DAIRY FARM EFFICIENCY IN GALICIA (NW OF SPAIN)

C. J. ALVAREZ, M. CARDIN, E. M. MARTINEZ, X. X. NEIRA and T. S. CUESTA
University of Santiago de Compostela, Agricultural and Forestry Engineering Department,
Campus Universitario s/n, E-27002, Lugo, Spain

Abstract

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A dairy cattle farming is the main industry in the Autonomous Community of Galicia, NW of Spain. The dairy sector is undergoing an important restructuring process prompted by the accession of Spain to the European Union in 1986. In the last twenty years, the great transformation of the sector has brought about the closure of less competitive farms. The break-even point for Galician farms is set at farms with 50 dairy cows, which means that only 5.4% of Galician farms are non-viable, even though the farms included in this percentage contain 20% of the cows required. An analysis of a representative sample of dairy farms has been carried out and the results obtained for labour productivity are very limited and burden farm profitability. A neural network was used to correlate farm variables such as milking system, cleaning system and feeding system with the labour required to perform these operations. The results of correlation analysis show a strong dependence between farm profitability and the milking, cleaning and feeding systems used. According to results, profitability increases with the increase in farm size. Considering the high potential for improvement of Galician farms, it has been concluded that further studies are required to determine the most suitable solutions for each particular farm and to achieve greater efficiency in production systems.

Key words: Neural network, productivity, efficiency, milk production

Introduction

Agriculture, particularly the livestock sector, is a major economic activity in the Autonomous Community of Galicia, located in Northwest Spain (Álvarez et al., 2008). In the last twenty years the Galician milk production sector has gone through a restructuring process with a reduction in the number of farms and an increase in the number and average size of farms specialized in milk production has increased significantly (Rodríguez-Couso et al., 2006). Despite the decrease in the total number of farms, caused by the dramatic reduction in farms with less than 10 cows, and despite the decrease in the total number of cattle heads, milk production has increased.

This research team has studied the evolution of the dairy sector using different approaches, focusing on farm design improvement (Pereira et al., 2005; Marco et al., 2008) and on the interdependence between the farm and the quality of life of farmers (Maseda et al., 2004). Based on these studies, our research team has analyzed the production processes used on cattle farms (Riveiro et al. 2008), according to the results, farms with less than 50 cows are below the break-even point. These results are in agreement with those reported by other authors who measured the profitability of the production activity in economic terms considering inputs and outputs (Álvarez et al., 2006).

The status of Galician farms in terms of facilities, cattle genetics, feeding and health meets the standard of other European countries (Marco et al., 2008). The critical aspects that affect low farm profitability are related to poor planning of production activities (Álvarez et al., 2008). This results in low productivity of labour. According to Mattila et al. (2008), efficiency improvement integrates factors that contribute to economic performance, such as feeding quality, genetic improvement and labour productivity.

The increase in average farm size has not caused an increase in farm production efficiency and, therefore, farm profitability remains far from optimum (IGE, 2010). Van Waveren (2009) use kilograms of Full Cream Milk per hour of work (kg FCMh^{-1}) to compare the values obtained for 'labour

productivity'. In the report, Spanish farms stood out significantly, with low average values: 111 kg FCMh[-1] in 2005 and 173 kg FCMh[-1] in 2009.

Cournut et al. (2010) and Haghiri et al. (2004) have studied possible actions for organizational improvement of dairy cattle production systems in different areas. Kompas and Che (2006) have suggested the need to consider the relative importance of the different inputs used and the effect of the technologies and operational procedures used on the farm.

This paper presents the efficiency parameters that affect farm profitability according to data obtained from a representative sample comprised of the 16 455 commercial dairy farms that exist in Galicia. A neural network has been developed to analyze efficiency performance for the different farm types defined. The neural network approach has been chosen because of the large number of variables involved and of the heterogeneity of the elements included in the sample, characteristic of the Galician dairy sector. Grzesiak et al. (2003) highlighted the difficulty in finding a clear correlation between efficiency and variables such as farm size or the technology used on dairy farms. In this sense, many researchers have used artificial neural networks to solve regression and classification problems in agriculture (Chen et al., 2010; Arribas et al., 2011) and, more specifically, to analyze the milk production sector (Jain et al., 2005).

Material and Methods

From a total of 32 137 dairy farms in Galicia, only the 16 445 farms that commercialize cow milk were considered (IGE, 2010). The 16 445 farms were classified into three farm types according to the production process used on the farm: dairy farms that use silage corn for feeding cattle, dairy farms without production of silage corn, and dairy farms that include beef production. In addition, five size classes were defined: 10 to 24 cows, 25 to 39 cows, 40 to 54 cows, 55 to 69 cows and 70 or more cows (Riveiro et al. 2008) (Table 1).

Based on the stratification shown in Table 1, a sample was determined using Neyman allocation. The sample size was determined by stratified random sampling according to the allocation of farms to the different groups considered (Scheaffer, 1987). For a confidence level of 95.0% (K=1.6),

and for p and q equal 0.5, 106 surveys were conducted among a population of 16,455 registered farmers, which yielded a sampling error of 1.15% (Table 2).

The survey contained more than 500 items that characterized dairy farms in terms of agricultural production process and farming activity. With a view to using kgFCMh[-1] as efficiency index (Van Waveren 2009), the survey considered the following parameters: number of cows per farm, annual milk production on the farm, milking system and cleaning system. In addition, the time devoted to cleaning, milking and feeding operations, and the number of workers involved in such operations, were measured.

With regard to the efficiency of cleaning, milking and feeding operations, three different measures were collected for each farm (Tuesday, Wednesday and Thursday). Milking time was measured from the moment the first cow entered the collecting yard until the milking parlour was ready for the next milking session. Feeding time was measured from the moment the worker started preparing the feed until food distribution was completed. Finally, cleaning time was measured as the time devoted to cleaning farm alleys daily.

Based on the information obtained, each farm was characterized according to the following parameters: number of cows, kg milk/cow and year, cleaning system (slotted floor, flush system or automatic scraper), milking system (tie-stall, static or rotary), cleaning efficiency, milking efficiency, feeding efficiency and total efficiency, derived from considering the other three efficiencies. The parameters considered to calculate total efficiency, expressed in kg FCMh[-1], were total farm milk production and the time devoted to each operation during the 305 day-lactation period, expressed in hours (Table 3).

In addition, the appropriate values for each parameter were calculated for the set of dairy farms considered. Such values were necessary to normalize data at a later stage of the work (Fernández et al., 2009).

Table 2
Characteristics of the sample of 106 dairy farms

Size class	R1	R2	R3	R4	R5
Nº of farms	29	26	16	18	17
Farm types	T1	T2	T3		
No. of farms	72	23	11		

Table 1
Distribution of the 16,455 commercial dairy farms in Galicia, Spain, according to the production process used

Production process	T1					T2					T3				
Farm size	R1	R2	R3	R4	R5	R1	R2	R3	R4	R5	R1	R2	R3	R4	R5
Number of farms	4,124	1,796	554	124	128	5,590	1,659	684	103	68	1,252	296	54	6	17

T1: dairy farms that use silage corn for feeding cattle, T2: dairy farms without production of silage corn, T3: dairy farms that include beef production, R1: 10 to 24 cows, R2: 25 to 39 cows, R3: 40 to 54 cows, R4: 55 to 69 cows, R5: 70 or more cows.

Table 3
Values obtained from the survey carried out on sampled farms

	Nº Cows	Kg. milk/cow per year	m²/cow	Efficiency, kgFCMh⁻¹			
				Cleaning	Milking	Feeding	Total
Average	41	6 895	18	1 116	193	405	97
Minimum	10	3 000	4	55	41	15	9
Maximum	90	10 462	68	6 575	770	3 288	438
Standard	26	5 000	15	_	_	_	170

A back-propagation artificial neural network, trained using supervised learning (Dam et al., 2008) was used in this study. Data for training the network comprised several pairs of input training patterns, five variables (number of milking cows per farm, kg of milk produced per year and cow, m² of farm buildings per cow, cleaning system and milking system used) and four output variables (cleaning efficiency, milking efficiency, feeding efficiency and total efficiency).

During the first training phase, input vectors are presented to the network in the input layer. This information is used to carry out various operations through the different layers to the output layer, where a result is generated. During the second and third phases, the result provided by the network is compared with the result expected for each training pattern. If the results are not coincident, the error is used to modify the weights in intermediate layers. This type of network is called 'back-propagation network" because the error propagates from the output layer to the input layer.

The network was designed and trained with three continuous input variables (number of milking cows per farm, kg of milk produced per year and cow, m² of farm buildings per cow) and two discrete input variables (cleaning system and milking system). By including these two discrete variables, the level of use of technology on the farm can be assessed. In this sense, the variable 'cleaning system' distinguishes among manual operations (CleanS1), a flushing wave of water from a tank (CleanS2) or automatic scraper cleaning (CleanS3). The variable 'milking system' operates similarly, and distinguishes among tie-stall milking (MilkS1), static milking parlours (MilkS2) and mechanized milking parlours (MilkS3).

The output variables used to design and train the network were milking efficiency, feeding efficiency, cleaning efficiency and total efficiency.

Results and Discussion

The neural network system designed in this study shows relatively good convergence, with R² equal to 0.95 (Figure 1). It can be affirmed that there is a relationship between the characteristics studied for each farm and the final value obtained for total efficiency (Yang et al., 2005).

To analyze efficiency performance in theoretically less evolved farms (Slimp1 and Sord1), two variables can be used, kg of milk produced per year and cow or area of farm buildings per cow. For the first variable, three production levels are considered: 3,000, 5,000 and 7,000 kg of milk per year and cow. Figure 2 shows that the trend of the evolution of total efficiency is an increase in total efficiency with the increase in farm size. Yet, total efficiency increases differently according to the milk production level per cow considered. This trend is coincident with the results obtained by Marey et al. (2011) for Galicia from statistical data for a similar period considered in this work.

Taking into consideration the area of farm buildings per cow, the analysis of 'CleanS1 and MilkS1' farms reveals a different performance depending on farm size (Figure 3), which becomes apparent from a farm size of 30-40 dairy cows. According Irimia et al. (2011) this interaction is determined by differents parameters such as installation costs and production (Escudero et al., 2012).

The same trend is observed for the analysis of farms with manual cleaning systems (CleanS1 and MilkS1; CleanS1 and MilkS2; CleanS1 and MilkS3). Thus, the analysis of total efficiency variation as a function of farm size reveals a different performance according to milking technology (Figure 4).
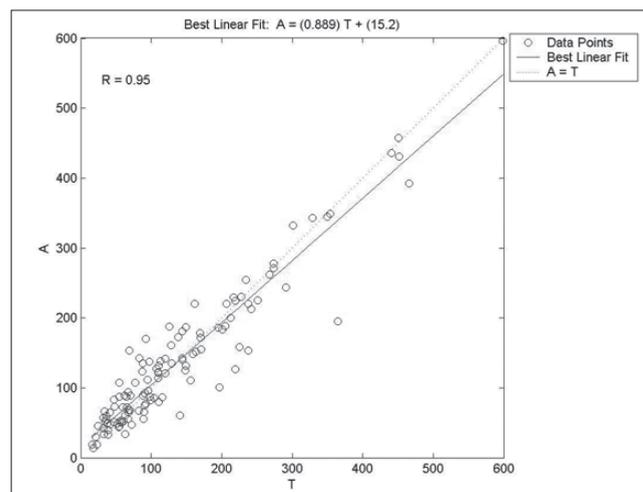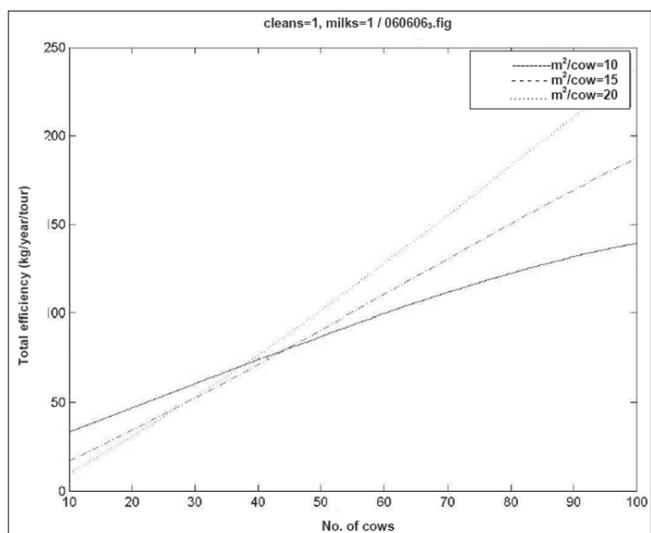

Fig. 1. Convergence of the neural network

For 'CleanS1 and MilkS1' farms, total efficiency shows an upward linear progression as a function of the number of cows on the farm. Efficiency values for farms with manual cleaning and static milking parlour (CleanS1 and MilkS2) are higher and show a steeper positive slope. 'CleanS1 and MilkS3' farms show a different performance, with an inflection point above 70 dairy cows.

When cleaning system is considered as the determining factor for characterizing farms as poorly mechanized, the results obtained are not conclusive. For a better under-
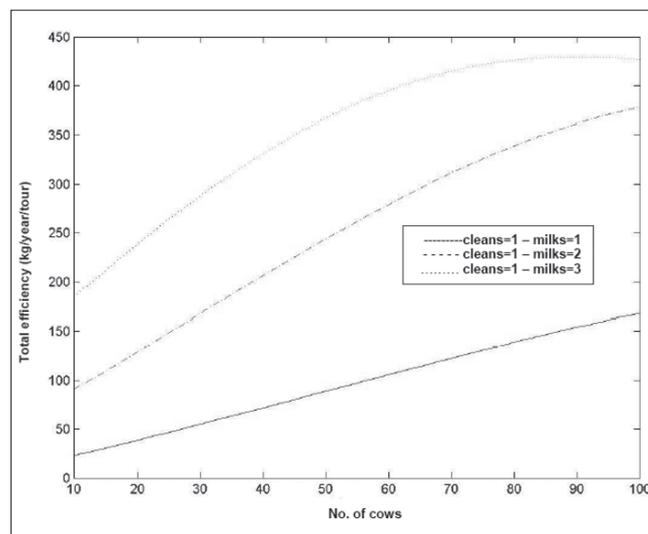
standing of this result, the effect of cleaning system on each of the farm groups defined according to the milking system used (tie-stall, milking parlour or mechanized milking parlour) must be analyzed. Figure 5 shows the results for farms without a milking parlour. Among these, 'CleanS1 and MilkS1' farms maintain the positive trend, while the efficiency of the other two farm groups is not affected by the cleaning system used. These results are coincident with the results obtained by Irimia and Alvarez (2010) with different methodologies.
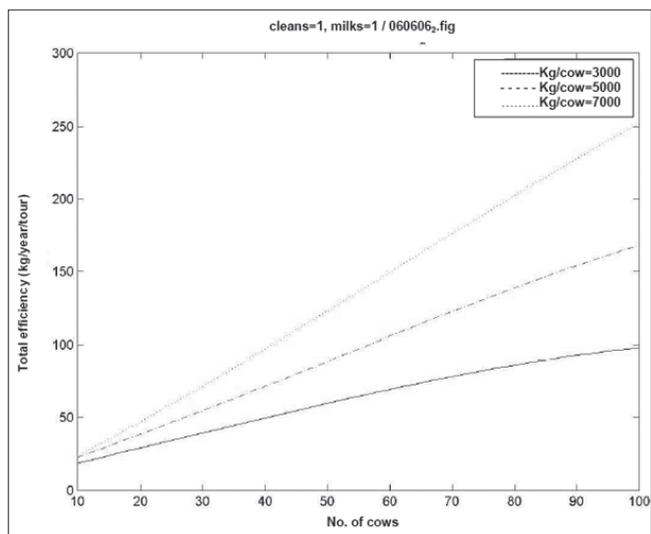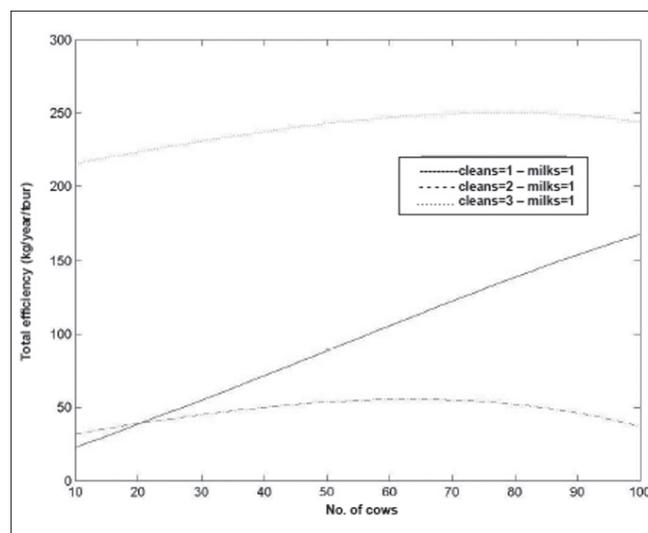

Fig. 2. Total efficiency of 'CleanS1 and MilkS1' farms for 3,000, 5,000 and 7,000 Kg of milk produced per year and cow (kg milk/cow and year)

Fig. 4. Total efficiency of 'CleanS1 and MilkS1', 'CleanS1 and MilkS2', and 'CleanS1 and MilkS3' farms

Fig. 3. Total efficiency of 'CleanS1 and MilkS1' as a function of area of farm buildings per cow (m²/cow)

Fig. 5. Total efficiency of 'CleanS1 and MilkS1', 'CleanS2 and MilkS1', and 'CleanS3 and MilkS1' farms

Conclusions

The average efficiency value for dairy farms in Galicia, obtained from 106 representative farms, amounts 97 kg FC-Mh^{-1}. By applying this value to the milk production volume sold in Galicia in the year 2004–1 959 726 000 kg of milk–a total of 20 203 361 hours of work are required for the sector. In contrast, by applying the average efficiency value for Europe, 170 kgFCMh^{-1}, only 11,527,800 hours of work are required for the same production volume. Improving efficiency on Galician farms to meet the European standard would save 8,675,561 hours of work. Assuming a value of 6 €/hour for the hours of work saved, the annual saving would account for more than 50 million Euro.

The application of neural networks to the data available, collected from surveys conducted among a representative sample of the Galician dairy sector, reveals a direct relationship between production efficiency and the characteristics considered for each dairy farm: farm size, cleaning system, milking system, and feeding system used.

The methodology -using an artificial neural network- are shown to be very strong. It has overcome the difficulty of the heterogeneity of the sample elements and a large number of variables.

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