ECONOMIC AND TECHNICAL OUTCOMES OF COMMUNITY-BASED SHEEP GENETIC IMPROVEMENT IN TÜRKİYE: A COMPARATIVE REVIEW OF THE FIRST TWO FIVE-YEAR PHASES

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Abstract. This study aims to provide a comprehensive overview of sheep farming in Türkiye while establishing a baseline for future evaluations. It further assesses the economic and technical impacts of a community-based animal breeding scheme first implemented in 2006 and extended in five-year intervals. Initially covering nine sheep breeds across ten provinces, the scheme later incorporated additional breeds; however, this analysis focuses solely on the original nine breeds and the first two intervals (2006–2015). Data were gathered from complete counts of scheme-participating farmers and randomly selected non-participants, yielding 442 valid responses (206 participants, 236 non-participants) through face-to-face interviews conducted between late 2014 and early 2015. Descriptive statistics, t-tests, chi-square tests, and least-squares dummy variable (LSDV) regression models were employed for data analysis. While descriptive findings indicated superior performance among participating farmers, regression results showed only a marginal difference in gross profit per ewe. Notably, breeders attentive to internal parasite management achieved higher lambing rates. The study concludes that enhancing women's involvement, feedstuff production, and housing conditions is essential for effective genetic improvement and sustainable sheep production.
Keywords: *gross profit, genetic improvement, sheep farming, farming challenges, sheep diseases and internal - external parasites, quasi-experimental design*

Introduction

The livestock sector contributes greatly to the economy by producing highly nutritious food and enabling the efficient, sustainable use of natural and farm resources, making it an important source of livelihoods for rural communities. Sheep and goats, adaptable and resistant to climate change, are especially important for the future (Gowane et al., 2017).

Animal grazing is the most economical way to use natural grazing lands, particularly those with sparse vegetation. Natural grazing lands cover 24.4% of the world's land and 67.1% of total agricultural land. In Türkiye, they constitute approximately 19% of the total land and 39% of agricultural land, rising to 47% when fallow lands are included (FAOSTAT, 2022). Sheep and goats are essential for utilizing these large meadows and rangelands; In Türkiye, there has been a shift from extensive rangeland-based farming to more intensive and semi-intensive cattle production models (Ertuğrul et al., 2010).

According to 2023 statistics, Türkiye ranks 7th globally in sheep assets and 3rd and 4th in sheep milk and mutton production, respectively. However, it ranks 43rd and 37th in sheep milk and mutton per head, respectively (FAOSTAT, 2023). This indicates that despite being a leader in total production, Türkiye lags in productivity per sheep. The low yield is due to an extensive sheep farming system with limited input use, reliance on

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grazing, and small-framed, low-productivity animals (Ertuğrul et al., 2010; Kayalık and Bingöl, 2015).

Considering its geography, Türkiye is divided into seven geographical regions with varying climatic characteristics. These regions host many low-framed, low-yielding indigenous sheep breeds and genotypes, well adapted to the natural conditions (Kayalık and Bingöl, 2015), which constitute over 90% of the country's sheep population (TURKSTAT, 2024).

Türkiye has significant advantages in sheep production due to favorable ecological conditions and proximity to major mutton-importing EU countries. However, livestock policies in Türkiye have historically favored bovine production, causing small ruminant production to lag until the early 2000s.

In addition to problems such as small, scattered, and disorganized farms, low-yielding animal material, degradation and shrinkage in rangelands, animal diseases, privatization of support institutions, insufficient incentives, unwillingness of the young population, and shepherd shortages, small ruminant production declined until the early 2000s due to the lack of government support and reliance on traditional methods based on natural resources (Yavuz, 2015; Cengiz et al., 2015).

However, in the 2000s, support policies shifted in favor of small-ruminant production. By 2003, associations between sheep and goat breeders and the infrastructure of state support for small ruminant production had begun to be established. A sheep-goat registration system was implemented, and subsidies were provided for each breeding animal.

To date, 33 sheep and six goat breeds and types have been officially registered under the "Edict on the Registration of Indigenous Animal Breeds and Lines" enacted based on the Animal Breeding Law published on March 10, 2001 (Anonymous, 2022). Additionally, Council of Ministers Decree No. 2005/8503 has facilitated the establishment of breeding and conservation infrastructure through projects focusing on in situ conservation of animal genetic resources and national small ruminant breeding. These initiatives are conducted in collaboration with the General Directorate of Agricultural Research and Policy, Breeder's Unions, University, and Research Institutes (Cengiz et al., 2015). Commencing with preliminary efforts in 2003, the National On-Farm Genetic Improvement Studies in Small Ruminants were initiated in 2006, initially involving 10 sheep and two goat genotypes, with subsequent five-year extensions. During the second five-year phase (2011–2015), Anatolian Buffalo was also included, leading to the renaming of the initiative as "the National Project of Animal Breeding in the Hands of the People." Presently in its fourth five-year period (2021–2025), the scheme encompasses 178 subprojects involving one water buffalo, 21 sheep, and seven goat breeds across 60 provinces (TAGEM, 2022).

Genetic improvements are long-term processes, requiring continuous evaluation and analysis of program outputs to ensure effectiveness (FAO, 2010). Besides genetic advancements, assessing program outputs is crucial for understanding economic impacts at both farm and national levels, guiding corrective measures, and sustaining support (Philipsson et al., 2011; AGTR, 2022).

This study aims to 1) assess the economic and technical impacts of Türkiye's community-based sheep breeding programs during the initial two five-year periods, beginning in 2006, 2) provide a comprehensive overview of sheep farming across the country, and 3) establish a baseline for future assessments. It is expected that these findings will provide valuable insights for similar studies globally and inform future decisions regarding sheep breeding efforts in Türkiye.

Materials and methods

The community-based animal breeding national scheme

Community-based breeding programs typically target low-input systems, with farmers within specific geographical boundaries who share a common interest in working together to improve their genetic resources (Mueller et al., 2015).

The Turkish version of the program, launched in 13 provinces in 2006, originally focused on ten sheep and two goat genotypes and has been extended every five years. In subsequent extensions, the scheme's scope was broadened to include other domestic breeds. The current fourth extension (2021–2025) includes 21 sheep and seven goat genotypes.

Following a three-tier open nucleus breeding model, elite, semi-elite, and base flocks were established for each targeted breed at the beginning of their inclusion in the scheme. In this breeding program, superior animals move up from inferior flocks to superior flocks, while superior flocks produce rams for one-degree inferior flocks, as shown in *Fig. 1*.

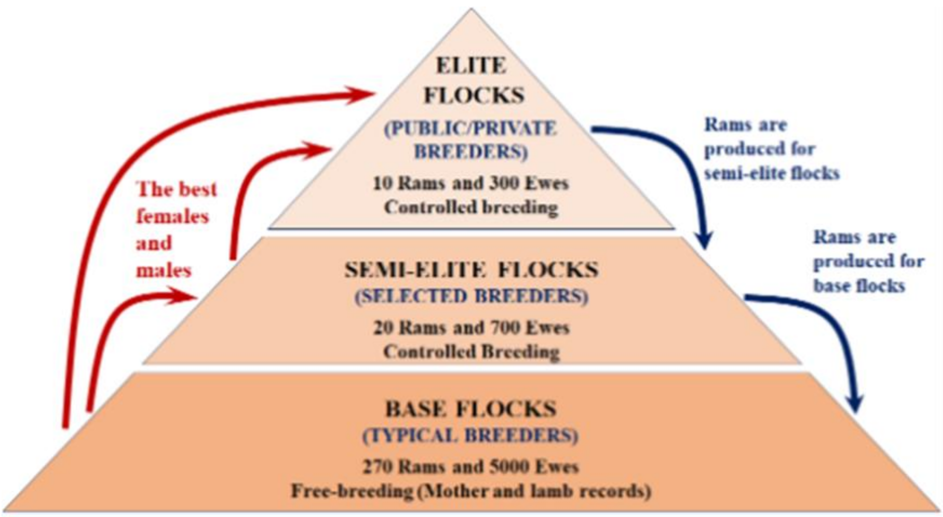

Figure 1. *Flow of breeding stock in a three-tier open nucleus breeding program employed in the Community-based Animal Breeding National Scheme (adapted from Karaca, 2014)*

The scheme is carried out in accordance with the Implementation Principles of the National Project on Community Based Animal Breeding Scheme issued by the Ministry of Agriculture and Forestry (TAGEM 2012). All specified work is conducted according to the work schedule prepared by the project leader of the targeted breed. A project technical staff is employed for each targeted breed to carry out the required operations and maintain relevant records. They regularly send the recorded data to the project leader in accordance with the work schedule. The project leader evaluates the data, presents it at the relevant meetings, enters it into the scheme registration system (DAKBİS), and conducts regular checks. Breeders who fulfill their obligations under the scheme receive

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support payments in amounts specified in the Council of Ministers' Decision on Agricultural Supports every year. The scheme is managed by the supreme, advisory, and executive boards.

Present study material

The main driver of producers' decision-making is the maximization of economic well-being, although traditional small ruminant production systems may also involve aesthetic, sentimental, or intangible considerations (James, 1986).

As Gertler et al. (2016) explained, assessing the impact of a program requires comparing its outcomes with those that would have occurred in its absence. This necessitates establishing a comparison group to estimate the changes attributable to the program or policy (Gertler et al., 2016).

The national genetic improvement scheme aims to improve native breeds to increase mutton and/or milk yields, ultimately leading to a positive contribution to farm income or profitability per head. While government measures may benefit all flocks, including those not part of the scheme, it is anticipated that scheme-included flocks will exhibit a positive difference in income per animal compared to excluded flocks if there is a discernible impact.

Accordingly, scheme participant farmers (PFs) were compared with non-participant farmers (non-PFs) operating under similar agroecological conditions and with the same sheep breed, focusing on gross profit per ewe (GPpE). Primary study data were collected using structured questionnaires from both PFs and non-PFs. PFs have voluntarily participated in the genetic improvement scheme since 2006, following signed contracts indicating that all rearing decisions would be made by the project leader. In contrast, non-PFs made decisions without any scheme involvement or signed contracts. Additionally, secondary material for the study included official records from relevant institutions.

Sampling

The study conducted a complete enumeration for contracted (participant) farmers (PFs) for all base flocks (Çiçek and Erkan, 1996). Additionally, a comparison group of non-participant farmers (non-PFs), randomly selected and approximately equal in number to the PFs, was included.

The questionnaire was developed based on the Edict on Implementation Principles and the Instructions for the Community-based Animal Breeding National Scheme Implementation Principles (TAGEM, 2012) as well as on a review of relevant literature. It was divided into three sections: the first section focused on the demographic characteristics of the farm family, the second on farm assets, and the third on animal husbandry practices and related topics. Data collection was conducted through face-to-face interviews over two months, from early December 2014 to the end of January 2015. Ethical approval was obtained from the Committee on Scientific Research and Publishing Ethics at Dicle University (decree dated October 1, 2014 and numbered 1550), ensuring adherence to accepted scientific and ethical principles.

Data handling

Several factors interact with and affect the success of animal production in the socioeconomic environment of extensive production systems. Therefore, it is necessary to consider these factors together when evaluating a program aimed at enhancing the overall system. In extensive farming systems, some of these factors are related to farmers (age and education), some to farm attributes (e.g., flock size, labor assets, sheep breeds, pen size, and feed supply), and others to flock management (e.g., animal feeding, housing conditions, and flock health). Therefore, the technical and financial performance indicators of PFs and non-PFs in different geographical locations were compared.

Technical Success Indicators. The technical indicators considered in this study were litter size, lambing rate, infertility rate, abortion rate, lamb live weight at birth, twin or multiple birth rates, and lamb mortality rate. Meaningful positive differences in these indicators in favor of scheme-included flocks may suggest a positive impact of the national scheme.

- Litter size: Number of lambs born alive divided by the number of lambed ewes.
- Lambing rate: Number of lambed ewes divided by the total number of ewes exposed to a ram.
- Infertility rate: Number of barren sheep divided by the number of ewes exposed to a ram.
- Abortion rate: Number of ewes that aborted divided by the number of ewes exposed to a ram.
- Twin or multiple birth rates: Number of twins or multiple births divided by the number of lambed ewes.
- Lamb mortality rate: Number of lambs that died at all ages divided by the number of lambs born alive (Menzies, 2007; Kaymakçı, 2016).

Breeders typically did not monitor the live weight of the lambs. However, in scheme-included flocks, project staff recorded lamb weights at birth and at intervals thereafter. Non-PFs generally did not record live weight at birth, making it difficult to compare live weight gains. Nonetheless, comparisons were possible for those non-PFs who did record birth weights.

Financial Indicators. Farm animal income is expected to increase due to improvements in the aforementioned technical performance indicators within the Genetic Improvement Scheme. In production economics and perfectly competitive markets, the gross production value should at least cover variable costs (Erkuş and Demirci, 1996; Drummond and Goodwin, 2004). In other words, variable costs play an important role in farmers' decision-making processes regarding farm production, i.e., gross profit is an important criterion indicating farm success and the competitive strength of farm activities. Therefore, GPpE was calculated as the key financial performance indicator for the impact assessment.

Gross profit was calculated according to the single-crop budget for sheep production, disregarding other farm activities (Aras, 1988; Çetin and Tipi, 2007). The gross profit per farm was divided by the total number of parent stock females at the beginning of the production season to obtain GPpE.

Gross profit was calculated by subtracting variable costs from the gross production value (Erkuş and Demirci, 1996; Karagölge, 2001). The gross production value includes the total value of byproducts and the main product obtained during the production period (Karagölge, 2001), adjusted by local trading prices and production assets increases (Erkuş and Demirci, 1996). Variable costs included expenses for roughage, concentrates, veterinary care and medicines, vaccination, energy, consumables, shepherd wages, and revolving capital interest (Karagölge, 2001).

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The revolving capital interest was calculated by applying the real interest rate to half of the variable cost. The real interest rate was 1.76% for 2014, based on a 7.9% producer price index increase and a 9.8% nominal interest rate (Kıral et al., 1999).

Labor assets of the farms were calculated as adult male equivalent (AME) to eliminate age and gender differences using conversion factors: 0.75 for adult females and 0.50 for child labor, as these rates were also applied to convert adult males and females aged 65 and over, respectively (Erkuş and Demirci, 1996).

Purchased animals were evaluated at purchase cost, while reared animals were evaluated at local trading prices (Yıldırım and Şahin, 2003). Farm-consumed roughages were not appraised separately (Erkuş, 1979).

Notable findings. General cleaning and limewash applications in sheepfolds, the most common sheep diseases and internal-external parasites (SDIEPs), and their effects on technical success indicators (e.g., lambing rate, litter size, and lamb mortality) were examined, along with the challenges faced by farmers in sheep farming.

Respondents rated SDIEPs and challenges on a 1–5 scale (from lowest to highest seriousness). Unanswered questions were treated as “not affected.” To streamline the data, scores of 4 and 5 were coded as 1, and the rest were coded as 0, assuming that farmers who suffered more would give higher scores.

Data analysis

Data analysis involved descriptive statistics to characterize the study farms, and independent-sample t-tests and chi-square tests for group comparisons. Regression analysis was employed to analyze the factors impacting the success of sheep farming.

In economics, the principle of ceteris paribus, or "holding all other things constant,” is crucial for determining causation (Gujarati, 2011). Linear estimators facilitate explaining the marginal effects of independent variables on the dependent variables. However, according to Baltagi (2005), individuals, firms, states, and countries (in this case, sheep breeds) are heterogeneous units. Failure to control this heterogeneity in data analysis other than panel data could yield inconsistent results.

Data were collected from small ruminant farms representing nine different genotypes across ten provinces spanning Türkiye’s diverse agroecological environments (*Fig. 2*).

Figure 2. *The study area encompasses the provinces where genetic improvement studies were conducted. The names in brackets indicate the sheep breeds associated with each province*

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This wide geographical coverage indicates heterogeneity in the dataset. Consequently, panel data regression was chosen for unbiased and consistent results. Fixed effect (FE) and random effect (RE) models are common techniques in panel data analysis. The Hausman test results (P<0.01) favored the FE panel regression (Torres-Reyna, 2007; Gujarati, 2011). However, in panel data regression, panel variables (here, sheep breeds) were not included as explanatory variables, preventing the model from indicating breed effects on dependent variables. Hence, least squares dummy variable (LSDV) regression was preferred over FE panel data regression. Both techniques yield equivalent results, and the sample size per breed is sufficiently large (Torres-Reyna, 2007; Gujarati, 2011).

Given the cross-sectional one-year data used in this study, the LSDV regression model can be expressed as Equation 1.

$$Y_i = \alpha_1 + \alpha_2 D_{2i} + \cdots + \alpha_k D_{ki} + \beta_1 X_{1i} + \beta_2 X_{2i} + \ldots + \beta_n X_{ni} + u_i \qquad \text{(Eq.1)}$$

where Yi and α represent the dependent variable and intercept, respectively; Xi and Di represent the explanatory continuous (independent) and dummy (independent) variables, respectively; β1 to βn represent slope coefficients; k and n represent the kth dummy and nth continuous variables, respectively; i represents the ith individual and ui represents the error term.

In the LSDV model, categorical variables are represented by dummy variables, with one less dummy than the number of categories, to avoid dummy variable traps. The reference category was excluded from the model, and other categories were represented by respective dummy variables (Gujarati, 2011). For example, D2 = 1 if the observation belongs to the second dummy and 0 otherwise; D3 = 1 if the observation belongs to the third dummy and 0 otherwise; and so on for Dk = 1, where k represents the number of dummies.

In this study, the sheep breed variable had ten categories and was represented by nine dummy variables. Since the lowest category (Morkaraman sheep) was omitted from the regression model, the coefficients of the other categories should be interpreted relative to this reference category. For continuous independent variables, coefficients represent the marginal change in the dependent variable due to a one-unit change in the independent variable, while holding all other variables constant (ceteris paribus) (Gujarati, 2011).

The model included male and female labor assets separately to explore gender-oriented differences in labor needs for small ruminant rearing. Additionally, interactions such as farmer age × experience and farmer age × schooling interactions were incorporated into the model.

The GPpE was modeled as a function of both continuous and discrete variables, as shown in *Table 1*.

The study utilized the two-sample Kolmogorov-Smirnov test to assess whether PFs and non-PFs were drawn from the same population (Sokal and Rohlf, 1994). Normality assumptions were evaluated using the Jarque–Bera test and graph methods (Gujarati, 1995; Torres-Reyna, 2007). Model specification error was tested using the Stata command link test, while multicollinearity was examined using the variance inflation factor (VIF) (Cameron and Trivedi, 2010). Given the common occurrence of heteroscedasticity in cross-sectional data, regression analysis employed a robust standard error procedure to address this issue (Torres-Reyna, 2007; Gujarati, 2011). Data analysis was performed using the Stata SE 14.2 software package (StataCorp, 2015).

Table 1. *Definitions of the study variables*

Variables	Definitions
Gross profit per ewe (GPpE)	: Gross profit per flock (farm) was calculated and then divided by the number of females at the beginning of the season for each farm (₺)
Farmer age	: Age of the respondent farmer (year)
Experience	: Number of years the farmer has been involved in sheep rearing (year).
Age × Experience	: Farmer age and experience interaction
Schooling	: Years of education completed by the respondent farmer (years)
Age × School	: Farmer age and schooling interaction
Male labor	: Male labor asset of respondent farmers in the adult male equivalent
Female labor	: Female labor asset of respondent farmers in the adult male equivalent
Own land	: The land possessed by the farmer in hectares
Rented land	: The land rented by the farmer in hectares
Project	: Dummy variable that indicates the participation status of the respondent farmers in the Scheme (1: Participant, 0: Non-participant)
Sheep breed	: Categorical variable that indicates the sheep breed raised by the respondent farm (1:Morkaraman; 2:Hemşin; 3:Karayaka; 4:Kangal Akkaraman; 5: Central Anatolia Merino; 6: Pırlak; 7: Karya in the Aydın Province; 8: Karya in the Denizli Province; 9: Akkaraman; 10: İvesi
Flock size	: Number of ewes at the beginning of the studied year (head)
Sheepfold type	: The technique used in sheepfold construction (1: concrete; 0: Traditional)
Sheepfold size	: The total floor area of the sheepfold (square meter)
Sheepfold size per ewe	: Sheepfold size divided by the number of females at the beginning of the studied year in each farm (square meter)
Sheepfold size per ewe^2	: Squared term for Sheepfold Size per Ewe
Farm-produced feed	: The percentage of feedstuffs produced in-house in relation to total feed consumption (%)
Purchased straw	: The percentage of purchased straw in relation to total feed consumption (%)
Purchased grains	: The percentage of purchased grains in relation to total feed consumption (%)
Purchased compounds	: The percentage of compounds purchased in relation to total feed consumption (%)
Purchased grasses	: The percentage of purchased grass in relation to total feed consumption (%)

Results

Descriptive statistics

Table 2 presents the descriptive statistics for the variables considered in the regression analysis.

The average farmer age was 48.1 ± 10.9 years, significantly greater for PFs than non-PFs (P<0.01). PFs also had significantly more breeding experience (P<0.01). Another demographic factor is educational level, which is the total number of years spent in formal schools; no significant differences were detected between PFs and non-PFs (P>0.1).

PFs had significantly higher male, female, and total labor assets (P<0.01), but there was no significant difference between owned and rented land, though PFs owned more land but rented less.

On the studied farms, approximately 62% of sheepfolds were traditional, with the rest being concrete. PFs had significantly more concrete pens (44% vs. 33%, P<0.05) and larger sheepfolds, but non-PFs had better pen size per ewe (P<0.01).

PFs used more homegrown feed and purchased more compound feed, while non-PFs bought more straw and grain. However, no significant difference was observed between

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PFs and non-PFs for feed costs per ewe (P>0.1). Main off-farm feed purchases included barley (15%), straw (27%), and compound feed (24%), with significant variations between farmer groups and sheep breeds. Notable percentages were for straw in İvesi sheep (50% PFs, 48% non-PFs), barley in Karya breeders in Denizli (42% PFs, 35% non-PFs) and for İvesi breeders in Şanlıurfa (32% PFs, 40% non-PFs), compound feed in Central Anatolia Merino (71% PFs, 27% non-PFs), Karayaka (49% PFs, 46% non-PFs), and Akkaraman (34% PFs, 66% non-PFs).

Table 2. *Descriptive statistics for the study variables*

Variable	Non-participant farmers			Participant farmers			t	p
	N	Mean	$S\bar{x}$	N	Mean	$S\bar{x}$		
Farmer age	236	45.49	0.72	206	50.98	0.69	-5.49	0.00
Farmer experience	236	26.95	0.86	206	35.23	0.80	-7.01	0.00
Farmer schooling years	236	5.96	0.17	206	5.97	0.16	-0.04	0.97
Male labor	236	2.61	0.09	206	3.11	0.14	-3.08	0.00
Female labor	236	1.83	0.07	206	2.18	0.11	-2.67	0.01
Total labor	236	4.45	0.14	206	5.29	0.21	-3.35	0.00
Own land	236	7.70	1.50	206	10.80	1.61	-1.40	0.16
Rented land	236	5.46	2.99	206	5.22	0.86	0.07	0.94
Flock size (number of ewes)	236	157.10	8.53	206	240.22	11.01	-5.97	0.00
Sheepfold size	236	219.17	17.10	206	277.86	18.80	-2.31	0.02
Sheepfold size per ewe	236	1.96	0.17	206	1.34	0.09	3.15	0.00
Own-produced feedstuffs (%)	236	39.56	2.52	206	45.57	2.64	-1.65	0.10
Purchased straw (%)	236	20.58	1.48	206	18.41	1.45	1.04	0.29
Purchased grains (%)	236	12.50	1.15	206	10.40	1.05	1.35	0.18
Purchased compounds (%)	236	9.22	0.87	206	11.01	1.12	-1.27	0.21
Purchased grasses (%)	236	11.80	1.38	206	7.67	1.05	2.38	0.02
Gross revenue per ewe	236	481.15	19.84	206	505.54	20.71	-0.85	0.40

Feedstuff costs accounted for the highest share (55%) of the total variable costs in sheep farming, followed by shepherd wages (30%). However, in the Morkaraman, Kangal Akkaraman, and Akkaraman sheep breeds, shepherd wages ranked first. There was no significant difference in feed costs per ewe between PFs and non-PFs.

The GPpE across sheep breeds and farmer groups is shown in *Fig. 3*. The highest gross profits were for Karya sheep in the Aydın Province and Central Anatolian Merino sheep. PFs in Central Anatolian Merino sheep had greater GPpE than non-PFs, but non-PFs in Aydın Province had greater GPpE than PFs for Karya sheep.

Technical success indicators

Lamb birth weight, milk yield and litter size, lambing rate, abortion rate, and lamb mortality

Genetic improvement studies are expected to result in increases in live weight gain, milk yield, lambing rate, and litter size per birth, as well as decreases in abortion rate, infertility, and perinatal and postnatal lamb deaths, although these findings are mainly related to management and breeder expertise. The findings related to these success indicators are presented in *Table 3*.

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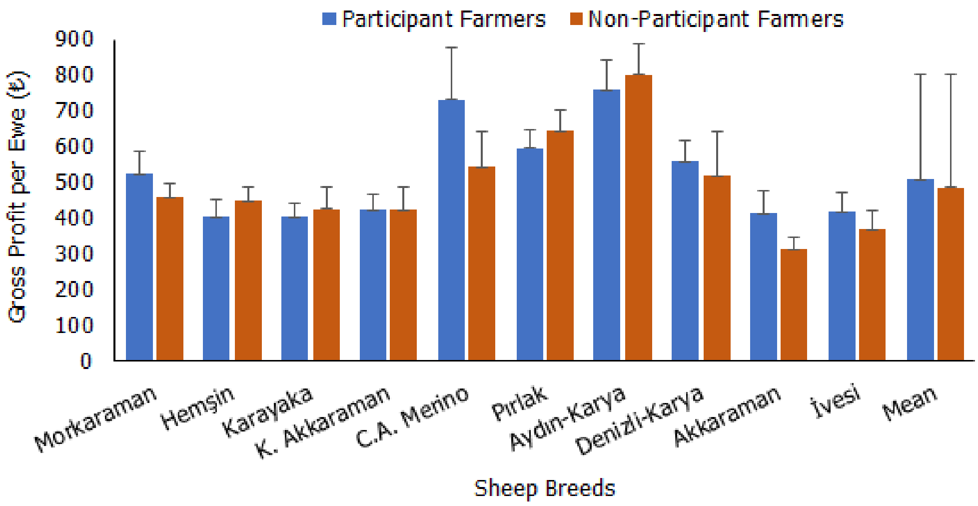

Figure 3. *Breed-specific variation in gross profit per ewe (GPpE)*

Table 3. *Comparative indicators of technical success and flock health across breeder groups*

Indicators	Non-PFs			PFs			t	P
	N	Mean	Sx̄	N	Mean	Sx̄		
Milk yield	*127*	*0.366*	*0.024*	*117*	*0.455*	*0.028*	*-2.433*	*0.016*
Lamb live-weight at birth	*138*	*3.220*	*0.084*	*204*	*3.944*	*0.061*	*-7.115*	*0.000*
Lambing rate	*236*	*0.859*	*0.008*	*206*	*0.878*	*0.006*	*-1.945*	*0.052*
Litter size	*236*	*1.158*	*0.010*	*206*	*1.204*	*0.012*	*-2.887*	*0.004*
Abortion rate	*236*	*0.044*	*0.004*	*206*	*0.034*	*0.003*	*2.202*	*0.028*
Infertility	236	0.075	0.006	206	0.063	0.005	1.591	0.112
Lamb mortality	*236*	*0.079*	*0.006*	*206*	*0.058*	*0.003*	*2.977*	*0.003*

Lamb live weight at birth, yield per delivery, and mortality rate were significantly associated with PFs. Milk yield was significantly higher, and the abortion rate was significantly lower for PFs ($P<0.05$), while lambing rate was only marginally ($P<0.1$) greater for PFs compared to non-PFs (*Table 3*). The difference in infertility rates was not significant ($P>0.1$).

Sheep diseases and internal-external parasites (SDIEPs)

SDIEPs cause lamb and adult deaths, as well as deterioration in the yield and quality of mutton and milk and in the reproductive performance of the flock. Small ruminants are known to live in flocks, grazing together and sharing the same pen. This exacerbates the spread of SDIEPs and makes controlling them challenging. Zoonotic animal diseases can threaten human health, if not controlled. PFs and non-PFs were compared for the most common SDIEPs, and the results are presented in *Table 4*.

The severity and ranking of the most important SDIEPs were similar in both groups. PFs performed better only for liver fluke, sheep tick, and mastitis, with very significant, significant, and marginally significant levels, respectively (*Table 4*).

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***Table 4.** Frequency of reported sheep diseases and parasitic issues (SDIEPs) across breeder groups*

Declared SDIEPs	Non-PFs (N = 236)		PFs (N = 206)		Total (N = 442)	Chi-square	P
	N	%	N	%			
Sheep tick	*122*	*51.7*	*84*	*40.8*	*206*	*5.269*	*0.022*
Tapeworm	118	50.0	94	45.6	213	0.841	0.359
Foot and Mouth Disease	113	47.9	83	40.3	196	2.567	0.109
Liver fluke	*101*	*42.8*	*55*	*26.7*	*156*	*12.481*	*0.000*
Brucellosis	96	40.7	88	42.7	184	0.188	0.664
Intestinal nematodes	95	40.3	83	40.3	179	0.000	0.994
Septicemia	89	37.7	82	39.8	171	0.203	0.652
Enterotoxaemia	85	36.0	77	37.4	162	0.088	0.767
Sheep pox	81	34.3	80	38.8	161	0.967	0.325
Scabies	78	33.1	59	28.6	137	1.000	0.317
Mastitis	*77*	*32.6*	*50*	*24.3*	*127*	*3.750*	*0.053*
Sheep plague	43	18.2	41	19.9	84	0.202	0.653
Meningeal worm	42	17.8	36	17.5	78	0.008	0.930
Pseudotuberculosis	41	17.4	29	14.1	70	0.896	0.344
Necrotic hepatitis	25	10.6	16	7.8	41	1.044	0.307
Contagious agalactia	19	8.1	17	8.3	36	0.006	0.938
Anthrax	16	6.8	14	6.8	30	0.000	0.995

Sheep farming challenges (SFCs)

Respondents identified the biggest challenges in sheep farming. High shepherd wages and shepherd shortages, being interrelated, were combined into a single "shepherd challenge" category. Similarly, old and insufficient sheepfolds were combined into a "sheepfold challenge." *Table 5* shows the distribution of the most frequently reported SFCs by PFs and non-PFs.

***Table 5.** Comparative overview of key challenges faced by participant (PFs) and non-participant farmers (non-PFs)*

Declared challenge	Non-PFs (N = 236)		PFs (N = 206)		Total (N = 442)	Chi-square	P
	N	%	N	%			
Low prices	182	77.1	168	81.6	350	1.312	0.252
Shepherd Challenge	160	67.8	157	76.2	317	3.842	0.050
High shepherd wages	136	57.6	146	70.9	282	8.357	0.004
Shepherd shortage	131	55.5	130	63.1	261	2.626	0.105
Sheepfold challenge	144	61.0	99	48.1	243	7.462	0.006
Old sheepfolds	112	47.5	73	35.4	185	6.531	0.011
Insufficient Sheepfolds	107	45.3	69	33.5	176	6.439	0.011
Lack of grazing water	137	58.1	123	59.7	260	0.125	0.724
Wild animals	133	56.4	108	52.4	241	0.685	0.408
Diseases	116	49.2	84	40.8	200	3.115	0.780
Insufficient vet. services	109	46.2	76	36.9	185	3.903	0.048
Rangeland violations	83	35.2	68	33.0	151	0.228	0.633
Lack of dairy houses	72	30.5	56	27.2	128	0.591	0.442
Other challenges	123	52.1	97	47.1	220	1.114	0.291

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Insufficient rangelands, high input prices, nomad intrusions into village rangelands, and a lack of livestock markets were the other SFCs in respective order for both groups of farmers.

The severity and ranking of most SFCs did not differ between the groups. Low product prices and the shepherd challenge ranked first and second for both groups. However, the sheepfold challenge lagged behind the challenges of lack of grazing water and wild animal attacks on PFs. The remainder followed the same order of importance in both groups (*Table 5*).

Regression analysis results

Before proceeding with the model estimates, the model specification test results were examined. An F test of 5.48 and a P-value of 0.000 confirmed that the LSDV model was statistically significant. However, the normality assumption failed according to the Jarque–Bera test ($P<0.01$). However, it should be noted that it is more difficult to meet the normality assumption with a larger sample because of the small, negligible differences detected. Therefore, normality may be problematic when the sample size is small (Lumley et al., 2002). Accordingly, the normal probability plot distribution of the residuals confirmed that the normality assumption was not violated.

However, the link test, with an alternative hypothesis claiming that the model was erroneously specified, did not reject this null hypothesis. Moreover, the calculated VIF values, ranging between 1.12 and 37.33 with a mean value of 6.76, indicated that the estimated model had a somewhat serious multicollinearity problem. However, high VIF values were detected only for the interaction terms and their components; this type of multicollinearity is called "inessential ill-conditioning" and is typically observed for models with interaction terms and powers (Francoeur, 2013) and has no adverse consequences (Allison, 2012). *Table 6* presents the results of the LSDV regression analysis.

According to the LSDV model estimates, the effects of age, experience, schooling, male labor assets, age × experience and age × schooling interactions, owned land, sheepfold type, percentages of own-produced feedstuffs, purchased straw, purchased grains, purchased compound feeds, and purchased grasses were not significant for GPpE. However, flock size, sheepfold size per ewe, and sheep breed were found to be significantly effective, whereas the effects of female labor, rented land, and project variables on GPpE were marginally significant.

Since sheep breed was a categorical variable and was represented by dummy variables in the model in number one, it was less than the number of its categories (Gujarati, 2011). The lowest category (Morkaraman sheep) was treated as the reference category, and the coefficients of the other dummy variables were interpreted accordingly.

The negative signs of the coefficients for Karayaka, Kangal Akkaraman, Akkaraman, and İvesi indicate that these breeds have a lower GPpE than the reference group. Except for the Karayaka sheep, this relationship was significant. In contrast, the Karya, Pırlak, and Central Anatolian Merino breeds had significantly ($P<0.01$) higher GPpE values than the reference group.

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Table 6. *Least squares dummy variable (LSDV) regression results assessing group-specific impacts*

Gross profit per ewe	Coefficient	Robust Std. error*	t	P	VIF
Age	-0.876	7.825	-0.110	0.913	16.83
Experience	4.327	6.832	0.630	0.542	22.90
Age × Experience	-0.049	0.130	-0.380	0.715	38.13
Schooling	4.139	38.453	0.110	0.917	20.57
Age × Schooling	-0.338	0.756	-0.450	0.665	21.64
Male Labor	12.544	9.628	1.300	0.225	1.46
Female Labor	*20.915*	*9.223*	*2.270*	*0.050*	*1.49*
Own land	0.443	0.395	1.120	0.292	1.29
Rented land	*-0.349*	*0.190*	*-1.840*	*0.099*	*1.11*
Project	*40.039*	*18.325*	*2.180*	*0.057*	*1.41*
Sheep breed					
Hemşin	*101.154*	*28.609*	*3.540*	*0.006*	*3.11*
Karayaka	8.006	22.870	0.350	0.734	2.96
Kangal Akkaraman	*-51.699*	*18.296*	*-2.830*	*0.020*	*2.35*
Central Anatolia Merino	*161.998*	*22.454*	*7.210*	*0.000*	*1.67*
Pırlak	*196.351*	*22.634*	*8.680*	*0.000*	*2.52*
Karya (Aydın)	*306.404*	*30.787*	*9.950*	*0.000*	*2.09*
Karya (Denizli)	*163.916*	*33.390*	*4.910*	*0.001*	*1.90*
Akkaraman	-36.139	29.880	-1.210	0.257	2.41
İvesi	*-106.597*	*37.905*	*-2.810*	*0.020*	*3.33*
Flock size (number of ewes)	*-0.274*	*0.091*	*-3.000*	*0.015*	*2.04*
Sheepfold type	21.590	31.553	0.680	0.511	1.13
Sheepfold size per ewe	*29.910*	*7.331*	*4.080*	*0.003*	*5.51*
Sheepfold size per ewe2	*-0.891*	*0.341*	*-2.620*	*0.028*	*4.91*
Own-produced feedstuffs (%)	2.042	1.312	1.560	0.154	8.37
Purchased straw (%)	1.414	1.227	1.150	0.279	3.99
Purchased grains (%)	0.575	1.779	0.320	0.754	3.92
Purchased compounds (%)	-0.851	1.513	-0.560	0.588	2.58
Purchased grasses (%)	-0.516	1.452	-0.360	0.730	3.28
Constant	280.584	525.450	0.530	0.606	
Number of observations	: 242	F (28. 413)	: 4.75	Mean VIF	: 6.60
R^2	: 24.36	Adjusted R^2	: 19.23	P	: 0.000

* Adjusted for 10 clusters of sheep breeds, VIF: variance inflation factor

Notable findings

Effect of sheepfold cleaning and limewash on SDIEPs

During the survey, respondents were asked whether they had carried out general cleaning and lime washing of sheepfolds. Respondents' answers were associated with complaints regarding the SDIEPs. The results are summarized in *Table 7*.

Table 7 shows that complaints of tapeworms, intestinal nematodes, foot and mouth disease, sheep pox, and liver flukes were significantly more common among the farmers who did not perform general cleaning of their sheepfolds. Similarly, *Table 8* clearly shows that tapeworms, intestinal nematodes, and liver flukes were significantly less common among the farmers who performed limewash in their sheepfolds.

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Table 7. *Reported incidence of sheep diseases and internal–external parasites (SDIEPs) among farmers by sheepfold cleaning practices*

Declared SDIEP	Farmers not performing general cleaning (N = 52)		Farmers performing general cleaning (N = 390)		Total (N = 442)	Chi-square	P
	N	%	N	%			
Tapeworm	*34*	*65.4*	*178*	*45.6*	*212*	*7.166*	*0.007*
Intestinal nematodes	*31*	*59.6*	*147*	*37.7*	*178*	*9.168*	*0.002*
Foot and Mouth Disease	*30*	*57.7*	*166*	*42.6*	*196*	*4.255*	*0.039*
Sheep pox	*27*	*51.9*	*134*	*34.4*	*161*	*6.112*	*0.013*
Liver fluke	*24*	*46.2*	*132*	*33.8*	*156*	*3.043*	*0.081*
Enterotoxaemia	23	44.2	139	35.6	162	1.458	0.227

Table 8. *Reported incidence of sheep diseases and internal–external parasites (SDIEPs) by limewashing practices among farmers*

Declared SDIEP	Farmers not limewashing (N = 120)		Farmers limewashing (N = 322)		Total (N = 442)	Chi-square	P
	N	%	N	%			
Tapeworm	*67*	*55.8*	*145*	*45.0*	*212*	*4.087*	*0.043*
Intestinal Nematodes	56	46.7	122	37.9	178	2.801	0.094
Sheep tick	56	46.7	150	46.6	206	0.000	0.988
Foot and Mouth Disease	54	45.0	142	44.0	196	0.029	0.865
Liver fluke	*54*	*45.0*	*102*	*31.7*	*156*	*6.795*	*0.009*
Septicemia	46	38.3	125	38.8	171	0.009	0.926
Enterotoxaemia	44	36.7	118	36.5	162	0.001	0.979
Sheep pox	43	35.8	118	36.6	161	0.025	0.875

Effect of SDIEPs on several technical indicators

The effects of certain diseases and internal and external parasitic infections on lambing rate, litter size, and mortality rates are shown in *Table 9*.

Table 9. *Impact of selected sheep diseases and internal–external parasites (SDIEPs) on lambing rate, litter size, and lamb mortality*

SDIEP	Farmers declaring no problems			Farmers declaring problems			t	P
	N	Mean	$S\bar{x}$	N	Mean	$S\bar{x}$		
Lambing rate								
Brucellosis	*258*	*0.877*	*0.007*	*184*	*0.855*	*0.007*	*2.092*	*0.037*
Necrotic Hepatitis	*401*	*0.872*	*0.005*	*41*	*0.830*	*0.018*	*2.254*	*0.029*
Sheep tick	*236*	*0.883*	*0.007*	*206*	*0.850*	*0.008*	*3.226*	*0.001*
Tapeworm	*230*	*0.858*	*0.007*	*212*	*0.879*	*0.007*	*-2.092*	*0.037*
Intestinal Nematodes	*264*	*0.860*	*0.007*	*178*	*0.879*	*0.007*	*-1.922*	*0.055*
Liver fluke	*286*	*0.859*	*0.007*	*156*	*0.884*	*0.007*	*-2.542*	*0.011*
Litter size								
Scabies	*305*	*1.200*	*0.010*	*137*	*1.134*	*0.011*	*4.435*	*0.000*
Anthrax	*412*	*1.185*	*0.008*	*30*	*1.104*	*0.014*	*4.913*	*0.000*
Lamb mortality								
Septicemia	*271*	*0.062*	*0.005*	*171*	*0.082*	*0.006*	*-2.631*	*0.009*

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As expected, farmers who reported sheep tick, brucellosis, and necrotic hepatitis infestations had significantly lower lambing rates. Surprisingly, those declaring internal parasites, such as tapeworms, intestinal nematodes, and liver flukes, had significantly higher lambing rates (*Table 9*).

Again, litter size was significantly lower (P<0.01) for farmers who reported scabies and anthrax compared to those who did not report any complaints against them. In contrast, significantly (P<0.01) higher lamb death rates were calculated for farmers who declared severe septicemia.

Discussion

Descriptive statistics and regression analysis results

Although not significant, the variations in the farmers' age, experience, and schooling were as expected. As farmers grow older, they gain experience and become more productive with improved managerial ability; however, their productivity may decline later in life (Tauer, 1995), i.e., the productivity of farmers is expected to increase up to a certain age and decrease thereafter. Although non-significant, the negative signs of farmer age and farmer age × experience interaction and positive signs of experience suggest that farmers' experience positively affects GPpE due to their improved managerial ability, which may not work at younger ages. Similarly, the non-significant positive sign of schooling suggests a positive contribution of educational level to gross profit, while the negative sign of schooling × age interaction implies that this positive contribution is only possible at younger ages.

The positively signed coefficients of both male and female labor variables indicate the importance of labor supply in small ruminant farming; however, only the effect of the latter was marginally significant. Notably, small ruminant farming is labor-intensive, and grazing, milking, caring, feeding, and shearing require considerable labor in sheep farming. The marginally significant (P<0.1) effect of female labor supply is because some breeders only sell lambs and ignore sheep milk due to labor shortages, while milk and milk product sales are important contributors to total revenue. Notably, the rule of sex separation is valid for farm families; therefore, men and women have traditionally played distinct roles and duties owing to differences in their characteristics and abilities. Similar to the findings reported by previous studies (Yılmaz et al., 2014; Dalgıç and Demircan, 2018), this study revealed that women generally handled milking and milk processing, while men performed shepherding, maintenance, and shearing. Both sexes participated in everyday work activities like cleaning and feeding, though these tasks were mostly done by men. The study data support this claim that breeders utilizing sheep milk had significantly more female labor (P<0.05) and a higher GPpE (P<0.01).

The financial impact of the Genetic Improvement Scheme was measured using the project variables. The positive sign of the project variable coefficient indicates that a shift from non-PFs to PFs yields an increase of approximately 40.0 TRY, equivalent to 18.74 USD (1 USD = 2.1344 TRY), as reported by the Central Bank of Türkiye on July 2, 2014 (TCMB, 2014). However, this positive difference in favor of PFs was only marginally justified (P<0.1), which implies that the progress achieved by the scheme in approximately ten years since its launch was insufficient in monetary terms.

According to Young et al. (2020), flock size can affect profitability, though it is not very important. Papanikolopoulou et al. (2023) found that larger flock sizes are required for better economic performance. However, our study showed a significant negative

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effect of flock size (P<0.05). This negative impact is likely due to decreased milk utilization with increased flock size (*Fig. 4*).

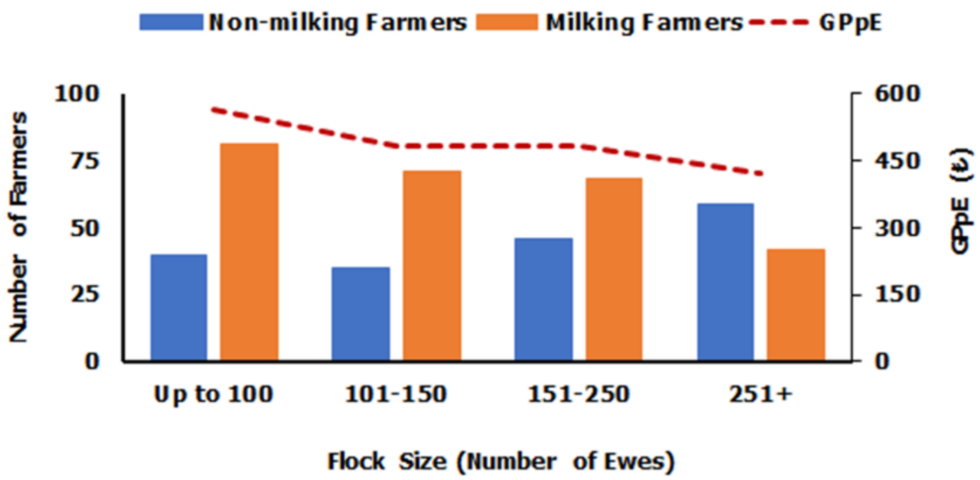

Figure 4. *Distribution of gross profit per ewe (GPpE) and farmer milking status across flock size groups*

Housing is an important animal welfare issue, and sheepfolds should protect animals from climate extremes to reduce stress and improve their growth, health, and reproductive performance. Unfortunately, small ruminant pens, particularly traditional sheepfolds, are often inadequate in terms of design and materials. They usually cannot ensure the required animal welfare facilities, such as light, drainage, space allowance, and ventilation, which can lead to poor control of ambient hygiene (Caroprese et al., 2009). This problem was also verified by a study in which the structural features of sheep farms in Elazığ were examined and compared with those in different regions of Türkiye (Şeker et al., 2022).

The present study addresses this issue. As stated earlier, approximately 62% of the sheepfolds were traditional constructions, and the rest were concrete buildings. Accordingly, more than 60% of non-PFs and approximately half of the PFs (55% on average) complained of insufficient and/or very old sheepfolds (*Table 5*). The significant difference between the two groups can be better understood by remembering that PFs had significantly more concrete pens (P<0.05).

However, in this study, the sheepfold construction type had no significant effect on GPpE, even though the positive sign coefficient of the relevant variable suggested an increase of approximately 23.6 TRY in GPpE when shifting from traditional sheepfolds to concrete sheepfolds, ceteris paribus (*Table 6*). The small floor area per ewe might have overshadowed the significant positive effect of the concrete pens because the average floor areas per ewe were calculated to be 1.75 and 1.60 square meters for traditional and concrete pens, respectively, indicating that the pen floor area per head is one of the most reliable animal welfare indicators of housing conditions (Caroprese et al., 2009).

Thus, in the present study, the effect of the sheepfold floor area per ewe was positive and highly significant (P<0.01). According to the model, a unit increase in floor area per ewe may cause an increase in GPpE of approximately 30 TRY, ceteris paribus. However, the inclusion of the quadratic term of pen size per ewe in the model increased the quality of the model (R2 increased from 22.16 to 22.58) and had a very significant effect on the dependent variable (*Table 6*). The negative sign of this quadratic term suggests that,

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although GPpE increases with a unit increment in pen size per ewe by approximately 30 TRY, the rate of increase declines with increasing sheepfold size. This implies that excessively large sheepfolds hinder the achievement of a higher gross profit. The space allocation requirements of sheep differ according to age; however, Sevi et al. (1999) suggested 2.0 m2 of space per ewe for sustainable production performance and animal health.

The most important cost component of sheep farming is feed expenditure, which constitutes approximately 55% of the total cost, although small ruminant feeding is easier than that of other domestic farm animals because of their considerably lower nutritional requirements. Their main feedstock source is roughage, and they effectively utilize rangelands. Grains suffice as an energy feed, and other feeds, especially compound feeds, are not needed, even in cases of high nutrient requirements, especially during lactation and the last 50 days of pregnancy (Çakır et al., 1995; Schoenian, 2015).

Therefore, although not significant, positive signs of purchased straw and grains, along with negative signs of purchased grasses and compound feeds, could be interpreted as straw, together with grains, being sufficient to cover animal needs. Moreover, the positive effect of land ownership on GPpE is likely to be associated with feedstock production.

Shepherd wages are the second-most important component of sheep farming. They are closely associated with the shepherd shortage, which is rooted in social causes such as lack of social security (Şahin et al., 2019) and low rank in society; that is, people look down on shepherds, and they do not give their daughters to shepherds to marry (Çınar, 2015).

Regarding the performance of the sheep breeds, Kangal Akkaraman, Akkaraman, and İvesi breeders had significantly lower gross profits per head than the breeders in the reference category. This may be because most Kangal Akkaraman breeders (82.7%) sell lambs and do not utilize sheep milk. The reasons for this discrepancy may vary. In general, Akkaraman breeders have large flocks, in which the sheepfold size per ewe is the lowest among all sheep breeds. Akkaraman breeders had higher feed and shepherd costs than the average for all the breeds in this study. Again, only 46.4% of the breeders used sheep milk. Moreover, the significantly lower gross profit of the İvesi breeders could be explained by their greater infertility (16.3%) and lamb mortality rates (8.1%).

The significantly higher GPpE in the Karya, Pırlak, and CA Merino breeds can be explained by the fact that Karya breeders had the lowest variable costs, whereas the Pırlak and CA Merino breeds had comparatively low variable costs among all studied breeds. Another reason for this may be the high genetic value of the three breeds. The CA Merino was obtained by crossing Akkaraman with the German Meatmerino. It inherits 80% of its genes from the German mutton Merino and the remaining 20% from Akkaraman (TAGEM, 2011). The German mutton merino is known for its non-seasonal breeding cycle, high meat yield, and high fecundity (Mason, 1996). Karya sheep were bred through unsystematic crossbreeding of sheep breeds in Western Anatolia with Sakız (chios) and Kıvırcık (curly) rams. They are known for their high milk yield and litter size values (Altın et al., 2003).

Pırlak sheep, on the other hand, were formed as a result of crossbreeding Kıvırcık ewes with Dağlıç rams. It is superior to Kıvırcık and high-merit sheep breeds in terms of hardiness to unfavorable environmental conditions, as it performs better than Dağlıç sheep in terms of live weight gain and litter size. Therefore, breeders prefer slaughterhouse lamb production (Çelikeloğlu and Tekerli, 2014). In the present study,

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Pırlak, CA Merino, and Karya breeders reported higher litter size per ewe than did other breeders.

Technical success indicators

The profitability of sheep farming depends on lamb, milk, and milk product sales, whereas efficient milk and mutton production are closely linked to fertility. It is accepted that it is possible and sustainable to have three pregnancies in two years under on-farm conditions. Nevertheless, at least one lamb per ewe per year is the basis for profitable production.

Economic breeding is impossible if a flock does not regularly yield offspring. Infertility (not conceiving) and abortion or miscarriage (termination of pregnancy) negatively affect offspring yield in a flock. Approximately 5-8% of infertility cases and approximately 3–5% of abortion cases in a flock are considered normal (Atasoy, 2016; Rişvanlı et al., 2016). Another important economic loss in flocks is perinatal and postnatal lamb deaths, and at most 10% of lamb death rates are acceptable (Atasoy, 2016). In general, infertility, abortion, and lamb mortality rates were below the upper limits reported in the literature, with the exception of high infertility rates in İvesi flocks.

Several studies have shown that parasitic diseases in livestock cause significant economic losses due to negative effects on weight gain, feed conversion efficiency, reproduction, and treatment costs (Hale and Coffey, 2011; Kumar et al., 2013; Roeber et al., 2013; Koyuncu et al., 2019). The study findings suggest similar implications for scabies, sheep ticks, and diseases such as brucellosis, necrotic hepatitis, and anthrax. However, they implied that tapeworms and liver flukes significantly increased sheep lambing rates. A similar finding was reported by Blackwell et al. (2015), who found that parasitic roundworms (*Ascaris lumbricoides*) increase fertility, causing earlier first births and shorter interbirth intervals, most likely by altering the immune system in women. Similar physiological mechanisms may function in sheep and other animals. The present study also suggests that sheepfold cleaning and lime wash application are significantly effective in controlling tapeworms, intestinal nematodes, foot and mouth disease, sheep pox, and liver flukes.

Limitations

This study is subject to several limitations. First, it employed a quasi-experimental design without random assignment of breeder groups (PFs and non-PFs). While randomization is typically used to enhance group homogeneity, thus strengthening causal inference between observed changes in technical and economic indicators and the treatment effect (genetic improvement interventions), its absence may raise concerns regarding the reliability of the estimated effects.

As shown in *Table 2*, the two groups differed significantly in several farm and farmer characteristics, including age, experience, gender-based labor composition, flock size, and sheepfold capacity. These disparities were largely unavoidable due to the criteria guiding the selection of breeders and animal material for inclusion. Preference was given to more experienced breeders and animals exhibiting phenotypic conformity with breed standards (TAGEM, 2012). Additionally, logistical considerations, specifically, the requirement to secure a minimum of 6,000 female and 300 male animals per breed at the outset of inclusion into the scheme, necessitated prioritizing breeders with relatively larger flocks. This strategy enabled the implementation team to minimize the number of participating breeders per breed, thereby facilitating operational efficiency and

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coordination within the scheme. As a result, breeders with larger flocks were disproportionately represented among the PFs, contributing to systematic differences in flock size between PFs and non-PFs (*Table 2*).

Although group homogeneity cannot be assumed, this limitation does not compromise the integrity of the analysis. Relevant covariates were incorporated into the LSDV regression framework to statistically control for these differences.

Second, reliance on self-reported data may introduce recall bias or subjective interpretation, particularly in relation to farm management practices and economic performance. To mitigate this, proxy indicators were employed to cross-validate key variables, improving both internal consistency and measurement reliability.

Third, the study considered only pen size per ewe as an indicator of sheepfold quality, while overlooking other critical welfare parameters such as light intensity, pen volume per ewe, ventilation rate, indoor temperature, and relative humidity. These factors can significantly influence animal health and productivity (Caroprese et al., 2009). Future research should aim to incorporate a broader set of indicators to more comprehensively assess sheepfold conditions and their implications for sheep breeding outcomes.

Conclusion

Genetic improvement efforts aim to achieve sustainable food production by increasing productivity per head of animal. These studies, which commenced in Türkiye in 2006, continue with five-year extension periods. Given that genetic improvement is a long-term process, analyzing program outputs is crucial to understanding their economic impact at both farm and national levels, taking corrective measures, and ensuring continued support. This study aimed to determine the economic and technical impacts of genetic improvement on sheep at the farm level, provide a comprehensive overview of sheep farming profitability across the country, and establish a baseline for future assessments.

Key technical success indicators examined included litter size per birth, lambing rate, infertility rate, abortion rate, lamb live weight at birth, twin or multiple birth rate, and lamb mortality rate. Gross profit per ewe (GPpE) served as the financial success indicator.

The results demonstrated that PFs generally perform better in most technical success indicators. For example, live lamb weight at birth, litter size per delivery, and milk yield were significantly higher among PFs, while lamb mortality and abortion rates were significantly lower among PFs.

However, these technical successes did not translate into significant differences in GPpE between PFs and non-PFs. Regression analysis revealed that PFs had marginally higher GPpE; the difference was not substantial. This might be understood by remembering that the severity and ranking of the most important SDIEPs were similar for both breeders. The PFs were better only for liver fluke, sheep tick, and mastitis infestations.

One of the key findings was the importance of housing conditions for sheep farming success. Poor housing was closely linked to higher incidences of SDIEPs. Complaints about SDIEPs were significantly more common among farmers who neglected general cleaning and lime washing of their sheepfolds. Moreover, the sheepfold floor area per ewe was the most significant factor affecting GPpE in *ceteris paribus*, with PFs having significantly smaller space per ewe.

Regression analysis also revealed that larger flock sizes had a negative impact on GPpE, whereas female labor had a positive impact on GPpE. This is likely because sheep

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milk utilization decreases with larger flock sizes, and milking is traditionally performed by women, making milk and milk product sales a critical revenue source.

Feed expenditure and shepherds' wages were the most significant cost components in sheep farming, accounting for approximately 55% and 30% of the cost, respectively. However, the rankings of these two cost components were interchanged in some sheep breeds, i.e., shepherd wages ranked first for the Morkaraman, Kangal Akkaraman, and Akkaraman breeds.

High feed expenditures hinder profitability, even though small ruminants generally have lower nutritional requirements. PFs tended to use more self-produced feed and purchase more compound feed, while non-PFs bought more straw and grain. The insignificant difference in feed cost per ewe between PFs and non-PFs implies that high feed costs are a general problem in sheep farming, and the study results could be interpreted in light of the relevant literature showing that straw together with grains suffices to meet animal needs, even in periods of higher requirements. Therefore, there is no need to purchase compound feed to increase feed costs. Therefore, feedstuff production should be encouraged to ensure profitable sheep-farming practices.

Shepherd wages were high due to a shortage of shepherds, a problem rooted in social issues such as a lack of social security and low societal status.

Farmers reporting SDIEPs like sheep ticks and necrotic hepatitis had significantly lower lambing rates. Interestingly, those declaring internal parasites like tapeworms, intestinal nematodes, and liver flukes had higher lambing rates. As similar results have been reported previously for women, this subject is worth considering in further studies to obtain robust evidence.

Based on these results, the following suggestions can be made for the success of genetic improvement studies and sheep farming:

(1) Support female labor: Measures are required to support and encourage women's participation in sheep farming.

(2) Encourage milk utilization: Financial support for milking machines and relevant farm equipment should be provided to reduce labor needs.

(3) Promote feedstuff production: Farmers should be encouraged to produce their own feedstuff to minimize feed costs and perform profitable sheep farming activities.

(4) Address shepherding problems: Shepherding is one of the most important challenges in livestock farming. Grant payments for farms employing certified shepherds who have completed herd management courses, initiated by the Ministry of Agriculture in 2014, are a step toward solving this problem. However, this practice did not solve the problem, despite its alleviating effects. As a solution:

- Certified shepherds should be provided with attractive social security benefits, making the job more appealing.
- Interim breeders' unions can recruit shepherds through service procurement from companies.
- Shepherds with herd management certificates can be employed by unions.
- In the long term, only graduates from associate degree programs in grazing and herd management offered at universities should be accepted into the profession to ensure sustainable grazing land use.

(5) Improving housing conditions: Farmers, especially PFs, should be encouraged and supported to renovate sheepfolds to ensure adequate floor area per ewe and improve other animal welfare aspects, such as adequate space, ventilation, aeration, and light per ewe.

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(6) Regular assessments: Assessments should be conducted at least every ten years to monitor progress and implement corrective measures.

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APPENDIX

Appendix A. *The characteristics of the sheep breeds and the provinces where the genetic improvement studies started first in the year 2006*

Provinces	Sheep Breeds	Characteristics of the Sheep Breeds
Erzurum	Morkaraman	An indigenous, dual-purpose mutton first sheep breed with S shaped fat tail. It is hardy to cold temperatures and well adapted to the long, harsh winter conditions and the mountainous geography of the eastern Anatolia. It has a high vitality and adaptability to unfavourable environmental conditions. Its herd and maternal instinct are good and can walk long distances, and well utilize high-altitude poor-quality rangelands. It is common in eastern Anatolia region.
Artvin	Hemşin	An indigenous dual purpose sheep breed with a medium sized firm body structure raised in Artvin and Rize provinces of Eastern Black Sea region. It has the longest tail structure among the indigenous sheep breeds of Türkiye. Climbing and walking capability in rugged and rocky terrain is quite good. It can make very good use of high altitude, poor condition rangelands. It has a high vitality, hardiness, and the capability to adapt to unfavourable environmental conditions. Maternal and herd instinct are well developed. It is a fierce-natured sheep and well adapted to rainy and humid Eastern black sea climate.
Tokat	Karayaka	A small framed, lean and long tailed, multipurpose indigenous breed raised in an area extending from the black sea coastal and mountainous line between Sinop and Trabzon and the intersection of the middle black sea and central Anatolia which covers Amasya, Tokat and their vicinity. Due to its strong hoof and leg structure, it can move quite fast in rugged and sloped rangelands. It is difficult to manage and has the coarsest fleece all among the native sheep breeds. Gene improvement studies in Morkaraman sheep started in Erzurum in 2006.
Sivas	Kangal Akkaraman	A large framed, multipurpose indigenous sheep breed common in Sivas and neighbouring provinces in Central Anatolia region. It is a dry climate sheep but has a high adaptability to various environmental conditions. It has a thin lip structure and is hardy to walking long distances. Herd instinct is well developed. It is raised in steppe climates with dry, hot summers and cold, snowy winters, and in the places with poor vegetation and not too rugged geography. Feeding is based on rangeland grazing, except snowy days.
Eskişehir	Central Anatolia Merino	A large framed, mutton and fleece dual purpose sheep breed raised in Central Anatolia. It was obtained by crossing of Akkaraman with German Meat merino. It inherits 80% of its genes from German meat merino and the rest 20% from Akkaraman. Since it has rooted from Akkaraman sheep, it is well adapted to the conditions of Central Anatolia, has high vitality and is resistant to diseases. Adaptability to various environmental conditions, herd and maternal instinct are quite well. Its lamb yield per birth and growth rate are higher than that of Akkaraman. It comes after the native breeds regarding the ability to make the best use of arid rangelands. It is successfully grown under the relatively good maintenance and feeding conditions.
Afyonkarahisar	Pırlak	A thin-to-semi-fat tailed, medium sized, multipurpose native breed raised in an area covering Kütahya, Afyon, Uşak and Manisa provinces in the inner western Anatolia and Isparta and Burdur provinces in the North-western Mediterranean region. It is hardy to unfavourable environmental conditions and diseases. It is a sheep of hot and dry climates but its adaptability to various conditions is good and can be grown under insufficient and unfavourable breeding conditions.

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Provinces	Sheep Breeds	Characteristics of the Sheep Breeds
Aydın and Denizli	Karya	A thin and low-fat tailed, medium sized, dual purpose (milk and calves) precocious breed raised in Aydın, İzmir and Denizli provinces in western Anatolia. It was formed as a result of unsystematic crossbreeding of the sheep breeds in Western Anatolia with Sakız (Chios) and Kıvırcık (Curly) rams. It has high milk and lamb yield. This breed is preferred especially in the farms with relatively good caring and feeding conditions and in the plain areas with a tendency to intensive production.
Konya	Akkaraman	A multipurpose, S shaped and fat -tailed indigenous sheep breed adapted to the steppe climates with hot, dry summers and snowy, cold winters. It is the most common, strong and large framed sheep among the other indigenous breeds and mainly raised in central Anatolia region of Türkiye. It has a thrifty and easily manageable nature and is hardy for unfavourable environmental conditions and diseases. Its herd and maternal instincts and abilities to walk long distances and to make use of poor-quality rangelands are well developed.
Şanlıurfa	İvesi	The most common sheep breed in the middle east, especially in Iraq, Syria, Lebanon, Jordan and Israel, where it is called as Awassi. In Türkiye is it common in South-eastern Anatolia especially along the border strip near the main habitat area of the breed in Syrian republic (Epstein, 1985). It is a fat tailed, dual-purpose milk first sheep breed with a robust and medium sized, white coloured body. It has a thin but solid bone structure suitable for milk type and is common in Eastern Anatolia region of Türkiye. It is well adapted to hot and dry climatic conditions and can walk long distances under these conditions. Its maternal instinct is developed. High ability to adapt various environmental conditions and well-developed herd instinct are accepted to be its superiorities against other dairy sheep breeds.

Source: TAGEM (2011)

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