster	Family Module Farms												
	Biologics (ml)			Feeds (kg)			Forages (kg)			Labor (man-days)			Mean Gain/loss (%)
	Actual	Target	Gain/loss (%)	Actual	Target	Gain/loss (%)	Actual	Target	Gain/loss (%)	Actual	Target	Gain/loss (%)	
Low	-	-	-	-	-	-	-	-	-	-	-	-	-
Moderate	-	-	-	-	-	-	-	-	-	-	-	-	-
High	2,114.00	1,770.82	-15.57	12,244.32	8,540.90	-26.94	279,209.70	253,389.85	-8.33	703.35	646.01	-8.09	-14.73
Fully efficient	1,686.29	1,686.29	0.00	10,492.97	10,492.97	0.00	239,474.86	239,474.86	0.00	765.26	765.26	0.00	0.00
Mean	1,864.50	1,721.51	-6.49	11,222.70	9,679.61	-11.22	256,030.88	245,272.78	-3.47	739.46	715.57	-3.37	-6.14

Table 9c: Actual, Targets and Percentage Gain/Loss in One Production Cycle, Nueva Ecija, 2021

TE Cluster	Semi-Commercial Farms												
	Biologics (ml)			Feeds (kg)			Forages (kg)			Labor (man-days)			Mean Gain/loss (%)
	Actual	Target	Gain/loss (%)	Actual	Target	Gain/loss (%)	Actual	Target	Gain/loss (%)	Actual	Target	Gain/loss (%)	
Low	-	-	-	-	-	-	-	-	-	-	-	-	-
Moderate	-	-	-	-	-	-	-	-	-	-	-	-	-
High	3,510.00	2,963.61	-15.98	30,304.95	21,883.09	-20.45	601,693.95	449,207.83	-20.05	2,520.75	1,015.51	-39.63	-24.03
Fully efficient	2,805.00	2,805.00	0.00	24,330.10	24,330.10	0.00	403,851.02	403,851.02	0.00	1,022.57	1,022.57	0.00	0.00
Mean	3,087.00	2,868.44	-6.39	26,720.04	23,351.29	-8.18	482,988.19	421,993.74	-8.02	1,621.84	1,019.50	-15.85	-9.61

Table 10a: Lambda Values of Input-Oriented DEA Model for Smallholder Farms, Nueva Ecija

Inefficient DMU ID No.	Efficient DMU ID No.								
	2	3	8	19	27	34	44	51	53
1	0	0	0	0	1	0	0	0	0
4	0.11	0	0.03	0	0	0.86	0	0	0
5	0	0	0	0	0.22	0.78	0	0	0
6	0	0	0	0	0.42	0.58	0	0	0
7	0.51	0	0	0	0	0.49	0	0	0
9	0	0	0	0	0	0.81	0.19	0	0
10	0	0	0	0	0.23	0.77	0	0	0
11	0	0	0	0	0	0.94	0.06	0	0
12	0	0	0	0	0.17	0.78	0	0	0.05
13	0	0	0	0.32	0	0.66	0	0	0.02
14	0	0	0	0	0.44	0.56	0	0	0
15	0	0	0	0	0.81	0.19	0	0	0
16	0	0	0	0	0.6	0.34	0	0	0.06
17	0	0	0	0	0.66	0.22	0	0	0.12
18	0	0	0	0	0.02	0.65	0	0.06	0.27
20	0	0	0	0	0.71	0	0.15	0.14	0
21	0	0	0	0	0.14	0.86	0	0	0
22	0	0	0	0	0.26	0.51	0	0.15	0.08
23	0	0	0	0.26	0	0.37	0	0	0.37
24	0	0	0	0	0	0.93	0.07	0	0
25	0	0	0	0	1	0	0	0	0
26	0	0.13	0	0.59	0	0	0	0.28	0
28	0	0	0	0	0.38	0.62	0	0	0
29	0	0	0	0	0.31	0.69	0	0	0
30	0	0	0	0	0.53	0.47	0	0	0
31	0	0	0	0	1	0	0	0	0
32	0	0	0	0	0.33	0.64	0	0	0.03
33	0	0	0	0.4	0	0.28	0	0	0.31
35	0	0	0	0	0	1	0	0	0
36	0	0	0	0	0.46	0.54	0	0	0
37	0	0	0	0	0.78	0.22	0	0	0
38	0	0	0	0	0	0	1	0	0
39	0	0	0	0	0.6	0.4	0	0	0
40	0	0	0	0	0.74	0.26	0	0	0
41	0	0.73	0	0.24	0	0	0	0.03	0
42	0	0.57	0	0.05	0.24	0.14	0	0	0
43	0	0	0	0.31	0.26	0	0	0.1	0.34
45	0	0	0	0	0.26	0.61	0.01	0.03	0
46	0	0	0	0	0.37	0	0	0.23	0.39
47	0	0	0	0.05	0	0.88	0	0.06	0.01

(Table 10). Continued.

Inefficient DMU ID No.	Efficient DMU ID No.								
	2	3	8	19	27	34	44	51	53
48	0	0	0	0	0.86	0.14	0	0	0
49	0	0	0	0	0.33	0	0	0.51	0.17
50	0	0	0	0	0.44	0.39	0	0	0.18
52	0	0	0	0	0.75	0	0.07	0.18	0
54	0	0	0	0.55	0.19	0	0	0.12	0.14
55	0	0	0	0	0.67	0.08	0.03	0.22	0
56	0	0	0	0	0.39	0.32	0.15	0.14	0
57	0	0	0	0.02	0.67	0	0	0.14	0.17
58	0	0	0	0	0	0	0	0	1

Table 10b: Lambda Values of Input-Oriented DEA Model for Family Module Farms, Nueva Ecija

Inefficient DMU ID. No.	Efficient DMU ID. No.						
	2	3	5	6	7	9	10
1	0	0.48	0	0	0.52	0	0
4	0	0.13	0	0	0.87	0	0
8	0	0.17	0	0	0.4	0	0.43
11	0	0	0.43	0.15	0.28	0.14	0
12	0	0	0.08	0.17	0.39	0.37	0

Table 10c: Lambda Values of Input-Oriented DEA Model for Semi-Commercial Farms, Nueva Ecija

Inefficient DMU ID No.	Efficient DMU ID. No.		
	1	2	5
3	0.32	0.68	0
4	0	0.10	0.90

was an inefficient farm, has model-determined benchmark frontier candidates (i.e., efficient DMUs), namely DMUs 2, 8, and 34. Benchmarking of DMU 4 with DMU 34 is recommended since their lambda value of 0.86 is higher than those shared with DMU 2 (0.11) and DMU 8 (0.03). The same analysis can be applied to other peer DMUs with the highest lambda values.

CONCLUSION

The study hypothesized that lower efficiencies are expected among smallholder DMUs than among bigger DMUs (i.e., family module and semi-commercial), which was proven to be true based on the results of the DEA. Smallholder DMUs had mean TE, AE, and EE scores of only 0.76, 0.79, and 0.60, respectively. In contrast, higher mean efficiency scores were observed among family module DMUs (0.97 TE, 0.92 AE, 0.89 EE) and semi-commercial DMUs (0.99 TE, 0.86 AE, 0.85 EE). The latter also had more investment and inputs in operating their respective dairy buffalo farms, which produced higher milk production outputs.

Still, overall, the dairy buffalo farms in Nueva Ecija were not at their maximum AE, indicating that there is a potential to reduce their costs of inputs by 19% without affecting the output (liters of milk produced). The mean EE score was 0.65 across all farm classifications, suggesting that a significant number of dairy farms can still improve their productivity and efficiency by reorganizing or adjusting their inputs and adopting available technologies in their farm. Therefore, there is a potential for increasing the milk production efficiency in the study area as long as the sources of technical and allocative inefficiencies can be addressed.

Government policies that aim to improve the production efficiency of dairy buffalo keepers should consider providing support mechanisms that will help increase the number of animals held per farmer to maximize the efficiency of their operations. The programs implemented in the field should be flexible enough to accommodate the diversity of former partners' situations. Extension and advisory service providers can assist in identifying the best management practices in a given farm situation and provide advice on how to improve farmers' efficiency.

Inefficient DMUs can improve their efficiencies further by learning the best allocation of resources. The results of this study would help set targets for the inefficient DMUs by benchmarking with the efficient DMUs under the smallholder, family module, and semi-commercial categories. Future studies could also explore how the various socio-economic, cultural, institutional, and management factors relate to the efficiency scores of the DMUs.

AVAILABILITY OF DATA

The raw data are available upon request.

CONFLICT OF INTEREST

The authors have no conflict of interest to declare.

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