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Assessment of Key Feeding Technologies and Land Use in Dairy Sheep Farms in Spain

María Teresa Bastanchury-López [1], Carmen De-Pablos-Heredero [2], Santiago Martín-Romo-Romero [1] and Antón García [3,*]

[1] Department of Business Economics (Administration, Management and Organization), Applied Economics II and Fundamentals of Economic Analysis, Universidad Rey Juan Carlos, Paseo de los Artilleros s/n, 28032 Madrid, Spain; teresa.bastanchury@urjc.es (M.T.B.-L.); santiago.martinromo@urjc.es (S.M.-R.-R.)
[2] Department of Business Economics (Administration, Management and Organization), Applied Economics II and Fundamentals of Economic Analysis, ESIC University, Universidad Rey Juan Carlos, Paseo de los Artilleros s/n, 28032 Madrid, Spain; carmen.depablos@urjc.es
[3] Animal Science Department, University of Córdoba, Rabanales University Campus, 14071 Córdoba, Spain
* Correspondence: pa1gamaa@uco.es

Abstract: Familiar mixed dairy sheep farm is the most widespread system in the Mediterranean basin, in Latin America and in developing countries (85%). There is a strong lack of technological adoption in packages of feeding and land use in small-scale farms. To increase competitiveness, it would be of great interest to deepen the knowledge of how innovation was selected, adopted, and spread. The objective of this research was to select strategic feeding and land use technologies in familiar mixed dairy sheep systems and later assess dairy sheep farms in Spain. This objective was assessed by combining qualitative and quantitative methodologies. In the first stage, with the aim to identify and select the appropriate technologies, a panel of 107 experts in dairy sheep production was used. A questionnaire was applied to all of them with successive rounds using Delphi methodology. Later, these technologies were grouped by principal components analysis (PCA) and cluster analysis (CA). In a second stage the technological results from a random sample of 157 farms in the Center of Spain were collected. The technologies selected were linked to the technological adoption level of the farms in Castilla la Mancha by a multiple regression model. Ten technologies were selected by the 107 experts. Four factors were retained by PCA that explained at 67.11% of variance. The first factor is related to feeding strategies, the second to land use for livestock production, the third to efficient management of land resources or ecoefficiency and the fourth to by-products use. The expert evaluation was grouped in three clusters using the Ward's method and the squared Euclidean distance measure, where the second showed higher values in the adoption level of each technology. The multiple regression model explained the relationship between the technologies and the technological level of the farms (R^2 73.53%). The five technologies selected were: use of unifeed (1), supplemental feeding (5), grazing (6), raw materials production (7) and sustainable use of water and soil (10). These ten technologies identified can be directly extended to small-scale dairy farms from other countries in the Mediterranean basin and Latin America. This technological selection was supported from the broad and diverse panel of experts used. Besides, five technologies identified by the quantitative model will be able to be taken into account for the development of public innovation policies. They are direct technologies and easy to apply on the farm and seeking increased viability through innovation vs. intensification.

Keywords: technological sustainability; multivariate analysis; regression model; innovation; mixed systems; dairy sheep farms

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1. Introduction

Dairy milk production in Castilla-La Mancha located in the center of Spain, is of great economic and social importance [1,2]. The dairy Manchega production is entirely destined to the production of quality cheese with great international recognition as "Queso Manchego" into the Protected Designation of Origin (PDO) [3]. Dairy farms show synergies with other activities within a mixed system, playing an important role in sustainability, acting preventively regarding fires and contributing to the territorial development of rural areas [1,3,4]. This sector is undergoing a profound restructuring and modernization to cope with the crisis it is experiencing [5], aggravated by the strong increase in the cost of energy and raw materials, over 30% in the period 2015–2020. The average ration price for sheep milk has increased by 16.0% between 2020 and 2021. Excluding labor, land, and capital, per sheep feed costs in 2020 account for 64.97% of operating costs, which has a direct impact on operating results [2,6]. Besides, COVID-19 pandemic had a strong influence on direct cost of dairy sheep farms, such as labor, feeding and energy [7]. Dairy sheep in Castilla la Mancha has been oriented towards improving production results: 1387 sheep per farm, 4 season mating, 328 d of lambing interval, 143 d of lactation length, a production over 150 kg per ewe and lactation and a prolificity of 1.4 lambs/parity [3]. It is difficult to continue looking for improvements "intensification way"; perhaps the production model should be redesigned, and innovations identified that facilitate production using the system's own resources and place production in zone of increasing returns [5,8,9].

The change from an intensive production model towards another more sustainable, with an efficient management of local resources of low cost, within a circular economy based on reduce, reuse, recycle principle (referred to as the 3-R principle) [10,11] . In this sense, the use of by-products and agro-industrial waste in animal feed reduces the risk of environmental pollution through the recycling of this waste. In addition, its strategic incorporation in the diet contributes to reduce the dependence of external inputs, favors the reduction of the cost of food and the environmental impact of livestock [10,12]. The dairy sheep sector will be able to increase its viability from a sustainability and circular economy approach [13–16]. In this sense, in the new CAP strategic plan for 2023–2027 period, these specific objectives were presented: contribute to climate change mitigation and adaptation; foster sustainable development and efficient management of natural resources such as water, soil and air; contribution to the protection of biodiversity, enhance ecosystem services and preserve habitats and landscapes and fostering; knowledge, innovation and digitalization in agriculture [17].

In previous research [6,18,19] different technological packages in dairy sheep were evaluated, reporting great advances in the areas of reproduction, health and milk quality. Given the high level of intensification of the dairy sheep system in Castilla la Mancha, the productive response to technological improvements were decreasing returns and with increasing variable costs (intensive margin). These previous results indicate a distance from sustainability and that we are approaching the limit of the system [4,5,18,20]. In contrast, food and land-use packages still show implementation levels of less than 60% and 35% respectively [21]. Furthermore, an improvement in technological level was linked to an increase in the long-term viability, productivity and competitiveness of farms [22–24]. There were several reasons why farmers have not adopted feeding and land use technologies; such us the small-size of the farms, poor financial capacity, risk aversion, lack of public support and advice, among others [4,25–27]. Besides, the scarcity of human resources, their old age and their low training level have been described as key factors that explain failure of technology adoption [4,6]. Therefore, the global novelty of this research it was trying to answer the following research questions from a sustainability approach based on system resources: What would be the most relevant and appropriate feeding technologies to start a successful innovation process in familiar dairy sheep farms sustainably? What should the priority technologies be in feeding and land use for the design of an appropriate innovation strategy? The technologies identified by the technicians and advisors were also important at the level of performance farms? In this research we have tried to identify and select those key feeding and land use technologies, applicable in familiar mixed dairy systems in Mediterranean basin, under the following criteria: proposal of appropriate technologies for small producers, with low cost and easy to implement in the farms [22,24,28–30].

In this research the objective was to select strategic feeding and land use technologies and later, to assess the effect of these technologies in dairy sheep farms in Spain. To achieve this objective, a two-stage qualitative and quantitative mixed methodology was used. On the one hand, the relevant feed technologies in the sheep dairy system were selected and grouped by Delphi method with a panel of experts (n = 107) and multivariate analysis. Subsequently, the effect of technologies on dairy sheep farms in the center of Spain (Castilla la Mancha) was measured by regression analysis.

The identification of relevant technologies in both food and land use, and their clustering in factors, favors the development of plans for the comprehensive improvement of farms, based on the preference of sector actors and validated with field results. All of this from a focus on precision (smart farms) and sustainability.

2. Materials and Methods

In this research two independent databases were used. Later on they were related by regression analysis (Figure 1). The first database was qualitative, by the evaluation of a panel of 107 experts and the second was quantitative, based on the results of 157 farms.

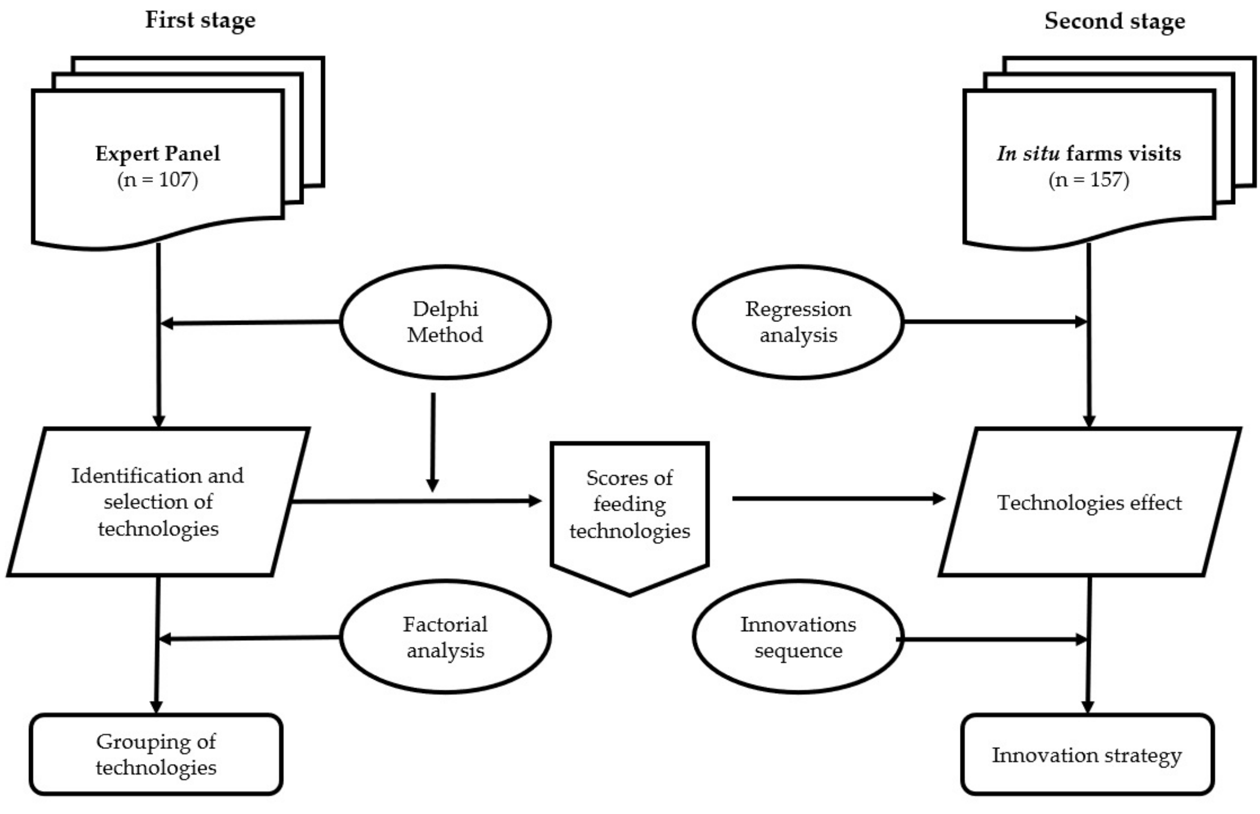

Figure 1. Research steps.

In the first stage, key technologies in food and land use were identified using an experts' panel judgment (Figure 1). A questionnaire was applied to 107 experts using the Delphi method [31,32]. The most outstanding technologies in familiar dairy sheep farms were selected by consensus. Subsequently, technologies were grouped into homogeneous factors to deepen the knowledge of their relationships and the incidence on obtained variability (left part of Figure 1).

Second stage, in the quantitative analysis, the selected technologies were compared to the technological results obtained in a database made up of 157 farms in the center of Spain (Castilla la Mancha) (right part of Figure 1). Multiple regression techniques were used in the evaluation.

2.1. Study Area

The assessment of technologies was realized in the center of Spain, dry zone with high density of familiar mixed dairy farms; 907 farms of Manchego breed in the center of Spain in the "La Mancha" region were the target population.

The "La Mancha" region presents a dry climate, under continental Mediterranean conditions. This region groups over 907 familiar farms of Manchego dairy sheep and presents a census over 600,000 ewes. La Mancha region has a surface area of 800,000 ha; 70% land arable with rainfed crops, 20% woodland and 10% natural pastureland [3,33]. The production area includes the Protected Designation of Origin (PDO) "Queso Manchego" is shown in Figure 2, with part of the provinces of Albacete (21.66%), Ciudad Real (33.16%), Cuenca (22.13%) and Toledo (23.05%). This system was characterized by a high diversity, synergies and low incomes [2,3,34,35]. These mixed farms combine different activities, such as cereal, wine grapes, ewe and cheese, among others.

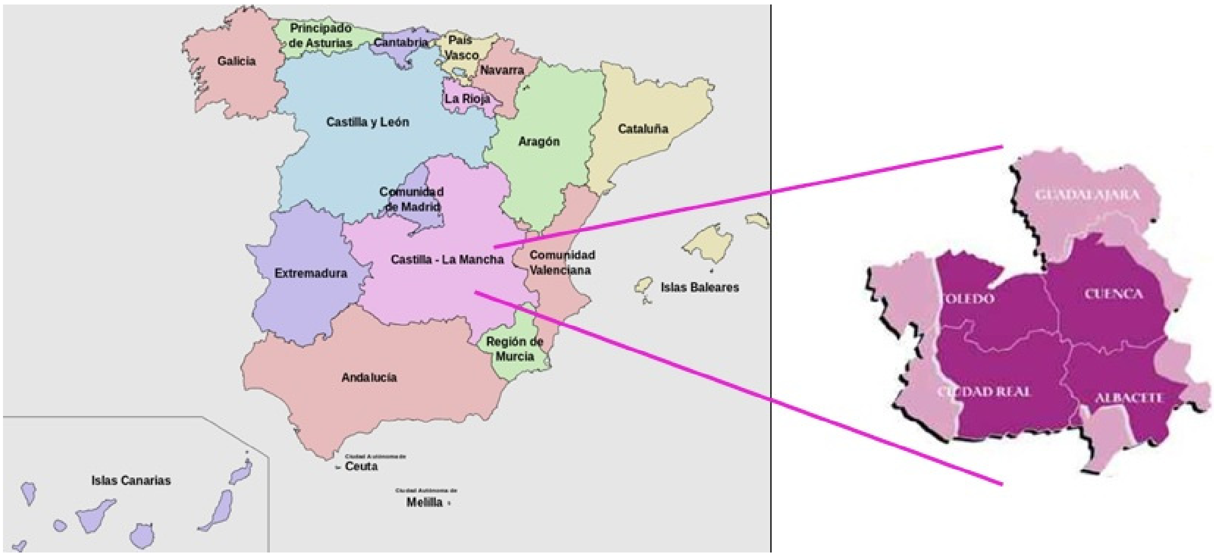

Figure 2. Production area of Protected Designation of Origin (PDO) "Queso Manchego" in the center of Spain.

2.1.1. Selection of Feeding Technologies through Delphi-Methodology

In this research, the identification and selection of feeding technologies took place according to a qualitative, consensus and participatory methodology applied by Noltze et al. [4], Torres et al. [28] and Rivas et al. [23], among others. The Delphi method was widely used in the field of technology forecasting and it has also been used as a tool to implement multi-stakeholder approaches for participative policy-making in developing countries [36]. The number of experts is variable, a range between 15–30 is recommended for focal issues and more than 100 for general issues [37]. A large number of participants representing different groups (such as policymakers, experts, citizens) collaborated in this research. A total of 107 experts from different countries of the Mediterranean Basin and Latin America participated, with extensive experience in family dairy sheep farms. Selected experts showed different professional profiles: 88.8% veterinary, 5.6% researchers, 2.8% techniques and 2.8% farmers. According to the level of education, the expert panel was disaggregated as follows: a 4.7% Phds, 91.6%, university degrees and 3.7% with intermediate education.

Firstly, a pre-selection of relevant technologies of feeding and best practices in the land use were identified according to their relevance on mixed familiar dairy system [3,23]. The first round of consultation was online, between September 2016 and January 2017. 25 over 75 potential technologies were identified by consensus. Subsequently, the selection process consisted of the experts' judgment through a questionnaire. In this step, each technology identified was evaluated according to its relevance in the farms and if it was appropriate in the context of the mixed sheep system. The experts assessed each technology by a Likert scale from one (least important) to five (most important) points. Those technologies which obtained the maximum score (five) in the opinion of twenty or more experts were directly selected.

The second round was held in March 2017 and experts were requested to submit their responses within 10 days. They were asked to rate the relevance of each technology in obtaining competitive advantages and the ease of their implementation in the exploitation; 45% of experts responded. The Ishikawa index was utilized considering the level of agreement, where the technologies with over 60% agreement and an average score over 3.5 were selected [9,23].

2.1.2. Sample of Farms

A random sample of 157 over a population of 907 Manchega breed farms was selected. In a quantitative data analysis of feeding and land use technologies, best practices (Figure 1) were considered, with a sample size over 17.2% of the population. The sample size was calculated with a confidence of 95% (Z = 1.96), an unknown expected proportion (p = 0.5) [3]. The information was collected by using in situ visits to the farms from 2012 to 2014, updated in 2018. In addition, information in situ from the 157 smallholders in their farms was collected [1,6,9] through the application of a broad survey. In each farm, a group of feeding technological indicators and land use were applied according to the proposal of the panel of experts [3]. With this information, we built an index with scores from 0 to 100 according to feeding and land technological level found in each farm. Each technology has been scored between 1 to 5 points and subsequently the evaluations have been considered until they reach a maximum of 10 points; in other words, a farm with a maximum score in each technology (5) would achieve a final score of 10 points [5,6,38].

2.2. Statistical Analysis

Principal components analysis (PCA) was applied to group technologies [1,2,39]. This approach was applied to the 2018 data yielding several feeding technology types as well as equations to estimate factors. Quantitative variables included land use, grazing, green fodder, by-products, silage, hay, processed feeding, water use, unifeed, composition of the farm crop and livestock portfolio, among others. Bartlett's chi-square test was used to ensure adequate correlations, and the Kaiser–Meyer–Olgin index was calculated to determine sampling adequacy when KMO value is greater than 0.50 and probability of Barlett test is less than 0.05 [1,3,39]. The standardized feeding technology variables were subject to a factor analysis using principal components to extract the factors [40,41]. Factors with eigen values larger than 1 were considered significant [42]. Once the components were selected, the orthogonal varimax rotation was applied. In addition, Cronbach's alpha was calculated by applying reliability analysis on designated factors [43], scoring over a punctuation of 0.75 in each component. The technology scores obtained by the panel of experts were classified in groups using cluster analysis (CA). Hierarchical groupings were developed based on Ward's method, using the Euclidean, squared Euclidean and Manhattan distances [44]. The optimal clustering was selected using discriminant analysis and analysis of variance [2,3].

Finally, using a multiple regression model (GLM) the selected reproductive technologies (endogenous variables) were faced with the technological results in dairy farms (exogenous variable). The technologies were taken as independent variables (expert panel n = 107), the technological outcome of the farms as a dependent variable (on-site visits to farms, n = 157) and multiple regression using ordinary least squares (OLS) was applied. The normality of the distribution was verified using Kolmogorov-Smirnov, Cramer-Von Mises and Anderson-Darling tests. Besides, Bartlett test was performed to verify equality of the data variance (homoscedasticity). The technological level was compared by analysis of variance (ANOVA), establishing the feeding technologies and land use as fixed effects.

For the comparison of means, the Tukey method was used. In the adjustment of the models, the multiple step to step regression procedure of the statistical package Statgraphics Centurion was used. The selection of the best model took place by using the coefficient of determination (R^2) and the mean squared error (MSE).

3. Results

The results obtained were presented below in three sections. First, the identification and selection of feeding and land use technologies by 107 experts (Delphi method). Second, the grouping of technologies with principal component analysis (PCA) and typology of experts was built by cluster analysis (CA). Finally, the effect of technologies in a sample of 157 farms in La Mancha by regression analysis was calculated.

3.1. Identification and Selection of Feeding and Land Use Technologies

Twenty-five feeding and land use technologies were pre-selected. The selection of technological innovations was accomplished through qualitative and participatory analysis based on the farmer's technological preferences. Ten technologies were identified and grouped in the technological areas of feeding (five technologies) and land use with other five technologies, within a transversal, collaborative and interactive process [45]. Table 1 shows scores of 10 technologies selected. In the feeding package: use of unifeed technology that combines concentrate with forage (1), use of agro-industrial by-products and crop residues in the diet (2), diets and balanced rations according to physiological and productive status of animals in feeding lots (3), use of mineral blocks (4), use of animal supplementation with nutritional blocks and concentrated feeding (5). In the land use, technological packages were selected: grazing management (6), sow of crops and raw materials production (7), use of conservation of forages techniques (hay and silage) (8), production management strategies (9) and sustainable and efficient use of water and soil (10). The technologies: Diets and balanced rations (3), productive management (9) and sustainable use of water and soil (10) got a high consensus with scores over 4. The remaining seven technologies obtained values between 3 and 4. The reliability of the survey was verified using Cronbach's alpha, with values greater than 0.7, acceptable to confirm internal consistency: the complete survey showed a Cronbach's alpha of 0.877 [3,46].

3.2. Grouping of Technologies

PCA retained four factors that comprised 67.11% of variance with an eigenvalue over one (Table 2); 27.67% of the variance were retained by the first factor, with the following variables: use of unifeed mixtures (1), use of mineral correctors in blocks (4) and use of supplemental feeding (5). The variables of this factor were linked with the diet and rationing of livestock according to their physiological and productive state (high, medium and low). This component was called rationing strategy. The second factor retained 17.84% of the variance. Land use for livestock food production (7) and the conservation of hay surpluses by (8) were the explained variables. This factor was linked to the land use strategy. 11.51% of the variance was explained by the third, with high scores in organization of animals in productive groups (9), sustainable water usage and land efficiency (10) within the group of activities carried out in these productive systems. In this way, this was the ecoefficiency component. The fourth factor explained 10.09% of variance, it was linked with use of by-products in livestock feed (2). This component is represented with use of by-products.

Table 1. Selection of feeding and land use technologies (points).

Technology (n_i) [Technology Package]	Selection (% Consensus)	Scores (Mean)	SD [1] (CV [2] %)	Q1 [3]	Q3 [4]
Unifeed (1) [feeding]	44.86	3.43	0.96 (0.28)	3.0	4.0
By-products and crop residues (2) [feeding]	32.08	3.09	0.93 (0.32)	2.0	4.0
Diets and balanced rations (3) [feeding]	96.27	4.68	0.65 (0.14)	4.5	5.0
Mineral blocks (4) [feeding]	64.49	3.77	0.87 (0.23)	3.0	4.0
Supplemental feeding (5) [feeding]	58.87	3.62	0.85 (0.24)	3.0	4.0
Grazing (6) [land use]	32.71	3.16	0.97 (0.31)	2.0	4.0
Raw materials production (7) [land use]	44.86	3.40	0.32 (0.27)	3.0	4.0
Conservation of forages (8) [land use]	55.14	3.48	1.08 (0.32)	3.0	4.0
Productive management (9) [land use]	82.24	4.17	0.83 (0.20)	4.0	5.0
Sustainable use of water and soil (10) [land use]	74.76	4.07	0.90 (0.22)	4.0	5.0

[1] Standard deviation, points, [2] Coefficient of variation, [3] First quartile, points, [4] Third quartile, points.

Table 2. Principal components analysis (PCA) loading matrix rotated.

Technology (n_i)	Loading [1]	Eigenvalue	Explained Variance (%)	PCA [2]
Unifeed (1)	0.59085	2.76	26.67	1
Diets and balanced rations (3)	0.45701			
Mineral blocks (4)	0.81578			
Supplemental feeding (5)	0.85443			
Grazing (6)	0.71075	1.78	17.84	2
Raw materials production (7)	0.81068			
Conservation of forages (8)	0.78413			
Productive management (9)	0.88827	1.15	11.51	3
Sustainable use of water and soil (10)	0.7514			
By-products and crop residues (2)	0.90389	1.00	10.09	4

[1] Correlation of variables with respective factor, [2] Principal component analysis.

From the variables coming from principal component analysis (PCA), a typology of experts was built by cluster analysis (CA). Three significant groups with Ward's method, based on the Euclidean distances (Figure 3) were identified. Cluster 1 correctly assigned 54.21%, Cluster 2 a 21.50% and Cluster 3 a 24.30% of the cases. Table 3 shows the centroid values for each selected technology of each expert group. Cluster 1 with intermediate values in the centroids, collected 54.21% of the cases. Cluster 2 with higher levels of centroids, comprised 21.50% of the experts and positive values in all components. Finally, Cluster 3 showed lower levels of centroids and grouped 24.30% of the cases ($p < 0.001$).

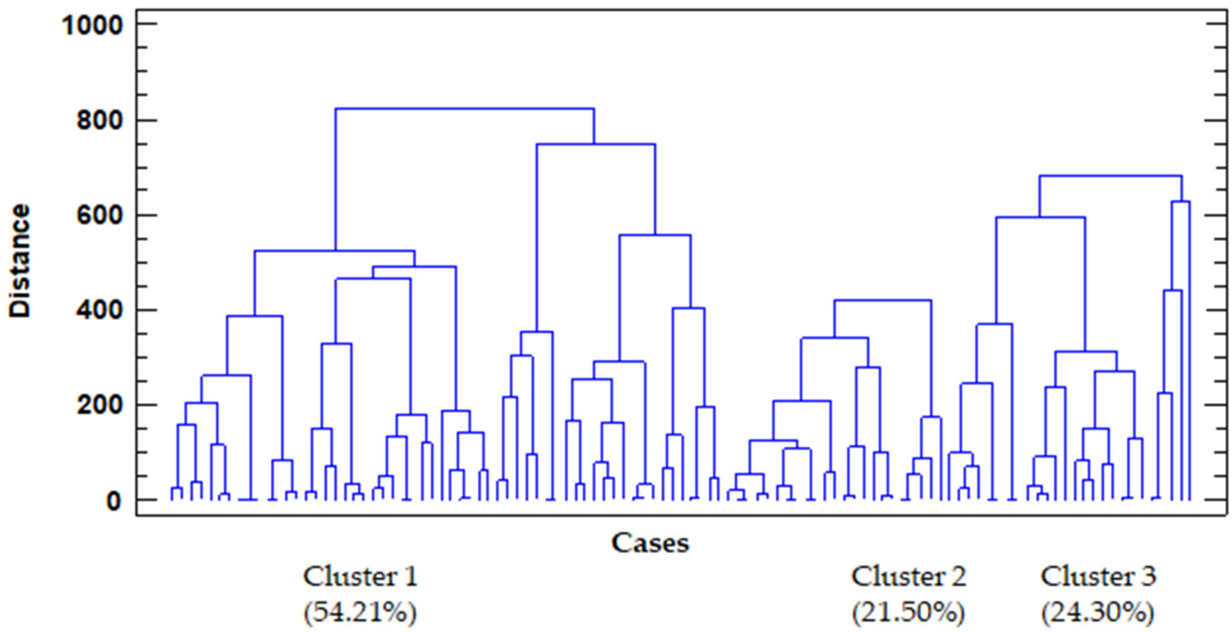

Figure 3. Dendrogram for hierarchical clustering using the Ward's method and the squared Euclidean distance measure.

Table 3. Technologies centroid values for clusters.

Technology (n_i)	PCA [1]	Cluster 1	Cluster 2	Cluster 3
Unifeed (1)	1	3.310	4.261	2.846
Diets and balanced rations (3)	1	4.741	5.000	4.385
Mineral blocks (4)	1	4.017	4.043	2.962
Supplemental feeding (5)	1	3.690	4.087	3.038
Grazing (6)	2	2.793	3.217	3.692
Raw materials production (7)	2	2.879	4.304	3.692
Conservation of forages (8)	2	2.793	4.435	3.923
Productive management (9)	3	4.052	4.696	4.000
Sustainable use of water and soil (10)	3	3.759	4.826	4.115
By-products and crop residues (2)	4	2.983	3.522	2.846

[1] Principal component analysis.

3.3. Technologies Effect

Table 3 shows the technological adoption level (TAL) estimated for feeding and land use technologies in the Center of Spain. The coefficient of determination (R^2), the mean square error (MSE) and the differences DW were calculated for each data set in each estimated model [47]. The parameters of quadratic equation (Table 4) were used to build the technological model. Use of unifeed (1), supplements (5), grazing (6), raw material production (7) and sustainable use of water and soil (10) were the technologies selected by the step-to-step multiple regression technique with an 83.53% adjusted coefficient of determination (R^2). Over ten technologies identified by the panel of experts, only five were selected by the model and three of them showed greater discriminant power. The fundamental ones were feeding strategies that combine the use of concentration with forage to cover the needs of the animals according to their productive status (1), sow and rational soil use for livestock production (5), and finally the ecoefficiency (10); understood as the efficient and sustainable management of land resources and water of the farm. The linear model related the technologies identified by the experts with the technological level of the sample of Manchego dairy sheep farms.

$$LT = 1.32326 + 0.329263*(1) + 0.348238*(5) + 0.263309*(6) + 0.404883*(7) + 0.346047*(10)$$

where: LT Technological level and (n_i) the technology applied.

Table 4. Multiple regression model.

Parameter	Coefficient	SD	T-Value	*p*-Value
Constant	1.32326	0.27636	4.78808	***
Unifeed (1)	0.32926	0.04185	7.86736	***
Supplemental feeding (5)	0.34824	0.04678	7.44418	***
Grazing (6)	0.26331	0.04121	6.38876	***
Raw materials production (7)	0.40488	0.04332	9.34696	***
Sustainable use of water and soil (10)	0.34605	0.04588	7.54246	***

Durbin Watson coefficient = 1.77571, R^2 (adjust) = 73.53%, SD Standard deviation, *** p-value < 0.001.

4. Discussion

4.1. Selection of Feeding and Land Use Technologies

The first analysis provided qualitative information on the identification, selection and valuation of technologies based on expert's experience and preferences. Delphi methodology was used with prospective objective and the participation of a group of experts that facilitates the decision-making process [36]. There is extensive literature on its application in social sciences [31,48–51] and in the agri-food sector [18,52–58]. The Delphi methodology seeks to reach a consensus among the participating group on a certain problem, whose possible solution is not easy to predict [37]. The first database collected the opinion of 107 experts from different countries and with different professional profiles although all of them broadly related to the mixed family systems of dairy sheep. The involvement of many experts is novel and contributes to the results being extended to different countries with mixed sheep farming systems on family farms [23].

In Delphi analysis, feeding and land use technologies were identified and selected. 10 selected potential technological areas were scored by the 107 experts and grouped by principal components analysis (PCA). In this research, a methodology for identifying and selecting feeding technologies in mixed farms has been built. A consensus methodology has allowed selecting and grouping feeding technologies in agreement with previous works done in dairy sheep farms and double purpose systems in Latin America [5,9,52,59,60]. Our findings were aligned with other authors that reported the need to involve the different stakeholders in the identification and selection of technologies, so that they can be successfully adopted [23,26,57,61].

Diets and balanced rations (3), productive management (9) and sustainable use of water and soil (10) were the technologies that gained wide consensus and highest scores. These technologies are described by Cuevas-Reyes et al. [29] and Rangel et al. [24] in dual purpose cattle in the Mexican tropics. Independent consideration of technologies is complex, and the sequential adoption of technological packages is recommended [62–64]. Therefore, the feeding technologies were grouped to design their implementation process in dairy sheep systems.

PCA results facilitated the technological adoption sequence. In the first factor technologies appeared, such as: use of mineral blocks, supplementary feeding. Unifeed technology and diets and balanced rations appeared at lower scores. They all are simple, concrete, and direct technologies strongly linked to feeding strategies in mixed systems, characterized by broad periods of food deficit and extreme climatic conditions [3,65]. The second factor was related to land use and management. These variables are key in the strategic aspects to be considered in the mixed systems of cereal and dairy sheep with dry climate in the center of Spain showing great interactions in between crops and livestock production and, the knowledge of synergies and tradeoffs are essential for the improvement of the system [4,15,25,66]. Success of technological adoption are the result of knowing the reason for being and the objectives of the smallholders, and a deep knowledge of the system, the synergies and trade-offs among different activities [5,9,11,29,34,59,63]. The third factor, that we name ecoefficiency, was related to the productive organization, with the efficient and sustainable use of the whole system, where once addressed the immediate problems becomes a more complete strategic planning [8,14,15,52]. In this way, Noltze et al. [4] and Dubeuf et al. [27] defined innovation in a mixed system as the result of integrated action that favors to improve agricultural productivity and agroecosystem resilience, involving different zootechnical and management components within a synergistic relationship. Finally, the use of crop residues and by products composed the fourth factor [10–12,41,52]. We were surprised by these results because there is wide bibliography that reiterates the need to increase its use in mixed farms [10,12].

The number of experts was high, and the valuations were properly classified by cluster analysis (CA). The expert evaluations grouped in clusters were behaved as a sigmoid function [57], where most were intermediate evaluations (cluster 1) and cluster 2 and 3 corresponded to the upper and lower tails of the distribution according with the findings of Toro-Mújica et al. [2] and Rivas et al. [3]. Cluster 2 (21.50%) reached the top scores in each feeding and land use technologies. In a context of 75 technologies, 23 experts gave top marks to food technologies (over four points). The technological level in food and land use is low in mixed systems [28,29,34] and experts considered these technologies to be very important in mixed systems.

The panel of experts was wide and diverse, therefore the selection of technological variables, their grouping in factors and their valuation could be directly used in family mixed dairy sheep system in several countries, mainly in the Mediterranean Basin and Latin American zones. De Janvry et al. [67], Lebacq et al. [68] and De Pablos et al. [5] proposed a hybrid methodology among knowledge, experience and individual preference of different stakeholders. Several authors [4,8,57,69] highlighted the importance to identify farmer's objectives, expectations and trade-offs between opposing objectives [61]. Thereby, Dubeuf [27] indicated that many technological projects of transfer have failed because they were unable to identify the conditions to be successful.

4.2. Effect of Technologies Selected in Dairy Sheep Farms

In the second part of the investigation, a database of dairy sheep farms from the center of Spain in Castilla la Mancha was used. Place with broad tradition in mixed system of cereal, vine, and milk sheep in dry climate, the effect of the ten feeding technologies selected by experts in sheep dairy farms in La Mancha was assessed. For assessment of key feeding technologies and land use in dairy sheep farms in Spain, the estimation of weights for each of the attributes was proposed [6]. Accurate main low cost and easy to implement technologies have been selected [70–72]. From this perspective, in each farm the selecting of appropriate technologies and best organizational practices was key. Through the use of a database of farms we have validated the technologies selected by the expert panel [32,36,47,49].

The regression model selected 5 out of 10 proposed technologies. The level of adjustment was 83.53% and all the coefficients were significant. The technologies use of unifeed, supplemental feeding, grazing, raw materials production and sustainable use of water and soil were selected by the model. Results agreed with the ones obtained by Toro-Mujica et al. [2] and Rivas et al. [3]. With this simple and direct technique, the effect of food and land use technologies over the technological improvement of dairy sheep farms, was measured. The technological variables selected by the regression model showed high factor loadings in the rotated matrix [5,8,39].

In this part, a multiple regression model between technologies selected by the panel of experts and indicators of feeding technological level has been built. The regression model showed the strong link between both methodologies. A positive relationship between the five technologies selected and the technological results of the farms has been found. All the correlations among technologies and results were positive, with special focus to the ones related to the use of raw materials production, supplemental feeding and sustainable use of water and soil in the farm. Besides, the model explains how a combination of technologies could be regarded as a predictable measure of technological performance in the center of Spain. At the same time, this analysis considers that the improvement in feeding, and land use technologies requires structural changes, such as enough capital and size, and changes in managerial organization, together with the control of the results [62].

This study had important limitations to be addressed in future research.

(a) The correlation between technology and economic performance by structural equation models (SEM) could be explored. De Pablos et al. [8] indicate that there is a positive relationship between the technological indicators, productivity and economic results of the farms. In this way, to count on predictive tools that assess the impact of technology on the results would be very useful to promote the technological adoption of smallholders.

(b) In our model we have assumed linear responses for each feeding technology. It would be of great interest to construct nonlinear programming models that explain the U-shape of the relationship between technology and results according to decreasing productive returns [5].

(c) It would be necessary to deepen the knowledge of the interaction amongst technological variables (synergies and trade-offs), which generates different utility curves according to the variable proportions law in technological adoption [1,3,6,21,73].

(d) Finally, within the paradigm between sustainability and intensification, it would be interesting to explore other technological solutions in smallholders that allow to place production in areas with "extensive margin", mean decreasing variable costs (Marginal cost < Mean variable cost), without losing mixed system attributes [1,4,5,8,9,23,34,35].

5. Conclusions

In this research a mixed methodology was used; qualitative with 107 experts and quantitative, through a sample of 157 farms. The experts selected the technologies, and the case of La Mancha was used to validate the results. The criteria of the experts were faced with the technological level of the farms.

In the selection and grouping of technologies, a broad panel of experts (n = 107), very diverse geographically and composed by key stakeholders, was used. Likewise, a participatory and consensus methodology was applied. Therefore, 10 technologies were selected that could be extended to all the farms and other countries with similar systems. Besides, these technologies were simple to apply, direct and at low cost (five for feeding and five for land use). So, they could be easily incorporated into territorial development programs.

The technologies were grouped into four factors at a retained 67.11% of variance. The first component was linked to feeding strategies (27.67%), the second was associated to land use strategies for livestock production (17.84%), the third, to efficient management of land resources or ecoefficiency and the fourth, to by-products use. These technologies are common in most small-scale dairy farms from Mediterranean basin and Latin American countries and should be considered for development of public innovation policies. In this sense, how technologies were grouped is a perennial issue for researchers, presents important implications for the development of public policies, seeking increased viability through innovation vs. intensification. In addition, our findings are strongly aligned with the goals of new CAP strategic plan for 2023–2027 period. In the second stage, the five technologies selected were associated to the technological adoption level by a multiple regression model in Castilla la Mancha. The model showed a strong relationship between the technologies and the technological adoption level of the farms. The model obtained was reliable and robust to assess the effect of feeding and land use of technologies in dairy farms. Besides, it could be used as a prediction tool in future innovation strategies.

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