Archivos de Zootecnia
Journal website: https://www.uco.es/ucopress/az/index.php/az/

Reproductive indicators as predictors of economic performance on sheep farms

Chekmam, L.[1]; Maza, M.T.[1,2@] and Pardos, L.[1]

[1]Department of Agricultural Sciences and Natural Environment. University of Zaragoza. Zaragoza. Spain.
[2]Instituto Agroalimentario IA2, Universidad de Zaragoza-CITA.

SUMMARY

Sheep systems are very important to ensure the sustainability of Mediterranean regions. In Europe, the dependence of farms on EU subsidies makes them very sensitive to changes in the CAP, so it is very necessary to ensure their economic viability. It has been seen that the improvement of reproductive practices improves the economic performance of farms, so the aim of this work is to analyse the predictive role that reproductive variables have on the economic indicator Gross margin per annual labour work unit, in both cases when the subsidies have taken into account or not. A sample of 128 sheep farms from the Aragon region (Spain) with records on a long time period from 1993 to 2016 has been used. Six technical variables have been synthesized into two factors carrying out a PCA, and three groups of farms significantly different from each other in both their technical and economic performance have been established from the factors. Linear regression analysis allows us to observe that the technical variables have a predictive effect on economic performance. The results differ when referring to the whole sample as well as to the different groups, and depending on whether subsidies are taken into account or not. It has been concluded that good reproductive management with improvements in productivity predict good economic performance by reducing the impact of subsidies.

Aditional Keywords

Sheep systems.
CAP subsidies.
Reproductive management.
Gross margin.
Linear regression.

Los indicadores reproductivos como predictores de los resultados económicos de explotaciones ovinas

RESUMEN

Los sistemas ovinos son muy importantes para asegurar la sostenibilidad de las regiones mediterráneas. En Europa la dependencia de las explotaciones con respecto a las ayudas comunitarias las hace muy sensibles a los cambios de la PAC, por ello es muy necesario asegurar su viabilidad económica. Se sabe que buenas prácticas reproductivas mejoran los resultados económicos de las explotaciones, por lo que el objetivo de este trabajo es analizar el papel predictor que las variables reproductivas tienen sobre el indicador económico Margen bruto por unidad de trabajo anual, teniendo en cuenta o no las subvenciones. Se ha utilizado una muestra de 128 explotaciones ovinas de Aragón (Spain) con registros del periodo 1993 a 2016. Se han sintetizado seis variables técnicas en dos factores mediante un ACP, y se han establecido a partir de los factores tres grupos de explotaciones significativamente diferentes tanto en sus resultados técnicos como económicos. El análisis de regresión lineal permite observar que las variables técnicas tienen un efecto predictor en los resultados económicos. Éstos difieren cuando se refieren al conjunto de la muestra o a los diferentes grupos, y en función de si se consideran o no las subvenciones. Se concluye que un buen manejo reproductivo con mejoras en la productividad predice unos buenos resultados económicos reduciendo el impacto de las subvenciones.

Palabras Clave

Sistemas ovinos.
Ayudas PAC.
Manejo reproductivo.
Margen Bruto.
Regresión lineal.

Information

Cronología del artículo.
Recibido/Received: 14.07.2022
Aceptado/Accepted: 20.10.2024
On-line: 15.01.2025
Correspondencia a los autores/Contact e-mail:
mazama@unizar.es

INTRODUCTION

Animal production systems are complex and interlinked by biological, social, cultural, climatic, economic, and technological indicators (Freitas et al., 2021). Small ruminant systems of the Mediterranean basin have considerable economic, social and environmental importance. Their current organization and resource endowment are the result of long-term historical, geopolitical and socio-economic changes (de Rancourt et al., 2006; Castel et al., 2011; Ryschawy et al., 2013, Toro-Mujica et al., 2015). Worldwide, sheep farming in semiarid regions is typically located in marginal areas, where other animal species with greater profitability, such as beef or dairy cattle, are not adapted to use the available pastoral resources (Toro-Mujica et al., 2019). In Spain, 82% of sheep farms are located in Extremadura, Andalusia, both Castillas and Aragon (MAPA, 2021). It is in the latter region where this work has been carried out and where sheep farming, although it can be considered in decline, continues to play an important role in the economic, social and environmental sustainability of many rural areas.

The sheep farming systems mainly the meat sheep farms has experienced a difficult period in the last decades, and their viability has been maintained at the majority thanks to subsidies (Milan et al., 2003; Weltin et al., 2016; Benoit et al., 2020, Soriano et al., 2018). But with the changes in the Common Agricultural Policy (CAP) regarding to the aids policy, the viability of these systems is threatened, because of their fragility and sensibility to every change. Improving technical indicators has been one of the solutions for these systems, mainly productivity is one of the solutions to alleviate the dependency of these farms to CAP subsidies (Benoit and Laignel, 2011). In the last decades, improving the reproductive management and practices of the meat sheep farms has been one of the solutions of the farms to improve their economic results. According to Pardos et al. (2008; 2014) in Aragon (Spain), the meat sheep farming systems have rapidly moved to intensive large flocks, focussed on lamb productivity and the use of the Rasa Aragonesa breed. In highly productive herds, the proportion of pregnant and lactating animals is greater, and these animals graze for shorter periods, as they are housed and fed more frequently (Bernués et al., 2011, Mena et al., 2016). According to Benoit and Laignel (2011) combine high animal productivity with increase of the use of fodder resources requires a certain technical know-how and an adaptation of farming systems, or even of the used genotypes.

In order to protect one of most important extensive systems, studying different farms indicators is a key to figure out the drivers of change in these systems and it could give to decision makers a clear insight on the dynamics of these farms. Though farm management indicators always aim to be simple statements of a complex reality, the assessment of a wide range of indicators can be quite complicated (Andersen et al., 2007). Studying the different indicators is generally related to the economic results. Improving the economic results of these farms has been the major preoccupation of farmers (Benoit and Laignel, 2008), because just with an economic autonomy the viability of these systems could be insured. Many studies have been carried out to figure out the influence of different technical variables on economic results.

The main objective of the present work is to figure out possible relationship between some selected technical indicators related to the reproductive management of the herds and the economic results. Given the existing heterogeneity of the farms in terms of this management and the obtained results, a previous typification of the farms will be made. This will make it possible to determine whether the technical variables associated with certain results differ according to the type of farm. From the management point of view, this will make it possible to make a greater effort to improve those parameters that have a more direct impact on results.

MATERIAL AND METHODS

It has been used a sample made up of 128 meat sheep farms which belong to a technical-economic recording data program of one of the most important sheep cooperatives located in Aragon (Oviaragón-Grupo Pastores). The farms are in the different three provinces (Zaragoza, Huesca and Teruel) of Aragon region (Spain). Given that the technical-economic program which recorded all the data used in this work began in the decade of the 90s and the continuity of many of the farms, in some cases we used data averages of 24 years that range from 1993 to 2016, for each farm the mean data of each variable corresponds to the average of the years for which there were records or registers. The length of the study period made it necessary for those variables expressed in monetary units to be converted to constant euros of 2016.

After consultation of various technical studies (Oliván and Pardos, 2000; Kleinhanß et al., 2007, Pardos et al., 2008; Olaizola et al, 2008; Benoit and Laignel, 2008; García Martínez, 2009; Ripoll-Bosch et al., 2014; Pardos, 2014; Earle et al., 2017; Bohan et al., 2018; Benoit et al., 2020; Gazzarin and El Benni, 2020; Bertolozzi-Caredio et al., 2021) it has been chosen six technical variables related to the reproductive management of herds to carry out the analyses of the present work. The chosen variables were Prolificacy (Pr), Number of lambings per present ewe and year (NL/PE), percentage of lambs' Mortality (% Mr), Number of ewes per stud (NE/S), Number of sold lambs per present ewe and year (NSL/PE) and the Annual ewe replacement rate (%FRep).

For economic results, the Gross margin per annual labour unit (GM/LU) was used. The gross margin per labour unit can be considered as the most significant measure of the obtained economic results and an indicator of the possible continuity of the farms by including the productivity per sheep and the correct size of the herd (Olaizola et al., 1996, Benoit and Laignel 2008, Charroin et al., 2012).

It has been used univariate analysis for the general description of the sample and the multivariate analysis for more deep analysis.

The multivariate analyses were factor analysis to reduce the number of variables and facilitate subsequent analysis of the results, two-step cluster analysis to obtain the homogeneous groups of farms, and multiple linear regression to establish dependency relationships (Hair et al., 2014).

Cluster analysis allows obtaining groups of farms that are as homogeneous as possible within each group and as heterogeneous between groups. The factorial scores of the individuals were taken into account to perform the cluster analysis. The proportions of the clusters were defined with the variable «cluster membership».

In the multiple linear regression analysis, the predictor variables were the six technical variables used to carry out the factor analysis, and the dependent variable was the Gross margin per labour unit with and without subsidies (GM/LUWS) and (GM/LUWTS), respectively. It has been performed a multiple linear regression for the whole sample and for each group resulted from the cluster analysis.

To perform the multiple linear regression analysis, it was used the stepwise method to keep only the significant independent variables in the resulting models. The linear generic model was formulated as follows:

(GM/LUWS) or (GM/LUWTS) = $\beta 0 + \beta 1\ X1 + \beta 2\ X2 + \beta 3\ X3 + ...\beta n\ Xn + e$

Where GM/LUWS (Gross margin per labour unit with subsidies) or GM/LUWTS (Gross margin per labour unit without subsidies) is the dependent variable, 0 is the regression constant, and 1 2 3 ... n are coefficients to be estimated, X1, X2, X3 .. Xn were the used technical variables and (e) is the error of the regression model. Regression coefficients were checked using the t-test. The coefficient of determination (R2) was used as a predictive criterion for the regression model (Drapper and Smith, 1998, Sakar et al., 2011). The SPSS version 26 package has been used to carry out the statistical analyses.

RESULTS

Sample description

As mentioned in the methodology section, the used sample was made up of 128 farms which belong to an important ovine technical economic management program in Aragon (Spain). Table 1 shows the sample description. The average ewes' number was (601) ewes handled by (1.32) total labour units. The average number of ewes per labour unit was (461) ewes. Regarding to the technical indicators, the average number of lambings per present ewe and year was (1.12), the average prolificacy recorded was (1.34) and the average percentage of lambs' mortality was (10.6 %). With respect to the annual ewe replacement rate was almost (14%), the average sold lambs per ewe and year was (1.17) and the average number of ewes per stud was (45 ewes). Regarding to economic variables, it has been recorded a mean of (25090 euros) for gross margin per labour unit with subsidies and (5272 euros) of the gross margin per labour unit without subsidies. With respect to the main sheep breed of the farms it is the "Rasa Aragonesa" breed where it has been recorded (107 farms) with this breed. Rasa Aragonesa is a rustic breed of meat aptitude located in the Northeast of Spain, with an average prolificacy of (1.30) (Alabart et al. (2016), and this breed can be exploited successfully with the system of 3 lambings in 2 years because it is a non-seasonal breed and because the lambs are weaned relatively early (at the age of six weeks), allowing the ewe to recover for the next mating (Folch et al., 2007). The rest of the farms has been distributed between (7) farms with "F1 prolifica", (7) farms with "Ojinegra", (3) farms with "Roya Bilbilitana", (2) farms with Lacaune, (1) farm with "Maellana" and (1) farm with "Segureña".

Table I. Sample description (Descripción de la muestra).

	Mean	Std. Deviation
Structural indicators		
Average number of ewes (NE)	601	303
Number of total labour units (TLU)	1.32	0.49
Number of ewes/Labour unit (NE/LU)	461	143
Technical indicators		
Number of lambings by present ewe and year (NL/PE)	1.12	0.13
Prolificacy (Pr)	1.34	0.134
Percentage of Lambs mortality (% Mr)	10.6	3.7
Annual ewe replacement rate (% FRep)	13.98	3.59
Number of sold lambs ewe and year (NSL/PE)	1.17	0.25
Number of ewes per stud (NE/S)	45.5	12.1
Economic indicators		
Gross margin/Labour unit with subsidies (GM/LUWS)	25090.8	10238.2
Gross margin/Labour unit without subsidies (GM/LUWTS)	5272.2	9227.8

Factor analysis

In order to reduce dimensions of the technical indicators used in the present study, it has been performed a factor analysis with Principal Component Analysis (PCA) as an extraction method.

It has been recorded KMO index = 0.50, it is considered as low, but according to various authors it is an average value between 0.5 and 0.6 is acceptable for sample sizes between 100 and 200 (Guttman, 1954; Kaiser, 1970; Tabachnick, and Fidell, 2013; Shrestha,2021). The Bartlett's (Chi-square) test for Sphericity was very significant at $p < 0.0001$ which allow us to continue with the interpretation of factor analysis results. As it can be seen in table 2, the communalities of the used variables were high except for annual ewe replacement rate (%FRep) was (0.271). According to (Child, 2006; Samuels, 2017) it is advisable to remove just items with a communality score less than (0.200). Furthermore, it has been highlighted those communalities between 0.25 and 0.4 have been suggested as acceptable cut-off values, with ideal communalities being 0.7 or above (Beavers et al., 2013; Eaton al., 2019). The six original variables related to technical ratios were reduced to two factors which explain 65.59 % of the total variance which is considered quite significant rate for variance explanation (Table 2).

It has been performed the Varimax method for factors rotation; the results are reported as follows in table 2.

Factor 1 is highly and positively correlated with three of the sixth initial variables; these variables are related to the Numbers of sold lambs per ewe and year (NSL/PE) and Number of lambings by present ewe and year (NL/PE), Prolificacy (Pr) and moderately and positively correlated with Annual ewe replacement rate (%FRep). This factor can be characterized by productivity and annual ewe replacement rate

Factor 2 is correlated with two variables. This factor is positively correlated with the percentage of lambs' Mortality (% Mr) and negatively correlated with the Number of ewes per stud (NE/S). This factor can be characterized by reproduction ratio and lambs' mortality.

Cluster analysis

In order to gather the sample into homogeneous groups it has been performed a two-step cluster analysis. It has been used the factorial scores resulted from the factor analysis as continuous variables to perform the cluster analysis. It was created a new variable when computing data which named «cluster membership». It has been used to define clusters `proportions. The quality of the resulted clusters is fair (Figure 1).

Statistics were significant for Variance ANOVA test at $p < 0{,}0001$. It has been demonstrated that each cluster is differently linked with respect to each factor.

The profiles reported in table 3 show that each cluster is correlated differently to each factor.

Table II. Components Rotated Matrix and Communalities for farms' technical variables (Matriz de Componentes rotados y Comunalidades de las variables técnicas).

Factors and variables	Factors		Communalities
	Factor 1	Factor 2	
Number of sold lambs per present ewe (NSL/PE)	**0.940**	-0.113	0.897
Number of lambings by present ewe (NL/PE)	**0.900**	0.013	0.811
Prolificacy (Pr)	**0.845**	0.102	0.724
Annual ewe replacement rate (%FRep)	**0.488**	0.182	0.271
Percentage of lambs' mortality (% Mr)	-0.131	**0.846**	0.732
Number of ewes per stud (NE/S)	-0.211	**-0.675**	0.500
Eigen value	2.714	1.222	
% Variance	45.230	20.359	
% Cumulative variance	45.230	65.589	

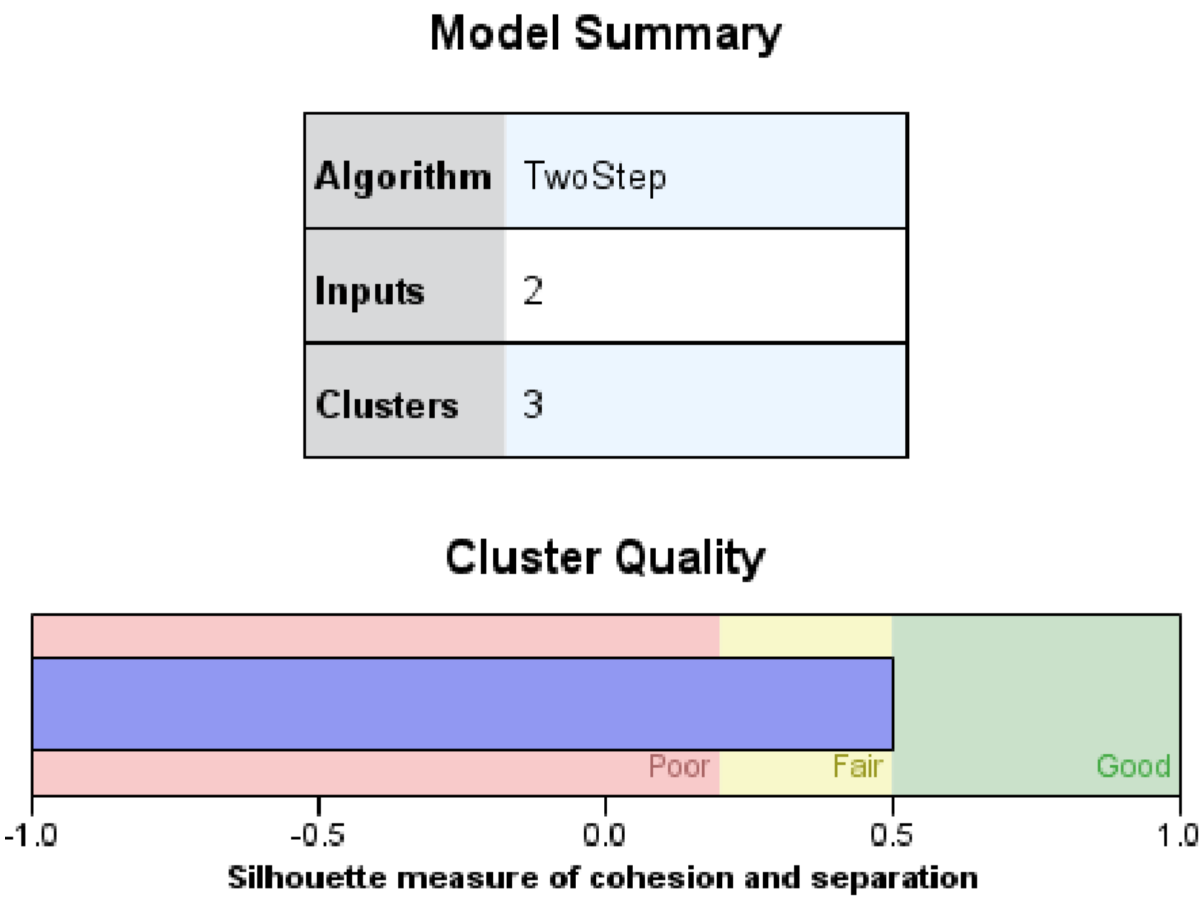

Figure 1. Cluster quality (Calidad del análisis Cluster).

Table III. Cluster's profile (Perfil de los Clústeres).

Factors	Cluster 1	Cluster 2	Cluster 3
Number of farms	31	65	32
Factor 1	1.4028021	-0.3134774	-0.7222135
Factor 2	0.3679013	-0.6640958	0.9925402

For farther description and more characterisation for each cluster, the variable «Cluster membership» has been crossed with the sixth initial technical variables used to perform factor analysis, the results are reported in the following table (Table 4).

Table 4 shows the description of the clusters. It has been used ANOVA to test the mean differences between groups. The mean differences for all the technical variables and the economic variables (gross margin per labour unit with or without subsidies) used in the present study were highly significant when the mean differences have been assessed between (C1, C2 and C3). When the mean differences were assessed between each two clusters, they kept the same trend and they were highly significant even there were some exceptions which were: the mean difference in prolificacy and the annual ewe replacement rate between cluster 2 and cluster 3 has been resulted not significant. The mean difference between the number of ewes per stud between cluster 1 and cluster 3 has been resulted not significant. And the mean difference in the number of lambings per present ewe and year has been resulted significant at 10% when comparing the means between cluster 2 and cluster 3. The mean differences for prolificacy and the annual ewe replacement rate have been resulted not significant too. The mean differences in the economic results between cluster 1 and cluster 2 has been resulted not significant. The description for each cluster is as follows:

Cluster 1- This group has been characterized more by factor 1 even if it is correlated positively with factor 2 but with lower importance. These farms have the highest means for the technical-economic variables characterising the factor 1: Prolificacy (Pr) (1.51),

Table IV. **Cluster's description** (Descripción de los Clústeres).

Variables	Cluster 1		Cluster 2		Cluster 3		Significance level (C1,C2,C3)	Significance level C1, C2	Significance level C1, C3	Significance level C2, C3
	Mean	Std.D	Mean	Std. D	Mean	Std.D				
Prolificacy (Pr)	1.51	0.10	1.30	0.09	1.26	0.09	***	***	***	NS
Number of lambings per present ewe and year (NL/PE)	1.28	0.08	1.08	0.09	1.03	0.09	***	***	***	*
Percentage of lambs' mortality (%Mr)	10.98	2.83	8.57	2.29	14.51	3.81	***	***	***	***
Number of sold lambs per present ewe and year (NSL/PE)	1.50	0.19	1.11	0.16	0.98	0.15	***	***	***	***
Annual ewe replacement rate (% FRep)	16.76	2.99	13.00	3.05	13.26	3.82	***	***	***	NS
Number of ewes per stud (NE/S)	38.49	6.69	51.34	13.03	40.47	7.68	***	***	NS	***
Gross margin per labour unit with subsidies (GM/LUWS) (€)	27209.00	10476.20	26668.17	10170.97	19834.95	8451.30	***	NS	***	***
Gross margin per labour unit without subsidies (GM/LUWTS) (€)	7166.60	8609.54	7142.12	8421.59	-542.91	9273.12	***	NS	***	***

Significance level at: (***) p < 0,0001. (**) p < 0.05 (*) p < 0.1 NS: Not significant

Number of lambings per present ewe and year (NL/PE) (1.28), Number of sold lambs per present ewe and year (NSL/PE) (1.50), Annual ewe replacement rate (% FRep) (16.76), Gross margin per labour unit with subsidies (GM/LUWS) (27209.00 €) and Gross margin per labour unit without subsidies (GM/LUWTS) (7166.6 €).

Where these farms have the lowest mean for the Number of ewes per stud (NE/S) (38.49) and the second mean for percentage of lambs' Mortality (% Mr) (10.98) comparing to other clusters resulting from this analysis. This group can be characterized as the group with the best technical productive indicators and best economic results.

Cluster 2- This group has been negatively correlated with both factors 1 and 2. This cluster presents the highest mean for the Number of ewes per stud (NE/S) (51.34 %) and the lowest mean for the percentage of lambs' Mortality (% Mr) (8.57 %). While it presents the second highest mean for the following variables: Prolificacy (Pr) (1.30), Number of lambings per present ewe and year (NL/PE) (1.08), Number of sold lambs per present ewe and year (NSL/PE) (1.11), and Annual ewe replacement rate (%FRep) (13 %). With respect to the economic results, it has recorded the second mean for the Gross margin per labour unit with subsidies (26668.17 €) and without subsidies (7142.12 €) respectively. This group does not have the high degree of reproductive intensification like cluster 1. This translates into lower lamb mortality, a lower replacement rate and a lower number of males per ewe. With a different reproductive strategy, they also achieve good economic results comparing to cluster 1, where the mean difference in the economic results has been resulted not significant between cluster 1 and cluster 2.

Cluster 3- This group has been negatively correlated with factor 1 and positively correlated with factor 2. It has been recorded the highest mean for lambs' Mortality (14.51 %) and the second highest mean record for the Number of ewes per stud (NE/S) (40.47). With respect to the rest of the used technical variables it has been recorded the lowest means: Prolificacy (1.26), Number of lambings per present ewe and year (NL/PE) (1.03), Number of sold lambs per present ewe and year (NSL/PE) (0.98), the average Annual ewe replacement rate (%FRep) (13.26). Regarding to the economic results it has been recorded the lowest means for the Gross margin per labour unit for both with subsidies GM/LUWS (19834.95 €) and without subsidies (GM/LUWTS) (-542.91 €). For this group, poor reproductive management translated into poorer economic results.

Linear regression analysis

It has been performed multiple linear regressions for the whole sample and by clusters as it has been commented previously in the methodological part. The dependent variables are the Gross margin with and without subsidies (GM/LUWS) and (GM/LUWTS) respectively. The independent variables were the six technical variables which have been used to perform the factor analysis in the present work.

The results of the multiple linear regression analyses for the whole sample and for each cluster have been presented in tables 5 and 6. As it has been highlighted in the methodological part that R-Squared (R^2 or the coefficient of determination) is a statistical measure in a regression model that determines the proportion of variance in the dependent variable that can be explained by the independent variables. The recorded adjusted R2 for the regressions were relatively low, but according to Falk and Miller (1992), they recommended that R2 values should be equal to or greater than 0.10 to be considered. Its relevance has been supported by the T, Durbin-Watson, F and VIF values which were significant.

As it can be seen in table 5, related to the linear regressions for the whole sample, that the first model for regression 1 where it has been taken into account the subsidies in the Gross margin per labour unit (GM/LUWS), the Number of sold lambs per present ewe and year (NSL/PE) and the Number of ewes per stud (NE/S) had a positive power on the economic results. It could be explained that the correct number of ewes per stud could improve the economic results. However, percentage of lambs' Mortality (% Mr) had a negative power on the economic results.

The second model for regression 2 where the subsidies have not been taken into account showed that just the Number of sold lambs per present ewe and year (NSL/PE) had a positive impact on the economic results and the percentage of lambs' Mortality (% Mr) had a negative impact on the economic results. The explanation for the fact that the Number of ewes per stud does not appear as an explanatory figure when subsidies are not taken into account is due to subsidies. While the subsidies were totally or partially coupled, farmers increased the number of ewes or sheep culling was slowed down in order to receive more premiums, but not the number of studs. This is why, when subsidies are taken into account, the economic results are associated with a higher number of ewes per stud.

Lambs' mortality has been an issue for sheep meat farms because it causes the decrease of the sold lambs per ewe independently of the production system.

Table V. Results of the multiple linear regression models for the whole sample (Resultados de los modelos de regresión lineal múltiple para el conjunto de la muestra).

	Parameters	Unstandardised coefficients (β)	Sd.D(1)	Standardised coefficient (β Std)	T(2)	P(3)	R^2 % (4)	Adjusted R^2 %	Durbin-Watson	VIF(5)
Regression 1 (GM/LUWS) (6)	Constant	3939.065	6617.663		0.595	0.553	24.1	22.2	1.823	
	Number of sold lambs per present ewe (NSL/PE)	14254.856	3238.342	0.360	4.402	0.000***				1.091
	Number of ewes per stud (NE/S)	213.018	69.153	0.252	3.080	0.003**				1.092
	Percentage of lambs' mortality (%Mr)	-495.854	224.353	-0.182	-2.210	0.029**				1.106
Regression 2 (GM/LUWTS) (7)	Constant	1954.694	4318.452		0.453	0.652	24.4	23.2	1.774	1.000
	Percentage of lambs' mortality (%Mr)	-841.325	195.315	-0.343	-4.308	0.000***				1.041
	Number of sold lambs per present ewe (NSL/PE)	10434.776	2834.851	0.293	3.681	0.000***				1.041

(1)(Sd D) Standard deviation; (2) (T) T-value; (3) (P) P-value; (4) (R^2 %) R squared; (5) (VIF) Variance Inflation Factor; (6) (GM/LUWS) Gross margin per labour unit with subsides;
(7) (GM/LUWTS) Gross margin per labour unit without subsides. Significance level at: (***) p < 0,0001. (**) p < 0.05 (*) p < 0.1

The results for group 1 are presented in table 6. The first model for the regression 1 where subsidies have been taken into account has been recorded that the percentage of lambs' Mortality (% Mr) had a negative effect on the economic results and when subsidies have not been taken into account, the Annual ewe replacement rate (% FRep) had a negative power on the economic results. As this group had recorded the highest annual ewe replacement rate the farms' couldn't support the additional cost without subsidies.

For group 2, the results showed in table 6 indicate that the Number of sold lambs per present ewe and year was the unique variable which had a positive power on the economic results in both cases when the subsidies were taken into account and when they weren't taken into account.

This group has recorded the lowest percentage of lambs' Mortality, it could be an explanation for the non-negative power of the percentage of lambs' Mortality on the economic results for this group.

The results (in table 6) for group 3 showed that for regression 1 when subsidies have been taken into account, the Number of lambings per present ewe and year had the positive power on the economic results. The percentage of lambs' Mortality (% Mr) had a negative power on the economic results when the subsidies weren't taken into account. This group had recorded the highest lambs' mortality rate. For this group, the economic results could be improved with better lambing rate only with subsidies. In addition, to be more efficient, lambs' Mortality must be controlled to improve the economic results.

Table VI. Results of multiple linear regression models for the three clusters (Resultados de los modelos de regresión lineal múltiple para los tres clústeres).

	Parameters	Unstandardised coefficients (β)	Sd.D(1)	Standardised coefficient (β Std)	T(2)	P(3)	$R^{2(4)}$	Adjusted R^2	Durbin-Watson	VIF (5)
Results of the multiple linear regression models for cluster 1										
Regression 1 (GM/LUWS)(6)	Constant	42848.640	7182.296		5.966	0.000***	14.8	11.9	2.031	1.00
	Percentage of lambs' mortality (%Mr)	-1424.512	634.100	-0385	-2.247	0.032**				
Regression 2 (GM/LUWTS)(7)	Constant	32326.988	7750.454		4.171	0.000***	27.3	24.7	2.000	1.00
	Annual ewe replacement rate (% FRep)	-1501.202	455.454	-0.522	-3.296	0.003**				
Results of the multiple linear regression models for cluster 2										
Regression 1 (GM/LUWS) (6)	Constant	562.247	7876.363		0,071	0,943	15.1	13.8	1.509	1.00
	Number of sold lambs per present ewe (NSL/PE)	23468.237	7001.810	0.389	3.352	0.001**				
Regression 2 (GM/LUWTS)(7)	Constant	-12843.096	6605.524		-1.944	0.056*	12,9	11.6	1.674	1.00
	Number of sold lambs per present ewe (NSL/PE)	17965.956	5872.079	0.360	3.060	0.003**				
Results of the multiple linear regression models for cluster 3										
Regression 1 (GM/LUWS)(6)	Constant	-26615.502	14879.840		-1.789	0.084*	24.7	22.2	1.683	1.00
	Number of lambings per present ewe (NL/PE)	44868.580	14316.597	0.497	3.134	0.004**				
Regression 2 (GM/LUWTS)(7)	Constant	13043.837	6171.695		2.113	0.043**	15.1	12.2	2.022	1.00
	Percentage of lambs' mortality (%Mr)	-932.848	409.973	-0.389	-2.275	0.030**				

(1)(Sd D) Standard deviation; (2) (T) T-value; (3) (P) P-value; (4) (R^2 %) R squared; (5) (VIF) Variance Inflation Factor; (6) (GM/LUWS) Gross margin per labour unit with subsides;
(7) (GM/LUWTS) Gross margin per labour unit without subsides. Significance level at: (***) p < 0,0001. (**) p < 0.05 (*) p < 0.1.

DISCUSSION

From the results obtained we can deduce that the studied technical factors have a positive or a negative power on the economic results of meat sheep farms thus in their economic viability. Several studies agree that productivity is a main driver of economic success in the sheep business (Bohan et al., 2018; Harrison, 1980; Keady and Hanrahan, 2006; Morel et al., 2004). Productivity is influenced by the ewe genotype, herd management and feeding, and the intensity of supervision and care before and after lambing (Gazzarin and El Benni, 2020). Benoit et al. (2020) have showed that variations in technical variables have larger effects on income variability than variations in economic variables.

The prolificacy rate can vary significantly between herds (Amer et al., 1999), which is the case in our study, the difference in prolificacy rate between the resulted 3 groups has been very significant even if the main breed is the same Rasa Aragonesa. There are different factors on which the prolificacy depends which are mainly the individual variation (presence of major genes), age, season of year, climatology, ewes' feeding and flushing, use of hormonal treatments, number of lambings and health status of the ewe, etc. (Pardos, 2016). Increasing prolificacy reduces the production costs which leads to better production efficiency (Earle et al., 2017; Bohan et al. 2018; Gazzarin & El Benni 2020) and consequently the number of lambs produced per ewe can be a suitable indicator of productive efficiency (Bertolozzi-Caredio et al., 2021). Ólivan and Pardos (2000) have concluded that an increase in prolificacy of 9.2% above the mean (1.43 vs 1.31) causes an increase of 23.3% in the sheep activity margin per ewe per year. Thus, a higher prolificacy rate is a key to improve the economic results of meat sheep farms. Ripoll-Bosch et al. (2014) have concluded that a higher prolificacy could mitigate the relative importance of the coupled subventions to farms gross margin. And from his side Galanopoulos et al. (2011) argue that less efficient sheep farms are more dependent on aids.

The average sold lambs per ewe was 1.17 which is lower than the rates recorded by Pardos (2014 and 2016) as the samples and periods of study were different. The number of sold lambs is correlated with prolificacy and the number of lambings per ewe and per year. According to Riedel et al. (2007) the intensification of production in meat sheep systems leads to an increase in the number of sold lambs per ewe and year, which is the case of the group 1. In our results, it is showed that for the whole sample and for group 2 , the number of sold lambs has a positive power on the economic results.

This productive parameter is very important in improving the incomes of the farms. Cabrera (2009) found that greater number of sold lambs leads to more incomes for the farms. Gazzarin and El Benni (2020) have concluded that productivity, defined as the number of sold lambs per ewe and year, is strongly related to gross margin. According to Pardos (2014), those farms that have a greater productive intensification: greater number of lambings per present ewe per year, greater prolificacy, less lambs' mortality percentage and greater number of sold lambs per ewe, which leads to best economic results.

With respect to the number of lambings per ewe per year, in the literature, two systems are mainly discussed: 1) the 8-month system, applied more frequently, which corresponds to a lambing interval of 240 days or, what is the same, 3 lambings per ewe in 2 years (Fogarty et al., 1992; Speedy and FritzSimons, 1977) and 2) the "STAR" system, which corresponds to a lambing interval of 220 days or, what is the same to 5 lambings in 3 years (deNicolo et al., 2008 Lewis et al., 1996). Shortening the lambing interval to 240 days (3 lambings in 2 years), improving annual fertility, resulted in a substantial increase in gross margin (+44%), return on labour (+27%) and income per hectare (+57%) compared to the reference scenario (Gazzarin and El Benni, 2020). In mountain areas with one lambing per year, the increase in prolificacy also improved economic results (Gazzarin and El Benni, 2020).

In the case of our study, the mean lambing interval for the whole sample (342) days, and the lowest mean was for cluster 1 (293 days), which gives the possibility to improve this parameter to be more efficient. Cluster 3 has the highest mean lambing interval with (369 days), which means that the highest mortality rate for this group is due to other factors. The short pregnancy period gives the possibility to implement multiperiod lambing which can buffer the variability in technical performance and enhance the adaptive capability of the system for instance by moving empty ewes to a new batch and remating them. Lambing rate is one of the main drivers of flock technical performance on ewe fertility and breeding management (Benoit et al., 2020).

The other important technical factor which has been studied in this work, the impact of lambs' mortality rate on the economic results of the farms. An important factor in productivity per ewe is the mortality or loss of lambs after birth, including stillborn lambs (Gazzarin and El Benni, 2020). Lambs' mortality increased in recent years due, apart from births of old sheep, health problems and reproductive intensification, labour intensification more lambings to handle for the same number of workers, concentrated in time and sometimes with unfavourable weather, the impossibility on some occasions of continuous monitoring of the same and the incorrect feeding of the ewes at the end of gestation and first days of lactation. Added to that in some cases, having the same facilities with a larger number of ewes, without lambing boxes or enough space to separate them (Pardos, 2016).

Positive correlations have been recorded between litter size and mortality. This could be explained mainly by the higher frequency of triplets (Morris and Kenyon, 2014). According to Morel and Kenion (2006) higher prolificacy is associated with an increase in the percentage of double- or triple-lambings showing higher mortality rates than simple delivery.

Our results showed that cluster 3 had recorded the highest mortality rate and the worst economic results, which support the strong impact of mortality on the economic results. Added to that the regression analysis confirmed this trend by figuring out the negative impact of lambs' mortality in predicting the economic results. According to Delgado and Gutiérrez (2009) the lambs' mortality rate must not exceed 5 %. Shiels et al. (2022) have concluded that lambs' mortality could be reduced with on farm management practices thus improve the flock gross margin.

With respect to annual ewe replacement rate was almost 14%, this result coincides with the result of Marín-Bernal and Navarro-Rios (2014) but not with Garcia et al. (2005) 20%, and Pardos (2014) with a percentage of replacement oscillating between 15.9% and 17.2 %. For replacement rate Farell et al. (2020) had concluded that larger increases in cash operating surplus (COS) occurred with a higher flock lambing rate and lower ewe replacement rate, which allowed for terminal sire use over a greater proportion of the flock. In our results even if the group 1 had the best economic results, but the replacement rate was higher, which means that the right replacement rate could improve the economic results by reducing the cost of unnecessary added cost for unproductive animals. According to Farell et al. (2020) better economic results obtained with the lower annual ewe replacement rate combined with the higher flock lambing rate. Thus, the correct annual ewe replacement rate is important to avoid more additional unnecessary cost of non-productive animals.

The average number of ewes per stud was 45 ewes. It coincides more or less with the results recorded by Pardos et al. (2008). According to Delgado and Gutiérrez (2009) the right number of studs in a sheep herd is the 3% of the total number of ewes. Thus, in our case the number of ewes per stud for Cluster 1 could be considered as a good one, but for cluster 2 and cluster 3 it is high and could be adjusted to have the right effect of this parameter on the productivity of the farm.

The participation of farmers in research projects for the selection of breeds and management systems, as well as the technical support of cooperatives, appear as a promising way to increase the efficiency of farms and the prolificacy of sheep (Bertolozzi-Caredio et al., 2021).

Sheep farming must find solutions to a) increase production efficiency and profitability (Morgan-Davies et al., 2021) and b) accelerate the pace of technology development and adoption to successfully compete in the future (Montossi et al., 2013).

We can conclude that these results show that all the studied technical factors had a positive or a negative impact in predicting the economic results of meat sheep farms. The productive parameters as number of sold lambs has a real power in improving the economic results with and without taking into account subsidies. And the number of lambings per present ewe could be a solution to improve the economic results by shortening the lambings intervals. Finally, lambs' mortality percentage must be taken into account to improve the economic results of the meat sheep farms. Even if other productive parameters were performed, if the farm doesn't control lambs' mortality, it will record loss in the economic profit. As the values recorded were above 10%, thus there are possibilities to improve this aspect, both sanitary and handling. Added to that, and regarding to the reproductive aspect the use of the correct annual ewe replacement rate could help to improve the economic results by reducing the production costs, thus mitigating the impact of subventions in the economic efficiency and viability of meat sheep farms. Implementing new technologies and participating in research projects and benefit from the technical support of specialised cooperatives would be a real help to improve the technical efficiency of meat sheep farms.

ACKNOWLEDGEMENTS

We would like to thank the Oviaragón-Grupo Pastores cooperative, without whose collaboration this work would not have been possible.

BIBLIOGRAPHY

Alabart, JL, Lahoz, B, Calvo, JH, Jurado, JJ, Fantova, E, & Folch, J 2016, "Estudios realizados y situación actual de la variante génica prolífica ROA (FecXR) de la raza ovina Rasa Aragonesa", Arch Zootec, vol. 65(251), pp. 449-452.

Amer, PR, McEwan, JC, Dodds, KG & Davis, GH 1999, "Economic values for ewe prolificacy and lamb survival in New Zealand sheep", Livest. Prod. Sci. 58, pp. 75 -90. https://doi.org/10.1016/S0301-6226(98)00192-4.

https://doi.org/10.1007/s13593-020-00638-z

Bernués, A, Ruiz, R, Olaizola, A, Villalba, D, & Casasús, I 2011 "Sustainability of pasturebased livestock farming systems in the European Mediterranean context: synergies and trade-offs", Livest. Sci., 139, pp. 44 -57.

Bertolozzi-Caredio, D, Soriano, B, Bardají, I & Garrido, A 2021 "Economic risk assessment of the quality labels and productive efficiency strategies in Spanish extensive sheep farms" Agric. Syst. 191.

Bohan, A, Shallooa, L, Creightonc, P, Earleb, E, Boland, TM & McHugha N 2018 "Investigating the role of stocking rate and prolificacy potential on profitability of grass-based sheep production systems" Livestock Science, 210, pp. 118 -124

Andersen, E, Elbersen, B, Godeschalk, F & Verhoog, D 2007, "Farm management indicators and farm typologies as a basis for assessments in a changing policy environment", Journal of Environmental Management 82, pp. 353-362. https://doi.org/ 10.1016/ j.jenvman.2006.04.021

Beavers, AS, Lounsbury, JW, Richards, JK, Huck, S. W, Skolits, GJ, & Esquivel, SL 2013, "Practical considerations for using exploratory factor analysis in educational research", Pract. Assess. Res. Eval. 18, 1.

Benoit, M & Laignel, G 2011, "Analyse sur le long terme de systèmes d'élevage ovins allaitants en France. Quelles trajectoires et quels facteurs de réussite économique ?", INRA Productions Animales 24(3), pp. 211-220. https://doi.org/10.20870/productions-animales.2011.24.3.3

Benoit, M & Laignel, G 2008, "Comparaison de trois systèmes d'élevage ovin viande en zone de demi-montagne : Quelles adaptations pour quelles performances en 2012" Renc. Rech. Ruminants, 15, pp. 139-142.

Benoit, M, Joly, F, Blanc, F, Dumont, B, Sabatier, R & Mosnier C 2020 "Assessment of the buffering and adaptive mechanisms underlying the economic resilience of sheep-meat farms", Agronomy for Sustainable Development, 40, pp. 34. https://doi.org/10.1007/s13593-020-00638-z

Bernués, A, Ruiz, R, Olaizola, A, Villalba, D, & Casasús, I 2011 "Sustainability of pasturebased livestock farming systems in the European Mediterranean context: synergies and trade-offs", Livest. Sci., 139, pp. 44 -57.

Bertolozzi-Caredio, D, Soriano, B, Bardají, I & Garrido, A 2021 "Economic risk assessment of the quality labels and productive efficiency strategies in Spanish extensive sheep farms" Agric. Syst. 191.

Bohan, A, Shallooa, L, Creightonc, P, Earleb, E, Boland, TM & McHugha N 2018 "Investigating the role of stocking rate and prolificacy potential on profitability of grass-based sheep production systems" Livestock Science, 210, pp. 118 -124.

Cabrera, 2009. Análisis de competitividad del sistema ovino y caprino del noroeste de la república dominicana, Tesis doctoral. 246 pp.

Castel, JM, Mena, Y, Ruiz, FA, Camúñez-Ruiz, J & Sánchez-Rodríguez, M 2011, "Changes occurring in dairy goat production systems in less favoured areas of Spain", Small Rumin. Res. 96(2-3), pp. 83 -92.

Charroin, T, Veysset, P, Devienne, S, Fromont, JL, Palazon, R & Ferrand, M 2012, "Productivité du travail et économie en élevages d'herbivores : définition des concepts, analyse et enjeux", INRA Prod. Anim, 25 (2), pp. 193-210.

Child, D 2006, The Essentials of Factor Analysis, 3rd edn. New York: Continuum

De Rancourt, M, Fois, N, Lavín, MP, Tchakérian, E & Vallerand, F 2006, "Mediterranean sheep and goats production: An uncertain future" Small Rum. Res. 62(3), pp. 167 -179.

Delgado, L & Gutiérrez, P 2009, "Manual práctico de manejo de una explotación de ovino de carne. Servicio de Formación Agraria e Iniciativas, D.L de ovino de carne" Escuela Universitaria de Ingeniería Técnica Agrícola INEA. 129 pp

DeNicolo, G, Morris, ST, Kenyon, PR & Morel, PCH 2008, "A comparison of two lamb production systems in New Zealand" New Zealand J. Agric. Res. 51, pp. 365 -375.

Draper, NR & Smith, H 1998. Applied Regression Analysis, Book. 736 pp.https://doi.org/10.2527/jas.2017.1427.

Earle, E, Boland, T, McHugh, N & Creighton, P 2017 "Measures of lamb production efficiency in a temperate grass-based system differing in ewe prolificacy potential and stocking rate" J. Anim. Sci. 95 (8), pp. 3504 -3512. https://doi.org/10.2527/jas.2017.1427.

Eaton, Ph, Frank, B, Johnson, K & Willoughby, Sh 2019 "Comparing exploratory factor models of the Brief Electricity and Magnetism Assessment and the Conceptual Survey of Electricity and Magnetism" Physical Review Physics Education Research 15: 020133, pp.1-11.

Falk, RF & Miller, NB 1992, A primer for soft modelling, Book. University of Akron Press.

Farrell, LJ, Kenyon, PR, Tozer PR, Ramilan, T & Cranston, LM 2020 "Quantifying sheep enterprise profitability with varying flock replacement rates, lambing rates, and breeding strategies in New Zealand", Agricultural system, 184. 102888.

Fogarty, NM, Hall, DG, Atkinson, WR 1992, "Productivity of three crossbred ewe types mated naturally at 8-monthly intervals over two years", Aust. J. Agric. Resour. Econ. 43, pp. 1819 -1832.

Folch, J, Alabart, JL, Echegoyen, E, Martí, JI, Sánchez, P, Fantova, E, & Roche, A 2007, "Manejo reproductivo de la oveja Rasa Aragonesa. Preparación de las ovejas destinadas a la inseminación artificial". Capítulo 6. CITA (Gobierno de Aragón) y Servicios Técnicos de Oviaragón, S.C.L.

Freitas Silveira, RM, Maria de Vasconcelos, A, José da Silva, V, Hernando Ortiz Vega, W, Toro-Mujica, P & Ferreira, J 2021, "Typification, characterization, and differentiation of sheep production systems in the Brazilian semiarid region, NJAS, Impact in Agricultural and Life Sciences, 93:1, pp. 48-73, DOI: 10.1080/27685241.2021.1956220

Galanopoulos, K, Abas, Z, Laga, V, Hatziminaoglou, I & Boyazoglu, J 2011, "The technical efficiency of transhumance sheep and goat farms and the effect of EU subsidies: do small farms benefit more than large farms?" Small Rumin. Res., 100, pp. 1 -7. https://doi.org/10.1016/j.smallrumres.2011.05.008.

García, J, Rouco, A, & Correal, E, 2005, "Análisis económico de las explotaciones de ganado ovino y caprino en la región de Murcia", An. Vet. (Murcia) 21, pp. 109-120.

García-Martínez, A, Olaizola, A, Bernués, A 2009, "Trajectories of evolution and drivers of change in European mountain cattle farming systems", Animals 3(1), pp. 152 -165.

Gazzarin, C & El Benni, N 2020, "Economic assessment of potential efficiency gains in typical lamb production systems in the alpine region by using local resources" Small Rumin. Res. 185, https://doi.org/10.1016/j.smallrumres.2020.106066.

Guttman, L 1954 "Some necessary conditions for common-factor analysis," Psychometrika, 19, pp: 149-161.

Hair, JF, Black, WC, Babin BJ & Anderson, RE 2014, Multivariate data analysis, 7th Ed. Pearson New International Edition, EE.UU. 739 pp.

Harrison, VL 1980, "Sheep Production: Intensive Systems, Innovative Techniques Boost Yields", Agricultural Economic Report 452. ESCS Publications, United States Department of Agriculture, Washington DC.

Kaiser, HF 1970, "A second generation little jiffy", Psychometrika, 35, pp. 401-415.

Keady, TWJ & Hanrahan, JP 2006, "Efficient sheep production in subsidy free environment - research from Athenry. Ir, Grassl. Anim. Prod. Assoc. J. 40, pp. 15 -27.

Kleinhanß, W, Murillo, C, San Juan, C & Sperlichd, S 2007, "Efficiency, subsidies and environmental adaptation of animal farming under CAP" Agricultural Economics 36, pp. 49 -64.

Lewis, RM, Notter, DR, Hogue, DE & Magee, BH 1996, "Ewe fertility in the STAR accelerated lambing system" J. Anim. Sci. 74, pp. 1511 -1522.

Ministerio de Agricultura, Pesca y Alimentación 2021, El sector ovino y caprino de carne en cifras. Principales Indicadores Económicos, MAPA, Madrid.

Marín-Bernal, AM & Navarro-Rios, MJ 2014, "Analysis and diagnosis of sheep production systems in Spanish southeast" Arch. Zootec. 63 (243), pp. 519-529.

Mena, Y, Ruiz-Mirazo, J.B, Ruiz FA & Castel, JM 2016, "Characterization and typification of small ruminant farms providing fuelbreak grazing services for wildfire prevention in Andalusia (Spain)", Science of the Total Environment 544, pp. 211 -219.

Milán, MJ, Arnalte, E & Caja, G 2003, "Economic profitability and typology of Ripollesa breed sheep farms in Spain", Small Ruminant Research 49, pp. 97 -105.

Montossi, F, Font-i-Furnols, M, del Campo, M, San Julián, R, Brito, G & Sañudo, C 2013, "Sustainable sheep production and consumer preference trends: compatibilities, contradictions and unresolved dilemmas" Meat Sci. 95, pp. 772 -789.

Morel, PCH, Kenyon, PR & Morris, ST 2004, "Economical analysis of year round lamb production. Proc" New Zealand Soc. Anim. Prod. 64, pp. 179 -182.

Morel, PCH & Kenyon, PR 2006, "Sensitivity analysis of weaner lamb production in New Zealand", Proceedings of the New Zealand Society of Animal Production, Vol 66, pp. 377-381.

Morgan-Davies, CJ, Kyle, J, Boman , IA. Wishart , H. McLaren, A. Fair, S & Creighton, P 2021 "A comparison of farm labour, profitability, and carbon footprint of different management strategies in Northern European grassland sheep systems", Agricultural Systems 191, pp. 103155. https://doi.org/10.1016/j.agsy.2021.103155

Morris, S & Kenyon, P 2014, "Intensive sheep and beef production from pasture --a New Zealand perspective of concerns, opportunities and challenges", Meat Sci. 98, pp. 330 -335. https://doi.org/10.1016/j.meatsci.2014.06.011.

Olaizola, A, Chertouh, T & Manrique, E 2008, "Adoption of new feeding technology in Mediterranean sheep farming systems: Implications and economic evaluation" Small Ruminant Research 79, pp, 137-145. https://doi.org/10.1016/j.smallrumres.2008.07.022

Olaizola, A, Manrique, E, Bernués, A & Maza MT 1996, "Incidence of programmes to discourage milk production on representative cattle farms in a less favoured area", Investigación Agraria, Economía 11, pp. 355-376

Oliván, A & Pardos, L 2000, "Importance of a sheep selection programme for prolificacy", Options Méditerranéennes : Série A, Séminaires Méditerranéens n° 43, pp. 93-100.

Pardos, L 2014, "Gestión técnico económica de ovino de carne. Manual de gestión técnico económica de explotaciones ovinas y caprinas", In:Sociedad Española de Ovinotecnia y Caprinotecnia. Editorial Agricola, 31-42.

Pardos L 2016, "Mejora de la rentabilidad económica en las ganaderías de ovino de carne". IV Jornada Técnica. Eficiencia de la Producción Ovina de Carne, Finca El Chantre, Teruel, 18 de noviembre de 2016.

Pardos, L, Maza, MT, Fantova, E & Sepúlveda, W 2008, « The diversity of sheep production systems in Aragón (Spain): Characterisation and typification of meat sheep farms", Spanish Journal of Agricultural Research, 6(4), pp. 497-507.

Riedel, JL, Casasus, I & Bernues A 2007, "Sheep farming intensification and utilization of natural resources in Mediterranean pastoral agro-ecosystem", Livest Sci 111, pp. 153-163. doi: 10.1016/j.livsci.2006.12.013.

Ripoll-Bosch, R, Joy, M & Bernués, A 2014, "Role of self-sufficiency, productivity and diversification on the economic sustainability of farming systems with autochthonous sheep breeds in less favoured areas in Southern Europe" Animal 8 (8), pp.1229 -1237. https://doi.org/10.1017/S1751731113000529.

Ryschawy, J, Choisis, N, Choisis, JP & Gibon, A 2013, "Paths to last in mixed crop-livestock farming: lessons from an assessment of farm trajectories of change", Animals 7(4), pp. 673-681.

Sakar, E, Keskin, S & Unver, H, 2011, "Using of factor analysis scores in multiple linear regression model for prediction of kernel weight in Ankara walnuts" The Journal of Animal & Plant Sciences 21(2), pp. 182-185.

Samuels, P 2017. Advice on Exploratory Factor Analysis. Study guide that explains the exploratory factor analysis technique using SPSS and Excel.

Shiels, D, Loughrey, J, Dwyer, CM, Hanrahan, K, John, FM. & Timothy WJK 2022, "A Survey of Farm Management Practices Relating to the Risk Factors, Prevalence, and Causes of Lamb Mortality in Ireland", Animals, 12, 30. https://doi.org/10.3390/ani12010030

Shrestha, N 2021, "Factor Analysis as a Tool for Survey Analysis" American Journal of Applied Mathematics and Statistics, Vol. 9, No. 1, pp. 4-11.

Soriano, B, Bertolozzi, D & Bardaji, I 2018, "Assessing how policies enable or constrain the resilience of the extensive sheep grazing system in Northeast Spain (Spain). An application of the Resilience Assessment Tool (ResAT)", Project acronym: SURE-Farm. Project nº: 727520.

Speedy, AW & FritzSimons, J 1977, "The reproductive performance of Finnish Landrace × Dorset Horn and Border Leicester × Scottish Blackface ewes mated three times in 2 years" Anim. Prod. 24, pp. 189 -196.

Tabachnick, BG & Fidell, LS, 2013 Using multivariate statistics (6th ed.), Pearson.

Toro-Mujica, MP, Aguilar, C, Vera, R, Barba, C, Rivas, J & García-Martínez, A 2015 "Changes in the pastoral sheep systems of semi-arid Mediterranean areas: association with common agricultural policy reform and implications for sustainability", Span. J. Agric. Res. 13(2), pp. 1-11.

Toro-Mujica, P., Arraño, C, Vera, R, Robles, L, del Río, C, Corvalán, E & Riveros FJL 2019 "Perspectives of abandonment/continuity of typological groups of sheep farms in the semi-arid region of Central Chile", Economia Agraria y Recursos Naturales, 19(2), pp. 113 -132. https://doi.org/10.7201/earn.2019.02.06

Weltin, M, Zasada, I & Piorr, A 2016, "The role of financial support: Strategies of farm households on diversification of income sources under two policy scenarios", 12th European International Farming Systems Association (IFSA) Symposium. Social and technological transformation of farming systems: Diverging and converging pathways, 12-15 July 2016, Harper Adams University, Newport, Shropshire, UK. 1-15 pp.