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Meat sheep farming systems according to economic and productive indicators: A case study in Southern Brazil

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ABSTRACT - This study aimed to characterize 24 representative sheep production farms from five mesoregions in the state of Paraná, Southern Brazil, so that economic and productive improvement strategies could be proposed. The representative farms for each region were defined at meetings with sheep farmers and technicians via the rapid appraisal methodology and represent 65% of the state's flock. The information of each representative farm was collected between March 2015 and February 2016. Principal component analysis was used to verify the relationships among the different variables that characterized the farms. These characteristics were: number of ewes (V1), total cost per kilogram of revenue-generating product (V2), feeding costs (V3), labor costs (V4), facility and equipment depreciation costs (V5), and gross margin in the production cycle (V6). Cluster analysis was performed, resulting in three distinct groups: one including eight, another seven, and the third, nine farms. The results aided in classifying the farms into groups with similar characteristics, such as production scale, reproductive efficiency, technical and managerial control, appreciation of cooperatives, and availability of continuous technical assistance. The production scale, reproductive and productive efficiency, adoption of technologies, and cooperative organizational structure can be emphasized as positive performance benchmarks and were the most important aspects to achieve positive economic results.

Keywords: cluster analysis, economy, farming, production systems

1. Introduction

Studies have sought to demonstrate the importance of sheep farming as an animal production alternative in different contexts all around the world. Small ruminant production has the potential to address the global challenge of greatly increased food production in impoverished rural areas in a manner that is socioeconomically sustainable and carbon-efficient (Lalljee et al., 2019). In Brazil, sheep farming systems prevail in warmer, low-rainfall areas (Hermuche et al., 2013) in the Caatinga biome and in the wetter and colder Pampa and Campos biomes on native grasslands in the south of the country. Sheep farming in these regions has attracted investors and expanded both in quantity and quality since the early 2000s (Raineri et al., 2015a) because of the higher purchasing power of the population, increasing the demand for lamb meat.

Because of these highly distinct regions, the Brazilian sheep farming status is complex; their socioeconomic diversity also makes each case peculiar (Chaves et al., 2010; Silva et al., 2013). In Northeast Brazil (Caatinga), sheep farming plays an important social and economic role, as a subsistence activity, in several areas. In the south and southeast of the country, sheep production is often worked in conjunction with crop and beef cattle production, adding to the farmer's income, although it is not always the main business of the farm (Silva et al., 2013; Raineri et al., 2015a).

In the state of Paraná, Southern Brazil, initiatives to encourage and structure the sheep business have been intensified since 2000, when private commercial groups were established and farmers later joined associations and cooperatives focused on meat production, following its previous history of cooperativism in the dairy, swine, and poultry businesses. This structure had the support of governmental and representative entities, which increased the number of sheep by about 15%, from around 549 thousand in 2000 to approximately 630 thousand in 2018 (IBGE, 2018). Therefore, the state of Paraná has maintained the greatest sheep flock growth rate among the southern states, and sheep farming has been developed in a more industrial way. More intensive production systems have been observed, with the adoption of new technologies, pasture cultivation, feed supplementation strategies for the animals, and more integration with crop production systems. Considering these changes in the last 15-20 years, the precise knowledge about technical indexes that can most impact the productive and economic results of sheep farming should be the ace in the role for the consolidation of the sheep business.

The objective of this study was to characterize and describe representative sheep production systems in Paraná to understand the diversity of their characteristics and identify technical indexes that most affect the economic and productive results so that improvement strategies could be proposed. Despite the diversity of the main sheep-producing regions in Brazil, already discussed, this knowledge can certainly be applied elsewhere.

2. Material and Methods

To collect data on territorial identity and diversity, the mesoregional approach was used. The state of Paraná was divided into ten mesoregions (IBGE, 2012), and the most significant mesoregions in sheep production were analyzed, considering their organizational structures, as rural producers' unions, supported by the Federação da Agricultura do Estado do Paraná (FAEP). Five mesoregions were identified as the most relevant in meat sheep production, which were sampled and are shown in Figure 1.

Figure 1 - Mesoregions in the state of Paraná, Southern Brazil.

In early 2015, in-person meetings were held to mobilize sheep farmers and other agents of each mesoregion, with support from the Secretaria da Agricultura. The rapid appraisal methodology was used to determine five representative farms from each mesoregion. In this method, performance drivers such as the production focus, organizational environment, use of technologies, market structures, and coordination mechanisms are defined. The method also assumes the adoption of three basic concepts: systemic analysis, a multidisciplinary approach, and interactive data collection and analysis (Beebe, 1995).

With the sheep farmers' consent, these farms were visited to characterize their production systems and identify the technological level and available technical production structure of each farm. The farmers were then instructed to record data on cash flow and production input measurements as well as the respective percentages spent on sheep production in the 2015-2016 lamb production cycle.

In view of the peculiarities and diversity of the studied sheep production systems, the following revenue composition items were considered: sale of lambs for slaughter (SL), price of animals slaughtered in the 2015 cycle for consumption by the farmer (calculated together with the sale of SL), market price of animals produced in the 2015 cycle (predominantly lambs) and kept on the farm for flock growth purposes, sale of culled adult animals, sale of animals to other sheep farmers (sale of individuals with best genetic standards), other revenues from the sale of sheep byproducts such as wool and manure, and distribution of profits in accordance with the policy adopted by the cooperatives.

The total live weight of all categories of income-generating animals was added, and the variable "kilogram of income-generating product" was used to report different production cost components. To determine the production cost composition, the method followed the same structure proposed by Raineri et al. (2015b) and Sartorello et al. (2018). The apportionment strategy was only applied to the use of resources in sheep farming activity. The depreciation was calculated using the linear method (Hoffmann et al., 1987), and the current equipment value informed by the farmer, which was then compared with the agricultural mechanization cost worksheets for 2015 from the Fundação ABC - Pesquisa e Desenvolvimento Agropecuário (2015), that used as a reference for the initial value. The prices of agricultural inputs were those that had been annotated as registered by the farmers in their cash flows or according to the reference values of the Survey of Prices Paid by Farmers in 2015 carried out by the Department of Agriculture of the state of Paraná (SEAB, 2015). The economic result was represented by the following indicators: gross margin (GM; gross revenue minus the effective operational costs), net margin (gross revenue minus the operational cost), economic result (total revenue minus the total cost, TC), profitability (net margin over initial investment), yield (economic result over initial investment), monetary productivity (revenue per ewe), net margin (per kilogram of product), and break-even point (BEP; TC over total revenue). The data was analyzed using Excel 2010 on the Windows platform.

Using multivariate analysis, the correlated variables were identified and reduced via principal component analysis (PCA), exploring the maximum variance proportion with a minimum number of components and with the least possible loss of information. This was performed in two stages: PCA and cluster analysis (CA). Cluster analysis seeks to build a hierarchically organized sequence for a given set of objectives. Through grouping, it also seeks to identify similar characteristics and presents them as a dendrogram that groups the objects according to their similarities (Köhn and Hubert, 2015).

The varimax orthogonal rotation method was applied to obtain more precise solutions. Subsequently, the Kaiser-Meyer-Olkin (KMO) and Bartlett sphericity tests were used to verify the adequacy of the factorial analysis. The analysis of commonality for each variable was carried out by analyzing only those variables with a commonality higher than 0.420. Data from one farm was considered an outlier and thus was not considered in the analysis, which was performed with R software (v.3.4.1).

The variables used in the analysis were as follows: V1 = number of ewes, V2 = TC per kilogram of revenue-generating product, V3 = feed cost of sheep per kilogram of revenue-generating product, V4 = labor cost per kilogram of revenue-generating product, V5 = facility and equipment depreciation cost per kilogram of revenue-generating product, and V6 = GM obtained in each system in the production cycle of 2015.

The number of ewes was chosen because it may be directly related to economies of scale and the optimization of available resources. The GM and TC per kilogram of revenue-generating product may reflect the efficiency of the sheep production system. Other items that make up the TC, such as feed and labor, were chosen because they have greater representativeness in the cost composition. The depreciation cost was used because it represents, in addition to the farmer's investment capacity, the technological level and the possibilities of optimizing the resources available on the farm for other agricultural activities.

To determine the number of components, eigenvalues higher than 1.0 were considered. Afterwards, CA was performed using components generated via PCA, aiming to group production systems with similar characteristics and identify the determinants of this differentiation. In CA, hierarchical agglomerative clustering was used to minimize the differences among the clusters via the K-means method (R software, v.3.4.1), which optimizes the homogeneity within each cluster (Bussab et al., 1990).

The similarity measure was also performed using the simple method since it groups objects separated by the shortest distance. The differences among the groups were measured by their characteristics and economic results; analysis of variance (ANOVA) and Tukey's test ($P<0.05$) were used to identify the occurrence of significant differences among the means. For categorical variables, the percentage frequency distribution of similar data was performed within each cluster.

3. Results

Results PCA were presented (Table 1) as Component 1, cost discrimination, which includes the TC per kilogram of revenue-generating product as well as the feed, labor, and depreciation costs; and Component 2, the production scale and economic results that includes the number of ewes and GM obtained in each farm.

The KMO test presented a result of 0.779, indicating the suitability of the sample. Values above 0.500 are recommended for CA. The Bartlett test result was significant (chi-square = 89.886; d.f. = 15; P = 0.000).

Two factors had eigenvalues greater than 1.0: Components 1 (eigenvalue = 1.773; explained variance = 52.44%) and 2 (eigenvalue = 1.137; explained variance = 21.54%). These two components explain 73.99% of the point variability and determine the grouping of farms under analysis (Figure 2).

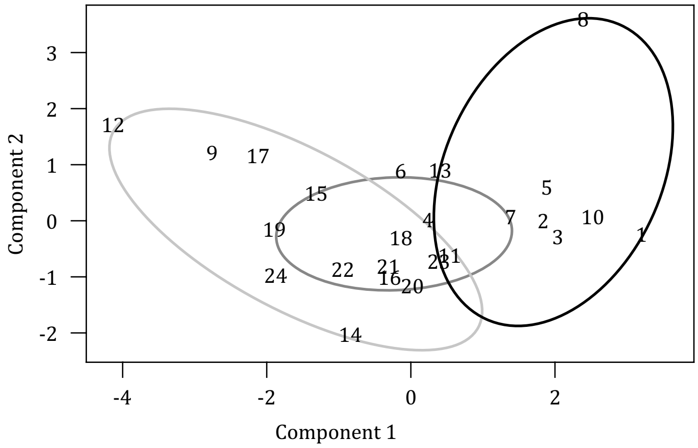
Cluster Analysis resulted in the formation of three distinct clusters with similar characteristics within each cluster, according to the dendrogram (Figure 3).

The comparison among clusters (Table 2) for the variables that best explained the variation of the data (Table 1) revealed significant differences ($P<0.05$) for the number of ewes, TC per kilogram of revenue-generating product, and total GM. Cluster 1 presented the largest flock and the highest total GM compared with the others.

The main similar characteristics that originated the formation of the clusters are described below (Tables 3, 4, 5, and 6). Cluster 1 is made up of eight representative farms from four of the five mesoregions under analysis. These farms are characterized by the following: larger-scale production

Table 1 - Factorial analysis: matrix with principal components of sheep farms in the state of Paraná, Southern Brazil

	Component 1	Component 2
Total cost per kg of revenue-generating product (V_2)	0.980	−0.180
Feed costs (V_3)	0.580	0.040
Labor costs (V_4)	0.420	−0.210
Depreciation costs (V_5)	0.770	−0.390
Number of ewes (V_1)	0.000	1.000
Gross margin (V_6)	−0.490	0.760



Component 1: costs discrimination; Component 2: production scale – number of ewes and economic results.

Figure 2 - Distribution of sheep farms of the state of Paraná, Southern Brazil, according to principal component analysis.

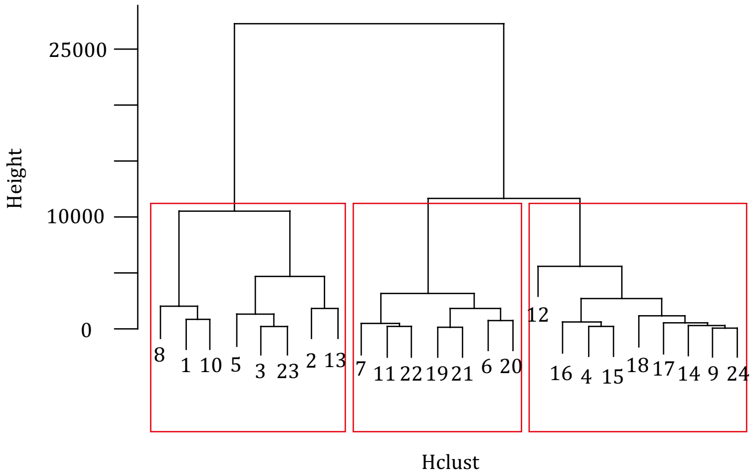


Figure 3 - Dendrogram of the three clusters from the multivariate analysis of the sheep farms in the state of Paraná, Southern Brazil.

Table 2 - Variables (mean and standard deviation) used in factorial analysis of sheep farm clusters in the state of Paraná, Southern Brazil

	Cluster 1 (n = 8)	Cluster 2 (n = 7)	Cluster 3 (n = 9)	Significant level
Number of ewes	279.25a (±97.97)	115.43b (±72.76)	110.00b (±70.46)	**
Total cost per kg of revenue-generating product (R$/kg)	7.58b (±1.18)	8.76ab (±1.19)	10.64a (±2.68)	**
Feed cost (R$/kg)	2.67 (±1.39)	2.90 (±0.45)	3.81 (±1.32)	
Labor cost (R$/kg)	1.29 (±1.01)	1.55 (±0.59)	1.80 (±0.71)	
Depreciation cost (R$/kg)	0.54b (±0.26)	0.99ab (±0.56)	1.19a (±0.64)	*
Total gross margin (R$)	19,866.15a (±3,789)	7,994.68b (±1,338)	1,544.61c (±1,731)	***

kg = kg of revenue generation product.
*P<0.0500; **P<0.0100; ***P<0.0010.

(782.88±384.87 animals; Table 4); higher crop production income in relation to the total income of the farms; greater sharing of inputs with crop production; exclusive use of meat-producing breeds; higher rates of ewe culling; higher number of ewe lambs for replacement (122.50±76.34; Table 4); greater use of specialized technical assistance; greater concern for family succession; greater appreciation of cooperativism; lower total (7.58±1.18), fixed (2.83±1.46), operational (6.73±0.87), and depreciation costs (0.54±0.26) per kilogram of revenue-generating product (R$/kg; Table 2); and better profitability (14.68±8.83; Table 6).

Cluster 2 is made up of seven representative farms from four of the five mesoregions. This group presented the following as characteristics: intermediate-scale production (280.57±239.60 animals; Table 4); the highest income from sheep farming and the lowest income from crop

Table 3 - Frequency of occurrence (%) of characteristics by category in each cluster and comparisons of categorical variables between clusters of sheep farms in the state of Paraná, Southern Brazil

Category	Characteristic	Cluster 1 (n = 8)	Cluster 2 (n = 7)	Cluster 3 (n = 9)
Farmer profile	Male	62.50	85.71	100.00
	Female	37.50	14.29	0.00
	Schooling: undergraduate level	50.00	42.85	66.66
Profile	Crop production income	73.94	45.21	65.33
	Beef cattle income	15.50	11.86	21.56
	Sheep farming income	9.56	17.93	8.56
	Income from other activities	1.00	25.00	4.55
	Area occupied by sheep farming	21.25	30.00	31.67
Feeding system	Pasture + feedlot	62.50	100.00	77.78
	Pasture system	25.00	0.00	11.11
	Feedlot system	12.50	0.00	11.11
Labor	Shared labor	100.00	100.00	89.89
	Temporary labor	37.50	42.85	77.78
	Family labor only	12.50	0.00	11.11
	Shared use of tractor	62.50	42.85	77.78
	Tractor for sheep farming use	53.75	37.14	31.67
	Use of facilities	37.50	85.71	55.56
Flock	Adult animal culling	21.00	15.29	13.89
	Flock growth expectation	89.13	109.43	144.04
	Sheep individual identification	75.00	85.71	66.66
	Woollen breeds	100.00	71.43	77.78
	Hair sheep breeds	0.00	57.14	55.56
Management	Profissional assistance	50.00	14.29	33.33
	Family succession	87.50	71.43	33.33
	Financing access	37.50	42.85	55.56
	Importance of cooperativism	87.50	71.43	55.56
Reprod. management	Accelerated lambing	25.00	0.00	33.33
	Estrus synchronization	37.5	14.29	0.00
	Breeding season	37.5	28.57	11.11
	Ram year round	0.00	57.14	55.56
Health management	FAMACHA® use	63.00	71.43	66.66
	Clostridiosis vaccination	100.00	85.71	33.33
	Other vaccines	37.5	28.57	22.22

production; exclusively mixed (pasture + feedlot) animal production systems; use of hired labor only, shared with other activities; greater use of preexisting facilities on the farm; higher ram:ewe ratio (45.13±27.48); higher lamb:sheep ratio (1.08±0.17); greater use of technology as a means of identifying individual animals and recording flock data; higher revenue from the SL (4.79±1.96) for slaughter; higher total income (8.72±1.16) per kilogram of revenue-generating product and higher income from sheep byproducts (wool and manure) per kilogram of revenue-generating product; lower variable cost (VC; 3.79±0.73) per kilogram of revenue-generating product; and positive profitability (12.69±10.49).

Table 4 - Characteristics (mean and standard deviation) of farming systems and flocks of sheep farm clusters in the state of Paraná, Southern Brazil

	Characteristic	Cluster 1 (n = 8)	Cluster 2 (n = 7)	Cluster 3 (n = 9)
Farming system	Sheep farming activity time (years)	12.50 (±5.71)	10.86 (±8.68)	14.56 (±8.79)
	Farmer age (years)	44.75 (±13.99)	44.14 (±9.15)	51.00 (±11.22)
Flock	Number of sheep	782.88a (±384.87)	280.57b (±239.60)	227.67b (±212.19)
	Number of ewes	279.25a (±97.97)	115.43b (±72.76)	110.00b (±70.46)
	Number of rams	6.50a (±1.69)	2.71b (±1.89)	2.67b (±1.73)
	Number of ewe lambs	122.50a (±76.34)	47.29b (±37.57)	36.00b (±39.55)
	Number of lambs	230.75a (±104.85)	121.14b (±83.51)	103.00b (±119.66)
	Ram:sheep ratio	44.58 (±18.48)	45.13 (±27.48)	40.67 (±9.82)
	Lamb:sheep ratio	0.84ab (±0.21)	1.08a (±0.17)	0.78b (±0.22)

Different letters in the same row show significant differences (P<0.05).

Table 5 - Composition of costs and revenues (R$/kg; mean and standard deviation) of sheep farm clusters in the state of Paraná, Southern Brazil

Component	Cluster 1 (n = 8)	Cluster 2 (n = 7)	Cluster 3 (n = 9)
Variable cost	3.90b (±1.44)	3.79b (±0.73)	4.61a (±1.29)
Fixed cost	2.83 (±1.46)	3.74 (±0.87)	4.58 (±1.75)
Operational cost	6.73b (±0.87)	7.53ab (±0.55)	9.19a (±2.10)
Total cost	7.58b (±1.18)	8.76ab (±1.19)	10.64a (±2.68)
Lambs for slaughter revenue	4.25 (±1.19)	4.79 (±1.96)	4.06 (±1.19)
Ewe lamb retention revenue	2.39 (±1.64)	3.09 (±1.14)	3.78 (±1.99)
Culled animals revenue	0.92 (±0.42)	0.51 (±0.61)	0.63 (±0.35)
Animals sold to other farmers	0.34 (±0.48)	0.00 (±0.00)	0.12 (±0.28)
Other revenues	0.03 (±0.06)	0.33 (±0.65)	0.00 (±0.00)
Total revenue	7.93 (±1.08)	8.72 (±1.16)	8.59 (±1.29)

Different letters in the same row show significant differences (P<0.05).

Table 6 - Economic results (mean and standard deviation) of sheep farm clusters in the Paraná state, Southern Brazil

Component	Cluster 1 (n = 8)	Cluster 2 (n = 7)	Cluster 3 (n = 9)
Variable cost balance	47,965.31a (±14,327.25)	24,444.50b (±16,428.50)	17,100.21b (±21,557.37)
Total operational cost balance	12,781.57a (±59,948.04)	3,093.18b (±2,942.81)	−2,978.34b (±5,927.89)
Total cost balance	2,482.03 (±8,958.12)	−2,731.61 (±7,166.51)	−8,857.88 (±13,116.13)
Initial investment	328,317.34 (±140,096.88)	162,841.73 (±153,117.70)	190,617.91 (±247,443.24)
Gross margin (GR – EfOPC)	19,866.15a (±3,789.44)	7,994.68b (±1,338.73)	1,544.61c (±1,731.25)
Net margin (GR – OPC)	12,781.98a (±5,948.04)	3,093.18b (±2,942.81)	−2,974.34b (±5,927.89)
Economic result (TR – TC)	2,482.04 (±8,958.12)	−2,731.61 (±7,166.51)	−8,857.88 (±13,116.13)
Profitability (NM/TR×100)	14.68a (±8.83)	12.69ab (±10.49)	−6.51b (±16.20)
Yield (ER/II×100)	1.73 (±3.17)	−1.78 (±16.93)	−3.64 (±2.53)
Monetary productivity (R$/ewe)	420.66 (±230.07)	442.67 (±241.63)	279.34 (±118.82)
Net margin (R$ per kg of revenue-generating product)	1.20a (±0.74)	1.19a (±1.01)	−0.60b (±1.33)
Break-even point % (TC/TR×100)	95.69a (±8.50)	101.24a (±13.61)	123.13b (±22.41)

GR - gross revenue (sum of revenues); EfOC - effective operational cost; OC - operational cost; TR - total revenue; TC - total cost; NM - net margin; ER - economic result; II - initial investment.
Different letters in the same row show significant differences (P<0.05).

Cluster 3 is made up of nine representative farms from the five mesoregions. These farms showed the following characteristics: smaller production scale (227.67±212.19 animals); longer time spent on sheep farming; highest percentage of beef cattle income among the groups; the largest proportional area used for sheep farming; greater temporary labor hiring; lower rate of adult animal culling; lower proportion of ewe lambs (36.00±39.55); lower ram:ewe ratio (40.67±9.82); lower lamb:sheep ratio (0.78±0.22); higher expectation of flock growth; the lowest use of technology as a means of the individual identification of animals and health management; greater access to financing; lower cooperativism appreciation; higher TC (10.64±2.68) per kilogram of revenue-generating product; and the worst profitability (−6.51±16.20), showing a positive balance only for VC and GM (Table 6).

The frequency of occurrence (%) of the characteristics by category in each cluster and comparisons of the categorical variables among the clusters of the sheep farms were presented (Table 3).

Considering the technical production and scale characteristics (Table 4), Cluster 3 presented a longer sheep farming operating time and an older farmer average age, and these aspects may be related to conservative behavior and strategies. As for flock characteristics, significant differences (P<0.05) among the groups were observed for variables related to flock size, animal categories, and relations among animal categories. For example, Clusters 1 and 2 presented higher flock sizes and better lamb:sheep ratios, significantly different (P<0.05) from the farms grouped in Cluster 3.

In terms of cost and revenue composition, significant differences were observed among the groups regarding VC, operational costs (OC), and TC, and Cluster 3 presented the highest costs (Table 5).

The best results were observed for Cluster 1 farms, mainly if we compare it with Cluster 3. This can be seen by the data referring to VC, OC, and TC (Table 5). In the cost composition, the most important items are related to animal feeding, and the pasture systems may have contributed to these results (Table 3). The sharing of manpower and equipment with other productive activities (Table 3) is also important in decreasing costs.

Considering farm revenues (R$/kg), no significant differences (P>0.05) were observed between the clusters (Table 5). Although there is no statistical difference, it is important to highlight the numerical difference regarding the ewe lambs retained in the flock. Farming systems grouped in Cluster 3, which had the highest flock growth expectation (Table 3), showed a higher ewe lamb retention revenue in the flock (RE; Table 5). Another aspect that is worth mentioning is the revenue from culled animals (Table 5) for Cluster 1. This group presented the highest average selection pressure (Table 3).

Specifically checking the economic indicators (Table 6), significant differences (P>0.05) were observed for the values of farming systems grouped in Cluster 1 in contrast to those in Clusters 2 and 3 for the following variables: VC balance, OC balance, GM, and net margin (NM). The systems grouped in Cluster 2 showed significant average differences compared with those grouped in Cluster 3 for the following variables: GM, NM (R$ per kg of revenue-generating product), and BEP. On the other hand, Clusters 1 and 2 did not differ (P>0.05) for profitability; NM (R$ per kilogram of revenue-generating product) and BEP. The farms grouped in Clusters 1 and 2 presented higher lamb:sheep ratios (Table 4) and also showed economic productivity in R$/ewe (Table 6).

4. Discussion

Group classification with regard to technological level and production intensification was influenced by heterogeneity among small ruminant farming systems, as commonly reported in Brazil. However, the best economic results of the farms grouped in Cluster 1 are outstanding in relation to those of the other clusters because of larger-scale production, higher ewe replacement rates, greater use of specialized technical assistance, and focus on meat production. Campos (2003) identified, in Northeast Brazil, that the larger the flock, the lower the average unit cost, thus showing the presence of economies of scale and efficiency gains with reference to production and profit maximization. This aspect has been reported by several authors in different regions of the world (Morris and Kenyon, 2014; Ripoll-Bosch et al., 2014; Toro-Mujica et al., 2015; Raineri et al., 2015b). Gelasakis et al. (2012) emphasized the importance of feed self-production in farms, especially roughage, to reduce production costs. The farms of Cluster 1 presented feeding systems more predominantly situated in pastures and lower feed costs (Table 2) than the other groups.

Marín-Bernal and Navarro-Ríos (2014), considering the particular productive aspects of Spain, demonstrated the tendency to increase the size of meat sheep flocks, which can be explained by factors such as the disappearance of small farms and the need to optimize the existing labor force toward a profitable sheep flocking size. The tendency to increase flock size, influenced by the relevance of production scale for the economic viability of the production systems, was evident in our study, considering the GM, NM, economic result, and profitability presented for Cluster 1 (Table 6).

Farms in Cluster 3, which access financial services more frequently (Table 3), had the smallest production scale, with lower technology adoption and lower production efficiency. The farmers were the oldest (highest mean age) and with the longest experience in sheep farming and can be considered the most conservative ones. In addition, they are involved in beef cattle and crop production. For small-scale farmers, diversification in rural activities is an important component for production system resilience to maintain family independence (Farias et al., 2014) if productive efficiency is observed.

Cluster 1 showed better economic results and stood out in terms of the organization of management and production as well, especially with reference to technical assistance, family succession, and cooperativism. In this study, production management and organization systems—as we can observe via identification, flock data recording, and technical assistance, facilitated by the cooperative model—demonstrated a direct relationship with efficiency and productivity gains. This has also been confirmed in several regions around the world, considering the productive specificities of each country (Lara et al., 2006; Suresh et al., 2008; Gerichhausen et al., 2009), because farmers can participate in formal organizations as these facilitate access to technical knowledge, lower inputs costs, and marketing processes. Campos (2003) found that the adoption of technical assistance and handling tools, careful pasture management, use of adequate facilities, and the best technical indexes were determinant technological factors for the success of sheep farming systems in Northeastern Brazil, which has the largest herd of small ruminants in the country.

In addition to the greater appreciation of cooperative systems (87.5% of frequency; Table 3), Cluster 1 was the most homogenous, i.e., showed a smaller mean value dispersion for sheep farming period and flock size (Table 4). Cluster 2 included farms with higher income from other activities related to sheep, such as wool and manure production, and higher frequencies of mixed animal feeding systems (pasture and feedlot). This group also presented flock data control efficiency and good health management (Table 3).

Farms grouped in Cluster 1 (Table 3) had a higher adult animal culling rate than those of Clusters 2 and 3, and this higher selection pressure may be directly related to better economic results (Table 6). Smaller-scale farmers grouped in Cluster 3 wanted the greatest flock size expansion (frequency of 144.04%). As such, they retained the largest number of ewes on the farm and, consequently, had a lower adult animal culling rate. As a result of low selection pressure, they compromised not only the flock production efficiency but also the economic outcome, as can be seen by the negative NM and profitability and higher BEP (Table 6). The highest number of culled adult females (Cluster 1, Table 3) and the highest number of young females for reproduction (Cluster 1, Table 4) lead to improved economic results; therefore, this strategy should be strongly recommended to sheep farmers. The literature (Silva et al., 2006; Aggelopoulos et al., 2016) emphasizes that the use of selected ewes, even with the replacement of females from the same flock, leads to increased sheep production profitability, which was confirmed by our results.

The lower mean VC of the representative farms grouped in Cluster 1 seems to be related to production scale and optimization of available resources, also identified in the feed, labor, and depreciation cost composition. A positive NM represents the possibility of a fixed capital return in the production factors. A negative NM can slow down capital accumulation in the short term and will result in capital stagnation in the medium term, only covering depreciations, and eventually lead to activity decapitalization in the long term (Campos, 2003).

Number of lambs produced per ewe, as obtained for Clusters 1 and 2, and lamb growth rate are directly related to selection pressure (Silva et al., 2006), being production characteristics of great economic influence in the profitability analysis of sheep farming systems. Clusters 2 and 3 showed BEP values higher than 100% (Table 6), which is worrying in terms of activity maintenance over time. Likewise, the technical indexes, e.g., ram:sheep and lamb:sheep ratios (Table 4), in the three clusters still need to be improved by about 30% to be considered appropriate to reduce the BEP until 85%, which is considered ideal for farming systems. Raineri et al. (2015a) considered technical indexes such as age of first lambing and pregnancy rate, lambing intervals, and number of lambs per year to be the most important ones so as not to compromise economic results and provide continuity of the activity in Brazil.

Especially considering those with better economic and productive results (Clusters 1 and 2), we can highlight the importance of the production scale together with the improvement in reproductive efficiency and technology adoption. This can be achieved through the management of the breeding season, a greater number of lambs born, and better culling and replacement rates for adult ewes. Other key factors are: greater efficiency in flock data control and the use of technological tools, even simple ones, for animal identification. The organization of small, medium, and large farmers in formal groups as cooperatives—in which they can have better input prices, cost sharing, and permanent technical assistance—is another important recommendation for sheep farmers, mainly for countries with socioeconomic characteristics similar to Brazil.

5. Conclusions

The annual selection of adult females, the consequent replacement of the flock with young females, and a superior lamb:sheep ratio were determinants in the economic results of sheep farming in Paraná and should be strongly recommended for sheep production systems in general. The improvement of reproductive and productive efficiency is related to a greater scale production, which is fundamental in lowering the total cost and, consequently, in achieving better economic results.

The promotion of a cooperative organizational structure and initiatives of sharing inputs, access to permanent technical assistance, and better flock control, which can promote a higher number of lambs per cycle, can also be emphasized as positive performance benchmarks. Cooperatives and other formal organizations that operate sheep farming businesses in Southern Brazil are the main regional enterprises responsible for sheep farming articulation processes.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Conceptualization: E.C. Debortoli, A.L.G. Monteiro and A.H. Gameiro. Formal analysis: E.C. Debortoli. Funding acquisition: A.L.G. Monteiro. Investigation: E.C. Debortoli and A.L.G. Monteiro. Methodology: E.C. Debortoli and A.H. Gameiro. Project administration: E.C. Debortoli. Resources: A.L.G. Monteiro. Supervision: A.L.G. Monteiro. Writing-original draft: E.C. Debortoli, A.L.G. Monteiro and A.H. Gameiro. Writing-review & editing: E.C. Debortoli, A.L.G. Monteiro, A.H. Gameiro and L.C.V.F. Saraiva.

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