How to cite: Adanacıoğlu, H., G. Saner, S. Engindeniz, D. Güler & Z. Şengül, 2023. The efficiency of water buffalo farms in semi-intensive feeding system: A case study from Balıkesir, Türkiye. Ege Univ. Ziraat Fak. Derg., 60 (2): 205-219, https://doi.org/10.20289/zfdergi.1247238

Research Article
(Araştırma Makalesi)

Ege Üniv. Ziraat Fak. Derg., 2023, 60 (2):205-219
https://doi.org/10.20289/zfdergi.1247238

The efficiency of water buffalo farms in semi-intensive feeding system: A case study from Balıkesir, Türkiye*

Yarı entansif besleme sisteminde manda işletmelerinin etkinliği: Balıkesir, Türkiye'de bir örnek olay

Hakan ADANACIOĞLU [1*]

Gamze SANER [1]

Sait ENGİNDENİZ [1]

Duran GÜLER [1]

Zekiye ŞENGÜL [2]

[1] Ege University, Faculty of Agriculture, Department of Agricultural Economics, 35100, Bornova, İzmir, Türkiye

[2] Siirt University, Faculty of Agriculture, Department of Agricultural Economics,, 56100, Siirt, Türkiye

* Corresponding author (Sorumlu yazar):
hakan.adanacioglu@ege.edu.tr

* This article was supported by the Ege University Scientific Research Projects Coordination Unit as project number 2015-ZRF-048.

Received (Alınış): **04.02.2023** **Accepted** (Kabul Tarihi): **09.05.2023**

ABSTRACT

Objective: The objective of this study was to determine whether or not the buffalo farms in the semi-intensive system are operating at an effective level.

Material and Methods: The data were obtained from face-to-face interviews with 102 buffalo breeders in Balıkesir province. Data Envelopment Analysis was used to determine the technical efficiency of the buffalo farms, and Tobit regression model was used to determine the factors affecting the technical efficiency.

Results: The results reveal that the buffalo farms don't work effectively in terms of both pure technical efficiency (VRSTE: 0.668) and scale efficiency (SE: 0.687). According to pure technical efficiency scores, 23.53% of buffalo farms operate at full efficiency level. 90% of the buffalo farms that implement the semi-intensive system operate at a decreasing return to scale. This condition shows that the farms exceed the optimal size limits.

Conclusion: The technical efficiency of buffalo farms may vary depending on various factors in the countries that apply semi-intensive feeding systems in buffalo farms.

Keywords: Anatolian buffalo, semi-intensive system, technical efficiency, Türkiye, Water buffalo farms

ÖZ

Amaç: Bu çalışmanın temel amacı yarı entansif sistemde faaliyet gösteren manda işletmelerinin etkin düzeyde çalışıp çalışmadığını belirlemektir.

Materyal ve Yöntem: Bu çalışmanın verileri Balıkesir ilindeki 102 manda yetiştiricisi ile yüz yüze gerçekleştirilen görüşmelerden elde edilmiştir. İncelenen manda işletmelerinin teknik etkinliğini belirlemek amacıyla Veri Zarflama Analizi (VZA), manda işletmelerinin teknik etkinliğini etkileyen faktörleri belirlemek amacıyla da Tobit regresyon modeli kullanılmıştır.

Araştırma Bulguları: Elde edilen bulgular hem saf teknik etkinlik (VRSTE: 0.668) hem de ölçek etkinliği (SE: 0.687) açısından manda işletmelerinin etkin düzeyde çalışmadığını ortaya koymaktadır. Saf teknik etkinlik skorlarına göre, manda işletmelerinin %23.53'ü tam etkinlik düzeyinde çalışmaktadır. Yarı entansif sistemi uygulayan manda işletmelerinin yaklaşık %90'ının ölçeğe göre azalan getiride çalışıyor olması bu işletmelerin optimal büyüklük sınırlarını aştığını göstermektedir.

Sonuç: Bu çalışmadaki bulgular, manda yetiştiriciliğinde yarı entansif besleme sistemi uygulayan ülkelerde manda işletmelerinin teknik etkinliğinin çeşitli faktörlere bağlı olarak değişebileceğini ortaya koymaktadır.

Anahtar sözcükler: Anadolu mandası, yarı entansif sistem, teknik etkinlik, Türkiye, manda çiftlikleri

INTRODUCTION

Water buffalo milk and water buffalo meat are considered important food source for the ever-increasing world population (El Debaky et al., 2019). It is possible to obtain high-quality milk and meat from water buffalo with poor-quality forages (Deb et al., 2016; Akdan et al., 2020). Buffalo farms are increasing both in Europe and other developing countries. This situation can be associated with the progressive saturation of the dairy market (Sabia et al., 2015).

According to the FAO data, there are approximately 204 million buffaloes in the world. These are in Asia (98%), Africa (0.8%), South America (0.9%), and Europe (0.2%). The world's leading countries in terms of the number of buffalos are India, Pakistan, China, Nepal, and Egypt. There are more buffaloes than dairy cows in Pakistan and Nepal. Water buffaloes in South Asia are the main source of milk. The world's leading countries in terms of buffalo milk production are India and Pakistan. Water buffalo farming is mostly carried out by mixed feeding systems in small-scale farms in developing countries. There are two subspecies of buffalo and these are river buffalo and swamp buffalo. Approximately 70% of world's buffalo population are river buffaloes (FAO, 2022).

There are differences between countries in terms of the buffalo feeding system. For example, the feeding system in Italy has changed from extensive to intensive farming (Sabia et al., 2015). Bangladesh's buffalo feeding system is both extensive and semi-intensive. The extensive feeding system is applied especially in coastal and hilly areas where there is large pasture land. In addition, the semi-intensive feeding system is applied on plain land and marshy land (Momin et al., 2016). The buffalo feeding systems in Sri Lanka, Iran, and Egypt are both extensive and semi-intensive (Borghese, 2010; Borghese, 2011; Vithanage et al., 2013; Mokhber et al., 2018; Abdel-Salam, 2019). Furthermore, buffaloes are raised under a semi-intensive system in Greece and Türkiye (Tsiobani et al., 2013; Degirmencioglu et al., 2015). It is stated that the buffalo feeding system differs from breed to breed. For example, the three main buffalo breeds in Iran are Azeri, Khuzestani and Mezandrani (Mokhber et al., 2018). Khuzestani breed can be raised outdoors throughout the year. Azeri and Mezandrani breeds are in buffalo sheds, especially in the autumn and winter seasons (Borghese, 2005; Mokhber et al., 2018).

Buffalo farming is generally under a semi-intensive system. There are studies that compare semi-intensive buffalo farming and other production systems. Momin et al. (2016) have investigated the performance characteristics of extensive and semi-intensive systems in Bangladesh. According to the findings, the system with the highest live weight and daily milk yield of buffaloes is a semi-intensive system. On the other hand, lactation length and lactation production are the highest under the extensive system. In addition, the profitability of an extensive system is higher than the semi-intensive system. Degirmencioglu et al. (2015) investigated the relationship between the feeding system and milk production in Anatolian water buffalo. The authors' findings revealed that semi-extensive feeding increased milk yield. This result is similar to the study conducted by Momin et al. (2016). Moreover, Degirmencioglu et al. (2015) explored that semi-intensive feeding reduced the fat ratio in milk. Liotta et al. (2015) investigated the effects of intensive and semi-intensive feeding systems on the quality and coagulation properties of buffalo milk in Sicily, Italy. According to the authors' findings, the average yield of milk and cheese and contents of protein and lactose were very similar between the feeding systems. The authors indicated that buffalo milk produced in intensive feeding showed good chemical composition and coagulation ability.

In the previous studies mentioned, some technical and economic results comparing the semi-intensive feeding system with other feeding systems are summarized. According to these results, there are advantages and disadvantages of semi-intensive system in buffalo farming compared to other feeding systems. It is possible to find more results comparing the technical aspects of buffalo feeding system in the previous studies. However, there are limited number of studies that examined the economic aspects of buffalo feeding system. No distinction was made between feeding systems in the previous studies examining the economic aspect of buffalo farming (Lambertz et al., 2012; Sweers et al., 2014; Singh et al., 2015; Vijayudu, 2015; Hasan et al., 2016; Işık & Gül, 2016; Popa et al., 2016; Roustemis et al., 2016; Islam et al., 2017; Gül et al., 2018; Gadhvi et al., 2021; Saner et al., 2022).

In order to evaluate the economic performance of buffalo farms according to their feeding systems, it is important to determine the efficiency as well as the profitability of the buffalo farms. Indeed, it can be said that there are a limited number of studies examining the efficiency of buffalo farms. These studies were conducted in Türkiye (Kaygısız et al., 2018), Sri Lanka (Malcolm et al., 2019), Philippines (Cuevas & Mina, 2022), and Nepal (Dhakal, 2022). Nevertheless, no distinction was made between feeding systems in these studies. The aim of this study is to reveal the efficiency of buffalo farms according to feeding systems. In this context, the results of a field study from Türkiye, which is one of the main buffalo milk producing countries in the world, were shared. According to the data of 2021, obtained from the TURKSTAT, there are 185574 buffaloes in Türkiye. The number of buffaloes in Türkiye has increased by 90% (97632 buffaloes) from 2011 to 2021 (TURKSTAT, 2022). After Italy, Türkiye is the second country in terms of buffalo milk production in the continent of Europe (Pantoja et al., 2022). According to the data of 2020, obtained from the FAO, the buffalo milk production in Italy and Türkiye are 253830 tonnes and 77781 tonnes, respectively (FAOSTAT, 2022). The buffaloes in Turkey are in the European buffalo group, which is called the Mediterranean Buffalo, and all of these are river buffaloes (Soysal et al., 2007; Sabia et al., 2015; Hamid et al., 2016; Yılmaz & Kara, 2019). The buffalo breed of Turkey is called the Anatolian Buffalo. The main regions where the Anatolian water buffalo are raised in Turkey are Black Sea, Marmara, Eastern Anatolia, and Central Anatolia, respectively (Ermetin, 2017).

The strategic question in this study is determined as “Are semi-intensive buffalo farms operating efficiently?” Specific research questions are listed below:

- Is there a difference between small, medium, and large buffalo farms in terms of total technical efficiency, pure technical efficiency, and scale efficiency?

What are the main factors that determine the pure technical efficiency of buffalo farms?

MATERIALS and METHOD

The findings in this study are based on primary data collection, including face-to-face surveys with buffalo breeders in Altıeylül and Gönen districts of Balıkesir province. The high number of buffaloes and the intensive production of buffalo milk were effective in the selection of these districts. A view of the buffalo herd crossing the river in the research area is depicted in Figure 1.

Figure 1. A view of the buffalo herd in the research area (Balıklı village, Altıeylül-Balıkesir).

Şekil 1. *Araştırma alanındaki manda sürüsünden bir görünüm.*

The surveys were conducted with buffalo breeders who were members of Balıkesir Water Buffalo Breeders Association in the research area in the period of 2016-2017. The study was conducted on the full count method and interviews were carried out with 102 buffalo breeders.

A semi-structured questionnaire was used to obtain information related to the demographic characteristics of farmers, structural characteristics, production technique, input costs, and outputs of water buffalo farms, and the knowledge and behavior of farmers on various subjects (production technique, marketing, support, etc.).

Measuring the technical efficiency of water buffalo farms

Data envelopment analysis (DEA) was used to determine the efficiency of water buffalo farms. DEA is widely used to measure the efficiency of production units. This nonparametric approach measures technical efficiency estimators as optimal solutions to problems. A non-parametric frontier is defined, and the efficiency of each DMU relative to that frontier is measured via DEA (Theodoridis et al., 2012).

Each decision-making unit's efficiency score is calculated based on an efficiency frontier. Decision-making units on the upper-efficiency frontier have an efficiency score of 1. Decision-making units below the efficiency frontier have an efficiency score of less than 1. This means that it is necessary to improve the future performance of these DMUs in terms of capacity. Two main models are used in DEA. One of these models is the assumption of constant returns to scale (CRS). The CRS model is considered appropriate when all DMUs operate at an optimal scale. However, this rarely happens. An efficiency score called constant returns to scale technical efficiency (CRSTE) is calculated in the CRS model. CRS efficiency is also named total efficiency. The second model is the assumption of variable return to scale (VRS). The VRS model is considered appropriate when DMUs don't operate at an optimal scale. In this approach, it is assumed that DMUs are often met with imperfect competition, government regulation, etc. Variable return to scale technical efficiency (VRSTE), which is an efficiency score, is calculated in the VRS model. VRS efficiency is also named pure technical efficiency (Ishizaka & Nemery, 2013). The efficiency of buffalo farms was calculated for both models (CRSTE and VRSTE) of DEA in this study.

The DEA model can be input or output oriented. The technical efficiency scores of the buffalo farms were calculated by the output-oriented model in this study. The output is maximized for a given input level in an output-oriented model. In other words, it shows how much a DMU can increase its output at a given input level (Ishizaka & Nemery, 2013). There are some reasons for using the output-oriented model in this study. It is very difficult for buffalo farms in the research area to keep under control ever-increasing input costs, especially for feed. By improving the production technique in buffalo farms, it is possible to maximize outputs. For example, farmers who can graze their buffaloes in the pasture are more likely to achieve a higher milk yield than those who do not.

An output-oriented VRS model is represented by the following formula (1) (Coelli, 1996):

$$\begin{aligned} & \max_{\phi,\lambda} \phi, \\ & \text{st} \quad -\phi y_i + Y\lambda \geq 0, \\ & \quad x_i - X\lambda \geq 0, \\ & \quad N1'\lambda = 1 \\ & \quad \lambda \geq 0, \qquad (1) \end{aligned}$$

The Y and the X in the formula indicate the outputs and inputs of the sample, respectively, and y_i and x_i indicate the outputs and inputs of the i-th farm, respectively. N is a vector of 1, and λ is a parameter matrix (Fogarasi & Latruffe, 2009). The ϕi, represents the proportional increase in the possible output of the i-th farm (or i-th DMU) (Theodoridis et al., 2012). $1/\phi$ defines the technical efficiency score, which varies between 0 and 1 (Coelli, 1996).

The gross production value of buffalo farms is defined as the output variables for analysis. The sale of animal products (buffalo milk, buffalo cream and meat, etc.), calf value, productive value increase, and manure value are used to calculate the gross production value. Calf value indicates 0-6 months calves, and productive value increase indicates the increases due to the growth of animals. The input variables used in the analysis are the number of buffalos per farm in terms of livestock units, feed, labor, veterinary, and other variable costs. Descriptive statistics for the output and input variables are tabulated in Table 2.

In addition, the scale efficiency (SE) of buffalo farms was determined in this study. A measure of scale efficiency can be obtained by comparing the CRSTE and VRSTE scores (Madau et al., 2017). If there is a difference between the two technical efficiency scores (CRSTE and VRSTE) of a specific DMU, this indicates that the DMU has scale inefficiency (Coelli, 1996). The scale efficiency of the i-th farm is calculated by the following formula (2) (Theodoridis et al., 2012):

$$SE_i = \frac{TE_i^{CRS}}{TE_i^{VRS}} \quad (2)$$

If SE_i=1, there is a constant return to scale. This means that the farm is operating at an optimal (or effective) scale (Ishizaka & Nemery, 2013). If SEi<1, there is scale inefficiency. Scale inefficiency results from increasing or decreasing returns to scale (Theodoridis et al., 2012).

The efficiency of water buffalo farms was analyzed according to their size. Thus, it was determined whether there is a difference in terms of efficiency scores according to the size of the farms. Buffalo farms were classified into three groups according to their size (small, medium, and large farms) 1-10 head of buffaloes (36 farms), 11-20 head of buffaloes (33 farms), and 21 and above head of buffaloes (33 farms) in the analysis of the data.

Determinants of technical efficiency of water buffalo farms

Tobit regression model was used to determine the factors affecting the technical efficiency of the buffalo farms. The Tobit regression model is used when limited dependent variables are involved. The fact that the technical efficiency scores obtained by DEA were between 0 and 1 was effective in the use of this model. The Tobit regression model, which is also known as the censored regression model, is widely used to determine the relationship between technical efficiency scores and other factors (Gonçalves et al., 2008; Ahmed et al., 2020).

A limited dependent variable Tobit regression model is written as (Gonçalves et al., 2008):

$$y_i^* = X_i\beta + \varepsilon_i \quad (3)$$

The y_i* in the formula is a latent variable. The X_i represents a vector of explanatory variables. The β is the parameter to be estimated. The errors are assumed to be normally distributed with zero mean and σ^2 variance.

The observed censored variable representing efficiency scores is defined as shown below (4) (Cecchini et al., 2021):

$$y_i = \begin{Bmatrix} y_i^* \ if \ 0 < y_i^* < 1 \\ 1 \ if y_i^* \geq 1 \\ 0 \ if y_i^* \leq 0 \end{Bmatrix} \quad (4)$$

The variables included in the Tobit regression model are shown in Table 1. The dependent variable value in the model represents the pure technical efficiency score ranging from 0 to 1.

The independent variables of the model are age, education, producer experience in buffalo farming, size of farmland, number of buffalo per farm in livestock unit (head), production system (buffalo-only or mixed), status of producer participation in buffalo farming training, status of producer membership in buffalo breeders association, status of benefiting from support by producers, feed, labor, veterinary, and other variable costs, and grazing time per livestock unit.

Table 1. Variable description

Çizelge 1. *Değişkenlere ilişkin açıklama*

Variables	Description	Category
Dependent variable		
PTE	the scores of pure technical efficiencies	continuous
Explanatory variables		
age	age of water buffalo farmers (years)	continuous
edu	water buffalo farmers' education level (years)	continuous
exp	water buffalo farming experience (years)	continuous
landsize	land size (hectares)	continuous
head	the number of heads of water buffalo (Livestock Units (LU))	continuous
prosystem	1=if farmers raise only water buffalo; 0= farmers are involved in mixed livestock	dummy
training	1=farmers had received training on buffalo farming; 0= otherwise	dummy
membassoc	Membership of the Balıkesir Water Buffalo Breeders Association (1=if yes; 0= otherwise)	dummy
subsidize	1=if farmers benefit from government subsidy programs; 0= otherwise	dummy
feed	feed costs of water buffalo per LU (TRY*)	continuous
labor	labor costs of water buffalo per LU (TRY)	continuous
vet	veterinary costs of water buffalo per LU (TRY)	continuous
other	other costs of water buffalo per LU (TRY)	continuous
Grazing	grazing frequency (monthly)	continuous

RESULTS

In addition to buffalo farming, 97% of producers in the study area are engaged in vegetable production, 62.80% in cattle farming, 13.70% in sheep farming and 11.80% in poultry farming.

The number of animals per farm was found to be 27.68 LU. According to the average of farms, the number of buffaloes per farm is 14.35 LU. Accordingly, water buffalo account for 51.84% of the total livestock. Number of buffalos per farm in small, medium, and large farms: 4.27, 9.81 and 29.87, respectively

The average agricultural land owned by the buffalo farmers is 5.67 ha. This land size is in small, medium, and large farms respectively: 3.80 ha, 5.52 ha and 7.85 ha. Silage corn, wheat, oats, alfalfa, rice, and barley are grown on about 91% of the acreage in buffalo farms where crop production is practised. The most grown product is corn for silage.

The average household size in the studied buffalo farms was 5.18 persons. The household size in small, medium and large buffalo farms was 4.67, 5.35, and 5.59 persons, respectively. The proportion of the male and female population is close in all farm groups. In general, the proportion of male and female population per farm is 2.67 and 2.51, respectively. 45.90% of the labor force used in buffalo farming is foreign labor force and 54.11% is the family labor force. 26.10% of the family labor force is used for buffalo activities.

Buffalo farms produce various buffalo products such as milk, yoghurt, cheese, cream, meat and fertiliser. Buffalo cream is the most produced product after milk. During the production period, buffaloes that are to be removed from the herd are usually sold at the slaughterhouse or butcher. Although few in the study area, there are also producers who sell buffalo meat to local food companies for sausage production.

Descriptive statistics on output and input variables used to determine buffalo farm efficiency are presented in Table 2 by farm size. Table 2 shows a statistically significant difference between farm sizes in terms of outputs and inputs. Outputs and inputs increase as the farm size increases.

Table 2. Descriptive statistics on variables used in efficiency analysis of water buffalo farms

Çizelge 2. *Manda işletmelerinin verimlilik analizinde kullanılan değişkenlere ilişkin tanımlayıcı istatistikler*

Efficiency measures	Small		Medium		Large		Total		Kruskal Wallis test p value
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Output									
GPV	26693.21	14880.42	40430.58	19283.37	117974.19	80395.07	60669.74	62133.55	0.000*
Inputs									
head (LU)	4.27	1.46	9.81	2.66	29.87	14.38	14.35	13.79	0.000*
feed cost	10738.75	11898.24	27382.87	28072.27	58252.03	36903.43	31495.56	33514.56	0.000*
labor cost	11998.51	14736.03	9870.89	7744.87	20443.27	13174.04	14042.29	13030.88	0.000*
vet. cost	262.44	355.90	473.18	764.49	1556.97	2186.00	749.44	1437.22	0.000*
other cost	2579.58	2963.38	3485.69	3283.81	10496.54	12013.71	5434.10	8044.01	0.000*

* denotes statistical significance at the level of 5%.

Note: Turkish Lira (TRY) is the unit of GPV and input costs. 1 US Dollar to Turkish Lira Exchange Rate for May 2016: 1 USD = 2.9266 TRY) (CBRT, 2016).

Three efficiency measures were calculated for the buffalo farms depending on the size of the farms. These calculated efficiency measures are technical efficiency assuming constant returns to scale (total efficiency), technical efficiency assuming variable returns to scale (pure technical efficiency), and scale efficiency. The values of the calculated efficiency measures are listed in table 3.

Table 3. Measures of efficiency by size of water buffalo farms

Çizelge 3. *Manda işletmelerinin büyüklüğüne göre etkinlik değerleri*

Efficiency measures	Small		Medium		Large		Total		Kruskal Wallis test p value
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Technical efficiency (CRSTE)	0.463	0.259	0.467	0.264	0.461	0.241	0.463	0.252	0.996 (>0.05)
Pure technical efficiency (VRSTE)	0.667	0.283	0.624	0.257	0.714	0.266	0.668	0.269	0.427 (>0.05)
Scale Efficiency (SE)	0.687	0.186	0.730	0.218	0.644	0.192	0.687	0.200	0.268 (>0.05)

The technical efficiency of buffalo farms assuming constant returns to scale was reported to be 0.463 on average. This result means that buffalo farms can reach the full efficiency level if they increase their output (gross production value) by 53.70% without changing their current input use and production technique. In other words, buffalo farms are at a weak level in terms of total technical efficiency value and need to improve their production. According to the Kruskal-Wallis test, under the assumption of constant returns to scale, there is no statistically significant difference between firm sizes in terms of technical efficiency score. The values for total technical efficiency in small, medium, and large enterprises are 0.463, 0.467 and 0.461, respectively.

According to the result of pure technical efficiency, the average efficiency of buffalo farms was calculated as 0.668. Accordingly, if buffalo farms can increase their output by 33.20% without changing their current input use and production technique, they can reach the full efficiency. Large buffalo farms have higher values for pure technical efficiency than small and medium farms. However, according to the Kruskal-Wallis test, there is no statistically significant difference between farm sizes in terms of pure technical efficiency. The values for pure technical efficiency in small, medium, and large farms are 0.667, 0.624 and 0.714, respectively.

The average efficiency of buffalo farms was found to be 0.687. According to this result, if buffalo farms reach the optimal size by improving their production scale, they can operate at full efficiency if they increase their output by 31.30%. According to the Kruskal-Wallis test, there is no statistically significant difference between farm sizes in terms of scale efficiency values. The values for scale efficiency in small, medium, and large farms are 0.687, 0.730 and 0.644, respectively.

The frequency distribution of buffalo farms by total technical efficiency score is shown in Table 4. In general, the proportion of small buffalo farms with a total efficiency score of 0.25 is 27.45% and the proportion of farms with a total efficiency score between 0.26 and 0.50 is 39.22%. This result shows that about 67% of buffalo farms have an efficiency score of 0.50 and below when considering total technical efficiency. In other words, assuming constant returns to scale, two-thirds of buffalo farms do not operate effectively enough. According to the total technical efficiency score, the proportion of buffalo farms operating at full efficiency is 4.90%. According to the Pearson chi-square test, there is no statistically significant difference between the sizes of buffalo farms in terms of the frequency distribution of the total efficiency scores.

Table 4. The distribution of water buffalo farms by total technical efficiency scores

Çizelge 4. *Manda işletmelerinin toplam teknik etkinlik skorlarına göre dağılımı*

Frequency distribution	Small		Medium		Large		Total		Pearson Chi-square p-value
	Number of farms	%	Number of farms	%	Number of farms	%	Number of farms	%	
≤0.25	8	22.22	12	36.36	8	24.24	28	27.45	0.551 (>0.05)
0.26-0.50	17	47.22	10	30.30	13	39.39	40	39.22	
0.51-0.75	5	13.89	5	15.15	7	21.21	17	16.67	
0.76-0.90	2	5.56	3	9.09	4	12.12	9	8.82	
0.91-0.99	2	5.56	-	-	1	3.03	3	2.94	
1.00	2	5.56	3	9.09	-	-	5	4.90	
Total	36	100.00	33	100.00	33	100.00	102	100.00	

The frequency distribution of buffalo farms by pure technical efficiency is shown in Table 5. The results show that about 74% of buffalo farms are clustered in three frequency ranges. These frequency ranges can be indicated as 0.26-0.50 (25.49%), 0.51-0.75 (24.51%), and 1.00 (23.53%). Accordingly, 23.53% of Buffalo farms operate at full efficiency. The percentage of farms with pure technical efficiency of 0.50 and below is more than 30%. The results of Pearson chi-square test showed that there is no statistically significant difference between the sizes of buffalo farms in terms of frequency distribution of pure technical efficiency values.

Table 5. The distribution of water buffalo farms by pure technical efficiency scores

Çizelge 5. *Manda işletmelerinin saf teknik etkinlik skorlarına göre dağılımı*

Frequency distribution	Small		Medium		Large		Total		Pearson Chi-square p-value
	Number of farms	%	Number of farms	%	Number of farms	%	Number of farms	%	
≤0.25	3	8.33	2	6.06	1	3.03	6	5.88	0.530 (>0.05)
0.26-0.50	8	22.22	9	27.27	9	27.27	26	25.49	
0.51-0.75	9	25.00	11	33.33	5	15.15	25	24.51	
0.76-0.90	5	13.89	3	9.09	8	24.24	16	15.69	
0.91-0.99	1	2.78	3	9.09	1	3.03	5	4.90	
1.00	10	27.78	5	15.15	9	27.27	24	23.53	
Total	36	100.00	33	100.00	33	100.00	102	100.00	

The frequency distributions of the studied buffalo farms according to the returns to scale are presented in Table 6. According to this, 89.22% of buffalo farms face decreasing returns to scale. This result shows that the majority of buffalo farms are already overscaled. In other words, most buffalo farms have exceeded the optimal size. This means that the majority of buffalo farms spend more on the inputs to produce the same output. To reduce the average total cost of buffalo farms under these conditions, the size (or scale) of these farms should be reduced.

The proportion of buffalo farms operating at decreasing returns to scale is 83.33%, 84.85%, and 100% for small, medium, and large farms, respectively. From these ratios, it can be seen that all large buffalo farms and a significant proportion of small and medium buffalo farms operate with decreasing returns to scale. The results of the Pearson chi-square test showed that there is no statistically significant difference between the sizes of buffalo farms in terms of the frequency distribution of returns to scale.

The percentage of buffalo farms operating at increasing returns to scale is 5.88%. This result shows that 5.88% of buffalo farms have not yet reached the optimal size. These farms need to increase their size to reduce their average total cost. Farms operating at increasing returns to scale are only included in small and medium farm groups. The percentage of these farms in small and medium farms is 11.11% and 6.06%, respectively.

Table 6. Frequency distributions of returns to scale by size of water buffalo farms

Çizelge 6. *Manda işletmelerinin büyüklüğüne göre ölçeğe göre getirilerin sıklık dağılımları*

Returns to scale	Small		Medium		Large		Total		Pearson Chi-square p-value
	Number of farms	%	Number of farms	%	Number of farms	%	Number of farms	%	
Constant returns to scale	2	5.56	3	9.09	-	-	5	4.90	0.131 (>0.05)
Decreasing returns to scale	30	83.33	28	84.85	33	100.00	91	89.22	
Increasing returns to scale	4	11.11	2	6.06	-	-	6	5.88	
Total	36	100.00	33	100.00	33	100.00	102	100.00	

The descriptive statistics of the variables used in the Tobit regression model are presented in Table 7. The value of pure technical efficiency, which is the dependent variable in the model, averages 0.67, with this value varying between 0.11 and 1. The average age of buffalo breeders is 45.89 years. The age range of producers varies from 26 to 74 years. The average education period of buffalo breeders is 6.58 years. The average period of education for producers is lowest at 5 years and highest at 15 years. Producer experience ranges from 1 to 55 years, with an average of 19.47 years.

The average agricultural area of buffalo farmers is 5.67 ha. This land size varies between 0.50 and 20 ha. The number of buffaloes per farm expressed as a livestock unit, ranges from 0.60 to 82.45 LU, with an average of 14.35 LU. In 36% of the farms surveyed, only buffalo breeding is practiced, and mixed animal breeding is practiced in 64% of farms. It has been noted that in mixed livestock farms, cattle and small ruminants are raised together along with buffalo. Regarding the participation of producers in training on buffalo breeding, it shows that only 21% of producers have attended training on this topic. The level of the professional organization of the water buffalo breeders surveyed was found to be high. Thus, 75% of producers were found to be members of the Balıkesir Province Buffalo Breeders Association. 95% of buffalo farmers declared they benefit from government support programs.

The feed, labor, veterinary, and other variable costs of the buffalo farmers surveyed are 2451.16 TRY (US$ 837.55), 1539.35 TRY (US$ 525.99), 59.03 TRY (US$ 20.17), and 467.50 TRY (US$ 159.74) per LU, respectively. According to these values, feed costs represent the highest cost factor for buffalo breeders. The pasture grazing period of the buffaloes raised by the interviewed producers varies from 3 to 12 months, with an average of 9.63 months.

Table 7. Descriptive Statistics of Variables

Çizelge 7. *Değişkenlerin tanımlayıcı istatistikleri*

Variables	Mean	SD	Min	Max
Dependent variable				
PTE	0.67	0.27	0.11	1.00
Explanatory variables				
age	45.89	12.18	26.00	74.00
edu	6.58	2.33	5.00	15.00
exp	19.47	12.22	1.00	55.00
lansize	5.67	4.12	0.50	20.00
head	14.35	13.79	0.60	82.45
prosystem	0.36	0.48	0.00	1.00
training	0.21	0.41	0.00	1.00
membassoc	0.75	0.44	0.00	1.00
subsidize	0.95	0.22	0.00	1.00
feed	2451.16	2091.54	284.67	11547.62
labor	1539.35	1891.80	202.90	14225.19
vet	59.03	91.54	0.00	568.18
other	467.50	518.26	41.28	3037.14
Grazing	9.63	2.07	3.00	12.00

Table 8 presents the Tobit regression model estimates showing the effects of the explanatory variables on buffalo breeding enterprises. Before interpreting the results of the Tobit model, the goodness of fit of the model was examined. For this purpose, the probability value (p) of the LR test (the likelihood ratio Chi-Square test) was examined. The probability value (p-value of the LR test) of the LR test is 0.0052. Since the probability value is less than 0.05, the H_0 hypothesis was rejected. This means that the explanatory variables in the model have the power to explain the dependent variable.

According to the results of the Tobit model, there is a statistically significant relationship between training, producer participation in training on buffalo breeding, feed per LU and veterinary costs, grazing time on pasture, and efficiency scores of buffalo breeders. On the other hand, age, producer experience in buffalo farming, size of farmland, number of buffaloes per farm in livestock units (head), production system, status of producer membership in buffalo breeders' association, status of benefiting from support given to water buffalo breeders, labor per LU, and other variables costs do not have a statistically significant effect on buffalo breeders' efficiency scores.

The results of the model show that there is a positive relationship between education and efficiency scores of buffalo breeders. In other words, an increase at education level results in the efficiency of the buffalo breeders also increases. When the education duration of buffalo breeders increases by one year, the efficiency also increases by about 0.03 units. This result confirms our hypothesis for the relationship between education and efficiency of buffalo breeders.

Table 8. Tobit regression model estimates of influential factors affecting output oriented efficiency scores of buffalo breeders

Çizelge 8. *Manda yetiştiricilerinin çıktıya yönelimli etkinlik skorlarını etkileyen faktörlere yönelik Tobit regresyon modeli tahminleri*

Explanatory variables	Coef.	Std. Err.	t	P>t	[95% Conf. Interval]	
age	0.0039188	0.0028703	1.37	0.177	-0.0018058	0.0096434
edu	0.0286345	0.0139140	2.06	0.043*	0.0008838	0.0563852
exp	-0.0006528	0.0029640	-0.22	0.826	-0.0065643	0.0052587
landsize	0.0052968	0.0074188	0.71	0.478	-0.0094994	0.0200931
head	-0.0002696	0.0022489	-0.12	0.905	-0.0047550	0.0042157
prosystem	0.0377465	0.0667515	0.57	0.574	-0.0953852	0.1708781
training	0.1190464	0.0693144	1.72	0.090**	-0.0191968	0.2572896
membassoc	0.0583551	0.0608530	0.96	0.341	-0.0630124	0.1797226
subsidize	0.1319394	0.1298642	1.02	0.313	-0.1270666	0.3909454
feed	-0.0000391	0.0000134	-2.92	0.005*	-0.0000658	-0.0000124
labor	0.0000015	0.0000149	0.10	0.919	-0.0000281	0.0000311
vet	-0.0005448	0.0003200	-1.70	0.093**	-0.0011831	0.0000935
other	0.0000149	0.0000566	0.26	0.793	-0.0000980	0.0001279
grazing	0.0454649	0.0134418	3.38	0.001*	0.0186560	0.0722738
_cons	-0.2427327	0.2568489	-0.95	0.348	-0.7550016	0.2695362
/sigma	0.2298585	0.0179174			0.1941233	0.2655936
Number of obs	84					
Log likelihood	2.6756506					
LR chi2(14)	31.22					
Prob > chi2	0.0052					
Pseudo R2	1.2069					

*and ** denote statistical significance at the level of 5% and 10%, respectively.

The fact that producers participate in training on buffalo breeding also increases their efficiency. The efficiency score of producers who participate in a training program on buffalo breeding is about 0.12 units higher than those who do not participate. This result also confirms our hypothesis for the relationship between farmers' participation in buffalo breeding training and their efficiency scores.

There is a statistically significant and negative relationship between the feed cost per LU of buffalo breeders and their efficiency scores. When buffalo breeders' feed costs increase by 1 TL(Turkish Lira), their efficiency score decreases by 0.0000391 units. This result also confirms our hypothesis that buffalo breeders' efficiency scores decrease due to the increase in feed costs.

According to the results of the Tobit model, a negative and statistically significant relationship was found between buffalo farmers' veterinary costs and their efficiency scores. When the veterinary costs of buffalo farmers increase by 1 TL, the efficiency value decreases by 0.0005448 units. According to this result, the increase in veterinary costs has a negative effect on the efficiency of water buffalo breeders. This result also confirms our hypothesis between the two variables.

A positive and statistically significant relationship was found between the grazing time of buffalo breeders and their efficiency scores. When the grazing period of buffalo breeders increases by 1 month, the efficiency score also increases by 0.045 units. This result also confirms the hypothesis we predicted in the Tobit model. Increased use of pasture by livestock producers in both buffalo and other livestock activities is thought to be important in reducing feed costs. In fact, feed costs are the most important variable cost element in livestock production.

DISCUSSION

The average technical efficiency of buffalo farms was 0.868 (86.8%) in Sri Lanka (Malcolm et al., 2019) and 0.505 (50.5%) in the Philippines (Cuevas & Mina, 2022). The average technical efficiency score (CRSTE: 0.463; VRSTE: 0.668) of buffalo farms in this study is similar to the Philippines in terms of constant returns to scale (total technical efficiency). Sri Lanka and the Philippines are Asian countries where a semi-intensive feeding system is common in buffalo farming (Wahid & Rosnina, 2011). However, there is a significant difference between the values of technical efficiency of buffalo farms in the two countries. This result shows that the technical efficiency of water buffalo farms in countries that use a semi-intensive feeding system in buffalo farming may depend on several factors. The buffalo breed, location, climatic conditions, and the intensity of free grazing in the feeding system are some of these important factors.

In a study conducted by Dhakal (2022) in Nepal, it was found that 57% of buffalo farms had a technical efficiency between 30-60%. On the other hand, in the study conducted by Malcolm et al. (2019) in Sri Lanka, it was found that the majority of water buffalo breeders had technical efficiency in the 90-100% category. The distribution of technical efficiency scores for the buffalo farms in this study is similar to Nepal compared to Nepal and Sri Lanka. According to the total technical efficiency rating, about 56% of the water buffalo farms studied are in the 26-75% category. In terms of pure technical efficiency, the share of buffalo farms in the same category is 50%. The frequency distribution of buffalo farm technical scores in different categories in previous studies makes the comparison difficult between countries. However, it is noteworthy that the buffalo farms in Sri Lanka operate with quite high technical efficiency.

In previous studies, analyzes were conducted to determine the factors that determine the technical efficiency of buffalo farms. According to Cuevas & Mina's (2022) study in the Philippines, a positive relationship was found between membership in agricultural cooperatives and length of farming experience and technical efficiency of buffalo farms. Dhakal (2022) in his study in Nepal found that investment in buffalo dairy farms and training of producers positively influenced technical efficiency. In this study, similar to Dhakal (2022), a positive relationship was found between farmer participation in buffalo breeding training and farm technical efficiency. Kaygısız et al. (2018) found a negative relationship between labor costs and technical efficiency of buffalo farms in another region of Turkey (Istanbul-Çatalca). In the region where this study was conducted (Balıkesir), feed costs were found to have a statistically significant and negative impact on the technical efficiency of buffalo farms.

CONCLUSION

The results of this study are expected to make a significant contribution to the literature to determine whether buffalo farming in the semi-intensive system is effective. Three efficiency measures were calculated for the buffalo farms depending on the size of the farms. The technical efficiency of buffalo farms assuming constant returns to scale was reported to be 0.463 on average. The values for total technical efficiency in small, medium, and large enterprises are 0.463, 0.467 and 0.461, respectively. According to the result of pure technical efficiency, the average efficiency of buffalo farms was calculated as 0.668. The values for pure technical efficiency in small, medium, and large farms are 0.667, 0.624 and 0.714, respectively. The average efficiency of buffalo farms was found to be 0.687. The values for scale efficiency in small, medium, and large farms are 0.687, 0.730 and 0.644, respectively.

The results show that buffalo farms are not effective in terms of both pure technical efficiency and scale efficiency. The fact that about 90% of buffalo farms using the semi-intensive system operate with decreasing returns to scale indicates that these farms exceed the limits of optimal size. This result can also be interpreted to mean that a significant proportion of buffalo farms are spending more on the input variables they use to achieve their current outputs. Given this situation, it is necessary to bring farms closer to the limits of optimal size to reduce the average total costs of buffalo farms operating with decreasing returns to scale.

Other variable costs, especially feed, are expected to be high in buffalo farms that exceed the optimal size. This increases the average cost of buffalo farms. In fact, the tobit regression analysis conducted in this study found a significant and negative relationship between pure technical efficiency of buffalo farms and feed and veterinary costs. The increase in feed and veterinary costs decreases the pure technical efficiency of buffalo farms.

The results of this study also show that bringing farms to the optimal size is not enough to increase the efficiency of buffalo farms. The results of the Tobit regression analysis showed that both breeder education and buffalo grazing time were among the determinants of pure technical efficiency of buffalo breeding farms. The fact that producers participate in training on buffalo breeding and the increase of buffalo grazing time on pasture have a positive effect on the pure technical efficiency of buffalo breeding farms. In terms of both technical and marketing knowledge, it is important for producers to participate in various training programs to reduce production costs and achieve high product output. In addition, increasing grazing density in semi-intensive feeding has a significant effect on reducing costs.

In this study, the technical efficiency of buffalo farms under a semi-intensive feeding system was investigated. However, further studies are needed to show the effects of various factors on the efficiency of buffalo farms. These studies are expected to consider the buffalo breed, location, climatic conditions, and intensity of grazing in the feeding system to find out how these factors affect the efficiency of buffalo farming. Today, some difficulties are mentioned for many livestock farms, including buffalo farming. In this context, there are some important expectations for livestock farms, such as reducing greenhouse gas emissions, ensuring animal welfare, requiring less intensive production and stable production (EIP-AGRI, 2019). Realizing these expectations is necessary to increase the durability and profitability of buffalo farms. In this context, there is a need for future studies that will allow us to understand how sustainable water buffalo farming is reflected in farm efficiency.

ACKNOWLEDGEMENTS

The authors thank Ege University Scientific Research Projects Coordination Unit for its financial support. In addition, the authors wish to thank the members of the Balıkesir Water Buffalo Breeders Association for their assistance and participation during the data gathering.

REFERENCES

Abdel-Salam, S.A.M., 2019. Characterization of buffalo dairy production systems in Egypt using cluster analysis procedure. Journal of Buffalo Science, 8: 13-19.

Ahmed, O., S. Abdel-Salam & S. Rungsuriyawiboon, 2020. Measuring the economic performance of mixed crop-livestock farming systems in Egypt: A non-parametric DEA approach. New Medit, 19: 133-145.

Akdan, C., Ö. Kınık & F. İçier, 2020. Manda Sütü ve Diğer Süt Karışımlarıyla Üretilen Kefirlerin Bazı Özelliklerinin Belirlenmesi. E.Ü Ziraat Fakültesi Dergisi, Özel Sayı: 39-50.

Borghese, A., 2005. Buffalo Production and Research. REU Technical Series 67, 316 pp.

Borghese, A., 2010. Development and perspective of buffalo and buffalo market in Europe and Near East. Revista Veterinaria, 21: 20-31.

Borghese, A., 2011. Situation and perspectives of buffalo in the World, Europe and Macedonia. Macedonian Journal of Animal Science, 1: 281-296.

CBRT, 2016. Turkish Central Bank exchange rates: 1 US Dollar to Turkish Lira exchange rate for May 2016. (Web page: https://evds2.tcmb.gov.tr/index.php) (Date accessed: September, 2022).

Cecchini, L., L. Vieceli & A. D'Urso, 2021. Farm efficiency related to animal welfare performance and management of sheep farms in marginal areas of Central Italy: A two-stage DEA model. Italian Journal of Animal Science, 20: 955-969.

Coelli, T.J., 1996. A guide to DEAP Version 2.1: A data envelopment analysis (computer) program. CEPA Working Paper 96/08, Department of Econometrics, University of New England, Armidale, Australia, 49 pp.

Cuevas, A.C. & C.S. Mina, 2022. Impact of cooperative membership on technical efficiency and marketing efficiency: The case of dairy buffalo farmers in the Philippines. DLSU Business & Economics Review, 31: 137-145.

Deb, G.K, T.N. Nahar & P.G. Duran, 2016. Safe and sustainable traditional production: The water buffalo in Asia. Frontiers in Environmental Science, 4: 1-7.

Degirmencioglu, T., H. Unal & H. Kuraloglu, 2015. Comparison of extensive or semi-intensive feeding for Anatolian water buffalo. Emirates Journal of Food and Agriculture, 27: 712-715.

Dhakal, S.C., 2022. Determinants of technical efficiency among dairy farms in Chitwan, Nepal. Journal of Agriculture and Forestry University, 5: 149-156.

EIP-AGRI, 2019. Sustainable livestock farming (Brochure). (Web page: https://ec.europa.eu/eip/agriculture/sites/default/files/ eipagri_brochure_sustainable_livestock_2019_en_web.pdf) (Date accessed: October, 2022)

El Debaky, H.A., N.A. Kutchy & A. Ul-Husna, 2019. Potential of water buffalo in world agriculture: Challenges and opportunities. Applied Animal Science, 35: 255-268.

Ermetin, O., 2017. Husbandry and sustainability of water buffaloes in Turkey. Turkish Journal of Agriculture - Food Science and Technology, 5: 1673-1682.

FAO, 2022. Buffaloes. (Web page:https://www.fao.org/dairy-production-products/production/dairy-animals/buffaloes/en/) (Date accessed: September, 2022).

FAOSTAT, 2022. Crops and livestock products: Raw milk of buffalo. (Web page: https://www.fao.org/faostat/en/#data/QCL) (Date accessed: October, 2022).

Fogarasi, J. & L. Latruffe, 2009. Technical efficiency in dairy farming: A comparison of France and Hungary in 2001-2006. Studies in Agricultural Economics, 110: 75-84.

Gadhvi, D.N., L.M. Sorathiya & A.L. Rathva, 2021. Comparative profitability analysis of specialized cattle and buffalo farms. Agricultural Science Digest, D-5354: 1-5.

Gonçalves, R.M., W. da Cruz Vieira & J.E. de Lima, 2008. Analysis of technical efficiency of milk producing farms in Minas Gerais. Economia Aplicada, 12: 321-335.

Gül, M., M.G. Akpinar & Y. Tascioğlu, 2018. Economic analysis of buffalo breeding in Turkey. Custos e @gronegócio on line, 14: 305-335.

Hamid, M.A., S. Ahmed & M.A. Rahman, 2016. Status of buffalo production in Bangladesh compared to SAARC countries. Asian Journal of Animal Sciences, 10: 313-329.

Hasan, T., S. Akter & H. Biswas, 2016. Economic analysis of small scale dairy buffalo enterprises in Bhola district of Bangladesh. Progressive Agriculture, 27: 502-510.

Ishizaka, A. & P. Nemery, 2013. Multi-Criteria Decision Analysis. Wiley, UK, 296 pp.

Işık, M. & M. Gül, 2016. Economic and social structures of water buffalo farming in Muş province of Turkey. Revista Brasileira de Zootecnia, 45: 400-408.

Islam, S., T.N. Nahar, J. Begum, G.K. Deb, M. Khatun & A. Mustafa, 2017. Economic Evaluation of Buffalo Production in Selected Regions of Bangladesh. Journal of Stock & Forex Trading, 6: 177. https://doi.org/10.4172/2168-9458.1000177.

Kaygısız, F., A. Evren, Ö. Koçak, M. Aksel & T. Tan, 2018. Efficiency analysis of dairy buffalo enterprises in Çatalca district of İstanbul. Ankara Üniversitesi Veteriner Fakültesi Dergisi, 65: 291-296.

Lambertz, C., C. Chaikong, J. Maxa, E. Schlecht & M. Gauly, 2012. Characteristics, socioeconomic benefits and household livelihoods of beef buffalo and beef cattle farming in Northeast Thailand. Journal of Agriculture and Rural Development in the Tropics and Subtropics, 113 (2): 155-164.

Liotta, L., V. Chiofalo, V.L. Presti, A. Vassallo, G. Dalfino & A. Zumbo, 2015. The influence of two different breeding systems on quality and clotting properties of milk from dairy buffaloes reared in Sicily (Italy). Italian Journal of Animal Science, 14 (3): 3669. https://doi.org/10.4081/ijas.2015.3669.

Madau, F.A., R. Furesi & P. Pulina, 2017. Technical efficiency and total factor productivity changes in European dairy farm sectors. Agricultural and Food Economics, 5 (17): 1-14. https://doi.org/10.1186/s40100-017-0085-x.

Malcolm, M.B.J.G.R., J.M.P. Jayasinghe, R.M.S.D. Rathnayake & A.M. Samaraweera, 2019. Production characteristics and technical efficiency of buffalo farming in Thanamalwila veterinary division, Sri Lanka. Sri Lanka Journal of Animal Production, 11: 16-22.

Mokhber, M., M. Moradi-Shahrbabak, M. Sadeghi, H. Moradi-Shahrbabak, A. Stella, E. Nicolzzi, J. Rahmaninia & J.L. Williams, 2018. A genome-wide scan for signatures of selection in Azeri and Khuzestani buffalo breeds. BMC Genomics, 19: 449. https://doi.org/10.1186/s12864-018-4759-x.

Momin, M.M., M.K.I. Khan & O.F. Miazi, 2016. Performance traits of buffalo under extensive and semi-intensive Bathan system. Iranian Journal of Applied Animal Science, 6 (4): 823-831.

Pantoja, L.S.G., E.R. Amante, A.M. da Cruz Rodrigues & L.H.M. da Silva, 2022. World scenario for the valorization of byproducts of buffalo milk production chain. Journal of Cleaner Production, 364: 1-10. https://doi.org/10.1016/j.jclepro.2022.132605.

Popa, R.A., L. Vidu, D.C. Popa & A. Bota, 2016. Economic efficiency - A key to biodiversity conservation. Analyze product cost structure and profit calculation in three types of buffalo farms in Fagaras Area. Scientific Papers, Series D. Animal Science, LIX: 240-245.

Roustemis, D., A. Ragkos, D. Patousis, A. Theodoridis & S. Savvidou, 2016. “Buffalo farming in Greece: Present and future, 355-358”. In: Ecosystem Services and Socio-Economic Benefits of Mediterranean Grasslands. (Eds. A.P. Kyriazopoulos, A. López-Francos, C. Porqueddu, P. Sklavou), Options Méditerranéennes: Série A. Séminaires Méditerranéens; n. 114, 454 pp.

Sabia, E., F. Napolitano, S. Claps, A. Braghieri, N. Piazzolla & C. Pacelli, 2015. “Feeding, nutrition and sustainability in dairy enterprises: The case of Mediterranean Buffaloes (*Bubalus bubalis*), 57-64”. In: The Sustainability of Agro-Food and Natural Resource Systems in the Mediterranean Basin. (Ed. A. Vastola) Springer Cham London, 397 pp.

Saner, G., S. Engindeniz, H. Adanacıoğlu, D. Güler & Z. Şengül, 2022. Manda yetiştiriciliğinin ekonomik yönü üzerine bir analiz: Balıkesir ili örneği. Hayvansal Üretim, 63 (1): 35-46. https://doi.org/10.29185/hayuretim.978601.

Singh, S.P., S.K. Singh & B.R. Singh, 2015. Buffalo farming profitability in beneficiaries and non- beneficiaries’ dairy farmers of Krishi Vigyan Kendra.Asian Journal of Dairy and Food Research, 34: 28-31. https://doi.org/10.5958/0976-0563.2015.00006.8.

Soysal, M.I., Y.T. Tuna, E.K. Gurcan, E. Ozkan, S. Kok, N. Castellano, O. Cobanoglu & C.M.A. Barone, 2007. Anatolian water buffalo’s husbandry in Turkey: preliminary results on somatic characterization. Italian Journal of Animal Science, 6 (sup2): 1302-1307. https://doi.org/10.4081/ijas.2007.s2.1302.

Sweers, W., T. Möhring & J. Müller, 2014. The economics of water buffalo (*Bubalus bubalis*) breeding, rearing and direct marketing, Archives Animal Breeding, 57 (22): 1-11. https://doi.org/10.7482/0003-9438-57-022.

Theodoridis, A., A. Ragkos, D. Roustemis, K. Galanopoulos, Z. Abas & E. Sinapis, 2012. Assessing technical efficiency of Chios sheep farms with data envelopment analysis. Small Ruminant Research, 107 (2-3): 85-91.

Tsiobani, E.N., Hasanagas, M. Yiakoulaki & K. Papanikolaou, 2013. Pluriactivity and professionalism in buffalo farming system: The case of Northern Greece. Indian Journal of Animal Sciences, 83 (7): 763-767.

TurkStat, 2022. Livestock Statistics of Turkish Statistical Institute. (Web page: https://data.tuik.gov.tr/Kategori/GetKategori?p=tarim-111&dil=1) (Date accessed: October, 2022).

Vijayudu, G., 2015. Economics of buffalo milk production - A case study of composite Andhra Pradesh. Journal of Rural Development, 34 (3): 305-326.

Vithanage, U.Y.N., M.B.P. Mahipala, L.H.P. Gunaratne & H.W. Cyril, 2013. A comparison of animal-crop mixed farming systems in dry lowland Sri Lanka. Livestock Research for Rural Development, 25 (9): 1-9.

Wahid, H. & Y. Rosnina, 2011. “Management of Dairy Animals: Buffalo: Asia, 772-779”. In: Encyclopedia of Dairy Sciences. 2nd ed. (Eds. P.L.H. McSweeney & J.P. McNamara), Elsevier Science & Technology Books, 4170 pp.

Yılmaz, A. & M.A. Kara, 2019. Status and future of water buffalo husbandry in the World and Turkey. Turkish Journal of Agricultural Research, 6 (3): 356-363.