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Abstract

This study uses Swedish data to examine if the availability of nearby manure is an important determinant of organic uptake. We calculate farms' N balance of manure (animals production of N relative to N use in crop and forage production) and use coordinates to aggregate neighbors' N balances. In plain districts, we find that a standard deviation change in the within-1km N balance of manure increases the probability of being organic with 11%. A smaller impact is found for other districts and for the within-2-3km N balance of manure. Thus, our findings suggest that a further expansion of organic farming relies, partly, on an expansion of livestock production. Paradoxically, however, to alleviate the environmental impact of agriculture − the goal of organic production − livestock production is, preferably, reduced.

JEL classification:

Key words: organic farming, manure, N availability, regional analysis

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1 Introduction

In Sweden 20% of the agricultural land (Swedish Board of Agriculture, 2019) is devoted to organic farming. However, the government target is 30% and the increase has stagnated. The main problem is a low organic uptake in relatively productive regions in Southern Sweden (Rundlöf och Smith 2006, Wallander et al. 2012, Koch et al. 2018). Suggested reasons for a low uptake include i) lower yields, ii) higher risks iii) behavioral factors, and iv) availability of manure.

This study analyses iv): if availability of nearby manure is an important determinant of organic uptake. A main requirement for sustainable organic crop production is to fertilize with manure or other nutrient sources. If the farm cannot produce enough manure on its own and other organic nutrients are absent, manure has to be imported from nearby farms. Thus, we analyse if nearby farms' surplus or deficit of manure (here measured as the nitrogen (N) balance of manure[1]) affects the probability to convert to organic farming. Because transportation of manure is costly, the impact of neighbors' N balance of manure is likely to differ with distance.

However, the main constraining factor of conversion is probably low yields which affects profitability (Fairweather,1999; Pietola and Oude Lansink, 2001; Defrancesco et al., 2008; Kuminoff and Wossink , 2010; Christensen et al., 2011; Uematsu, and Mishra, 2012). Around 20-25% lower yields than conventional farming (Seufert and Ramankutty, 2017; Lamine and Bellon, 2009; Meemken and Qaim, 2018).), may be due to higher pest pressure (Gardiner et al. 2009) or lower nutrient uptake by crops from organic than mineral fertilizers. For the same reasons organic farmers also face larger production risk, particularly because they are banned from using pesticides. Pest control by neighbors may either constrain or expand production: if nearby pesticide use harm natural enemies of pests (Bianchi et al. 2013), or decrease pests locally (Avery 2001).

Behavioral factors[2] is an important determinant of conversion. First, a reluctance to change is probably an important reason why farmers do not adopt agri-environmental farming practices (Burton, Kuczera and Schwarz, 2008; Kuhfuss et al., 2016). This is explained by individuals' preference to stick to status quo (Samuelson and Zeckhauser, 1988; Hermann, Musshoff and Agethen, 2016) and a meta-analysis showed that a high percentage of farmers

[1]In the future, we may also focus on phosphorus. However, phosphorus applications rates for every crop and every production region, which we use for calculating the use of nutrients, is difficult to obtain.

[2]However, it is difficult to estimate causal behavioral effects, and to our knowledge, no study has used an experimental or quasi-experimental approach to analyse the relationship between behavioral factors and participation in organic farming. Thus, we have to keep in mind that the results in the surveyed studied are not causal and there is a chance that e.g. a neighborhood effect is mainly capturing unobserved regional characteristics.

systematically reject change (Barreiro-Hurle et al., 2018). Explanations to the status quo bias are a combination of loss aversion (Kahneman and Tversky, 1979) and the endowment effect (Kahneman et al., 1990). Second, collective behavior may increase participation through the creation of norms. It has been suggested that other farmers' efforts and practices change own behavior (Burton, 2004). For example, Läpple and Kelly (2013) show that organic farming is constrained by the social acceptance of organic farming. Finally, the concentration of farming practices may also affect adoption through knowledge spillover (Šūmane et al. 2018), and both incompatible and beneficial agricultural practices seem to cause clustering of organic farms (Parker and Munroe, 2007; Gabriel et al. 2009). In Germany, organic farms seem to cluster in areas with poor soil quality, low livestock density and a high share of protected nature areas (Schmidtner et al., 2012).

We use farm level data from the Swedish Board of Agriculture for the years 2005-2013. From data on farms' number of animals and hectares of crops, and information on animals' production of N in manure and recommended applications rates of N we calculate the expected N balance of manure at the farm. Note, our N balance of manure is conceptually different from the standard N balance. Whereas the standard N balance assess a potential nutrient leakage, our N balance of manure assess if the farm's use of N can be satisfied by own production of manure. Using farm coordinates and GIS we determine the N balance of manure in the nearby area. First, we calculate the distance between farms and next we aggregate the N balances' of manure in the very nearby area (within <1 km) and the nearby area (within 1-3 km).

In a regression framework, we investigate if the (very) nearby N balance of manure affects the probability to convert to organic farming. Importantly, by considering the share of organic farms in the nearby area we try to control for underlying factors that, according to the above, could induce clustering of organic production, which otherwise may bias our result. By interacting the N balance with the number of nearby farms we also assess if competition effects exist, i.e. if the impact of the nearby N balance is larger or smaller in areas with many neighboring farms.

To our knowledge, no study has analyzed if a nearby shortage of manure affects the probability of conversion to organic farming. It has been shown that nutrients are exported from conventional to organic farms (Nowak et al., 2013), but research has mainly analyzed if farms supply of available N is affecting the productivity of organic farms. Berry et al. (2002) who reviews the early literature concludes that crop production in organic systems is restricted by N availability. Also, a recent study, Smith et al. (2018), who models the production impact of organic farming finds that organic systems largely depend on the supply of manure. For developing countries it has been established that the main problem is high transportation cost of manure (Odhiambo and Magandini, 2008; Babasola et al., 2018).

2 Conceptual framework

For farms with a deficit of own manure the probability of converting to organic farming is assumed to depend on the cost of buying external manure. Theoretically, the cost of manure is determined by the transportation cost of manure and the price of manure, which depend on supply and demand of manure. A deficit of manure – common in most regions – would therefore imply a high price of manure. This assumption is, however, not considering the use of mineral fertilizers, which conventional farmers generally prefer because these are easier to apply, and desired nutrient ratios are easier to obtain (Buckwell och Nadeu, 2016). Thus, farming system with mineral fertilizers implies that the demand for manure is also low, and in consequence that the price of manure is often zero. In regions with a substantial supply of manure, the price may even be negative. In the Netherlands, farmers sometime have to pay the receiver of manure (Leenstra m.fl., 2019), and in Denmark it is common that the seller and receiver shares the transportation cost of manure (Asai m.fl., 2014). But these countries are exceptions with a large surplus of manure, and in the Netherlands manure is mainly a waste problem; too much manure leads to nutrient leakage polluting water.

The cost of manure is the thereby primarily determined by the transportation cost of manure. On the other hand, supply still matters but not as a determinant of price but as an outcome of regulation. In nitrate vulnerable zones, which makes up a large share of the agricultural land in Sweden, farmers have to spread the manure according to EUs nitrate directive (max 170 kg N per ha). If a farm has a large surplus of manure (manure in relation to hectares of agricultural land) it may be favorable to export the manure to a neighboring farm. In fact, manure implies an opportunity cost, i.e., a decreased opportunity to use the more convenient mineral fertilizer. Hence, farm's nutrient balance from manure is assumed to affect the willingness to be a manure-exporting farm. For organic farms who rely on manure, neighbors' willingness to export may therefore be a decisive factor for conversion.

To sum up, the regional balance of manure may affect farms' probability of converting to organic farming: with a regional surplus, or a small deficit, of manure the likelihood of finding a neighbor willing to export manure, increases. We consider the transportation costs of manure, which is substantial since manure is heavy and impractical to transport, and assumes that only local manure affects conversion. In our econometrical setting we use distance as a proxy for transportation costs and models the impact of a local N balance of manure as determined by distance.

Finally, the competition for local manure may affect the probability of getting hold of nearby manure. That is, for a given nearby N balance of manure the number of neighbors may affect the chance of finding manure and therefore the probability of converting to organic farming.

3 Material and Methods

3.1 Data

From the Swedish Board of Agriculture we receive the total population of Swedish farms for the years 2005-2013, but since we have a spatial and not a longitudinal approach a single year, 2013 is used in the econometrical analysis. We remove the 30% smallest farms (based on farms livestock and hectares of arable land) who may be perceived as hobby farmers. These small farms have on average less than 4 ha of arable lands and 4 livestock and only 4.8% are organic farms; in the rest of the population the share is 15.6%. Hence, given this restriction it implies a sample of 40,009 farms in which 6,235 are organic. However, small farms may also export manure and therefore all 57,170 farms are included when calculating the nearby N balance (and other independent variables as e.g. the nearby share of organic farms).

3.2 Calculating the N balance of manure

The approach for calculating the N balance of manure is the same for all farms (crop and animal farms, and organic and conventional farms). Unlike a standard N balance, which calculates the overall N balance at the farm (net input and output of N) our N balance of manure assess if the farm's use of N can be satisfied by own production of manure. The data contains detailed information on number of farm animals and hectares of crops. For 11 animal categories, we have animals' yearly production of nitrogen in barn[3] manure (Malgeryd et al., 2002; Swedish Board of Agriculture, 2005, 2013). Thus by multiplying the number of animals with the N production rates we receive each farm's N availability through manure. We exclude manure from horses and industry pig production[4] because regulation does not allow this manure to be used in organic systems (although it could potentially affect overall demand of manure).

[3]Manure produced during (expected) grazing is not included.
[4]Note, pig production is considered industrial already at >5 pig livestock units.

The use of N is calculated by multiplying farms hectare of arable land (for each crop and forage) with recommended applications rates of N. The application rates varies with crops and regional yield levels. Finally, the expected N balance at the farm level is received by subtracting the N availability with the N use. Farms total N balance is used in the econometrical analysis but below, in the descriptive section, we use the N balance per ha.

3.2. N balances of manure per ha

Figure 1 shows the N balance of manure per ha (kg) over time and for Sweden's main production districts. Although 8.7% of the farms have a surplus of N in manure, at the aggregate level there is a deficit of N manure in all production districts. The deficit have increased with around 15% since 2005, and it is much larger in plain districts (the 3 lines in the bottom of Figure 1). In 2013, the deficit is about 90% (or 30 kg per ha) larger in plains districts than in other districts. The largest deficit, around 70 kg of N per ha is found in the most productive district: the plain district of Southern Götaland. Because application rates of N per ha is around 120-180 kg in the plain district of Southern Götaland, depending on the type of crop, the deficit in plain district of Southern Götaland is vast. Only about half of the crops can be fertilized with manure produced in the district.

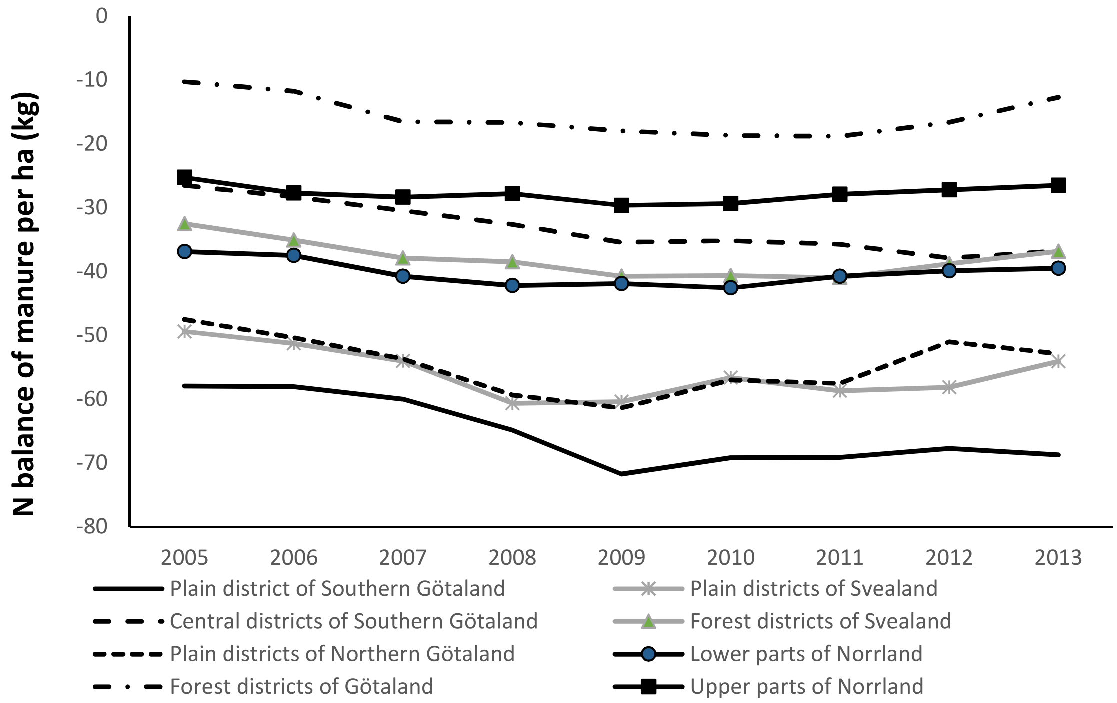


Figure 1. N balance per ha (kg) in each production district over time (2005-2013)

Next, we scrutinize our research question spatially. To the left, Figure 2 shows the distribution of organic farms in Sweden, and to the right the distribution of farms with a surplus of N from manure is shown. The main intention with the figure is to show that organic farms seem to cluster in areas where there is a surplus of manure. In the southern part of Sweden (Skåne) it is clear that the organic farms cluster in areas where a surplus is common (see the two elliptics in the bottom of the figure). This is also true for the elliptic to the left and in part for the elliptics in the Forests districts of Götaland (pink area). However, the main clustering of organic farms is found in the plain district of Götaland (purple area), where relatively few farms with a surplus of manure are located.

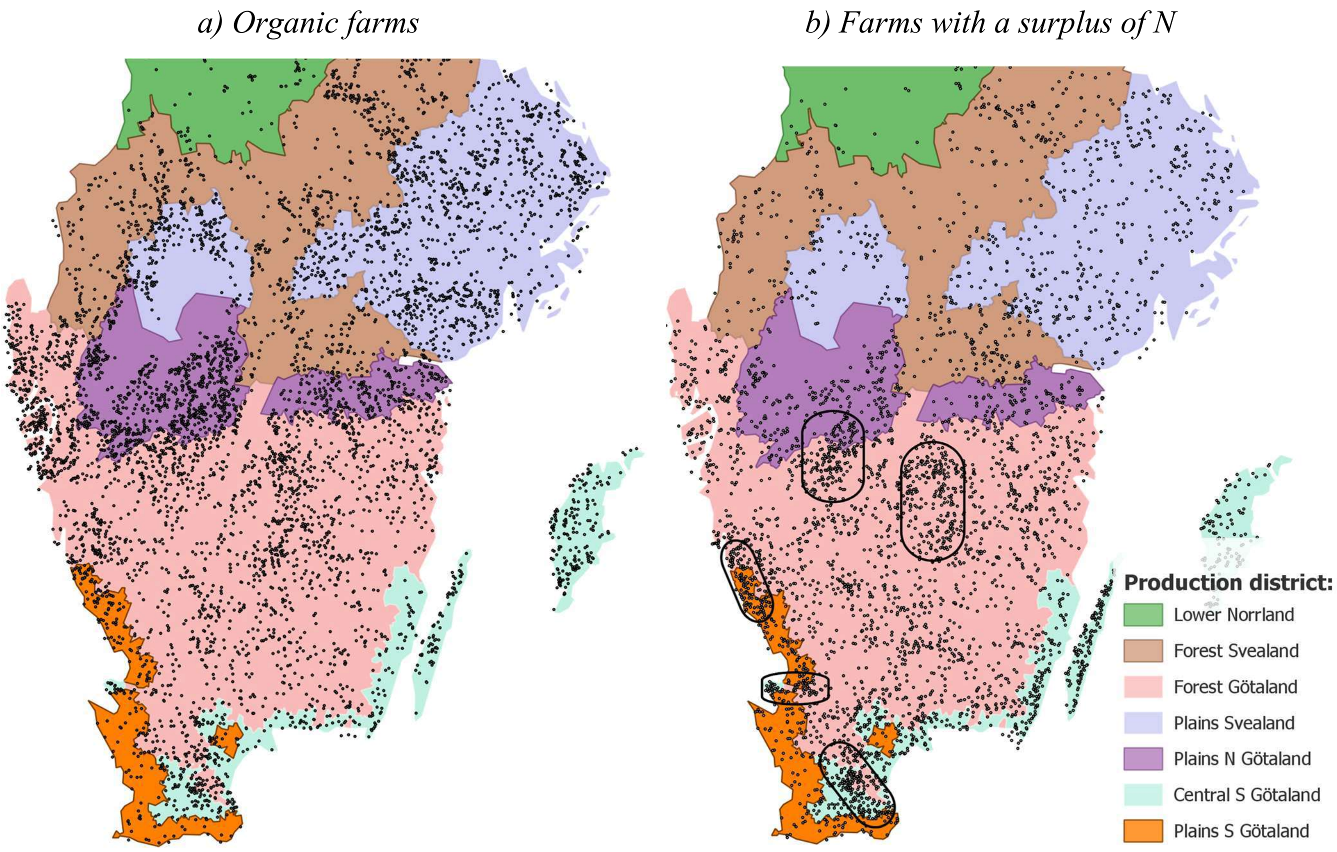


Figure 2. Distribution of organic farms (left) and farms with a surplus of N from manure (right) in 2013.
Note: The elliptics in the right figure illustrates a clustering of farms with a surplus of N.

3.2.2 The nearby N balance

Next, we calculate the nearby N balance. Since we know each farm's coordinates, we can identify the nearby farms within different distances.[5] We identify farms located within 1km and 1-3km and aggregate the nearby farms' N balances for each area, respectively. For farms further

[5]This is done in the spatial package QGIS.

away the N balances do not seem to affect the decision to be an organic producer (not reported). However, when aggregating the nearby N balance we have to consider the impact of extreme values. Table 1 reports farm observations with around 2,500 hectares of arable land or up to 156,000 livestock, which produces huge farm N balances (ranging from around -350 tons to 160 ton) that cannot have a linear impact on neighbors' probability of being an organic farm. To reduce the impact of these extreme values we aggregate the square root of the neighbors' N balances instead of the unadjusted values[6]. Later we show that this transformation improves the result, plausibly because it reduces the impact of outliers. Farms own N balances is not adjusted.

Table 1. Descriptive statistics

	Plain districts (n=16,164)				Central districts of southern Götaland (n=4,380)				Forest districts and Northern Sweden (n=19,465)			
	Mean	*St. Dev.*	*Min*	*Max*	*Mean*	*St. Dev.*	*Min*	*Max*	*Mean*	*St. Dev.*	*Min*	*Max*
Share organic	14%	0.35	0	1	10%	0.3	0	1	18%	0.39	0	1
N balance, farm (tons)	-5.93	11.2	-346.35	98.19	-3.3	9.7	-182.5	61.1	-1.65	4.39	-70.13	163.84
N balance (<1km)	-8.76	14.79	-382.22	102.98	-6.02	12.93	-185.5	102	-2.28	5	-64.6	92.56
N balance (1-3km)	-73.4	66.95	-572.76	104.7	-46.49	46.77	-339.2	100.8	-12.74	17.69	-237.1	162.71
Sq.r. N balance (<1km)	-3.34	3.43	-26.97	10.77	-3.08	3.59	-20.7	11.06	-1.66	2.15	-16.4	9.62
Sq.r. N balance(1-3km)	-25.47	15.89	-97.58	10.1	-21.55	15.56	-92.77	17.41	-8.91	8.3	-86.3	17.67
No close neighbor	17%	0.37	0	1	11%	0.32	0	1	25%	0.43	0	1
No neighbors (<1km)	2.17	1.73	0	13	2.92	2.27	0	13	1.82	1.75	0	14
N neighbors (1-3km)	15.31	8.1	0	54	19.76	12.34	0	68	9.97	7.73	0	63
Livestock	225.8	3,474	0	156,320	328.2	4,076.6	0	120,000	84.58	1,971.7	0	159,500
Arable land (ha)	75.6	107.57	0	2,583	63.96	91.85	0	1,893	39.7	53.02	0	1,001

Note: The N balances of manure are reported in tons.

Figure 3 shows the relationship between the share of farms that are organic and the nearby, <1km, (square root) N balance from manure for: a) Plain districts, b) Central district of Southern Götaland and c) Forest and Northern districts. a) and b) contains the nitrate vulnerable zones[7] in Sweden where EU regulation restricts the amount of N that can be spread. Because the deficit of N in manure is much smaller in b) than in a) (see Figure 1) we do not merge these districts. The larger variation in the N balance for the 1-3km relationship (to the right) is due to an aggregation of a much larger number of farms in the 1-3km area. We have censored[8] the relationship in Figures 3-5, otherwise the difference would be even larger. Table 1 report, on

[6]To reduce the impact of extreme values it is more common to use the logarithm, but since we have both zeros and negative values, we prefer the square root of the values. Negative values are here transformed from: $-\sqrt{-N\ balance}$

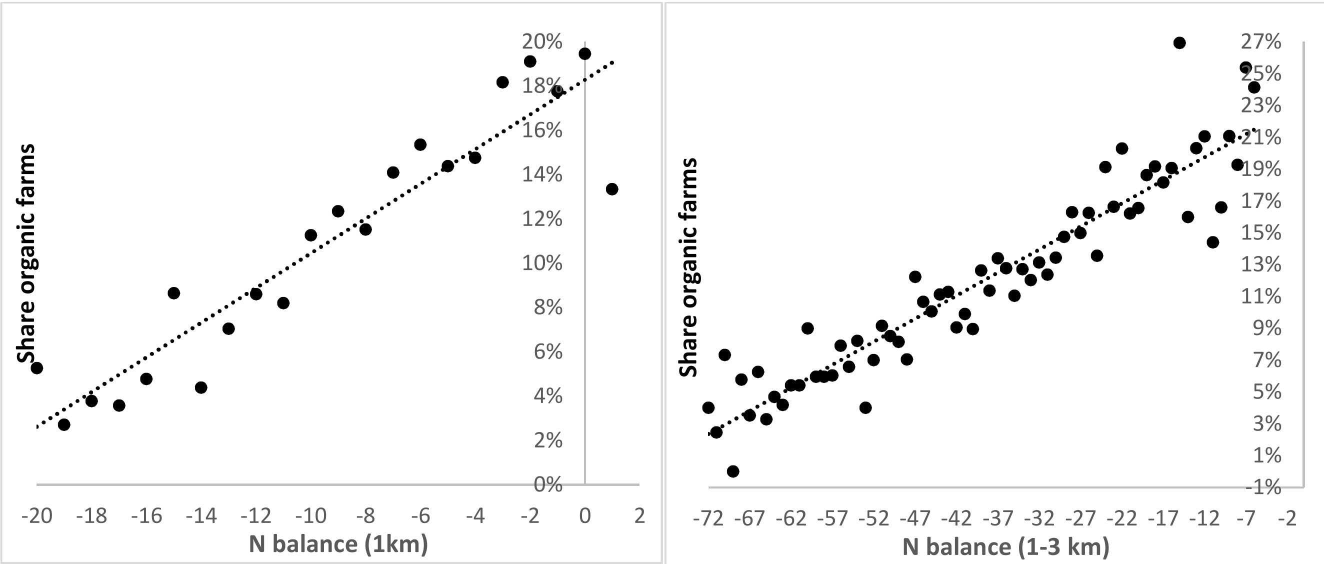
[7]Production districts and the Nitrate vulnerable zones do not match perfectly, but they overlap largely.

[8]The x-values are censored in Figure 3. With few observations in the tails, the variation in the tails of the N balances are large and therefore we remove around 0.2-0.5% of the observations at the top and bottom of Figure 3.

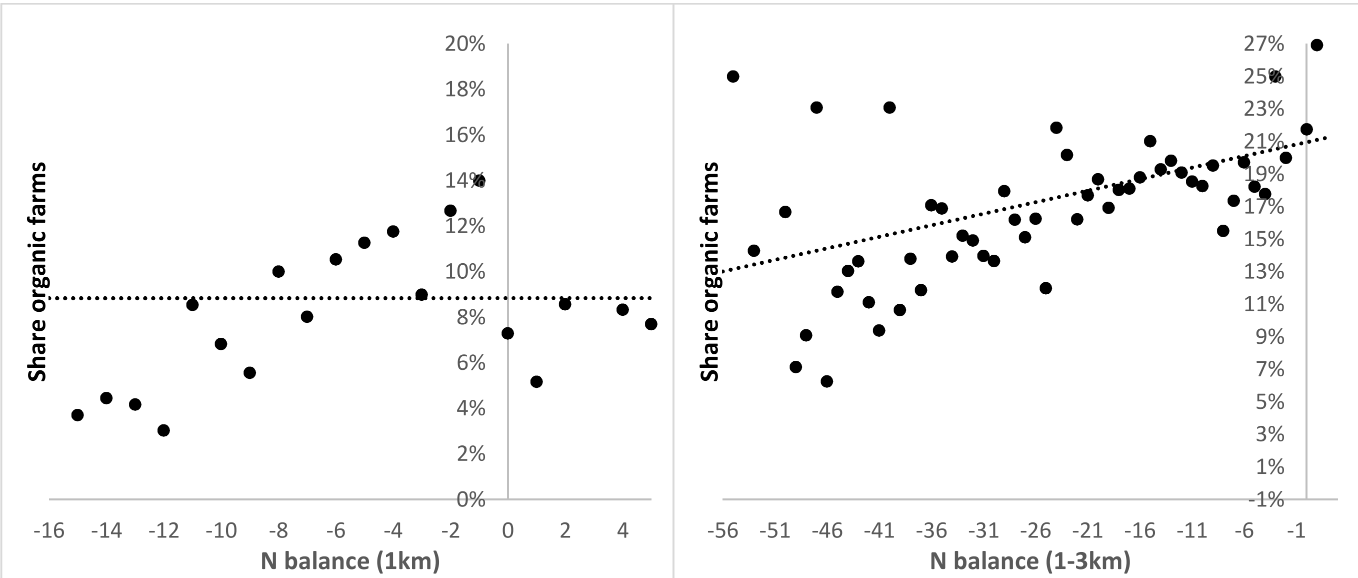
average, around 2-3 and 10-20 (depending on district) neighbors in the nearby 1km and 2-3km area, respectively.

For plain districts (a), we find a clear positive relationship indicating that the nearby N balance is affecting conversion. The positive relationship is found for each plain district (not reported), but the relationship is somewhat weaker in the Plain district of Southern Götaland. For the Central district of Southern Götaland (Figure 4) there might be a weak relationship, but for the Forest and Northern districts (Figure 5) we do not detect a relationship.

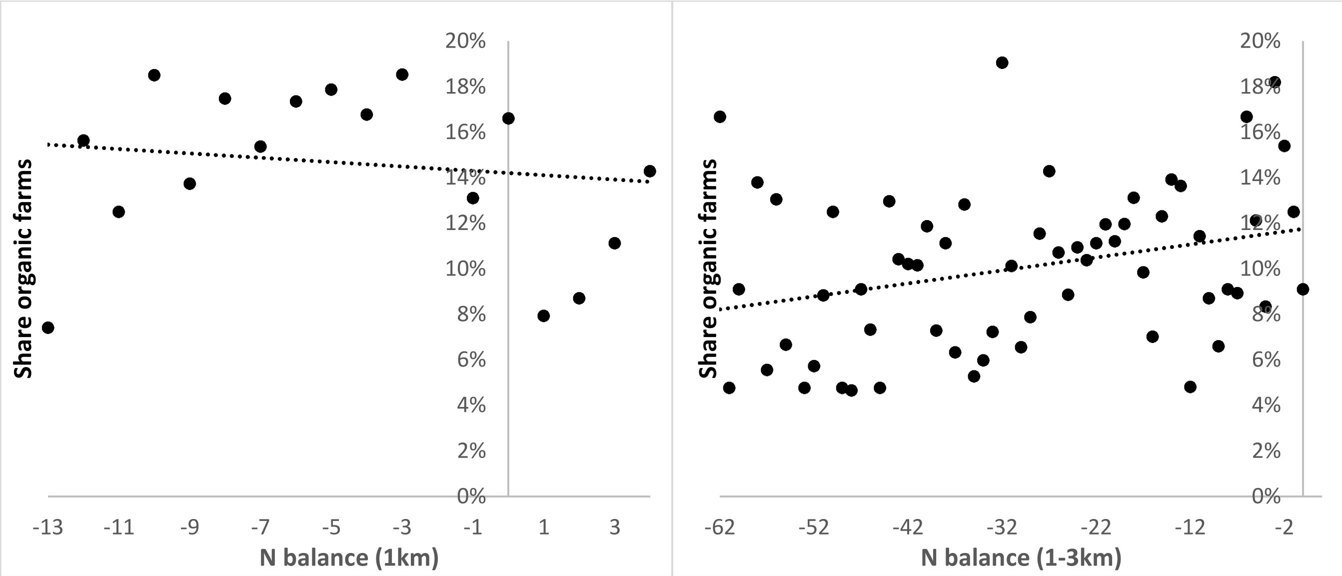
a) Figure 3: Plain districts



b) Figure 4: Central district of Southern Götaland



c) Figure 5: Forest districts and Northern Sweden



Figures 3-5. Relationship between the share of organic farms and the nearby N balance of manure (tons). 2013.

3.3 Econometrical method

The relationships in Figure 3-5 could be spuriously caused by farm or regional characteristics (e.g. high uptake and many livestock in same regions). But before handling this caveat we specify a naïve linear probability model[9] of the relationship between the nearby N balance and the probability of being an organic farmer. The decision to be an organic farmer, Org_i, for farm i is assumed to depend on farm's N balance of manure, $N{:}\,Own_i$, and the total (square root) N balance of manure of neighboring farms within a distance of 1km and 1-3km, $N{:}\,1km_i$ and $N{:}\,1-3km_i$, respectively. α_j are district fixed effects capturing differences in agricultural conditions in the eight main production districts.

$$Org_{ij} = \alpha_j + \beta_0 N{:}\,Own_i + \beta_1 N{:}\,1km_i + \beta_2 N{:}\,1-3km_i + \gamma No\ close\ farm_i + \delta Org\ farms_i + \pi Farms_i + \rho X_i$$

However, a strong correlation between $N{:}\,1km_i$ and $N{:}\,1-3km_i$ (corr=0.43) makes the interpretation of each coefficient difficult and therefore we add $N{:}\,1-3km_i$ in a second step. For some farms there is no farm within 1km (around 11-25% depending on district), implying that $N{:}\,1km_i$ is zero. This is a problem to handle because a balance of zero indicates a large N balance (see e.g. figures 3-5) and by not considering the zeros, the effect may be biased. We do

[9]We have tried using a probit and a logit model also. But since the choice of model does not change our results and the linear model is easier to interpret we prefer the linear probability model. Heteroscedasticity in the linear probability model, is solved with robust standard errors (Wooldridge, 2002).

this by including a dummy variable, $No\ close\ farm_i$, which describes the lack of a nearby farm.[10]

To reduce the risk of a spurious relationship we first add farm characteristics: livestock, ha of arable land and CAP payments[11], and second the share of nearby (1km) organic farms, $Org\ farms_i$[12]. If this was a study of organic "neighborhood effects", the assumption is that $Org\ farms_i$ identifies behavioral factors as e.g. norms and knowledge spillover. However, the $Org\ farms_i$ neighborhood effect is plausibly biased, because the variable also capture general prerequisites for organic production in the nearby area[13]. Hence, by controlling for $Org\ farms_i$, we do not only capture behavioral factors but also unobserved regional characteristics that benefits organic systems. That is, we plausibly capture factors that may bias β_1 and β_2.

Finally we include the number of farms, $Farms_i$, and the number of nearby farms interacted with $N{:}\,1km$. With this model we try to test if the competition of manure affect conversion.

4 Results

In Table 2, we report the impact of $N{:}\,1km_i$ on conversion. Estimates are shown for the total sample and separately for a) Plain districts, b) Central district of Southern Götaland and c) Forest and Northern districts. In columns (1), (3), (5) and (7) we control for farm's N balance of manure, $N{:}\,Own_i$, and in (2), (4), (6) and (8) we add other farm characteristics. In all models, district fixed effects and *no close neighbor* are included.

Importantly, the $N{:}\,1km_i$ effect do not change when adding farm characteristics. This is important because it indicates that the effect is not biased due to omitted farm characteristics. Our argument is: if the effect is not affected by including observed key characteristics as livestock and arable lands, unobserved characteristics are less likely to impact the effect. The $N{:}\,1km_i$ effect is roughly twice as large in a) than in b) and c). In b) the effect turns significant when adding farm characteristics and in c) the effect is only significant at the 10%-level. To interpret the size of the effect we also report the effect as a standardized $N{:}\,1km_i$ effect score. In a) a standard deviation increase in $N{:}\,1km_i$, increases the probability of conversion by 1.6

[10]Without this dummy variable, a surplus of 0 in the nearby area is assumed.
[11]The organic support (and other environmental payments) is not included because this implies that you partly add the dependent variable on the right hand side of the equation.
[12]The share within 1-3km has also be controlled for, but at this distance the share of organic farms has no impact.
[13]Also, the simultaneity of the neighborhood effect cause endogeneity problems: if farm *i* is affected by its neighbor *j*, then farm *j* is affected by its neighbor *i*.

percentage points. Calculated at the mean organic share (14% in a)) it implies a 11% increase in the probability of being an organic farm. In b) and c) the standardized effects are 0.9 and 0.7 percentage points (9% and 4% at the mean), respectively. Table A1 show similar, but somewhat smaller, estimates for $N\colon 1km_i$ when neighbors' N balances of manure are not in square root before being aggregating on the local level (see discussion on p. 7). Our explanation is that the estimates in Table A1 are underestimated when the influence from outlier N balances of manure is not restricted, i.e. because the effect is potentially decreasing at large values.

Table 2. The relationship between organic farming and the nearby N balance.

	Total sample		**Plain districts**		**Central districts of southern Götaland**		**Forest districts and Northern Sweden**	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
N balance (1 km)	.0037***	.0035***	.0057***	.0053***	.0021	.00296**	.00248*	.00236*
	(.0007)	(.00068)	(.0009)	(.0009)	(.0013)	(.0013)	(.00142)	(.00140)
Standardized effect	.0110***	.0104***	.0171***	.0158***	.0064	.00892**	.00748*	.00713*
N balance (farm)	-.0028***	.0035***	-.0011***	.0031***	-.0018***	.00318***	-.0136***	-.0065***
	(.0002)	(.0003)	(.0002)	(.0004)	(.0005)	(.0007)	(.0006)	(.0007)
No close neighbor	.0307***	.0313***	.0163**	.0160**	.0417***	.0433***	.0391***	.0343***
	(.0049)	(.0048)	(.0081)	(.0078)	(.0148)	(.0143)	(.00702)	(.00691)
Livestock		-.0075***		-.0051***		-.0068**		.00475
		(.0016)		(.0020)		(.0028)		(.00351)
Arable land (ha)		.131***		.139***		.143***		.171***
		(.0036)		(.0049)		(.0092)		(.0065)
CAP payments		yes		yes		yes		yes
District fixed effects	yes	yes	yes	yes	yes	yes	yes	yes
Observations	40,005	40,005	16,164	16,164	4,380	4,380	19,461	19,461
R-squared	0.027	0.064	0.029	0.091	0.007	0.079	0.035	0.070

Notes: The dependent variable is the incidence of organic farming. The N balance (1 km) is the nearby farms' aggregated square root N balances. Robust standard errors in parenthesis. *=Significant at the 10%-level, **=Significant at the 5%-level, ***=Significant at the 1%-level.

In Table 3, columns (1), (3), (5) and (7), $Org\ farms_i$ is added and in columns (2), (4), (6) and (8) $N\colon 1-3km_i$ is added, as well. $Org\ farms_i$ is clearly associated with the probability of being organic. When the share of nearby organic farms increase with 1%, the probability of being an organic farm increases with 0.15 percentage points. The inclusion of $Org\ farms_i$ does, however, not have an impact on the $N\colon 1km_i$ effect. Actually, for the total sample, and b) and c) the $N\colon 1km_i$ effect increases some when adding $Org\ farms_i$. Based on this finding, we perceive the $N\colon 1km_i$ effect as causal.

As expected, when including $N: 1-3km_i$ to the model, the $N: 1km_i$ effect decreases but remains significant in the total sample and in a) Plain districts. The $N: 1-3km_i$ effect is significant in all models, but roughly half the size of the $N: 1km_i$ effect.

Table 3. The relationship between organic farming and the nearby N balance when controlling for the organic share within 1 km.

	Total sample		Plain districts		Central districts of southern Götaland		Forest districts and Northern Sweden	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
N balance (1 km)	.0041***	.0024***	.0054***	.0038***	.0032**	.0018	.0042***	.0023
	(.0007)	(.0007)	(.0010)	(.0009)	(.0013)	(.0013)	(.0014)	(.0015)
N balance (1-3 km)		.0015***		.0016***		.0010***		.0016***
		(.0002)		(.0002)		(.0003)		(.0004)
Share organic (1km)	.151***	.147***	.148***	.140***	.146***	.142***	.152***	.150***
	(.0080)	(.0080)	(.0118)	(.0118)	(.0243)	(.0243)	(.0117)	(.0117)
Observations	40,005	40,005	16,164	16,164	4,380	4,380	19,461	19,461
R-squared	.073	.075	.100	.105	.086	.088	.078	.079

Notes: The dependent variable is the incidence of organic farming. The N balance (1 km) is the nearby farms' aggregated square root N balances. In all models No close neighbor, Livestock, Arable land (ha) CAP payments and district fixed effect are controlled for. Robust standard errors in parenthesis. *=Significant at the 10%-level, **=Significant at the 5%-level, ***=Significant at the 1%-level.

In Table 4 we analyse if a competition of manure affects conversion. We add to the model the number of farms, $Farms_i$ and we replace the $N: 1km_i$ variable with five separate $N: 1km_i$ variables, each capturing the specific $N: 1km_i$ effect for different part of the $Farms_i$ distribution. That is, $N: 1km_i$ is interacted with five binary variables (indicating 1, 2, 3-5. 6-9 and ≥10 farms) explaining the number of neighboring farms. Table 4 shows that the number of farms affect conversion negatively. This shows that organic farming is less common in agricultural dense areas, which has to be considered when assessing if there is competition over manure. Thus, given the control of $Farms_i$ the finding of a decreasing $N: 1km_i$ effect with the number of neighbors (in the total sample and in a)) suggests that there is competition over manure among organic farms. Figure 6 illustrates the relationship between the number of neighbors and the $N: 1km_i$ effect in the total sample.

Table 4. The relationship between organic farming and the nearby N balance when considering competition effects.

	Total Sample	Plain districts	Central districts of southern Götaland	Forest districts and Northern Sweden
	(1)	(2)	(3)	(4)
Number of neighbors	-0.00423**	-0.00530*	-0.00175	-0.00576*
	(0.00174)	(0.00293)	(0.00285)	(0.00344)
N balance (1 km) effect for farms with:				
1 neighbor	0.00799***	0.0131***	-0.000156	0.00516
	(0.00217)	(0.00300)	(0.00452)	(0.00436)
2 neighbors	0.00425***	0.00685***	-0.000893	0.00283
	(0.00125)	(0.00154)	(0.00305)	(0.00295)
3-5 neighbors	0.00308***	0.00443***	0.00250*	0.00254
	(0.000749)	(0.000947)	(0.00145)	(0.00211)
6-9 neighbors	0.00239**	0.00346**	0.00309*	0.00114
	(0.00110)	(0.00148)	(0.00182)	(0.00299)
≥ 10 neighbors	-0.00114	-0.00860	0.00390	-0.00426
	(0.00392)	(0.0127)	(0.00322)	(0.0108)
Observations	40,005	16,164	4,380	19,461
R-squared	0.073	0.100	0.087	0.078

Notes: The dependent variable is the incidence of organic farming. The N balance (1 km) is the nearby farms' aggregated square root N balances. In all models No close neighbor, Livestock, Arable land (ha) CAP payments and district fixed effect are controlled for. Robust standard errors in parenthesis. *=Significant at the 10%-level, **=Significant at the 5%-level, ***=Significant at the 1%-level.

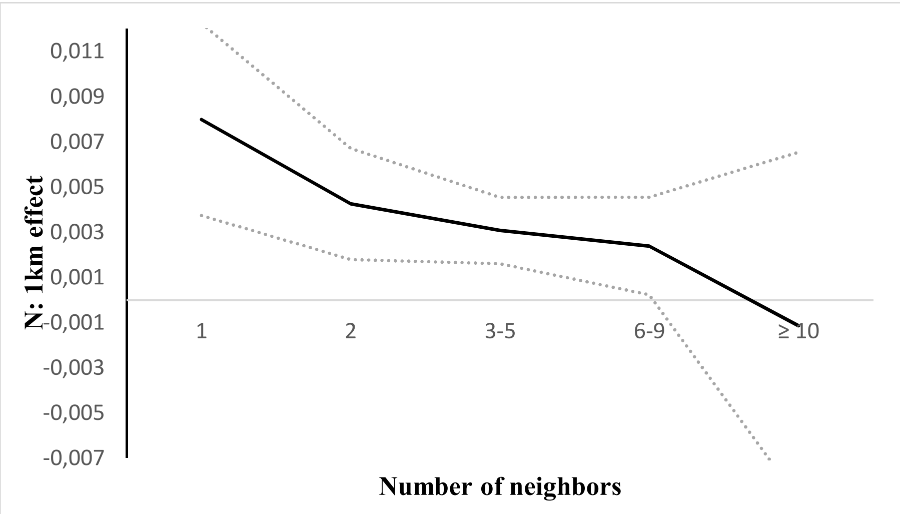


Figure 6. The relationship between the number of neighbors and the $N\colon 1km_i$ effect (dashed line is the 95% coefficient bound). Total sample.

5 Conclusion

Organic farming addresses the environmental problems in conventional production system. An important feature of the organic system is the requirement to replace the use of mineral fertilizer. Availability of manure is hence essential.

Using Swedish data, we contribute by examining how a deficit of manure can be an obstacle for organic expansion. Our results show that the nearby N balance of manure affects the probability of conversion to organic farming. Importantly, the robustness in result indicates a causal impact. In plain district, a one standard deviation change in the nearby N balance increases the probability of being an organic farmer with 11%. The impact decreases with distance and for farms further away than 3km the neighbors' N balance of manure has no impact on conversion. Also, suggestive findings indicate that there is competition for manure among organic farms.

In other production districts of Sweden the impact is smaller. The heterogeneity in results may be related to the Nitrate directive, which regulates the spread of manure: in plain regions where the spreading of manure is restricted, neighbors' may be more inclined to export their manure to organic farmers. Outside nitrate vulnerable areas, it may be more convenient to over-fertilize grassland areas than to export manure.

Our findings suggest that a further expansion of organic farming relies, partly, on an expansion of livestock production or an increased use of other organic nutrients. This, indeed, expected result highlights a paradox with organic farming. To alleviate the environmental impacts of agriculture, livestock production which is the main contributor of greenhouse gas from agriculture is, preferably, reduced, but to expand organic farming livestock production should, preferably, be increased. An alternative way forward would be to revise the organic requirements by easing the ban of mineral fertilizers, and thus weaken the link between livestock production and organic farming. Because the general equilibrium impacts of changing the regulation is unknown, further research is needed. Sincere climate considerations, however, motivates such an action. The climate has to be significantly upgraded vis-à-vis other environmental concerns; EU's agri-environmental schemes largely lacks climate measures.

The result also affects the calculation of climate emission from manure and the comparison of emissions from mineral fertilizers and manure. Usually, the calculated emissions from manure does not include animals' emissions. However, when evaluation the climate impact of a *measure* it is different. In our context, for a measure increasing the organic cereal areal, by increasing the availability of manure, the animals' emissions has to be accounted. Therefore, a measure changing the fertilization from mineral to manure increases the climate emissions largely. Hence, even if the production of mineral fertilizers implies large emissions, the production process (i.e. mainly cattle) of a comparable amount of nutrients in manure pollutes vastly more. To illustrate the argument we do a back-of-the-envelope comparison of production-related emissions from cattle manure and mineral fertilizers. The production-related

CO2-equivalent GHG emissions per kg nitrogen for cattle's manure is 53[14], and the CO2-equivalent GHG emissions per kg nitrogen for mineral fertilizers is 3-7 (Swedish Board of Agriculture, 2011). This is important because the standard method of calculating emissions from manure (basically, the breaking down of manure) may come to another solution.

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[14] CO2-equivalent GHG emissions per cattle (170 (kg meat from one cattle) × 22 (CO2 per kg (Avery and Avery, 2008) relative to the N produced by cattle (47 (kg N)×1.5 (for cattle slaughtered after 18 month).

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Appendix

Table A1. The relationship between organic farming and the nearby N balance (when using unadjusted N balances).

	Total sample		Plain districts		Central districts of southern Götaland		Forest districts and Northern Sweden	
N balance (1 km)	.0009***	.0007***	.0011***	.0009***	.0001	.0003	.0006	.0006
	(.0002)	(.00017)	(.0002)	(.0002)	(.0004)	(.00034)	(.0006)	(.0006)
Standardized effect	.0090***	.00792***	.0123***	.0108***	.00123	.00345	.00688	.00727
N balance (farm)	-.0029***	.00352***	-.0013***	.00310***	-.0018***	.00323***	-.0136***	-.00645***
	(.0002)	(.000326)	(.0002)	(.00044)	(.00046)	(.000672)	(.00063)	(.000712)
No close neighbor	.0366***	.0370***	.0270***	.0263***	.0483***	.0513***	.0427***	.0376***
	(.00463)	(.00455)	(.00756)	(.00734)	(.0143)	(.0139)	(.00652)	(.00642)
Livestock		-.00746***		-.00506**		-.00673**		.00475
		(.00156)		(.00198)		(.00283)		(.00351)
Arable land (ha)		.131***		.139***		.143***		.171***
		(.00364)		(.00485)		(.00922)		(.00653)
CAP payments		yes		yes		yes		yes
District fixed effects	yes	yes	yes	yes	yes	yes	yes	yes
Observations	40,005	40,005	16,164	16,164	4,380	4,380	19,461	19,461
R-squared	.027	.064	.029	.091	.007	.078	.035	.070

Notes: The dependent variable is the incidence of organic farming. The N balance (1 km) is the nearby farms' aggregated N balances. Robust standard errors in parenthesis. *=Significant at the 10%-level, **=Significant at the 5%-level, ***=Significant at the 1%-level.

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