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Potential land use of Cantabria for grass-fed milk production

Ibán VÁZQUEZ-GONZÁLEZ[1*], Francisca RUIZ-ESCUDERO[2], Juan BUSQUÉ[2] and Ana VILLAR[2]

[1] *University of Santiago de Compostela, Escola Politecnica Superior de Enxeñaría (Department of Applied Economics), Campus Universitario s/n, 27002 Lugo, Spain.* [2] *Centre for Agricultural Research and Training (CIFA), Government of Cantabria, 39600 Muriedas, Spain.*

*Correspondence should be addressed to Ibán Vázquez-González: iban.vazquez.gonzalez@usc.es

Abstract

Aim of the study: To analyse the territorial potential of Cantabria to produce grass-fed milk.

Area of study: Cantabria (N Spain) is a territory associated with livestock, in particular cattle and grasslands. Over the last few decades, the livestock sector has been immersed in a process of structural adjustment, leading to a reduction in the number of farms, an increase in their size and the intensification of production. Moreover, the market is being increasingly supplied with milk labelled “grass fed”, due to growing consumer interest in healthier and more environmentally friendly products.

Material and methods: To do this, 99 livestock farms were classified according to the percentage of fresh grass (FG) in the spring diet of the lactating cows (non-grass-fed: <25% FG; grass-fed: ≥25% FG); these were characterized and, subsequently, a multiple linear regression analysis was carried out to estimate the percentage of FG based on 41 territorial variables.

Main results: The predicted feeding model had an accuracy rate of 70.7%, and discriminated better the non-grass-fed, it had some limitations, suggesting that territorial structure is important but not enough to differentiate grass-fed milk. In addition, 33% of the farms studied produce grass-fed milk, but only half do so under territorial conditions typically associated with this type of production. Meanwhile, 12% of the farms, with similar territorial conditions, do not carry out this type of production (grass fed).

Research highlights: To support grass-fed production, other internal, cultural or economic values must be taken into account.

Additional key words: dairy cattle; fresh grass; spatial metrics; multiple linear regression; Spain.

Abbreviations used: AL (arable land); DM (dry matter); FG (fresh grass); FN (false negative); FP (false positive); GF (grass-fed); MLR (multiple linear regression); NGF (non-grass-fed); PG (permanent grasslands); TN (true negative); TP (true positive); UAA (utilised agricultural area).

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Introduction

Agricultural holdings have undergone a significant process of structural adjustment in Spain in recent decades, characterized by a major decrease in the number of farms and an increase in their productive capacity (Sineiro et al., 2010; García-Suarez et al., 2019). The result has been a progressive differentiation of the productive structure (bipolarisation) (Iraizoz et al., 2007), with the smallest farms shutting down due to issues related to their economic and/or demographic unfeasibility, while the largest (fewer in number) continue to expand and concentrate production. There has also been a process of territorial concentration into certain dairy farming areas or counties, together with an intensification of production (Sineiro et al., 2010). In addition, traditional production systems in Europe, associated with extensive pasture- based farms located in less favoured areas, has been significantly reduced during the last years (Hadjigeorgiou et al., 2005; Van den Pol-van Dasselaar et al., 2018), due among other factors to low productivity, land fragmentation or other agronomic constraints (Gueringer et al., 2009; Sturaro et al., 2013; Hennessy et al., 2020). According to the latest report on the structure of the dairy cattle sector in Spain (MAPA, 2022), between 2017-2021 the number of livestock farms decreased by 18%, from 14,862 to 12,318 while the number of cows decreased only 4% in the same period, from 855,766 to 824,155 units. Meanwhile, milk production increased by 7%, from 7.02 million tonnes in 2017 to 7.49 million in 2021, due to a 11% increase in production yields per cow.

In recent years, the market is being increasingly supplied with liquid milk and other dairy products labelled “from grazing” or “grass-fed” (Fariña & Chilibroste, 2019; Lombardi et al., 2019; Hennessy et al., 2020), in an attempt to meet the growing interest on the part of the consumer in products that are healthier and more respectful to the environment and to the welfare of animals (Olaizola et al., 2012; Villar et al., 2021a). These products have a better nutritional quality (Couvreur et al., 2006; Slots et al., 2009; Roca-Fernández, 2014; Villar et al., 2021b). There are other benefits associated with these grass-fed production systems, including greater savings in the consumption of concentrate (Flores et al., 2017), which makes them more sustainable from an economic point of view (Bernués et al., 2011; Roca-Fernández, 2014; Fariña & Chilibroste, 2019; Hennessy et al., 2020), and can improve the immune function of livestock (Hadjigeorgiou et al., 2005); as well as other non-productive social and environmental functions (Gibon, 2005; Aldezabal et al., 2015), such as food security, animal welfare, habitat conservation, biodiversity maintenance (Hadjigeorgiou et al., 2005; García-Martínez et al., 2006; Sturaro et al., 2013), carbon sequestration (Qi et al., 2018) and lower vulnerability to forest fires (Beaufoy & Ruiz-Mirazo, 2013). Despite grasslands represent 40% of the total European utilised agricultural area (UAA) (Huyghe et al., 2014), the growing demand for grass-fed milk and its benefits, the volume of grass-fed milk marketed in Spain is very small. In Galicia, the leading region in milk production (40% of Spain), pasture-raised milk accounts for less than 10% (Botana et al., 2020). Even worse is the situation in Cantabria (N Spain), where no liquid pasture milk is marketed, and a very limited number of farms produce dairy products (cheese) labelled as pasture milk; all of them belong to the cooperative Agrocantabria.

The rural landscape is the product of complex interactions between biophysical, economic, social, historical, cultural and political factors (Hadjigeorgiou et al., 2005; Schmit et al., 2006; Gueringer et al., 2009; Swagemakers et al., 2017). An analysis of the landscape can reveal its heterogeneity, through information on land uses (land cover) and its spatial configuration (landscape metrics). Recognizing and quantifying the characteristics of these landscapes is essential to understand agricultural production systems, evaluate the impact of certain policies or plan future actions (Almeida et al., 2016).

Only a few studies have analysed the spatial distribution of agricultural areas and their characteristics, mostly referring to grasslands, and those that determine a relationship with the feeding system are practically non-existent. Schmit et al. (2006) analysed the structure of agricultural plots and the location of farms in Belgium; they highlight the proximity of grasslands to cattle farms. Almeida et al. (2016) carried out a spatial analysis of land uses in Rondonia (Brazil) to regionalize agricultural production; they concluded that farms used for beef cattle and dairy production, are smaller and have a poorer geometric layout. Wehn (2009) developed a method to analyse how grazing pressure from livestock affects changes in landscape vegetation, later used as a rural planning and development tool. Fariña & Chilibroste (2019) analysed at the farm level in Uruguay the opportunities and challenges of the growth of grass-fed milk production; they believe that a sustainable intensification of grazing would be advantageous both from an environmental and social point of view. Qi et al. (2018) estimated at the territorial level the yields of grasslands in the United Kingdom through modelling that took into account technological factors, climate change and pollution.

Due to the growing interest in grass-fed milk products, their relevance, the regressive evolution of their farms and the lack of studies that address the connection between the territorial base and the feeding system, the aim of this paper was to determine the territorial potential of Cantabria for the production of differentiated grass-fed milk. We hypothesised that territorial structure is important to differentiate grass-fed milk production and exist a potential to increase it. The following specific objectives should be achieved in order to do this: 1) analyse the relationships between animal diet and the main variables of production; 2) analyse the relationship between diet and territorial structure; 3) find a connection between the feeding model and the territorial potential.

Fulfilling these objectives will also provide policy makers with the scientific information necessary to implement more efficient agricultural policies and highlight the importance of a sustainable milk production system linked to the territory (grass-fed milk).

Material and methods

Area of study

Cantabria is an autonomous community in the north of Spain, with a surface area of 5,329 km² and 582,905 inhabitants. It has a temperate Atlantic climate with abundant rainfall. It is a predominantly livestock farming region in which the cattle sector is a strategic part of the economy, of society and of the territory (García-Suárez et al., 2019); cow's milk is the basis of the region's agriculture, contributing half the economic value of all agricultural production (Calcedo, 2013). Average annual milk production per farm is medium to low, with 409,000 kg in 2021; there is also a bipolarised productive structure, with the smallest farms (<500,000 kg year^{-1}), which make up the majority (77% of the total), contributing a low production volume (37% of the total) (MAPA, 2022).

Grasslands are a significant feature in Cantabria, representing 44% of the UAA (CIFA, 2007). Pasture commons are also prevalent, present in a third of the territory, which are mainly used for beef cattle production in mountain areas (Busqué, 2015). Cantabria also has one of the highest levels of forage production in Europe (Huyghe et al., 2014), due to its edaphoclimatic characteristics, which can be used in livestock feeding and therefore reduce the dependence on purchased food.

Information gathering

The information obtained regarding the feeding system and other productive characteristics comes from primary data sources: (i) 25 collaborating dairy farms in Cantabria within the framework of the national research project RTA2014-0086-C03 (interviewed in 2016); the farms were selected to ensure the greatest possible diversity of productive management and feeding systems (Villar et al., 2021a); (ii) 86 surveys of dairy farms within the framework of a doctoral thesis project on the bovine sector in Cantabria, carried out between November 2016 and February 2017 (García-Suárez, 2021). This selection of farms was carried out based on milk production in the 2015-2016 season, using a stratified random sampling with Neyman's minimum variance, for a sampling error of 5% and a confidence level of 95%.

The territorial information was obtained from secondary data sources, from the Integrated Aid System (or IAS), corresponding to the year 2015, for all Cantabria dairy farms. Using the ClassStat function of the SDMTools package of the R computer application, a series of spatial metrics were created (McGarigal, 2017), from which seven information files were obtained with a total of 89 variables: (i) 8 variables with information relative to mean altitude and standard deviations (sd) of the PG (permanent grasslands) and AL (arable land) plots; total and those existing within a 1 km radius of the farm; (ii) 12 variables related to the land surface structure; (iii) 18 variables related to spatial metrics in terms of area and edge, shape, core area, contrast, aggregation and diversity; (iv) 18 variables with information similar to point 3 but within a 1 km radius of the farm; (v) 10 variables with the percentage of the surface associated with soil qualities for agricultural use (A, B, C, D, E); total and a 1 km radius of the farm; (vi) 3 variables on the number of respondents within a radius of 1 km (dairy farms, non-dairy farms, non-livestock farms); (vii) 20 variables on the use of the land (WG (wooded grassland), SL (scrubland), PG and AL) and type of declaration (not declared, declared by non-livestock farms, declared by non-dairy farms, declared by other dairy farms, declared by the same farm), within a radius of 1 km.

After calculating the spatial metrics, the information from the surveys (111) was collated with the territorial information already obtained for each of the surveyed livestock farms in a single database (primary and secondary). However, due to the absence of territorial information for 5 municipalities in Cantabria (12 farms), the total number of farms analysed in this study was reduced to 99.

Estimation of diet

The composition of the diet of the lactating cows in spring was expressed in terms of the percentage of dry matter (DM) intake of each component of the ration per cow and day, that is: % fresh grass (FG; consumed either indoor or through grazing), % grass silage (GS), % maize silage (MS), % dry forage (DF; sum of DM ingested such as hay, straw, dehydrated alfalfa, etc.) and % concentrate (C).

In the livestock farms in which the lactating cows did not consume FG, the percentage of DM of each component of the daily ration was calculated based on the information provided by the farm. This calculation was especially simple for the farms with a mixer-wagon. In the case of farms in which the cows consumed FG, either through grazing or indoor, it was necessary to estimate this intake based on the theoretical requirements of total net energy of the dairy cows and applying the prediction equations of the National Research Council (NRC, 2001; Villar et al., 2021a). The daily fresh grass intake (kg DM) was estimated by subtracting the sum of the DM intake from the other ingredients present with respect to the theoretical total daily consumption of each cow.

Table 1. Percentage composition of the spring diet and productive characteristics, according to farm type. Mean values per farm and standard deviation.

Diet composition (% with respect to the total DM)	NGF group [(2)] <25% FG (N=66)	GF group [(2)] ≥25% FG (N=33)	Total (N=99)	Sig. [(3)]
Grass silage	16.9 ± 10.7	2.6 ± 6.1	12.2 ± 11.6	***
Maize silage	14.0 ± 13.2	0.57 ± 3.2	9.5 ± 12.6	***
Fresh grass	2.3 ± 6.2	52.0 ± 17.7	18.8 ± 26.1	***
Concentrate	49.1 ± 6.7	35.2 ± 12.7	44.5 ± 11.2	***
Dry forage	17.7 ± 13.9	9.6 ± 9.8	15.0 ± 13.2	**
Productive characteristics [(1)]				
UAA (ha)	43.1 ± 23.6	29.1 ± 17.1	38.5 ± 22.6	**
LSU (unit)	162.2 ± 115.6	59.5 ± 37.4	127.9 ± 108.1	***
Livestock density (LSU/UAA)	3.9 ± 1.6	2.4 ± 1.1	3.4 ± 1.6	***
Annual milk production (×1000 L)	1049.1 ± 815.8	294.7 ± 266.8	797.7 ± 769.7	***
Concentrate consumption (kg cow^{-1} day^{-1})	10.9 ± 4.1	7.6 ± 3.7	9.8 ± 4.3	***
Grazing hours day^{-1}	1.0 ± 3.22	6.6 ± 6.21	2.9 ± 5.13	**

[(1)] UAA: utilised agricultural area. LSU: livestock units. [(2)] NGF (non-grass-fed); GF (grass-fed). [(3)] Statistical significance: ** (p<0.01); *** (p<0.001). Source: own elaboration.

Selection of territorial variables

From the territorial information obtained through the spatial metrics, 41 variables were selected (Table S1 [suppl]), based on the quality of the information and representativeness. The variables provided information related to altitude (4 variables), surface structure (7 variables), spatial metrics (11 variables), surface structure within ≤1 km (11 variables), soil quality (2 variables), presence of neighbouring livestock farms (3 variables) and potential available surface area (3 variables).

Statistical analysis

All available data (primary and secondary) were collected in a database for 99 Cantabrian dairy farms and analysed with the statistical software package SPSS (vers 21).

Descriptive statistical analysis and ANOVA

The livestock farms were classified into 2 groups based on the percentage of fresh grass (FG): farms without grass-fed (NGF; <25% FG) and farms with grass-fed (GF; ≥ 25% FG). This threshold was selected based on the results obtained in a previous study (Villar et al., 2021a), to evaluate the predictive ability of an equation to estimate a cow´s diet based on its milk characteristics (chemical composition, fatty acid profile, and fat-soluble antioxidants); different thresholds for the DM percentage of fresh grass in the ration were marked (15%, 20%, 25%, and 30%), above which milk could be considered "grass-fed milk", and the highest percentage of success (89.7%) was obtained by marking a threshold of 25% FG. Once the farms had been classified according to the feeding system, descriptive statistical analyses (mean values, standard deviation and number of cases) and an analysis of variance (ANOVA) (Tables 1 and 2) were carried out, to obtain a characterization of both the production and territorial structure. Only the statistically significant territorial variables are presented in Table 2, the rest can be identified with an (A) in the Table S1 [suppl].

Multiple linear regression analysis

To analyse the territorial potential of Cantabria to produce "grass-fed milk", a Multiple Linear Regression Analysis (MLR) was carried out, creating a model that would help determine the % of FG in the diet (continuous response variable), from the 41 territorial variables (explanatory variables). Successive analyses were carried out, first using the Stepwise method, as predictive method, and then using the Enter method, starting from a large number of variables with little correlation (R^2<0.9) (Köbrich et al., 2003) until a valid solution was obtained that met the following conditions (no multicollinearity, no collinearity, linear regression residuals, homoscedasticity and autocorrelation).

The validity of the model was evaluated by means of a prediction validation (T test for related samples). Another way to evaluate the predictive value of the model is to mark a threshold of 25% FG (defined in 'Descriptive statistical analysis and ANOVA'), to be considered within the definition of "grass-fed milk". Based on the concordance

Table 2. Territorial characteristics according to farm type. Means values per farm and standard deviation.

Territorial variables[1]	NGF group <25% FG (N=66)	GF group ≥25% FG (N=33)	Total (N=99)	Sig. [3]
Altitude PG plots (masl)	146.0 ± 148.7	302.5 ± 245.9	198.1 ± 199.8	***
Altitude PG plots at ≤ 1 km (masl)	140.0 ± 141.0	289.1 ± 240.9	189.7 ± 192.7	***
Altitude AL plots (masl)	73.4 ± 60.8	138.0 ± 119.4	83.3 ± 74.7	*
PG area on the total area (PG+AL) (%)	81.4 ± 23.6	96.4 ± 10.4	86.4 ± 21.3	**
Largest PG patch index (%)	20.2 ± 14.6	28.3 ± 22.8	22.9 ± 18.0	*
Shape index mean value	1.7 ± 0.2	1.6 ± 0.1	1.7 ± 0.2	*
Central core surface of PG patches over total area (PG + AL) (%)	76.4 ± 22.4	90.8 ± 10.2	81.2 ± 20.3	**
Landscape division index (%)	89.4 ± 11.9	81.9 ± 24.1	86.9 ± 17.2	*
PG area with category [2] A soil (%)	12.6 ± 20.0	4.3 ± 9.0	9.9 ± 19.1	*
AL area, declared as milk, at ≤ 1 km (ha)	18.2 ± 28.0	4.3 ± 8.2	13.6 ± 24.2	**

[1] PG: permanent grassland. masl: meters above sea level. AL: arable land. [2] Quality of soil (A = highest and E = lowest). [3] Statistical significance: *(p<0.05) **(p<0.01); ***(p<0.001). Source: own elaboration.

between the sample classification, using the equation, and the prior classification (GF/NGF), the samples were classified in four groups: true positives (TP), true negatives (TN), false positives (FP) and false negatives (FN). From the classification samples, different variables were calculated: sensitivity, specificity, the positive and negative predictive value of the equation; in addition, descriptive analyses, ANOVAs and post-hoc tests (HSD Tukey) were performed. Only the statistically significant territorial variables are presented, the rest can be identified with a (B) in Table S1 [suppl].

Results and discussion

Relationship between diet and production system

The first objective consisted in the productive characterization of the two established groups, farms NGF (<25% FG) and farms GF (≥ 25% FG). Table 1 shows the mean values of the data obtained from the 99 surveyed farms, with 66 corresponding NGF farms, of which 57 did not provide any FG (86%); as a result, it is not possible to define "grass-fed milk" only by establishing the presence or absence of fresh grass in the diet without taking into account the proportion of fresh grass in the DM (Lombardi et al., 2019; Villar et al., 2021a).The remaining 33 farms (GF) correspond to those that include 25% or more FG (Table 1).

In the NGF group, concentrate was the main component, constituting 49.1%, while in GF farms, the main component was fresh grass, constituting an average of 52% of DM. However, it is also worth noting the significant proportion of concentrate (35.2%) which is also used as part of the diet in these GF farms. Flores et al. (2017) found in Cantabria´s dairy farms that average diet contained 21.1% FG and 39.6% concentrate, figures similar to the average values found in this study (19% and 44% respectively). Lombardi et al. (2019) reported mandatory minimum values for the percentage of fresh grass and hay in DM intake set by different international associations for considering grass-fed milk (75% in Austria, 60% in the USA and 60-70% in Italy). Our results on GF farms, adding 9.6% of dry forage to the percentage of fresh grass, were at these levels.

To a lesser extent and in descending order for both groups, other inputs included dry forage, grass silage and maize silage, the latter being a minor component in the GF farms. These characteristics are in line with the results of other studies which show, for example, that forage maize is the main component of the diet for intensive livestock farms (Jiménez-Calderón, 2015) or that the highest milk production, in intensive systems, corresponds to those farms that dedicate a higher percentage of UAA to maize cultivation (Santiago et al., 2017; Sturaro et al., 2013). Furthermore, Van den Pol-van Dasselaar et al. (2018) argued that the conversion of grasslands into arable crops like maize is the main cause of its reduction in Europe over the last 30 years; while Roca-Fernández (2014) considered that the cause of this reduction is due to a lower milk yield per cow.

In terms of the productive characteristics, the GF farms had a smaller productive dimension in terms of both territory (UAA) and livestock (LSU), in addition to a lower livestock density, annual milk production and consumption of concentrate (Table 1); Hadjigeorgiou et al. (2005) and Sturaro et al. (2013) obtained similar results. However, the daily hours dedicated to grazing were substantially higher; Hadjigeorgiou et al. (2005) argued that a few hours of daily grazing can improve the immune function of livestock. Two variables stand out due to the significant difference between the two strata: LSU and annual milk production. The LSU figure for the NGF group was almost triple that of the GF group (162 vs. 59.5) and the annual milk production difference was even greater, almost 4 times higher for the NGF group; this is a consequence of the higher productive yields of livestock in intensive systems (NGF). Lombardi et al. (2019) observed a similar behaviour in grass-fed milk farms. Along the same lines, the production per cow in farms with a higher percentage of UAA dedicated to maize cultivation, associated with intensive systems, is higher (Santiago et al., 2017; Van den Pol-van Dasselaar et al., 2018).

In the study by Flores et al. (2017), those farms with the higher FG in the diet, which corresponded to those in the lowest productive strata (<175 t of milk per year), had, on average, fewer cows and LSUs per farm, and lower milk production per cow. Similarly, a later study (Villar et al., 2021b) showed that in these same regions, diets rich in FG had a negative correlation with LSU, LSU ha^{-1}, annual production $farm^{-1}$ and milk production cow^{-1} day^{-1}.

Relationship between diet and territorial structure

Table 2 shows the mean values of the only 10 territorial variables for the two groups of farms (GF and NGF), with statistically significant differences. Three of these are related to altitude (height of PG plots, height of PG plots at ≤ 1 km from the farm and height of AL at ≤ 1 km) and four are related to landscape metrics (largest PG patch index, shape index, percentage of central core area of PG patches over total area and landscape division index); the remaining three variables are related to the use of the area and the quality of the soil for agricultural use (Table 2).

One of the most notable differences between the farms was the altitude. For the GF group, the average height of the PG plots of the farm, as well as those that are at a distance equal to or less than 1 km from the farm, was higher than for the NGF group. This indicates that the NGF group is usually larger and located in valleys and coastal areas where the land is more suited to mechanized agriculture. The percentage of area dedicated to PG over the total area was also higher in the GF group, which is linked to the greater dedication to the cultivation of maize or other preserved forage in the NGF farms (Table 2); this behaviour was also observed by Santiago et al. (2017) and Van den Pol-van Dasselaar et al. (2018). Therefore, there appears to be a relationship between the feeding system, the altitude of the plots and their use. Qi et al. (2018), who defined uplands as being at a height ≥ 250 m, found similar results and associated these with a lower productive yield and higher use of PG for cattle grazing. Sturaro et al. (2013) found the same relationship and Hadjigeorgiou et al. (2005) stated that high altitude characterises the topography of Southern European grazing areas.

The GF farms had a lower average shape index, 1.6 (average value resulting from the normalised relationship perimeter/area of one PG patch; see Table S1 [suppl]), which indicates a better geometric shape; Sturaro et al. (2013), using the same metric, found no differences in four dairy farming systems in Italian mountainous areas, with different feeding strategies. The landscape division index (percentage probability that two landscape places, chosen at random, do not correspond to the same PG patch) was also lower in GF farms (81.9% compared to 89.4%), which is a positive factor and is associated with greater continuity in neighbouring plots for the same use. In addition, the largest PG patch index (percentage representing the largest of the PG patch) over the total surface (PG + AL) was higher in the GF farms (28.3% vs 20.2%), which seems to indicate that the better geometric shape of the plots and lower division index is due to the larger size of the plots in GF farms. Almeida et al. (2016) also studied the configuration of the landscape across different types of land, such as cropland or pastureland for livestock, and concluded that the latter are more irregular in shape, contrary to what our results seem to indicate. This may be conditioned by the fact that in our case we are analysing land management for livestock use, while those authors compared the distribution of land based on use, regardless of whether it was for livestock or agriculture.

Regarding the quality of the soil, we have used the classification of the Government of Cantabria which has 5 levels (A = highest quality and E = lowest quality), according to its ability to support the usual crops without any prior treatment (Alonso del Val et al., 2008). From Table 2 it can be deduced that GF farms have a poorer soil quality for agricultural use, as shown by the lower percentage of category A soil (4.3% vs 12.6%) and a higher percentage of category E soil (16.5% vs 9.6%); Hadjigeorgiou et al. (2005) and Hanrahan et al. (2018) found similar relationship. This agronomic constraint, together with others, may be due to the fact that the plots managed by these GF farms, located in higher altitude areas, away from the coast and with a steeper gradient, are normally associated with use as pasture (Gueringer et al., 2009).

Analysis of the territorial potential of Cantabria to produce grass-fed milk

Out of the more than 10 MLR models run, the only valid statistically significant solution ($p<0.005$) has a coefficient of determination $R^2=0.16$; it consists of the following four variables: (i) total area (ha) used for PG; (ii) % of PG area with respect to the total (PG + AL); (iii) edge density (division of the average edge length (perimeter, in m) of the PG patches by the total area (PG+AL) of the farm); (iv) landscape forms index (relationship between average edge

Table 3. Multiple linear regression model (MLR) and prediction validation of percentage of fresh grass in the diet of lactating cows, as a function of territorial variables.

MLR				Prediction validation (T-test related samples)		
Equation	R^2	F (gf)	Sig.	Average % FG model (sd)	Real % FG (sd)	Sig. (bilateral)
% FG / DM=- 31.928*** – 1.051 $X^{(1)*}$ + 0.918 $X^{(2)***}$ - 0.089 $X^{(3)*}$+ 6.086 $X^{(4)t}$	0.16	4.47 (4-94)	0.002	18.64 (10.4)	18.84 (26.14)	0.930

(1) Total permanent grassland (PG) area. (2) PG area on the total area (PG+AL) (%). (3) Edge density. (4) Landscape forms index. Statistical significance MLR model: t (5-10%); *(p <0.05); **(p <0.01); ***(p <0.001). Source: own elaboration.

length (perimeter, in m) of the PG patches, divided by the length of a square with the same area) (Table 3).

There was a positive correlation between the estimate of the percentage of FG supplied in the diet and the percentage of area dedicated to PG with respect to the total area (PG+AL) (2 in Table 3), as well as with respect to the landscape forms index (4), whose increase is indicative of plots with a worse geometric shape. Meanwhile, there was a negative correlation between the percentage of FG and the size of PG area (1) in absolute terms, that is, with the size of the farm, and with the edge density (3), whose increase would indicate larger PG plots.

To evaluate the predictive value of the algorithm, the equation was applied to the 99 livestock farms, calculating the percentage of correct answers according with the threshold selected (25% FG). This threshold coincides with the minimum degree of pasture dependency stablished for grazing animals in Greece (25% of annual requirements), according to Hadjigeorgiou et al. (2005). Furthermore, Lombardi et al. (2019) reported on the need to establish feeding thresholds to differentiate a grass-fed milk, due to existing differences in fatty acids and other chemical components (Couvreur et al., 2006; Slots et al., 2009; Roca-Fernández, 2014; Villar et al., 2021b). The model was correct in 70.7% of the cases (TP + TN). The algorithm better identified NGF farms compared to the GF farms since 54 of the 66 NGF farms were classified as such (81.8%); however, only 16 of the 33 GF farms were identified as such (48.5%) (Table 4). This may indicate that territorial variables discriminate better the non-grass-fed model.

Despite the statistical validity of the model and its acceptable predictive capacity, we are aware of the limitations of the model due to its low self-determination coefficient. We believe that the inclusion of only technical (territorial) variables, unaccompanied by other management and sociological factors, may have influenced. Van den Pol-van Dasselaar et al. (2018) reported the results of previous research from the Netherlands aimed at studying the technical and social factors affecting the extent of grazing on dairy farms. They concluded that including only technical factors, in a MLR analysis, the model did not work well; however, by combining the technical and social factors, the MLR improved (R^2=0.47). Gueringer et al. (2009) stated that the consequences of changes in livestock activities on land use did not include farm´s internal factors, such age and renewal. Fariña & Chilibroste (2009) or Hennessy et al. (2020) believed that future changes in labour and lifestyle choice will be a challenge for the growth of milk production from pasture, associated with the adoption of automatic milking systems. Van den Pol-van Dasselaar et al. (2018) pointed out that the mind-set of the farmer (education) should play a crucial role in promoting grass-fed production systems. Swagemakers et al. (2017) reported that farmers' differing values influence their decisions about agroecosystem management, and farms practices are influenced by cultural beliefs. Finally, Snider et al. (2021) suggested that, to secure the future of their farms, producers are choosing to adopt grass feeding systems in part due to economic reasons, but also for other reasons such as personal philosophy, health/safety and environmental sustainability. An analysis of the productive variables of the grouped farms, depending on the classification (TP/TN/FP/FN) (Table 5), shows that the TP farms (GF farms included by the algorithm as ≥25% FG) were associated with a small

Table 4. Classification of farms according to concordance of the equation with the validation indicators.

Concordance (1)	N	Indicator	Calculation	%
TP	16	Sensitivity	TP/TP+FN	48.5
TN	54	Specificity	TN/TN+FP	81.8
FP	12	Predictive value +	TP/TP+FP	57.1
FN	17	Predictive value -	TN/TN+FN	76.1
Total farms	99	% accuracy	TP+TN/total	70.7

(1) TP = true positive; TN = true negative; FP = false positive; FN = false negative. Source: own elaboration.

Table 5. Percentage composition of the spring diet and productive characteristics according to the classification (TP, TN, FP, FN)[1]. Mean values per farm and standard deviation. Different letter indicates significantly different subsets at the 5% level.

Variables	TP (N=16)	TN (N=54)	FP (N=12)	FN (N=17)	Total (N=99)	Sig.[3]
Diet composition (% with respect to the total DM)						
Grass silage	1.6b ± 4.6	17.2a ± 10.1	16.0a ± 13.5	3.6b ± 7.3	12.2 ± 11.6	***
Maize silage	0.0b ± 0.0	16.6a ± 12.7	2.4b ± 8.2	1.1b ± 4.5	9.5 ± 12.6	***
Fresh grass	50.2a ± 14.8	1.3b ± 4.6	6.7b ± 9.9	53.7a ± 20.4	18.8 ± 26.1	***
Concentrate	37.2b ± 12.0	48.9a ± 6.2	49.8a ± 8.8	33.3b ± 13.5	44.5 ± 11.2	***
Dry forage	11.0b ± 10.0	16.0ab ± 14.4	24.1a ± 8.0	8.3b ± 9.6	15.0 ± 13.2	***
Productive characteristics [2]						
UAA (ha)	21.7c ± 14.8	46.6a ± 23.5	27.5c ± 17.1	36.2ab ± 16.4	38.5 ± 22.6	***
LSU (unit)	47.2b ± 18.1	178.3a ± 120.4	89.5b ± 45.7	71.1b ± 46.9	127.9 ± 108.1	***
Livestock density (LSU milk/UAA)	2.7ab ± 1.1	3.9a ± 1.7	3.6a ± 1.2	2.1b ± 1.1	3.4 ± 1.6	***
Annual milk production (×1000 L)	192.9b ± 107.3	1,173.7a ± 844.1	488.8b ± 285.5	390.7b ± 333.7	797.7 ± 769.7	***
Concentrate consumption (kg cow^{-1} day^{-1})	7.8ab ± 4.4	11.2a ± 4.2	9.7ab ± 3.6	7.4b ± 3.0	9.8± 4.3	***
Grazing hours day^{-1}	6.5a ± 6.3	0.79b ± 3.0	2.2b± 4.1	6.6a ± 6.3	2.9±5.1	***

[1] TP = true positive; TN = true negative; FP = false positive; FN = false negative. [2] UAA: utilised agricultural area. LSU: livestock units. [3] Statistical significance: *** (p <0.001). Source: own elaboration.

livestock model of farm, with low livestock density, low production, low consumption of concentrate, with small herds and grazing. The TN farms (NGF farms included by the algorithm as <25%FG) (intensive farms, with little or no fresh forage in the diet) were associated with larger farms, with a high livestock density, high production, high consumption of concentrate, with large herds and hardly any grazing. Consequently, the productive variable values were completely different between the TP farms and the TN farms, especially the LSU and the annual milk production (Table 5); these findings are in line with the works revised (Hadjigeorgiou et al., 2005; Sturaro et al., 2013; Roca-Fernández, 2014; Lombardi et al., 2019).

The only productive difference between the farms FP farms (NGF farms included by the algorithm as ≥25%) and the TP farms was their lower intensity of grazing (daily hours), which translates into noticeable differences in the diet and in having some area of AL. The only significant difference between the farms FN farms (GF farms included by the algorithm as <25%FG), and the TP farms is their larger average size (UAA).

Regarding the diet, the average ration of the FP farms was different to that of the TP farms in the relative presence of all the components, with the exception of maize silage, with a very low average consumption of FG (6.7%); while the FN farms presented a diet similar to the TP farms, though with a lower use of concentrate. For their part, the farms TN farms, had completely different feeding models, in which concentrate was clearly the main component.

Regarding the territorial characteristics, the TP farms are small farms (little UAA); their entire area is dedicated to PG production, with plots at a certain altitude and slope, but close to the farm, and with little disaggregation of said plots; no area devoted to crops (AL) and soil which in general has little capacity for agricultural use (Table 6). In summary, the typical profile of these "grass-fed" milk producing farms was that of a small farm, located in a mid-mountain area, with soil unsuited to agriculture, but with well-formed nearby plots (larger and more evenly shaped).

In contrast to the TP farms, the TN farms are large (large UAA), located in flatter areas that dedicate part of their UAA to growing crops, usually maize in rotation with ryegrass. In general, they are highly subdivided, with greater distance between the plots and the farm, and with medium-high quality soil for agricultural use. These farms are committed to an intensive and productivist model, with little grazing in which the livestock is fed mostly maize silage and concentrate.

The FP farms are small farms (small UAA), with plots at medium altitude, less slope than the TP farms, with almost the entire area dedicated to PG (99.9%); a soil of better quality than the TP farms for agricultural use (greater area of soil A and less of soil E), total area and pastures close to the farm and little disaggregation of plots. They are, therefore, farms which are more suited compared to other groups, and even compared to those that produce "grass-fed milk", to produce this type of milk, and yet they

Table 6. Territorial characteristics according to the classification (TP, TN, FP, FN) (1). Mean values per farm and standard deviation. Different letter indicates significantly different subsets at the 5% level.

Territorial variables (2)	TP (N=16)	TN (N=54)	FP (N=12)	FN (N=17)	Total (N=99)	Sig.(4)
Altitude PG plots (masl)	380.5a ± 258.9	141.9b ± 151.9	164.1b ± 138	229.1ab ± 215.1	198.1 ± 199.8	***
Altitude PG plots at ≤ 1 km (masl)	365.3a ± 260.1	135.7b ± 145.8	159.4b ± 120.7	217.3ab ± 203.3	189.7 ± 192.7	***
Altitude AL plots (masl)	---	68.8 ± 54.1	252.0 (3)	138.0 ± 119.4	83.3 ± 74.7	***
Altitude AL plots at ≤ 1 km (masl)	---	73.2 ± 67.3	252.0 (3)	102.6 ± 82.3	81.4 ± 73.4	*
Number of PG plots	18.7bc ± 24.9	31.5ab ± 21.0	11.3c ± 7.3	37.2a ± 20.3	28.0 ± 21.8	**
Total PG area (ha)	17.9b ± 10.0	29.0ab ± 17.4	20.5ab ± 8.8	31.1a ± 13.1	26.5 ± 15.5	*
Distance from the PG plots to the farm (m)	905.8b ± 592	1375.3ab ± 823	1036.0ab ± 1251	1797.3 a ± 1368	1330.7 ± 990	***
Number of PG patches	18.6bc ± 24.6	32.0ab ± 21.1	11.3c ± 7.2	37.3a ± 20.3	28.2 ± 21.9	*
PG area on the total area (PG+AL) (%)	100.0a ± 0.0	77.2b ± 24.2	99.9a ± 0.48	93.0ab ± 13.8	86.4 ± 21.3	***
Density of discontinuous patches	0.82ab ± 0.52	0.95ab ± 0.57	0.61b ± 0.31	1.2a ± 0.50	0.93 ± 0.54	*
Edge length of PG patches (m)	10679.7b ± 10892	17652.8ab ± 9835	9438.5b ± 3866	19878.0a ± 9119	15912.3 ± 9986	**
Landscape forms index	5.6b ± 3.7	8.1a ± 2.5	5.2b ± 1.4	8.8a ± 2.5	7.4 ± 2.9	***
Largest PG patch index (%)	38.8a ± 28.7	16.0b ± 9.9	39.3a ± 17.4	18.4b ± 7.3	22.9 ± 18.0	***
Average area of PG patches (ha)	2.2ab ± 2.3	1.1b ± 0.57	2.9a ± 3.0	1.0b ± 0.83	1.5 ± 1.6	***
Shape index mean value	1.6b ± 0.15	1.7ab ± 0.16	1.8a ± 0.25	1.7b ± 0.09	1.7 ± 0.17	**
Central core surface of PG patches over total area (PG + AL) (%)	94.9a ± 1.88	72.3 b ± 22.7	95.1 a ± 1.3	87.0ab ± 13.1	81.2 ± 20.3	***
Aggregation index	99.0a ± 0.53	98.5 a ± 0.71	99.0 a ± 0.25	98.6a ± 0.33	98.7 ± 0.62	*
Landscape division index (%)	71.0b ± 31.3	93.0a ± 6.4	73.0b ± 16.8	92.0a ± 4.5	86.9 ± 17.2	***
Number of PG plots, at ≤ 1 km, over total PG (%)	64.7ab ± 24.6	58.9ab ± 25.1	78.3a ± 21.6	52.7b ± 19.1	61.1 ± 24.5	*
PG area, at ≤ 1 km, over total PG (%)	76.8ab ± 18.3	59.0bc ± 25.6	79.5a ± 19.0	52.8c ± 20.1	63.3 ± 24.6	***
PG area, declared milk at ≤ 1 km from the farm, over the total area (PG + AL) (%)	82.5ab ± 37.0	69.4b ± 31.3	97.8a ± 2.7	84.8ab ± 27.0	77.6 ± 31.0	*
AL area, declared as milk, at ≤ 1 km (ha)	2.5b ± 6.8	21.5a ± 29.9	3.0b ± 4.6	6.1b ± 9.2	13.5 ± 24.2	**

(1) TP = true positive; TN = true negative; FP = false positive; FN = false negative. (2) PG: permanent grassland. masl: meters above sea level. AL: arable land. (3) No deviation possible; only one case with value. (4) Statistical significance: *(p<0.05); **(p<0.01); ***(p<0.001). Source: own elaboration.

do not by some socioeconomic reasons (price, market, promotion...) (Sturaro et al., 2013; Lombardi et al., 2019; Hennessy et al., 2020; Snider et al., 2021).

The FN farms are larger than the TP farms, almost their entire area is dedicated to grass-fed milk production, but with some crop cultivation; the plots are somewhat smaller than in the TP farms, with a slope similar to the latter, but with very high subdivision or disaggregation and distance between the plots and the farm, in addition to having, like the TP farms, poor quality soil for agricultural use. The typical profile of these farms, which produce “grass-fed milk”, is that of production under difficult conditions with a lot of disaggregation and distance between the plots and the farm and, like the TP farms, soil with little capacity for agricultural use. In these cases, internal farms values, such as age, education, personal philosophy or cultural beliefs, can play an important role in decision-making (Gueringer et al., 2009; Swagemakers et al., 2017; Van den Pol-van Dasselaar et al., 2018).

The results obtained on territorial potential reveal a correlation between grass-fed milk production TP-FN farms and their territorial location. These are the highest farms, located in mid-mountain areas, and they dedicate their land almost exclusively to pastures, among other reasons, due to its low capacity for agricultural use. They are therefore reliant on fresh grass as the basis of their diet, which means they are highly involved in the management and maintenance of the landscape in these rural and mountain areas. In general, these farms have fewer cattle, lower livestock density, annual milk production and involve less use of concentrate, dedicating more hours to grazing, in contrast to the characteristics of FP-TN farms.

Conclusions

The grass-fed (GF) milk farms are smaller, have fewer cattle, lower livestock density, annual milk production and involve less use of concentrate, dedicating more hours to grazing, in contrast to the characteristics of non-grass-fed (NGF) milk farms.

There are differences in the territorial structure of farms that produce grass-fed milk compared to farms that do not use or use little fresh grass in the diet of lactating cows (NGF), but these are less significant than expected. This may be due to the fact that other social, cultural and economic factors may influence the decision to produce milk according to a specific production model based on animal feed. The territorial structure of GF farms is characterised by higher altitude and better geometric shape, as well as greater continuity and larger plot size, poorer soil quality for agricultural use, and almost exclusive use of the area for PG.

It should be noted that we were able to create a predictive feeding model based on territorial variables only, with a limited self-determination coefficient. Despite this, by setting a threshold of 25% of fresh grass, over DM in the diet of lactating cows to define feed production system (grass-fed milk or non-grass-fed milk), the model was correct in 70.7% of cases. This suggests that territorial structure is important, but not enough to differentiate grass-fed milk.

The potential to produce grass-fed milk in Cantabria is somewhat lower than half of the farms analysed (45.5%). Most of the farms (33.3%) produce “grass-fed milk” (TP and FN farms), of which half do so using a suitable territorial model (represented by the TP farms) and the other half using a different model, in more difficult territorial conditions (FN farms). In addition, 12% of the farms (FP farms) that do not produce “grass-fed milk” could do so based on their territorial model that is similar to that of the TP farms, so there is potential to increase it. Of the 66 farms that do not supply FG to lactating cows, almost 82% (TN farms) do so using a territorial model (intensive and productivist) and only 18% (FP farms) do so with a territorial model that is compatible with the production of “grass-fed milk”.

Therefore, it follows that there is no single model for carrying out this type of production and that there are many farms that, despite having the territorial conditions compatible with this model, do not do so, for reasons that go beyond territorial conditions (internal farm factors such as health, safety, age, renewal, labour, mind-set, philosophy or other cultural and economic factors); this means that these conditions are influential, but do not decisive in the territorial and feeding management.

Finally, it should be pointed out that the results obtained suggest a path for future research, while also contributing knowledge to a subject that has barely been investigated in scientific literature. It could become a valuable basis for future studies to use predictive models to evaluate the potential impact of the expansion or contraction of certain production systems, in our case grass-fed milk. These results are also undoubtedly useful for assessing and guiding public policies to support grass-fed production systems, which should not only focus on territorial issues, but also on the internal, cultural or economic values of farms.

Authors’ contributions

Conceptualization: I. Vázquez-González, J. Busqué, A. Villar.
Data curation: I. Vázquez-González, J. Busqué, A. Villar.
Formal analysis: I. Vázquez-González, F. Ruiz-Escudero, A. Villar.
Funding acquisition: A. Villar, I. Vázquez-González.
Investigation: I. Vázquez-González, F. Ruiz-Escudero, A. Villar.
Methodology: J. Busqué, I. Vázquez-González.
Project administration: A. Villar.
Resources: Not aplicable.
Software: Not aplicable.
Supervision: A. Villar, J. Busqué.
Validation: A. Villar.
Visualization: I. Vázquez-González, F. Ruiz-Escudero.
Writing – original draft: I. Vázquez-González.
Writing – review & editing: I. Vázquez-González, F. Ruiz-Escudero, A. Villar.

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