What explains dairy pasture farming in Germany

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Introduction

Dairy farming traditionally is based on grazing during the vegetation period in most German regions. Dairy grazing systems are considered as beneficiary for the environment and the animal health as they imply periods outside of the stable, low stocking densities and hence the maintenance of grassland, less nitrogen pollution and reduced greenhouse gas emissions. In addition, landscape composition, farm size & specialisation and regional specificities might determine the duration of grazing for feeding and keeping cows. A good understanding why farmers choose such a grazing system is of important to promote this method under the CAP. Structural change towards larger herd sizes, increased milk output per cow and changes of the diet support the increase of zero-grazing systems (year-round indoor housing).

We use survey on agricultural production methods (SAPM) in 2010, which collects farm level data on agri-environmental measures to support monitoring of the relevant European Union policies (e.g. the common agricultural policy, rural development policy, etc.) and to establish agri-environmental indicators (AEI). The results are linked at the level of individual agricultural holdings to the data obtained from the farm structure survey (FSS) in 2010, so that cross-comparisons can be made on characteristics covered in both surveys (e.g. land use, livestock, etc.).

In our paper we show how regional and agronomic characteristics determine the different intensities with regard to pasture grazing and year-round stable keeping. We regress e.g. categories of herd size, stocking density, organic/non-organic farming and herd size growth against two categories: grazing more than 6 hours a day and grazing less than 6 hour a day, which include also no grazing. This analysis is examined based on a sample of 19,169 surveyed farms in Germany with dairy cows. More recent data is not available because detailed information on pasture grazing was only conducted for the survey of 2010.

Methods

Regression approach

In our analysis we focus on logistic regression models and estimate odds ratios. The question is how the explanatory variables influence the probability of grazing for more than 6 hours a day. Following Gujarati (2003: 595 pp.) to estimate the probability of a farm i of grazing more than 6 hours a day (Y) given a set of explanatory variables (X) ($P_i = E(Y_i = 1|X_i)$, we consider the following representation:

$$P_i = \frac{1}{1+e^{-(\beta_1+\beta_2 X_i)}} \quad (1)$$

We can set $Z_i = \beta_1 + \beta_2 X_i$ and rewrite (1) to:

$$P_i = \frac{1}{1+e^{-(Z_i)}} = \frac{e^Z}{1+e^Z} \quad (2)$$

Equation (1) is the representation what is known as the (cumulative) logistic distribution function. Z_i can range from minus to plus infinity and consequently P_i ranges between 0 and 1. The probability of grazing more than 6 hours a day is given in equation (2), $(1 - P_i)$ is the probability of grazing less than 6 hours a day and is given by:

$$1 - P_i = \frac{1}{1+e^{Z_i}} \tag{3}$$

We can write:

$$\frac{P_i}{1-P_i} = \frac{1+e^{Z_i}}{1+e^{-(Z_i)}} = e^{Z_i} \tag{4}$$

Where $P_i/(1 - P_i)$ is the odds ratio in favour of grazing more than 6 hours a day. For instance, if $P_i = 0.75$, it means that odds are 3 to 1 in favour of grazing more than 6 hours a day. If we take the natural log of equation (4), we get the following equation:

$$L_i = \ln\left(\frac{P_i}{1-P_i}\right) = Z_i = \beta_1 + \beta_2 X_i \tag{5}$$

L is the log of the odds ratio and it is linear in X and in the parameters. The resulting estimation model finally is giving by the following equation:

$$L_i = \ln\left(\frac{P_i}{1-P_i}\right) = \beta_1 + \beta_2 X_i + u_i \tag{6}$$

We estimated the model with the full set of variables and also a stepwise backward selection based on the Bayes information criterion (BIC) to find the best prediction model. We estimated this model for five different regions. The first is for whole Germany, which is the one we have closer look in this paper, second for East Germany, the third for south Germany, the fourth for the remaining federal states (western and northern Germany) and the fifth for Lower Saxony separately. The set of explanatory variables is described in the data chapter.

Scientific questions

In general the research question is which farm structural indicators are correlated with grazing in German dairy farms. Specifically, the following questions arise: (1) does the probability of grazing more than 6 hours a day decline with increasing herd size? (2) Reduces increasing stocking density the probability of grazing more than 6 hours a day? (3) Are farms with a large growth in herd size are less likely to have grazing more than 6 hours a day? (4) Are organic farms more likely for grazing more than 6 hours a day? (5) Do farms have a higher likelihood of grazing more than 6 hours if they can use communal pasture? Within these questions are there any differences between the regions analysed?

Data

In Table 1 one can find the descriptive statistics of the variables used in the estimation. It is based on the data from the Research Data Centres of the Federal Statistical Office and Statistical Offices of the Länder. The data is based on a sample of the farm census and contains only farms with dairy cows and has 19,169 observations. First, our independent variable is “Over 6 hours of pasture farming per day” and about 37% of the farms apply grazing over 6 hours a day. Of all farms, only 4% are organic farms and only 0.3% use communal pasture. Around 69% had an absolute growth of dairy cows from 2003 to 2010 of below 10, whereas around 26% grew by 10 to 49 dairy cows, 3.6% by 50 to 100 cows and only 2.1% grew by over 100 cows. Most of the farms (76%) have more than 2 roughage-eating livestock units (LU) per hectare of silage maize. Further, around 64% of the farms have more than 2 roughage-eating LU per hectare of permanent grassland. The herd size of dairy cows is evenly distributed in the categories between 20 and 49 as well as between 50 and 99 cows with each 30% of all farms, followed by the smallest size class between 1 and 19 cows (~19%). The remaining farms (~21%) have more than 100 cows.

Table 1: Descriptive statistics

Variable	Categories	Frequency	Ratio
Organic farm (C0501)	0	18410	0.96
	1	759	0.04
Growth (Wachstumssprung)	[<10]	13156	0.686
	[10-49]	4909	0.256
	[50-99]	695	0.036
	[>100]	409	0.021
Use of communal pasture (GemWeideNutzung)	0	19108	0.997
	1	61	0.003
roughage-eating LU per hectare of silage maize (RGV_Silo_Kat)	[0]	3937	0.205
	(0-0.5)	49	0.003
	[0.5-1)	116	0.006
	[1-1.5)	228	0.012
	[1.5-2)	333	0.017
	[>=2]	14506	0.757
Number of dairy cows (Kat_C0316)	[1-19]	3589	0.187
	[20-49]	5751	0.3
	[50-99]	5696	0.297
	[100-149]	1898	0.099
	[150-199]	689	0.036
	[200-499]	1159	0.06
	[>=500]	387	0.02
roughage-eating LU per hectare of permanent grassland (RGV_DGLAGLUZ_Kat)	[<1)	1397	0.073
	[1-1.5)	2596	0.135
	[1.5-2)	3007	0.157
	[>=2]	12169	0.635
Over 6 hours of pasture farming per day	0	12077	0.63
	1	7092	0.37

Source: RDC of the Federal Statistical Office and Statistical Offices of the Länder, Farm Structure Survey / Agricultural Census, 2003/2010, own calculations.

Results

Odds ratios

In Figure 1 one can find the odds ratio of the estimated model. We analyse the results of the stepwise backward selection models as they seem to have more reasonable results.[1] The figure reads as follows: the point indicates the estimated value of the odds ratio and the horizontal line gives the 95% confidence interval. A value left (right) to the dashed line means the likelihood of grazing over 6 hours a day decreases (increases) on average if a farm is changing the specific category from the reference. The reference is a farm located in the soil climate region 101 (medium flooded soils of Mecklenburg-Vorpommern and Uckermark, which belong to the eastern and lowland/hilly part of Germany), is a conventional farm, growth of dairy cows is below 10, does not use communal pasture, has zero roughage-eating LU per hectare of silage maize, has roughage-eating LU per hectare of permanent grassland below 1 and has less than 20 dairy cows. The derivation of the soil climate regions can be found in Roßberg et al (2007) and the map of the climate soil regions in Germany can be found in the annex (Figure 3).

With these results we can answer the stated questions above. Therefore, we take a look at Figure 1. (1) The probability of grazing more than 6 hours a day declines with increasing herd size (cow number per farm). For the second smallest group, the likelihood is even larger than for the smallest (reference) group. For the third largest group, the likelihood is almost the same, while the likelihood is decreasing even more when the size is increasing. For the second smallest herd size group the odds ratio of roughly 1.1 means, that the likelihood of grazing more than 6 hours a day increases by 10%, which mean on average the likelihood of a farm in this size group grazing more than 6 hours a day is roughly 41%.[2] (2) The stocking density with respect to roughage-eating LU per hectare of silage maize shows, that all categories decrease the probability of grazing more than 6 hours a day compared to no roughage-eating LU per hectare of silage maize. For roughage-eating LU per hectare of permanent grassland the picture is different. For the largest category with more than two LU the likelihood is decreasing, whereas for the second smallest category the likelihood is increasing compared to the smallest reference group. (3) Growth in herd size does not contribute to the explanatory power of the model and is therefore dropped. (4) Organic farms are more likely for grazing more than 6 hours a day; the likelihood is almost 22% higher than for a conventional farm. (5) Farms have a higher likelihood of grazing more than 6 hours if they can use communal pasture; it is almost 21% higher.

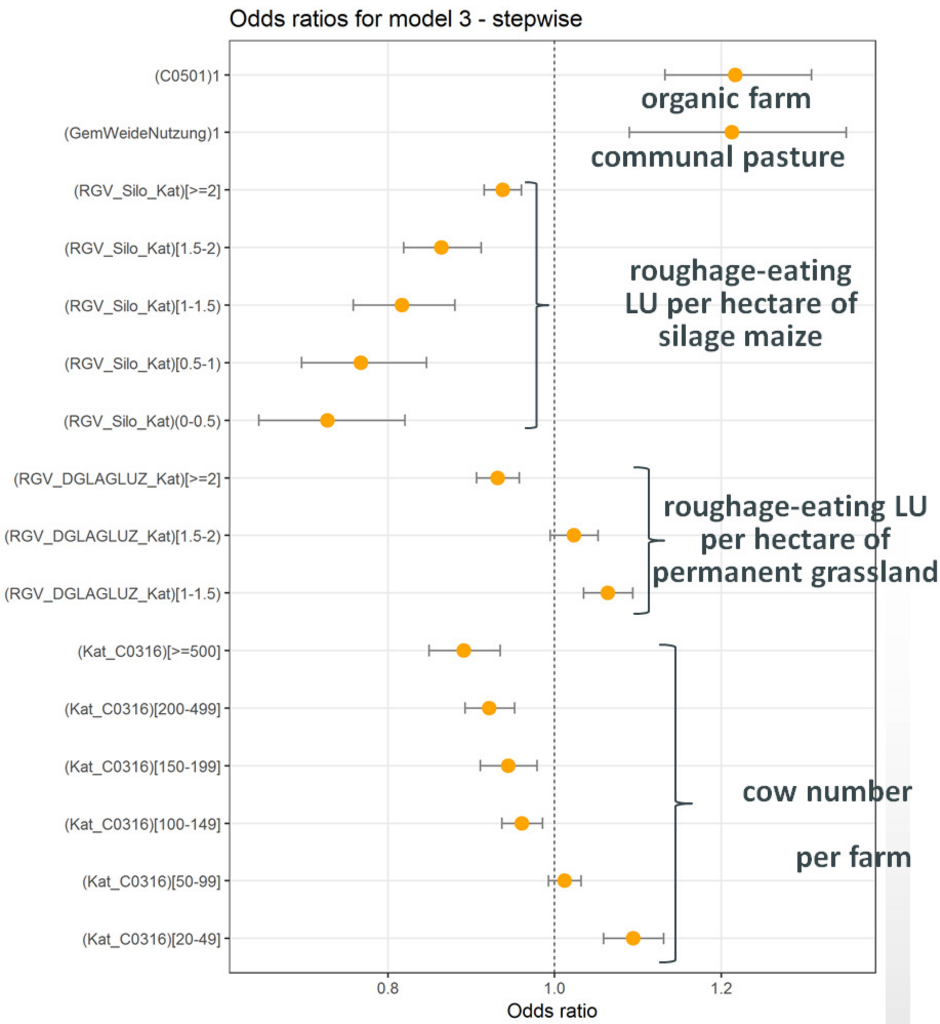
As can be seen in Figure 2 the soil climate areas play also a very important role in determining the likelihood of grazing more than 6 hours a day.[3] For instance, compared to the average farm in the reference group, the likelihood is between 28% and 34% higher if the farm is located in the marshes in the north-west lowland part of Germany and the likelihood is between 24% and 40% lower for the soil climate areas in the hilly central-south part of Germany. This is maybe explained by the fact that tethering of animals is traditionally very high in this area in southern Germany (Bergschmidt et al., 2018).

[1] Compared to the full model, the estimated odds ratio and their confidence intervals for all the model are much smaller and of comparable level within the models between the variables selected.

[2] This value is calculated by multiplying the empirical mean of 37% by (1+10%) which yields 41%. The empirical probability of grazing more than 6 hours a day for the Germany model can be seen in Table 1. For the other estimated models these probabilities are stored in the annex in Table 3.

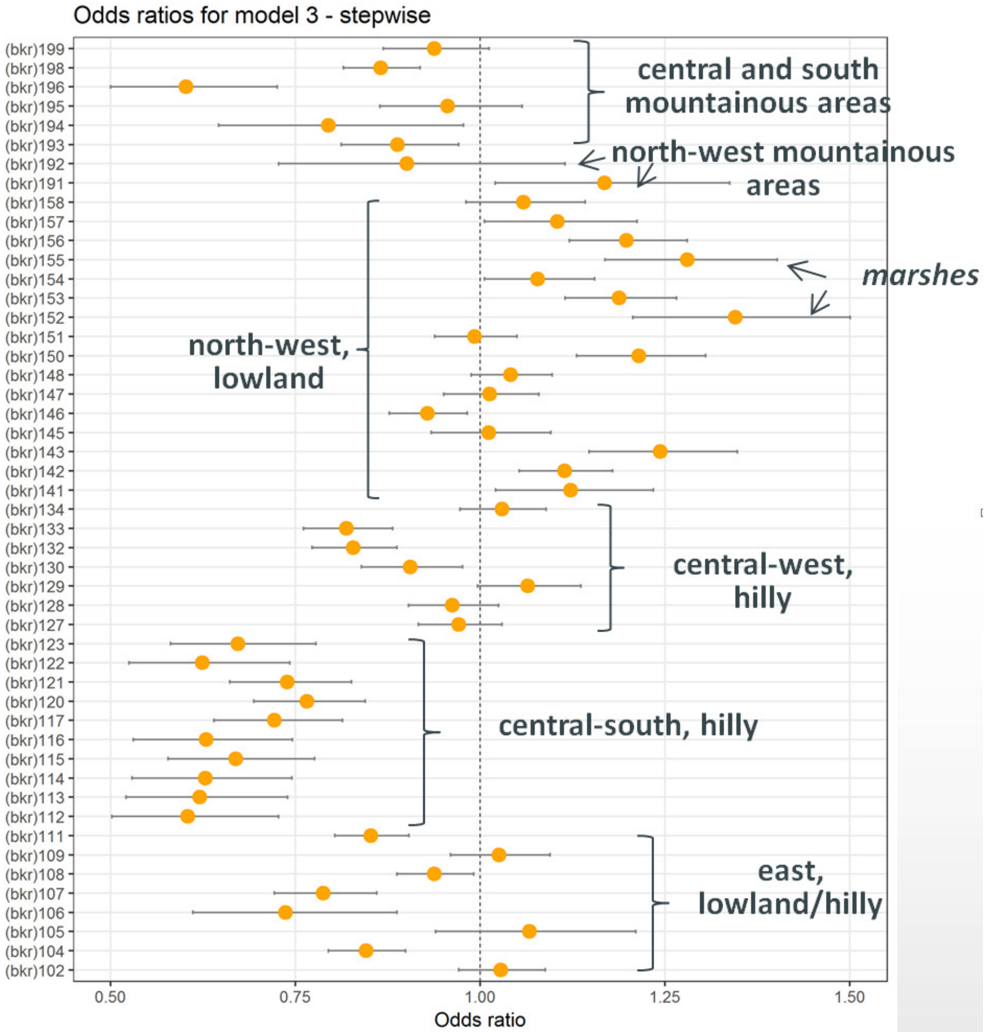
[3] Figure 3 in the annex gives an overview of the soil climate areas in Germany.

Figure 1: Odds ratio from the estimated model without soil climate area



Source: RDC of the Federal Statistical Office and Statistical Offices of the Länder, Farm Structure Survey / Agricultural Census, 2003/2010, own calculations.

Figure 2: Odds ratio from the estimated model with only soil climate area



Source: RDC of the Federal Statistical Office and Statistical Offices of the Länder, Farm Structure Survey / Agricultural Census, 2003/2010, own calculations.

In the annex in Figure 4 one can find the odds ratio of the estimated models for Eastern Germany (model 4a), South Germany (model 4b), Western and Northern Germany (model 4c) and Lower Saxony (model 4d). With this comparison we seek to find out how different these sub-regions are compared to the Germany model.

For model 4a, growth in cow numbers and use of communal pasture has no explanatory power and are therefore not part of the model. The results are similar to the Germany model with regard to the odds ratio without soil climate area. The only difference is that larger size categories do not decrease the likelihood of grazing more than 6 hours a day. The model for South Germany reveals that growth in cow numbers plays no role in explaining the model and somewhat surprising the herd size as well. This is maybe explained by the fact that in Bavaria and Baden-Württemberg tethering of animals is very widespread in this area (Bergschmidt et al., 2018). The remaining odds ratio shows the same pattern as for the model of Germany. Further interesting is the fact, that for the regions Black Forest and the Alps (soil climate area 198 and 199) the likelihood increases strongest compared to the other variables, which can be explained by commonly applied alpine pasture management in these areas. The model for Western and Northern Germany shows also the same pattern as the Germany model. Growth in cow numbers and use of communal pasture has no explanatory power and are therefore not part of the model. Model 4d of Lower Saxony has only the herd size categories and roughage-eating LU per hectare of permanent grassland in the model and these variables show the same pattern as for the Germany model, but the size categories between 50 and 499 are not statistically distinguishable compared to the reference group. The other variables have no explanatory power and are not part of the model.

Accuracy level

After analysing the odds ratio of the estimated models we know have a look at the predictive power of the models. In general there are a lot of ways how to measure prediction for classification models.[4] In our paper we want to analyse the accuracy of the models. Accuracy is calculated as the ratio of the sum of true positive and negative predicted observations and total observations. Table 2 gives the overview of the percentage of correctly and falsely predicted classification of the farms of grazing more than 6 hours per day of all estimated models. The percentage values are given for two different thresholds. The first one with the threshold of the empirical mean ("mean threshold") of farms that are grazing more than 6 hours a day and second for the threshold of 0.5 ("half threshold"). In the first place, the binary outcome is predicted for each farm. This prediction takes a value between 0 and 1. For the "mean threshold", the predicted value is compared with the empirical mean of the model and if the predicted value is equal or larger than the empirical mean, the farm is classified as grazing more than 6 hours a day and otherwise if the predicted value is lower than the empirical mean. For the "half threshold" the predicted value is compared with 0.5 as the threshold.[5] For instance, for the "mean threshold" of the Germany model the accuracy is 73.5%, which is calculated by summing up the percentage values of true negative (observed=0 and predicted=0; 50.7%) and true positive (observed=1 and predicted=1; 22.8%) outcomes. For the "half threshold" the accuracy is 70.3%. Depending on the threshold, the accuracy can be very different. For the "mean threshold" it can be stated that all estimated models perform better than just taking the empirical mean as benchmark.[6] Table 1 for the Germany model and Table 3 for the remaining models depict the empirical means of the estimated models. The Germany model increases the predictive power by about 10 percentage points, the Eastern Germany model by roughly 6 percentage points, the Southern Germany model by roughly 2 percentage points, the Western & Northern Germany model by about 8 percentage points and the Lower Saxony model by round about 13 percentage points.

[4] One could measure terms like precision, sensitivity, specificity or accuracy, to name a few. See for instance Powers (2011) for the definition of terms to measure binary outcome.

[5] The "mean threshold" can be used as a good comparison tool as one could say that the researcher already has the empirical mean, which is the empirical probability of grazing more than 6 hours a day.

[6] If one takes the empirical mean of grazing more or less than 6 hours a day – depending on which of both categories is the highest – which would give the best prediction if nothing else is known to the researcher and compare this with the accuracy of the model, one finds out how good the models predict. The commonly used "half threshold" is only worse for the Southern Germany model as the empirical mean is quite far away from 50%.

Table 2: Classification table for the estimated models for two different thresholds

Model	Observed	Mean threshold			Half threshold		
		Predicted					
		0	1	Correct	0	1	Correct
Germany	0	50.7%	12.3%	73.5%	39.7%	23.3%	70.3%
	1	14.2%	22.8%		6.3%	30.7%	
Eastern Germany	0	49.3%	10.4%	65.5%	38.2%	21.5%	64.1%
	1	24.1%	16.2%		14.4%	25.9%	
Southern Germany	0	83.7%	2.4%	88.0%	62.1%	24.1%	72.8%
	1	9.5%	4.3%		3.1%	10.8%	
Western & Northern Germany	0	22.4%	21.1%	64.4%	29.3%	14.3%	64.6%
	1	14.5%	42.0%		21.1%	35.3%	
Lower Saxony	0	31.3%	14.6%	67.3%	31.9%	14.0%	67.1%
	1	18.1%	36.0%		18.9%	35.2%	

Source: RDC of the Federal Statistical Office and Statistical Offices of the Länder, Farm Structure Survey / Agricultural Census, 2003/2010, own calculations.

Policy relevance and conclusions

The analysis has shown that the estimated models are able to predict affiliation of more intensity of grazing very well. It can also be seen that depending on the regional stratification (federal states considered) the models perform differently and some of the explanatory variables have no predictive power. For all models, the variable growth of cow numbers seems to have no additional explanatory power. Grazing is relevant only in smaller herd sizes which means that structural change will further diminish grazing systems. On the other hand, grazing is dominant in organic farming and if more farms convert from conventional to organic farming, grazing systems will be maintained or even increased. The analysis also highlights that there are large regional differences within Germany due to natural and climate conditions, farm structure and traditions (like tethering of animals) for which one should control for. This means that there is no feasible "one-size-fits-all" standard for minimum grazing.

This information is a starting point for further discussions about climate issues and animal welfare with regard to grazing. Although pasture access is generally seen as beneficial to animal health and welfare, several studies find mixed results (Schulte et al, 2018).[7] But according to the Welfare Quality® Protocol (Welfare Quality®, 2012), pasture access increases animal welfare. Additionally pasture grazing can increase biodiversity, depending on intensity amongst other factors (Schoof et al, 2018). While regions differ, policy interventions like agri-environmental and climate-friendly or other practices should be well targeted to address climate issues or animal welfare. From the methodological point of view it should be further found out if adding more explanatory variables can increase the accuracy of the models.

[7] If positive effects really outweighs negative effects in our case or vice versa needs to be addressed in further research.

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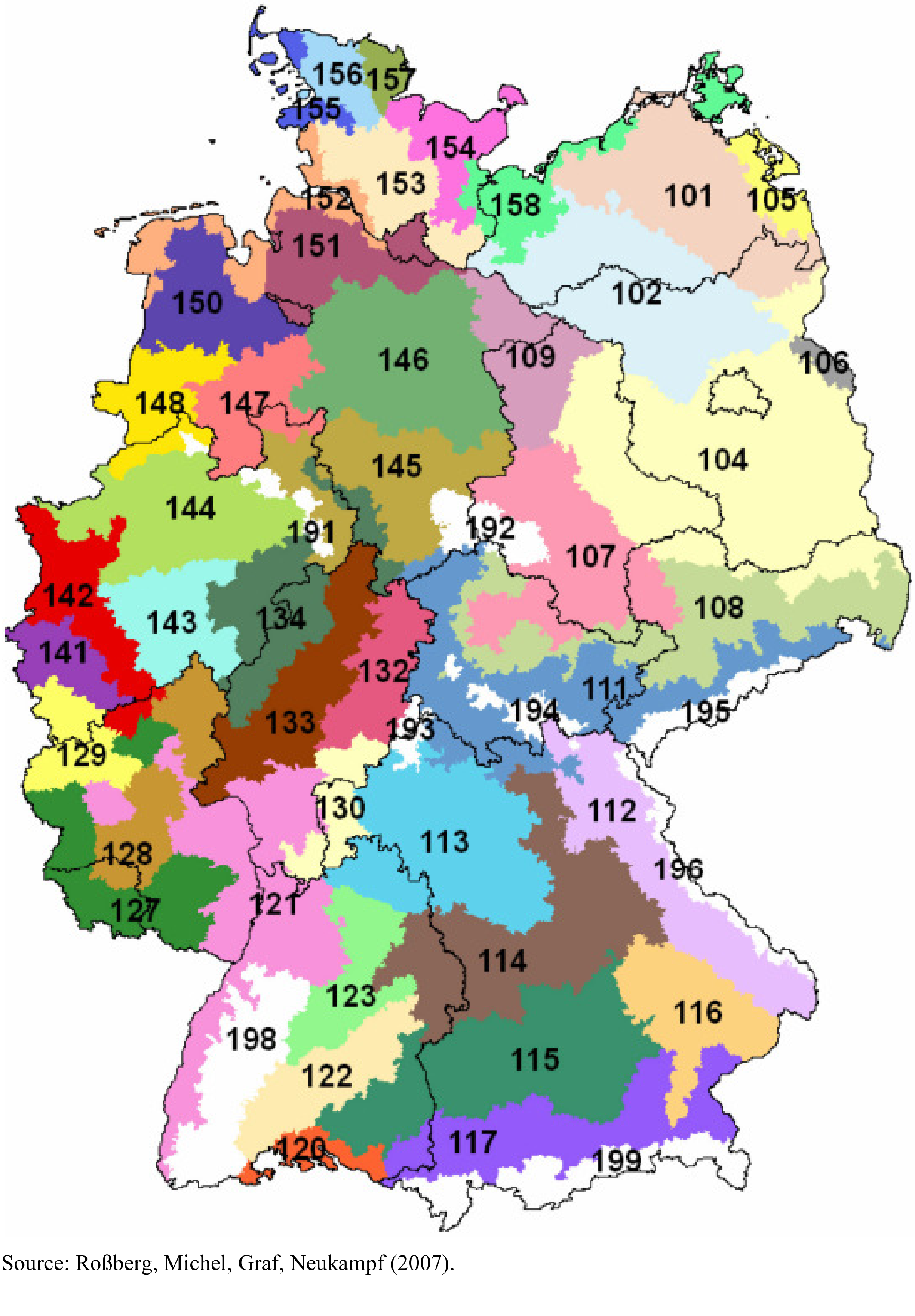
Annex

Table 3: Distribution of pasture farming over 6 hours of per day for the remaining models

Model	Category	Number of farms	Percent
Eastern Germany	0	1916	59.7%
	1	1293	40.3%
Southern Germany	0	6495	86.1%
	1	1047	13.9%
Western & Northern Germany	0	3666	43.5%
	1	4752	56.5%
Lower Saxony	0	1067	45.9%
	1	1257	54.1%

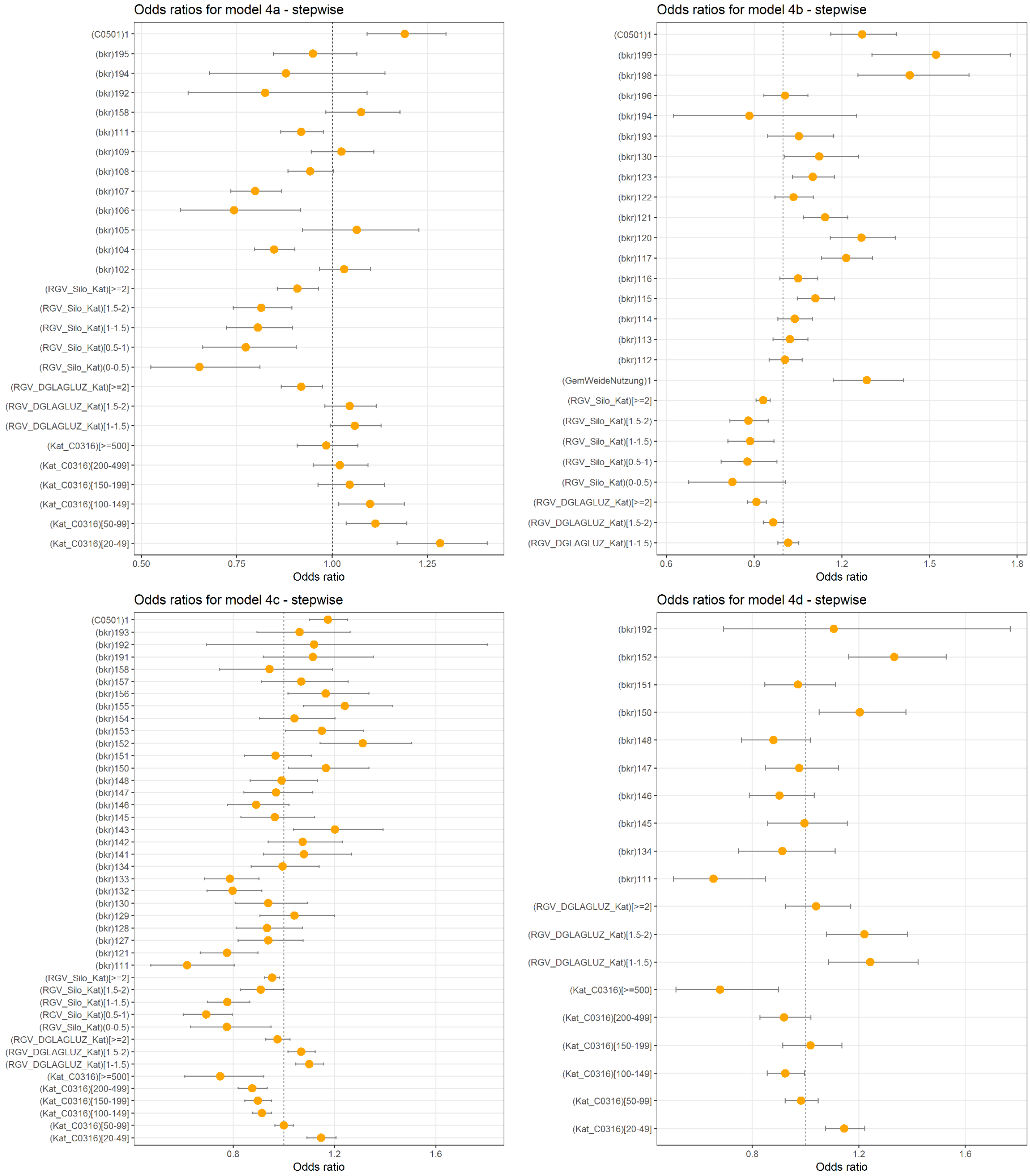
Source: RDC of the Federal Statistical Office and Statistical Offices of the Länder, Farm Structure Survey / Agricultural Census, 2003/2010, own calculations.

Figure 3: Soil climate regions in Germany



Source: Roßberg, Michel, Graf, Neukampf (2007).

Figure 4: Odds ratio for East Germany (model 4a), South Germany (model 4b), Western and Northern Germany (model 4c) and Lower Saxony (model 4d)



Source: RDC of the Federal Statistical Office and Statistical Offices of the Länder, Farm Structure Survey / Agricultural Census, 2003/2010, own calculations.