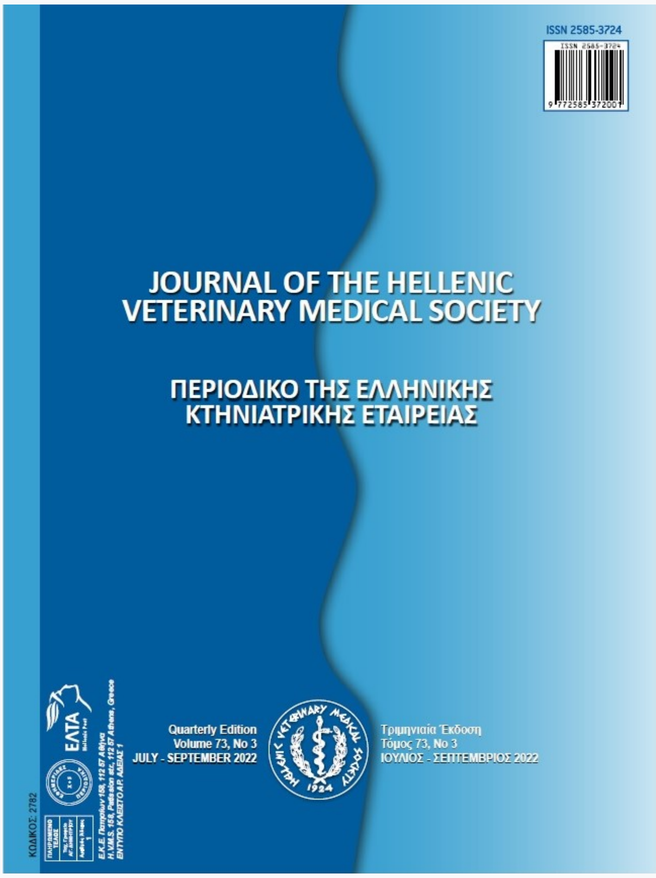
Journal of the Hellenic Veterinary Medical Society

Vol 73, No 3 (2022)



Assessing efficiency of dairy goat farms by performance evaluation and benchmarking

A Batzios, A Theodoridis, T Bournaris, A Semos

doi: [10.12681/jhvms.27233](https://doi.org/10.12681/jhvms.27233)

To cite this article:

Batzios, A., Theodoridis, A., Bournaris, T., & Semos, A. (2022). Assessing efficiency of dairy goat farms by performance evaluation and benchmarking. *Journal of the Hellenic Veterinary Medical Society*, *73*(3), 4389–4398. https://doi.org/10.12681/jhvms.27233

J HELLENIC VET MED SOC 2022, 73 (3): 4389-4398
ΠΕΚΕ 2022, 73 (3): 4389-4398

Research article
Ερευνητικό άρθρο

Assessing efficiency of dairy goat farms by performance evaluation and benchmarking

A. Batzios[1], A. Theodoridis[2], T. Bournaris[1], A. Semos[1]

[1] *School of Agriculture, Aristotle University of Thessaloniki, Thessaloniki, Greece*

[2] *School of Veterinary Medicine, Aristotle University of Thessaloniki, Thessaloniki, Greece*

ABSTRACT: The efficiency of goat farming sector in Greece is analyzed in this study. A survey was carried out in 96 goat farms, randomly selected in the area of Macedonia and Thrace, Greece. Accounting data were recorded through face-to-face interviews with farmers and Data Envelopment Analysis was applied to estimate technical efficiency (TE) of goat farms. The mean TE estimated at 0.791, indicating that input savings of 20.9% could be achieved. 75% of the goat farms are deemed as inefficient. The gross revenue varies considerably between efficient and inefficient farms, with the first achieving €210.09 and inefficient farms €143.41/doe. Farm size classification reveals significant difference of TE among groups of small and medium sized farms (P≤0.05). The analysis of the existing structure of the farms, compared to the optimal plan resulted from DEA, shows that farms could achieve higher economic results, through a rational use of the available inputs.

Key words: Technical Efficiency; Goat farming; Data Envelopment Analysis

Corresponding Author:
Batzios Athanasios, School of Agriculture Aristotle University of Thessaloniki
54124 Thessaloniki, Greece
E-mail address: thanos.batzios@gmail.com

Date of initial submission: 08-06-2021
Date of acceptance: 11-09-2021

INTRODUCTION

Goat farming is an important sector of livestock production in Greece, accounting for 22% of the livestock output in the country (Pulina et al., 2018). Greece has the largest dairy goat population in the EU; in 2019 3,580,042 goats, were reared by 64,286 farms, producing 355,760 tons of milk and 26,480 tons of goat meat (FAO, 2021; ELSTAT, 2020). At the same time, goat sector provides employment to rural population in disadvantaged and remote areas of the country, ensuring a fair income for them and their families (Kitsopanidis, 2002; Voltsou, 2005; Miliadou D., 2010; Arsenos et al., 2014; Laliotis, 2018).

Goat farming in Greece is a traditional activity, which is characterized by a strong element of succession, passing from generation to generation. Goat farms are mainly situated in LFAs rearing animals of local breeds, which usually achieve low milk yields. Farms are characterized by low investment in facilities and machinery and use family labor (Theodoridis et al., 2019). In most cases these farms depend on grazing and survive due to their important environmental role in specific regions (Zygogiannis and Katsaounis, 2009; Gelasakis et al., 2017; Vouraki, 2019). In lowland areas, improved or nonindigenous goat breeds (Zaanen, Alpine, Damascus, etc.) that achieve high milk yields are reared under intensive or semi-intensive system by farms with modern infrastructure that depend mostly on concentrates and forage produced on-farm (Vouraki, 2019, Theodoridis et al., 2019).

In general, the extensive production system confirms its dominance in the Greek goat industry, contributing by 91.0% in the total goat milk production. At the same time, according to ELSTAT (2018), goat farming contributes significantly to the total milk production of the Greek economy (21.28%).

Greece is the main dairy goat producing center in the European Union, rearing 30.34% of the total goat population in EU (27), followed by Spain (22.53%), Romania (13.55%), France (10.52%) and Italy (8.97%) (FAO, 2021).

The goat sector in Greece, but also in Europe, is experiencing a significant structural adjustment, where more intensive farms that rear animals of high yields and depend heavily on capital endowments are emerging (Gelasakis et al., 2017). Despite this development, the dairy goat industry is still facing structural weaknesses and significant problems which are linked to the small size of goat farms, poor infrastructure, low level of zootechnical knowledge and lack of training of goat farmers, inability of goat farmers to incorporate the outcomes of current scientific research in livestock management by adopting best practices and innovations, and , finally, the absence of collective actions in the sector (Vouraki, 2019; Katsaounis and Zygogiannis, 2009; Gelasakis et al., 2017). All these structural weaknesses that characterize the sector jeopardize its integration into the liberalized market. The severe price fluctuations and limited liquidity in goat sector (Pappa, 2021), the challenging market conditions and in general the volatile economic conditions require by the farmer to utilize efficiently the available resources and the existing production technology, making good decisions.

Management is the most important activity in the farm, with a catalytic role in the rational utilization of inputs to produce the final output and to ensure the farm's sustainability (Liontakis, 2015). The manager is the driving force of the farm and his/her ability to identify problems, to evaluate the relevant information (Jalali, 2020) and to make correct decisions directly affect the efficiency and profitability of the farm. The goat farmer can make use of a plethora of tools to assess any deviations from the rational organization of the available resources of his/her farm and to evaluate its overall efficiency which outlines the level of utilization of the available resources and assesses their potential waste. Estimation of farm efficiency provides a specific quantitative measure of the productive performance of the industry (Psychoudakis and Theodoridis, 2006), revealing useful information for the goat farmers, as well as for the actors/bodies that are responsible for the design and implementation of policies concerning the development of the sector (Kounetas and Chatzistamoulou, 2015). Technical Efficiency (TE) is defined as the ability to produce the largest possible volume of product with given levels of production inputs (Thanassoulis et al., 2008; Theodoridis, 2008), and it assesses the deviation of the existing production from the optimal output that the farm could produce. Technical efficiency expresses differences in the level of managerial skills and can be a useful decision tool for adopting management strategies and policies (Fousekis et al., 2001; Rezitis et al., 2002; Vlontzos, 2015; Theodoridis, 2017).

The purpose of this study is to analyze the structural relationships of the Greek goat sector and to examine the presence of inefficiency in the allocation of the resources in the goat sector. Based on farm accounting data of 96 goat farms a Data Envelopment Analysis (DEA) is applied to estimate the level of technical efficiency of the farms. The estimated level of technical efficiency is further statistically analyzed in regard to “farm size” in number of goats as a classification variable of the farms. The findings of this study could provide valuable information to the goat farmers and could be used for a more rational management of goat farms towards increasing the productivity and enhancing the competitiveness of goat farming products. Moreover, it could also provide a base for identifying research priorities with a view to formulating a specific policy for the goat sector.

MATERIALS AND METHODS

Theoretical considerations and the model of DEA

DEA is a non-parametric method, which uses linear mathematical programming techniques and attributes any deviation from the “production frontier” (the limit of the objective capabilities of the production technology) to inefficiency (Charnes et al, 1978 & 1979; Theodoridis 2008; Theocharopoulos, 2009). The method constitutes a particularly useful tool for assessing the efficiency of homogeneous production units (‘Decision Making Units’ or ‘DMUs’) operating within a system.

DEA was originally developed based on the CCR model (Charnes, Cooper & Rhodes) (Charnes et al., 1978 & 1979), assuming constant returns to scale (CRS-Constant Returns to Scale) and resulting to estimates of technical efficiency. Banker et al. in 1984 further developed the original DEA analysis framework, formulating the BCC model (Banker, Charnes & Cooper), which assumes variable returns to scale (VRS) and allows the estimation of technical efficiency separately from the effects caused by scale inefficiency.

The technical efficiency of a production unit can be assessed using as a reference either the quantities of production inputs it uses or the quantities of outputs it produces. Input-oriented Technical Efficiency (TE) indicates the ability of a farm to produce a given quantity of outputs with the minimum quantity of inputs. In this study, for the investigation of the technical efficiency in the Greek goat industry, an input-oriented VRS DEA model was applied. The DEA Frontier software was used for the analysis (Zhu, 2009).

On this basis, we assume that there are **n** goat farms (DMUj, with j = 1, 2, .., n), where each farm produces **s** different products (outputs) $\mathbf{y}_{rj}$(with r = 1, 2, 3, .., s), using **m** different inputs $\mathbf{x}_{ij}$ (with i = 1, 2, .., m). Let $\mathbf{x}_{ij}$ be the observed level of an $\mathbf{i}^{th}$input and $\mathbf{y}_{rj}$ be the observed level of a $\mathbf{r}^{th}$ output for a $\mathbf{j}^{th}$ goat farm. Based on DEA’s BCC model, with variable returns to scale (VRS) and input -oriented (input -oriented) input reduction, the technical efficiency for farm $\mathbf{j}_0$ can be estimated by solving the following mathematical programming model (Fousekis et al. 2001; Papadopoulou et al., 2021):

(1) $\min \theta$

subject to:

(2) $\theta_0 \chi_{i0} - \sum_{j=1}^{n} \lambda_j \chi_{ij} \geq 0 \quad \mu\varepsilon \;\; i = 1, 2, 3, ..., m$

(3) $\sum_{j=1}^{n} \lambda_j y_{rj} - y_{r0} \geq 0 \quad \mu\varepsilon \;\; r = 1, 2, 3, ..., s$

(4) $\sum_{j=1}^{n} \lambda_{j=1}$

(5) $\lambda_j = 1 \quad \mu\varepsilon \;\; j = 1, 2, 3, ..., n$

Where $\boldsymbol{\theta}_0$ is the estimation of the technical efficiency level (^{I}TE) of the **DMUo** representing one of the **n** farms under evaluation, $\mathbf{x}_{io}$ is the **ith** input and $\mathbf{y}_{ro}$ the rth output, **λj** are intensity variables indicating to what extent a particular activity can be used in production, somehow identifying the optimal group of farms. If $\boldsymbol{\theta}_0$**=1**, then the current level of inputs cannot be further reduced, indicating that the DMUo is operating at the efficiency frontier. If $\boldsymbol{\theta}_0$**<1**, then the DMUo is far from the efficiency frontier and has room to reduce its level of inputs used without changing the amount of output it produces in order to operate efficiently. The maximum possible reduction of all inputs for a given level of output is $\mathbf{1-\theta_0}$. The $\mathbf{j}^{th}$ goat farm is considered efficient when: $\boldsymbol{\theta}_0$**=1, λj=1 and λj=0 for j ≠ i.**

Statistical analysis

The estimated level of technical efficiency by DEA was further statistically analyzed in terms of “farm size” [number of does (adult female animals in the farm)]as a classification variable of goat farms. Three size groups were formulated, “Small size farms: ≤199 does”, “Medium size farms: 200 to 399 does”, and “Large size farms: ≥ 400 does”.

Both parametric and nonparametric methods were applied for the statistical evaluation of the estimated technical efficiency of goat farms, regarding the classification variable "farm size". Shapiro-Wilk test was performed for assessing departures from normality, while variances were tested for homogeneity using the Levene's test. The Kruskal-Wallis nonparametric test was finally applied to evaluate farm size depended differences, while differences between mean values of specific farm size groups were evaluated using the Mann-Whitney U-test. All analyses were conducted using the statistical software program SPSS for Windows (v. 25.0). Significance was declared at P≤0.05, unless otherwise noted.

Study area and empirical data

The surveyed goat farms for the empirical application of DEA model are located in Northern Greece, covering the areas of Macedonia and Thrace (Figure 1). Each goat farm in the sample uses different quantities of inputs and produces different quantities of outputs (products), generally following similar management conditions and production technology.

Figure 1. Location map of the study area

Macedonia and Thrace constitute an important goat farming center in Greece, accounting for 26.16% of the total goat population of the country and 28.93% of the total number of does (ELSTAT, 2019 data). Moreover, goat farming in the area produces 30.62% (124,881 tonnes) of the total quantity of goat milk in the country (ELSTAT, 2018 data).

The farm accounting data for the empirical application were collected through a farm management survey of 96 goat farms during 2018-2019.These farms operate under various production systems (intensive, semi-intensive, extensive and semi-extensive), and are mainly of medium size. Data Envelopment Analysis (DEA) was implemented on these primary data to estimate the efficiency level of the goat farms.

The inputs used for the empirical application of the DEA model included: (a) number of does (the productive animals), (b) human labor (hours/year/doe), (c) the variable cost (€/year/doe) (expenses for purchased and home-grown feed and other expenses of farm operation such as water and energy supply, veterinary care and medicines, fuel, accountant and consultant services, etc.), (d) fixed cost (annual cost of mechanical equipment, buildings, livestock capital etc.) (€/year/doe). These inputs are representative of the production factors used in the production process of a goat farm. At the same time, the gross revenue of the farm (€/doe) was used as an output in the DEA model to incorporate the effects of price fluctuations and the yield of the products of the goat farms in the estimation of technical efficiency.

RESULTS AND DISCUSSION

Technical efficiency estimates and technical and economic characteristics of goat farms

Table 1 presents the estimations of the mean value of TE as well as the relative descriptive statistics both for the whole sample of goat farms surveyed and the groups of farms classified according to the level of technical efficiency.

Table 1. Frequency distribution and descriptive statistics of technical efficiency (TE)

Efficiency level	Number of farms	% of farms	Mean value ofTE	Standard Deviation	Median
0.60	9	9.37	0.484	0.0697	0.514
0.60-0.79	40	41.67	0.677	0.0574	0.671
0.80-0.99	23	23.96	0.892	0.0556	0.895
1.00	24	25.00	1.000	0.0000	1.000
Total sample	96	100.0	0.791	0.1740	0.789

For the average goat farm in the sample, the technical efficiency is estimated equal to 0.791±0.174 (Mean±SD), indicating a significant deviation from the 'efficient frontier'. This finding shows that the same level of gross revenue could be achieved with a reduction of 20.90% in inputs use if the farms were operating fully efficiently. The relatively high variability of TE achieved among the goat farms in the sample, indicates the application of different management practices, which are associated to the different farm types that exist in the sector and the general diversification in the level of zootechnical management applied by the farms.

Moreover, 75% of the sample farms are classified as technically inefficient (TE<1.000) and an estimated mean value of TE equal to 0.721±0.145, while 25% of the farms (n=24) are efficient and use their available input units in the most effective way (TE=1.000).

Further classification of inefficient farms into classes based on the TE score estimated by DEA (Table 1) results in 9 farms (9.37% of the sample) with efficiency score lower than 0.60 and a mean value of TE=0.484, 40 farms (41.67% of the sample) with technical efficiency score between 0.60 and 0.79 and a mean value of TE=0.677, and 23 farms (23.96% of the sample) with technical efficiency between 0.80% and 0.99% and a mean value of TE=0.892.

Technical efficiency in small ruminant farms has been studied by various researchers in the past. Fousekis et al. (2001), studying a sample of 101 sheep farms in mountainous areas of Greece, estimated the TE=0.893±0.13. Theodoridis et al. (2006), using data from 108 sheep and goat farms in Western Macedonia, found that TE was 0.669, while Theocharopoulos et al. (2007), applying the DEA method to 217 Greek sheep farms, estimated a TE score of 0.663±0.206. Galanopoulos et al. (2011), applied Data Envelopment Analysis under CRS to 106 transhumant sheep and goats' farms in Greece, estimated the overall technical efficiency to 0.476. Theodoridis et al. (2012), in a research study of 58 Chios sheep breed farms, estimated the technical efficiency equal to 0.76. Tsiouni (2018) studied 120 goat farms and estimated technical efficiency 0.76±0.27, an estimate not far from the estimates of this study (0.791±0.174).

Moreover, Gül et al. (2016) estimated the technical efficiency (TE) of goats reared in Isparta province of Turkey to be 0.66, using DEA. Meanwhile, Setyorini et al. (2017) found that the TE score for goat farming in Kediri district of Indonesia was 0.74 for the farms in lowland areas and 0.81 for farms in the mountainous areas. Also, Theodoridis et al. (2018), in a survey

Table 2. Technical and economic characteristics of the technical efficient and inefficient farms

Technical and economic data	Efficiency groups: Inefficient (n=72) TE =0.721±0.145	Efficiency groups: Efficient (n=24) TE=1.000	Average farm (n=96) TE =0.791±0.174
Technical			
Milk Production (kg/doe)	137.73	201.20	155.17
Farm size (number of does)	323	367	334
Total labor (hours/doe)	19.41	16.42	18.59
Family labor (hours/doe)	13.95	10.75	13.07
Hired labor (hours/doe)	5.47	5.67	5.52
Economic			
Land cost (€/*doe*)	5.00	13.01	7.20
Total labor cost (€/*doe*)	53.69	51.03	52.97
Family labor cost (€/doe)	41.84	32.24	39.21
Hired labor cost (€/doe)	11.85	18.79	13.76
Variable capital cost (€/*doe*)	84.44	108.16	90.95
Feed cost (€/doe)	64.43	82.54	69.40
Miscellaneous costs (€/doe)	20.01	25.62	21.55
Fixed capital cost (€/*doe*)	31.12	38.01	33.01
Production cost (€/*doe*)	174.25	210.22	184.13
Gross Revenue (€/*doe*)	143.41	210.09	161.73
Gross Margin (€/*doe*)	58.98	101.93	70.77
Profit or Loss (€/*doe*)	-30.84	-0.13	-22.41

of 60 extensive sheep farms in a region of the Western Pyrenees Mountains of France, estimated a technical efficiency level equal to 0.774. Similarly, Twumasi et al. (2020) investigated the technical efficiency of goat farming in Ghana, arriving at a TE =0.724.

The main technical and economic characteristics of the goat farms are presented in Table 2, both for the average farm in the sample as well as for the inefficient and efficient farms.

Regarding the technical characteristics of the goat farms, the milk yield per doe for the average farm in the sample is 155.17 kg, while the respective milk yield for the average inefficient farm is 137.73 kg and for the efficient farm is 201.2 kg (higher by 29.66% compared to the average farm). The average farm size breeds 334 does, while the inefficient and efficient farms breed on average 323 and 367 does (12% more than the inefficient farm), respectively. The average farm uses 18.59 hours of labor per doe, of which 13.07 hours are allocated to family members, while 5.52 hours is hired labor. The efficient farms use 3 hours less family labor per doe compared to the inefficient farms and this can be attributed to the higher level of management organization that efficient farms generally apply and the exploitation of economies of scale since the efficient farms breed more animals.

Regarding the economic characteristics of the goat farms, the analysis resulted in the following findings:

The rent for the land used to produce feed is €7.20 per doe for the average farm, while for the inefficient farms it is estimated at €5.00 and for technically efficient group at €13.01 per doe. This variation is because efficient farms operate under more intensive pattern and depend on home-grown feed to reduce their feeding cost.

The total labor cost per doe for the average farm is €52.97, with no substantial differences between efficient and inefficient farms (€51.03 and €53.69, respectively). Following the trend of labor use, significant structural differences exist between the efficient and inefficient farms regarding the composition of total labor cost. In particular, family labor cost for the average farm is €39.21/doe, while labor cost for the inefficient farms is €9.60 higher than the efficient farms. On the other hand, efficient farms spend €7.00 more in hired labor than the inefficient farms (€18.79 versus €11.85), while the average farm pays €13.76 per doe.

Variable cost, including feeding cost and other farm expenses, is €90.95 per doe for the average farm. The variable cost for the efficient farms is €108.16 per doe, 28% higher than in the inefficient farms (€84.44). This difference is mainly attributed to the feeding cost.Feeding cost for the average farm is €69.40 per doe, while for the average inefficient farm is lower (€64.43). The inefficient farms pay €18 per doe more on purchased and/or on-farm produced feed, compared to the efficient farms.Efficient farms spend €25.62 on other expenses, while inefficient farms spend 20% less (€20.01 per doe).

Concerning fixed capital cost, in the average farm it is €33.01 per doe, while in the efficient group is €38.01 and for inefficient farms is €31.12 per doe. This difference can be attributed to the fact that efficient farms are larger in size, animals are confined and have better infrastructure.

The overall effect of the above cost categories is reflected on the total production cost. Production cost for the average farm is €184.13 per doe, while for efficient and inefficient farms is €210.22 and €174.25 per doe, respectively.

For the efficient farms the gross revenue per doe is €210.09 and for the inefficient farms is €143.41. The gross revenue for the average farm is €161.73 per doe. The gross margin for the relatively efficient farms is estimated at €101.93 per doe, whereas, as it was expected, for the inefficient farms it is estimated to be considerably lower at €58.98. Similarly, for the average farm it is estimated at €70.77 per doe.

Similar findings occur regarding the profit/loss of the farms. The farms exhibit loss, with the average farms' loss estimated at -€22.41 per doe. Inefficient farms exhibit loss of €30.84 per doe, while technically efficient farms show a much lower loss (€0.13 per doe), as it was expected.

Comparative analysis of the level of technical efficiency in terms of farm size

Table 3 presents the estimations of the technical efficiency in terms of the classification variable "farm size" [number of does (female adults in the farm)]. In "Small farms" the mean value of TE (mean±SD) is 0.874±0.158, in "Medium farms" is 0.734±0.167, while in "Large farms" it is 0.805±0.171.

Statistical evaluation of the TE score reveals a significant difference between "Small farms" and "Medium farms", with that of "Small farms" being significantly higher (P≤0.05). No significant differences were observed between "Large farms" and "Small farms", as well as between "Medium farms" and "Large farms" (P>0.05).

Technical input efficiency (TE) and optimal management of goat farms

Table 4 presents the estimated levels of four basic inputs both for the existing and for the optimal production plan, in terms of the classification variable "farm size", but also for the average farm.

As long as the goat farms reduce the inputs to the levels indicated by the optimal plan, they will operate at the efficiency frontier, i.e., they will be able to achieve the same gross revenue by reducing substantially their inputs. The efficiency target depends on the management skills demonstrated and the decisions that goat farmers must make.

According to the DEA results, the average farm could achieve the same gross income breeding 35% less animals (from 334 to 218 does). In terms of farm size, "Medium farms" could reduce the number of dairy goats by 43%, followed by the "Large farms" with a potential reduction of 31% and then by "Small farms" with a reduction of 20%. This finding shows that the adjustment is larger for the medium farms and smaller for the small farms, which usually operate under traditional system with low inputs.

The estimates of other inputs for the average farm in the sample show a similar picture, with the working hours per goat in the optimal plan being reduced by 29%, i.e., from 18.59 hours to 13.14 hours/goat. Likewise in this case, the classification of farms in terms of "farm size" revealed substantial variations in the level of labor utilization. "Medium size farms" could reduce labor hours (per doe) to a greater extent (by 35%), followed by "Large farms" and "'Small farms"', which could achieve the same gross revenue by reducing labor hours about 27% and 23%, respectively.

Regarding the variable cost, the adaptation of the average farm towards a more efficient organization could be achieved with about 20% less variable costs than in the current framework (from €90.95 to €72.45/goat). For "Medium size farms", the variable costs could be reduced by 30% and they could operate efficiently, receiving the same gross revenue, while for "Small" and "Large size farms" the recommended reduction in variable costs is around 15 to 16%.

Table 3. Technical efficiency in terms of farm size

Farm size group	n	Technical efficiency Mean ± SD	Technical efficiency Median (50%)
"Small farm: ≤199 does"	23	0.874 ± 0.158^{b}	0.996
"Medium farm: 200 to 399 does"	42	0.734 ± 0.167^{a}	0.691
Large farm: ≥ 400 does"	31	$0.805 \pm 0.171^{a,b}$	0.809
Total sample	96	0.791±0.174	0.789

a, b, c: Mean values in the same column with a superscript in common do not significantly differ (P>0.05)

Table 4. Comparison of inputs in existing and optimal plans

Farm size group	Mean value of TE	Inputs: Number of does/farm)		Labor (hours/ doe/ year)		Variable Costs (€/doe/ year)		Fixed Costs (€/doe/year)	
		Existing plan	Optimal plan	Existing plan	Optimal plan	Existing plan	Optimal plan	Existing plan	Optimal plan
"Small farm: ≤199 does"	0.874	134	108	27.57	21.35	161.84	135.58	65.38	59.05
"Medium farm:200 to 399 does"	0.734	275	156	20.01	12.99	87.84	61.62	32.86	22.75
Large farm: ≥400 does"	0.805	562	384	16.05	11.78	80.44	68.43	27.37	22.35
Average farm	0.791	334	218	18.59	13.14	90.95	72.45	33.01	26.03

At the same time, the fixed cost would not affect the gross revenue of the average farm if it was reduced by 21%, i.e., from €33.01 to €26.03 per doe. Similarly, the classification of farms in terms of size reveals substantial differences in fixed cost per animal, based on the two production plans. Thus, "Medium farms" are those with the greatest potential for reducing fixed costs (around 30%), followed by the "Large farms" with a reduction of 18% and "Small farms" with a reduction of 10%.

CONCLUSION

Empirical analysis showed that the mean TE of goat farms is 0.791, indicating that improved management practices in goat farms could result in 20.9% input savings. A quite high variability in the level of TE among goat farms is observed, indicating significant variation in the general level of animal husbandry and financial management applied by goat farmers. The average farm breeds 334 does, while the efficient and the inefficient farms breed, on average, 367 and 323 does, respectively. Milk yield is 155.17 kg for the average farm, while for the inefficient farms it is lower (137.73 kg/doe annually), in contrast to the efficient farms which achieve a higher milk yield (201.20 kg/doe annually). The gross revenue per goat varies considerably between technically efficient and inefficient farms; efficient farms achieve €210,09 per doe and inefficient farms €143,41 per doe. Farm size classification of goat farms reveals significant difference among groups of small and medium sized farms, regarding the achieved level of TE ($P \leq 0.05$).

The analysis and evaluation of the existing structure of the farms, compared to the optimal plan resulted from DEA, shows that goat farms could achieve higher economic results, with better management and more rational use of the productive inputs available. The current structure of the goat sector seems to use a higher number of does per farm, employs more labor per goat/year, and has higher variable and fixed capital/doe/year compared to the optimal structure plan. This indicates poor management of livestock, relatively high investments in building and machinery, and increased feeding costs, which are the most important variable cost item, all of which affect the profitability of the farms and ultimately their viability. In other words, goat farms in Greece, with more efficient organization and management of the available inputs, could achieve the same gross margin by reducing inputs to the levels estimated in the appropriate (optimal) production plan.

In summary, larger number of animals and high investments in land, buildings and machinery do not necessarily lead to higher economic results. It is the management capacity of the goat farmer that will lead him/her to adopt the necessary adjustments in order to achieve higher economic results. This capacity can be acquired or improved by investing in know-how and training, overcoming the concepts of past decades and adapting them to today's standards, so that the goat farmer is able to meet the demands of the modern and demanding market and operate as an entrepreneur. Improving the management capacity of goat farmers will lead to a more rational use of the inputs used and will ultimately enhance the economic viability and the competitiveness of the goat sector, not only in Greece, but also in Europe.

ACKNOWLEDGMENTS

The data and results presented in this paper are part of a research conducted in the context of a PhD Thesis. The implementation of the research was co-funded through the Action "ENHANCING HUMAN RESEARCH RESOURCES THROUGH THE IMPLEMENTATION OF DISSERTATION RESEARCH" from funds of the Operational Programme "Human Resources Development, Education and Lifelong Learning", 2014-2020. Authors are grateful to the Greek State Scholarship Foundation (I.K.Y.).

CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

Arsenos G., Gelasakis A., Pinopoulos S., Giannakou R. and Amarantidis A. (2014) Description and typology of dairy goat farms in Greece. In: Proceedings of the 4th ISOFAR Scientific Conference, Istanbul, Turkey: pp 571-574.

Banker R.D., Charnes A. and Cooper W.W. (1984) Some Models for Estimating Technical and Scale Inefficiency in Data Envelopment Analysis. Management Science 30:1078-1092.

Charnes A., Cooper W.W. and Rhodes E. (1978) Measuring the efficiency of Decision-Making Units). European Journal of Operational Research 2(6):429-444.

Charnes A., Cooper W.W. and Rhodes E. (1979) Short communication: Measuring the efficiency of Decision-Making Units. European Journal of Operational Research 3(4):339

ELSTAT (2018) Livestock and Livestock Products 2018. Hellenic Statistical Authority Digital Library.https://www.statistics.gr/en/statistics/agr [accessed 21 May 2021].

ELSTAT (2019) Livestock Surveys 2019. Hellenic Statistical Authority Digital Library.https://www.statistics.gr/en/statistics/agr [accessed 21 May 2021].

ELSTAT (2020) Livestock surveys (pigs-bovines-sheep-sheep-goats-eggs): year 2019. Hellenic Statistical Authority Digital Library. https://www.statistics.gr/en/statistics/agr [accessed 21 May 2021].

FAO (2021) FAOSTAT, Food and agriculture data. Statistical Databases. http://www.fao.org/faostat/en/#data [accessed 1 April 2021].

Fousekis P., Spathis P. and Tsimboukas K. (2001) Assessing the Efficiency of Sheep Farming in Mountainous Areas of Greece. A Non-Parametric Approach. Agricultural Economics Review2(2):1-11.

Galanopoulos K., Abas Z., Laga V., Hatziminaoglou I. and Boyazoglu J. (2011) The technical efficiency of transhumance sheep and goat farms and the effect of EU subsidies: Do small farms benefit more than large farms? Small Ruminant Research 100:1-7.

Gelasakis A., Rose G., Giannakou R., Valergakis G.E., Theodoridis A., Fortomaris P. and Arsenos G. (2017) Typology and evolution of dairy goat production systems in Greece. Livestock Science197:22-29.

Gül M., Demircan V., Yilmaz Has. and Yilmaz Hil. (2016) Technical efficiency of goat farming in Turkey: a case study of Isparta province. RevistaBrasileira de Zootecnia 45(6):328-335.

Jalali A., Bagheri A., Allahyari M.S., Aghjehgheshlagh F.M., Surjulal J. and Michailidis A. (2020) Information needs and information seeking behavior of dairy farm managers. International Journal of Sustainable Agricultural Management and Informatics 6(2):107-122.

Kitsopanidis G. (2002) Economics of goat farming in Greece. New Medit 1(3):48-53.

Kounetas K. and Hadjistamoulou N. (2015) Introduction to Operational Research and Linear Programming. Solving problems using the R Programme [online]. Athens: Hellenic Academic Libraries, http://hdl.handle.net/11419/5705 (accessed 21 May 2021].

Laliotis G. (2018) Structural weaknesses of Greek sheep and goat farming: a technocratic approach or just a scientific issue? ELGO-Dimitra Magazine 24:5 (In Greek).

Liontakis A. (2015) Introduction to Data Envelopment Analysis (DEA). Interactive seminar for doctoral candidates in Agricultural Economics.https://mediasrv.aua.gr/eclass/modules/document/index.php?course=AOA172&openDir=/5515c85bfjdU/55191b692ngi (In Greek) [accessed 21 May 2021].

Miliadou D. (2010) Economic and environmental approach of the organic sheep and goat sector in Greece. Ph.D. Thesis. Aristotle University of Thessaloniki, Thessaloniki, Greece (In Greek).

Papadopoulou A., Ragkos A., Theodoridis A., Skordos D., Parissi Z. and Abraham E. (2021) Evaluation of the Contribution of Pastures on the Economic Sustainability of Small Ruminant Farms in a Typical Greek Area. Agronomy11(1):63 [online],https://doi.org/10.3390/agronomy11010063 [accessed 21 May 2021].

Pappa E.C., Kondyli E., Sotirakoglou K., Bosnea L., Mataragas M., Allouche L., Tsiplakou E., Pappas A.C. (2021) Farmers Profile and Characterization of Sheep and Goat Dairy Chain in Northwestern Greece. Sustainability13:3, https://doi.org/10.3390/su13020833 [accessed 21 May 2021].

Psychoudakis A. and Theodoridis A. (2006) A Full-Scale Application of DEA to Sheep-goat Farming in Greece. Agricoltura Mediterranea136(1):52-62.

Pulina G., Milan M.J., Lavin M.P., Theodoridis A., Morin E., Capote J., Thomas D.L., Francesconi A.H.D. and Caja G. (2018) Invited review: Current production trends, farms structures, and economics of the dairy sheep and goat sectors. Journal of Dairy Science101:1-15.

Rezitis A., Tsiboukas K. and Tsoukalas S. (2002) Measuring Technical Efficiency in Greek Agricultural Sector. Applied Economics 34(11):1345-1357.

Setyorini E., Soepranianondo K. and Hidanah S. (2017) Efficiency Production Cost of Goat Farming in the Lowland and the Highland Areas in Mojo Sub-district of Kediri Regency. International Journal of Environmental & Agriculture Research (IJOEAR)3(12):27-31.

Thanassoulis E, Portela M. and Despić O. (2008) Data envelopment analysis: The mathematical programming approach to efficiency analysis. In: Fried H.O., Knox Lovell C.A. and Schmidt S.S. (eds.), The measurement of productive efficiency and productivity growth. Oxford University Press, New York: pp.251-420.

Theocharopoulos A., Melfou K., Papanagiotou E. (2007) A microeconomic approach for agricultural development: A DEA application to Greek sheep farms. New Medit6(4):48-54.

Theocharopoulos A. (2009) Economic and environmental analysis of alternative forms of agriculture. PhD thesis. Aristotle University of Thessaloniki, Thessaloniki, Greece (In Greek).

Theodoridis A., Psychoudakis A., and Christofi A. (2006) Data envelopment analysis as a complement to marginal analysis. Agricultural Economic Review 7(2):55-65.

Theodoridis A. (2008) Effects of the existing policy in the dairy cow sector. PhD thesis. Aristotle University of Thessaloniki, Thessaloniki, Greece (In Greek).

Theodoridis A., Ragkos A., Roustemis D., Galanopoulos K., Abas Z.and Sinapis E. (2012) Assessing Technical Efficiency of Chios Sheep Farms with Data Envelopment Analysis. Small Ruminant Research 107:85-91.

Theodoridis A., Batzios C., Ragkos A. and Angelidis P. (2017) Technical efficiency measurement of mussel aquaculture in Greece. Aquaculture International 25:1025-1037.

Theodoridis A., Tafidou A., Koutouzidou G., Morin E., Arsenos G. (2018) Best observed practices in efficient farms: How Data Envelopment Analysis (DEA) can serve as an innovation identification tool. Paper presented at the 1st European Symposium on Livestock Farming in Mountain Areas, 20-22 June 2018, Bozen-Bolzano, Italy.

Theodoridis A., Ragkos A., Zaralis K., Smith L. and Arsenos G. (2019) Towards a Pan-european typology of sheep and goat farms: a meta-analysis. Joint Seminar of the Sub-Network on Production Systems & Sub-Network on Nutrition, Innovation for Sustainability in Sheep and Goats. Vitoria-Gasteiz, Spain, 3-5 October 2017. Options Médi-

terranéennes A, 123:65-69.
Tsiouni M. (2018) Financial structure and efficiency of the goat industry. PhD thesis. Aristotle University of Thessaloniki, Thessaloniki, Greece (In Greek).
Twumasi M.A., Jiang Y., Danquah F.O., Frempong L.N., Ankrah E.K. and Dogbe B.S. (2020) Efficiency analysis of goat producers in Ghana: An instrumental variable approach. Custos e @gronegócio [on line] 16(2):345-360.
Vlontzos G. (2015) Measuring efficiency of the Greek flourmill firms using data envelopment analysis. International Journal of Sustainable Agricultural Management and Informatics1(1):61-75. DOI: 10.1504/IJSAMI.2015.069046
Voltsou A. (2005) Agricultural Production Systems and Agricultural Policy in Mountainous and Disadvantaged Areas of the Country. PhD thesis, Aristotle University of Thessaloniki, Thessaloniki, Greece (In Greek).
Vouraki S. (2019) Evaluation of the productive characteristics of goats resistant to classical scrapie. PhD thesis. Aristotle University of Thessaloniki, Thessaloniki, Greece (In Greek).
Zhu J. (2009) Quantitative Models for Performance Evaluation and Benchmarking: Data Envelopment Analysis with Spreadsheets. 2nd ed., Springer International Publishing, Cham, Switzerland.
Zolman J. (1993) Biostatistics. Experimental Design and Statistical Inference. Oxford University Press, New York.
Zygogiannis D. and Katsaounis N. (2009) Goat farming (Issue B)., Synchroni Paideia Publications, Thessaloniki, Greece (In Greek).