Abating Ammonia Emissions: Farmers' Willingness to Use Slurry Acidification Techniques during Spreading

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Abstract

This article seeks to determine farmers' willingness to apply slurry acidification during spreading. Slurry acidification is a novel technique to reduce ammonia emissions, which has been pioneered in Denmark. In an online discrete choice survey of German livestock farmers, the respondents were asked to choose between different policy schemes to promote the use of acidification techniques and the status quo. The support schemes were characterised by the following attributes: cost share, expected emission reduction as well as reliefs from, and tightenings of, the German Fertilizer Ordinance. In addition, the characteristics of farmers and farms were elicited. The data were estimated using a mixed logit model. The estimated probability of farmers to choose a support scheme is 89 %. All policy variables are significant for acceptance and show the expected signs. Emission reduction is important to farmers and increases the chances of participation in a support scheme significantly. Furthermore, the cost share offered and the exemption from the requirement to incorporate slurry immediately after spreading have a significantly positive impact on farmers' willingness to participate. By contrast, the higher the nitrogen load factor by which the extra nitrogen in the slurry must be counted in a farmer's fertilizer planning (a provision of the German Fertilizer Ordinance), the lower the probability of participation. Concerning farm and farmer characteristics, farmers with grazing livestock show lower acceptance as do sow holders. Older farmers and better educated farmers are more likely to participate.

Keywords: Slurry Acidification, Emission Abatement, Ammonia Emissions, Discrete Choice

1 Introduction

Society's requirements for sustainable agriculture are increasing. In this context, nitrogen surpluses like ammonia emissions are viewed critically, as they contribute to the eutrophication of water bodies and fine dust loads. In order to lower ammonia emissions, the EU stipulates maximum amounts per member state. Only 550,000 tons of ammonia per year may be emitted by Germany since 2010, but this target has not yet been met. In addition, the NEC-Directive requires a further reduction of 29 % compared to 2005 (Federal Environmental Agency, 2017). In terms of the necessary emission abatement, special attention is being paid to agriculture, as this is where almost all ammonia emissions occur (95 %). They are mainly emitted in livestock husbandry, especially in the barn (30 %) and during application (42 %) (Wulf *et al.*, 2017). A novel technique from Denmark to significantly reduce ammonia emissions is slurry acidification (Fangueiro *et al.*, 2015). Ammonia (NH_3) emissions are reduced by lowering the pH value of slurry. The pH-value influences the ratio of ammonium (NH_4) and ammonia (NH_3). In lower pH more NH_4 is present, which is salty and less gaseous NH_3 leaks into the atmosphere (Tamm *et al.*, 2013).

This article determines farmers' willingness to use slurry acidification during application using a Discrete Choice Experiment (DCE). The article is structured as follows: At first the technique of acidification during spreading is briefly described, before the methods and construction of the questionnaire are illustrated. Afterwards the results are presented and critically discussed.

2 Theoretical background

2.1 Slurry acidification during spreading

Using the technique during spreading sulfuric acid is added to the slurry immediately before spreading until the target pH value of 6.5 to 5.5 is reached. For this purpose, 96 % sulphuric acid (H_2SO_4) is carried in a specially secured container at the front of the tractor and added at the end of the tanker. Afterwards the slurry is spread with trailing hoses. Existing application technology on farms is usable as well, as the system can be installed on a wide range of tractors and tankers (Birkmose and Vestergaard, 2013; Fangueiro *et al.*, 2015). An illustration of the technique is shown in Figure 1 (Fangueiro *et al.*, 2015).

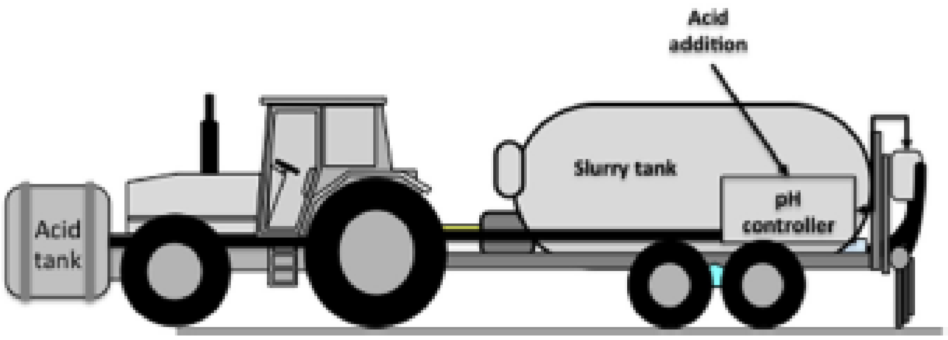

Figure 1. Acidification of slurry during spreading. Sulfuric acid is transported in special secured containers and mixed with the slurry at the end of the tanker (Fangueiro *et al.*, 2015).

In this experiment the Danish Syre-N system was described to farmers. It is particularly safe due to the use of a non-drip coupling, which ensures a fast and drip-free exchange of the IBC - acid containers (IBC Immediate Bulk Container). Furthermore, the dosing of the acid in the mixer is automatically controlled by a computer program, therefore no intervention by the farmer is required and there is no contact with the acid (Sindhöj and Mazur, 2017). Another advantage of using these mixing devices is that micronutrients or odor-reducing compounds such as iron sulphates can be added during acidification (Tamm *et al.*, 2013). A disadvantage of the usage of the technique is that special regulations have to be fulfilled due to the handling of the hazardous substance sulphuric acid. These regulations can increase the costs of the processes. So far drivers a required to have a license to transport dangerous goods, as the acid is subject to the ADR conventions (Kupper, 2017).

The following emission abatements are achieved: VERA (Verification of environmental technologies for agriculture) determines a reduction of 49% for the Syre-N system on grassland compared to conventional trailing hose application (VERA, 2012).

But the reduction of emissions varies: The extent to which they are reduced depends on the amount of acid used, the temperature and the crop. On grassland greater reductions can be achieved (- 22%) than on land cultivated with cereals (- 12%) if 1.5-3 l of acid per ton of cattle slurry are used. With an increased amount of acid (3.5-5 l per ton) emission abatement increases and 44% lower emissions on grassland and 26% lower emissions in cereals are determined (Nyord, 2016). In these experiments slurry acidification is compared to trialing hose application as well.

These emission reduction results in an improved fertilizer efficiency. Assuming an abatement of 50 %, experiments have shown that approx. 14 kg/ha more N is available in cereals. Overall crops a possible improvement of the mineral fertilizer equivalent by nine units per hectare is assumed (Birkmose and Vestergaard, 2013). Moreover, fertilizer planning becomes easier, because the nitrogen content is more stable (Vestergaard, 2015). In addition to the nitrogen supply, the process also influences the sulphur supply (S), since sulphuric acid (H_2SO_4) is mainly used for manure acidification (Tamm *et al.*, 2013). But, depending on the requirements of the crop, an oversupply is possible. If it occurs, depends on the concentration of acid, the amount of fertilizer applied and the number of times acidified slurry is spread during the year (Birkmose, 2016). Still the effect of sulphur on the environment is considered to be low and there are no disadvantages for the plant (Eriksen *et al.*, 2008).

In comparison with other methods of slurry application, acidification seems to be competitive. This is illustrated for example in Seidel *et al.*, (2017). They find a reduction of emissions by 42 % both during injection and acidification to a pH value of 6.5. An advantage of acidification compared to other emission-reducing application methods such as direct incorporation or injection is that it can also be applied to already grown crops such as winter cereals (Bull, 2016). In addition, acidification and application with the trailing hose eliminates disadvantages of injection methods. These are a high fuel consumption, a high wear-off of discs and wheels and the separation of roots by the injection device which results in lower yields (Webb *et al.*, 2010). Moreover, injection methods are only possible on light, stone-free, load-bearing grassland sites and allow a narrow working width (Bussink *et al.*, 1994). A disadvantage of acidification and an application with the trailing hose compared to injection is the increased contamination of grassland, which can lead to a later harvest or grazing date (Neser *et al.*, 2010).

2.2 Additional costs and existing political support schemes

Acidification during spreading is usually carried out by a contractor (Birkmose and Vestergaard, 2013). The investment sum for the acidification technology without a tanker is approximately 65,000 € for the acidification system alone, which can also be installed on existing application technology. If the technology of a contractor is used, the farmers are charged approx. 0.55 € /m^3 for the use of the acidification technology (front unit). In addition, costs for spreading and the costs for the sulphuric acid occur. On average 1.5 l H_2SO_4 /m^3 are used at a price of approx. 0.35 €/l H_2SO_4. Thus, the additional costs in total are expected to be 1.08 €/m³ higher than the costs for spreading without acidification (Tamm *et al.*, 2013).

In the SEGES Report comparable costs between 27 €/ha and 49 €/ha are assumed, this corresponds to costs between 0.90 €/m³ and 1.63 €/m³, if an application quantity of 30 m³/ha is assumed. The variation of the costs in the report is explained by different acid input quantities (Vestergaard, 2015).If residues of biogas plants are spread even higher acid quantities are necessary, they are treated with 4 - 5l H_2SO_4/m³, as the higher CO_2 content increases the buffer capacity of the raw material and the dry matter content is higher (Vestergaard, 2015).

Theoretically, the use of sulphuric acid results in a higher lime requirement in order to maintain the approximately neutral pH value of the soil. Petersen and Eriksen (2016) estimate an additional lime requirement of 153 kg $CaCO_3$/ha if cattle slurry is used, for pig slurry 122 kg $CaCO_3$/ha.

An important detail the SEGES report points out is that the current fertiliser ordinance must be considered in the evaluation of costs. The procedure only leads to increased yields in countries where fertilisation is required to be below the economic optimum, such as Denmark, but the additional nitrogen contained in the manure is not considered. In countries where fertilization is applied at the economic optimum, only savings due to the lower purchase of nitrogen and sulphur can be considered. As a result, the technique is cost-covering in Denmark because of the additional yields; in countries with less restrictive fertiliser regulations, the amount of mineral fertiliser saved may not be enough to cover the additional costs (Vestergaard, 2015).

In total, around 20% of the cattle and pig manure produced in Denmark is acidified (Peters, 2016). A reason for this is that the use of slurry acidification is politically encouraged. In Denmark farmers don't need to consider the extra amount of nitrogen contained in the acidified slurry. Therefore, farmers can expect higher yields if the technique is used, as explained above (Ravnborg, 2016). Farmers are also provided with simplified legal requirements for the application of acidified slurry. If they spread acidified slurry no injection method needs to be used. Otherwise, these are mandatory on uncultivated fields or grassland (Lyngso, 2016; Danish Parliament, 2012). In order to further promote the usage of the technique, investment in acidification systems are encouraged. The purchase of the acidification systems are supported with up to 40% of the investment costs (Kupper, 2017).

The usage of techniques that lower emissions is also supported in Germany. For example, a political promotion program in the state Schleswig-Holstein subsidized the use of the drag shoe method with 80 €/ha if the spreading was carried out by a contractor and stricter requirements for storage and spreading times were accepted (Blunk, 2016).

3 Methodology

3.1 Behavioral assumptions and model

Discrete Choice Experiments are widely used to elicit information about consumers' or farmers' preferences on hypothetical markets. In the context of agricultural production, the approach assumes that farmers seek to maximize their utility (utility maximization theory), that utility is abstractly measurable in experiments (random utility theory) and that the utility that arises in each choice alternative is determined by the alternative's attributes (characteristics theory of value).

These assumptions are formalized in the following model by Train (2003). Each decision maker (n) chooses from j alternatives his or her most preferred alternative. From each alternative a non-observable level of utility arises (U_{nj}). Because of these non-observable aspects, researchers can only estimate the observable part of utility (V_{nj}), the non-observable aspects are captured in the error term (ε_{nj}). The observable part of utility depends on the attributes of the alternatives and the characteristics of the decision-maker.

$$U_{ni} = V_{ni} + \varepsilon_{ni} \qquad 2.1.1$$

The probability of choosing alternative i depends on the probability that the alternative provides the highest utility of all alternatives presented:

$$P_{ni} = Prob\ (U_{ni} > U_{nj} \qquad \forall\ j \neq i) \qquad 2.1.2$$

$$= Prob\ (V_{ni} + \varepsilon_{ni} > V_{nj} + \varepsilon_{nj} \qquad \forall\ j \neq i) \qquad 2.1.3$$

$$= Prob\ (V_{ni} - V_{nj} > \varepsilon_{nj} - \varepsilon_{ni} \qquad \forall\ j \neq i) \qquad 2.1.4$$

The utility arising to the decision-maker by each alternative is an additive function. How much utility each attribute contributes is shown by the estimators *ß* (Ausprug and Liebe, 2011).

$$U_{ni} = V(X_{ni}) + \varepsilon_{ni} = ß_i + ß_n X_{in} + \varepsilon_{ni} \qquad 2.1.5$$

For the estimation, a mixed logit model is used. It solves limitations of the standard logit model and allows for random taste variations, unrestricted substation patterns and the IIA (Independence of irrelevant alternatives assumption) does not need to be met. In mixed logit models, the *ß* coefficients for each individual and their distributions (d(ß|θ) are estimated. Therefore, the model is solved via simulation. The choice probabilities of the alternatives result from an integration of the standard logit probabilities:

$$P_{ni} = \int L_{ni}(ß) d(ß|\theta) \qquad 2.1.6$$

Where:

$$L_{ni} = \int (\frac{e^{ß\prime xni}}{\sum e^{ß\prime xnj}}) \quad 2.1.7$$

3.2 Hypotheses

The following hypotheses about farmers' acceptance of slurry acidification during spreading are examined in this article. The first four hypotheses refer to the attributes used in the choice sets:

It is assumed that a higher expected ammonia emission abatement increases farmers' willingness to participate in support schemes. On the one hand, more nitrogen remains in the slurry, which leads to lower costs of mineral fertiliser purchases. On the other hand, it is possible that farmers themselves value environmental protection (Hypothesis 1). It is also expected that a higher cost share offered has a positive effect on the acceptance of the support scheme. Especially in case of a refund of costs of more than 100 % additional revenues are generated by the nitrogen saved (Hypothesis 2). In contrast, if a higher nitrogen load factor is required to be considered in the calculation of fertiliser plans, the acceptance of the technique will decline. This is, because farmers reach the limit of a maximum of 170 kg N/ha from organic fertilisers per hectare earlier and therefore might need more farmland for spreading (German Fertiliser Ordiniance, 2017) (Hypothesis 3). Currently, according to the German Fertilizer Ordinance, at least 50 % of the nitrogen (N) contained in cattle slurry and Biogas plant residues and 60 % of the nitrogen contained in pig slurry must be considered in a farmer’s fertiliser plan (Annex 3 - Fertiliser Ordinance, 2017). The last attribute in the Choice sets is a relief on the fertilizer Ordinance. It is assumed, that if the political bonus is offered that direct incorporation is not necessary, the acceptance of the method increases, because the farmer saves the costs of incorporation (Hypothesis 4). Otherwise, direct incorporation must be carried out within four hours on uncultivated farmland (German Fertilizer Ordinance, 2017).

In terms of farmers’ and farms’ characteristics: It is assumed that larger farms are more likely to take part in political promotion schemes than smaller ones. A reason for this is that larger companies are under greater social pressure to use more environmentally friendly techniques (Magyla, 2017) (Hypothesis 5). In terms of management practices, it is assumed that organic farms are more likely to choose to participate than conventional farms. They are only allowed to use organic nitrogen fertilisers and may therefore have a greater interest in reducing emissions and increasing the nitrogen content of slurry (Hypothesis 6). The same applies to farms that already use an N-sensor. They may be more likely to use manure acidification, because they have a greater awareness of environmental protection or have identified cost saving potential through better fertiliser management (Hypothesis 7). It is also assumed that farmers who pay contractors for slurry spreading are more likely to participate in support schemes. Farmers who spread slurry themselves might not be able to invest in the technology, since own investment in acidification technique is only recommended if large quantities of slurry are produced (Hypothesis 8).

For farmers who had problems in the past with maintaining the nitrogen balance of 60 kg N/ha (German Fertilizer Ordiniance, 2017), a higher willingness to participate is assumed. Acidification improved efficiency and makes it possible to save mineral fertiliser and reduce the balance (Bull, 2016) (Hypothesis 9a). On the other hand, the nitrogen surpluses above 60 kg N/ha in the past could also lead to a negative attitude, as too much fertiliser already seems to be present and even more nitrogen is available when using the technique (Hypothesis 9b). In Germany farmers are only allowed to cause 60 kg N/ha surpluses. Farms with a small area of land in relation to the number of animals may refuse the technique for the same reason (commercial livestock farmers). This is because slurry with a higher nitrogen content may require more land for application, because they are only allowed to spread 170 kg N/ha from organic sources (Hypothesis 10). For farmers already exporting slurry to regions with more crop production a lower willingness to accept is expected, as this indicated fertilizer surpluses as well (Hypothesis 11). Considering farming types, lower acceptance is expected for farmers with grazing livestock. In comparison to injection, the trailing hose causes a higher contamination of grassland (Neser *et al.*, 2010) (Hypothesis 12). In terms of personal characteristics, it is expected that farmers with higher education are more likely to participate in the support programs. For example, Boehlje (1992) describes a greater willingness to use technical innovations if farmers are higher educated (Hypothesis 13). In addition, other studies about farmers' acceptance of innovations show that younger farm managers are more willing to use new technologies (Breustedt *et al.*, 2008) (Hypothesis 14). Furthermore, studies have shown that a farm succession has a positive influence on the willingness of farmers to use innovations. This is also assumed to apply for slurry acidification (Breustedt *et al.*, 2008) (Hypothesis 15).

3.3 The experimental design

The questionnaires used start with a description of the technique and it's advantages and disadvantages. Afterwards, the attributes in table 1 were presented to the participants.

Table 1. Attributes and levels used in the choice sets. The level for the option out (no participation) are shown in bold.

Attributes	Levels
Ammonia emission reduction	**0 %,** 20 %, 40 %, 60 %
Cost share in % of direct costs	**0 %,** 60 %, 80 %, 100 %, 120 %
Nitrogen accounting factor[1)]	**+ 0 %-points**, + 5 %-points, + 10 %-points, + 15 %-points*
Reliefs of the fertilizer ordinance	**No relief**, no direct incorporation

* Factor by which the amount of nitrogen in organic fertilizers must be accounted for in a farmers' fertilizer plan

The first characteristic is ammonia emission abatement that is achieved by using the technique. In the political promotion schemes for slurry acidification, the levels vary between 20 %, 40 % and 60 %. The variation is explained by the influence of temperature, pH value, type of slurry and the crop were acidified slurry is spread. The second characteristic is the refund of additional costs in percent. In the acidification promotion schemes, the levels vary between 60 %, 80 %, 100 % and 120 %. Possible savings of mineral fertilizers or additional yields are not considered. A refund of 120% is offered to compensate farmers for familiarizing themselves with the technology and the costs of application for the program. The third attribute is the amount of nitrogen that must be considered in a farmers' fertilizer planning. In the Choice Sets, these quantities increase by 0 %-points, 5 %-points, 10 %-points or 15 %-points. The fourth attribute is a relief from the existing fertiliser ordinance. In some alternatives, it is offered that direct incorporation is not necessary if acidified slurry is spread. In each Choice Set four alternatives are offered, three alternatives are political support schemes of slurry acidification, the fourth attribute is the status quo. This fourth alternative is called Option Out and must be given, otherwise biased results would be obtained (Huenchuleo and Schröder, 2012). As an example, figure 2 shows one of the Choice Sets used.

	Alternative 1	Alternative 2	Alternative 3	Alternative 4 – no support scheme
Emission reduction	40%	20 %	60 %	0 %
Refund of additional expenses in %	60%	100 %	80 %	0 %
Increase in the nitrogen accounting factor	5 % - points	+ 10 % - points	+ 0 % - points	50 % cattle slurry 60 % pig slurry **+ 0%-points**
Reliefs on fertilizer ordinance	No direct incorporation	Direct incorporation	Direct incorporation	Direct incorporation
I choose:	☐	☐	☐	☐

Figure 2. Example of a choice card used the online questionnaire.

The design of the choice sets is D-efficient and was determined using *decreate* in *Stata*. The quality of the selected design can be described by the D-efficiency (Kuhfeldt, 2010). For the questionnaire used, two blocks were identified, each containing eight choice sets. The determined D-efficiency of the questionnaire is 94 %.

4 Results

4.1 Sample Description

The survey was conducted on the *Unipark* website. The survey was promoted through a variety of channels: Email distribution lists of the Water Protection Association, the Chambers of Agriculture of Schleswig-Holstein and Mecklenburg-Vorpommern and a livestock marketing cooperative were used. In addition, a contracting company, two agricultural journals and farmers' associations advertised online. The participants could take part between December 2017 and March 2018. During this period 130 full-time farmers answered the questionnaire completely. The descriptive statistics of the sample are shown in table 2.

Table 2. Descriptive statistics of respondents

	Mean	Standard-Deviation	Explanation
Age	38.580	11.711	Age of the farmer in years
Education	0.923	0.267	Participant has got an agricultural education (Dummy)
Successor	0.354	0.478	There is a successor (Dummy)
Commercial	0.1	0.300	Animals are kept commercially (Dummy)
Arable land	218.692	430.097	Hectares of land cultivated
Grassland	47.415	70.172	Grassland in ha
Hogs	928.285	1619.247	Livestock places for pig fattening
Sows	67.292	197.153	Livestock places for sows
Dairy cows	89.931	201.736	Livestock places for dairy cows
Beef cattle	36.3	121.021	Livestock places for beef production
Pasture grazing	0.315	0.465	Cows fed through pasture grazing (Dummy)
Organic	0.023	0.150	Farm is organic (Dummy)
Export	0.177	0.382	Farm sells slurry to crop farming areas (Dummy)
N-Balance	0.154	0.361	Farm exceeded nitrogen balance of 60 kg N surpluses in the past (Dummy)
Technique	0.7	0.458	Techniques to reduce N-surpluses is used such as N-sensors (Dummy)
Biogas	0.331	0.471	Farmer owns a biogas production plant (Dummy)
Contractor	0.462	0.499	Slurry is spread by contractors (Dummy)

The average respondent is 39 years old and manages about 219 hectares of arable land and 47 hectares of grassland. In addition, 928 hogs and 90 dairy cows are held. 31.5% of farmers also practice grazing. The proportion of pig and cattle holdings is about the same in the sample. 10 % of the participants are engaged in both agricultural and commercial animal husbandry. Most of the farms operate conventionally (98 %).

The following technology is available on the farms; about 33% operate a biogas plant and on 70% of farms use emission-reducing technology. Regarding the fertilizer ordinance, 15 % have had problems to keep the nitrogen balance in the past. The personal characteristics show that about 36 % of the farms will be continued, 3 % are certain that there will be no succession, the majority is uncertain about the farm's future. Almost all participants have an agricultural education. In most cases they are certified farmers (57 %) or have a university degree (34 %). Most participants are from Lower Saxony (28.46 %), Schleswig-Holstein (16.92 %), Bavaria (10.77 %) and North Rhine-Westphalia (12.31 %).

4.2 Estimation and Results

Stata 13 was used for the estimation of the data. Before the model was estimated a test for linearity was performed for the attributes expected ammonia emission reduction, cost share in % and increase in nitrogen load factor that must be considered in a farmers' fertilizer planning. The H0 hypotheses of a linear influence on utility is rejected for emission reduction. Therefore, the levels of the attribute enter the estimation as dummies (Hensher *et al.*, 2015; UCLA, 2019).

To determine the acceptance of slurry acidification techniques during spreading, 1040 completed choice sets were analyzed. Based on the likelihood ratio test, it was determined that the variable "Contractor partly" can be left out of the model. The selected model is shown in table 4. The pseudo R^2 is 0.366. The predicted probability to choose a political promotion scheme is 89,07%. It is shown by the significant estimators, that that an increasing emission reduction as well as a higher refund of costs are positive for acceptance. Therefore, the first two hypotheses can be confirmed. However, only the high levels of emission reduction of 40% and 60% show a significant influence. According to the third hypothesis, an increase of the amount of nitrogen that must be considered in a farmers' fertilizer plan has a negative effect on acceptance. This hypothesis is confirmed as well, since a negative estimator is estimated. The last hypothesis that relates to the attributes of the choice sets is that the relief that acidified slurry doesn't have to be incorporated directly has a positive effect on acceptance. This hypothesis is confirmed, too.

The other hypotheses relate to the participants and their farms: It is assumed that larger farms are more likely to use the method than smaller ones. If farm size is determined by hectares of land no effect is found. Considering herd size larger dairy and bull keepers show higher acceptance. Only if participants are in pasture grazing lower acceptance is found. In comparison, sow farmers reject the technique; the estimator is significantly negative. Regarding current fertilizer use no higher or lower probability is found for farmers who exceed the nitrogen balance or those already exporting slurry to crop farming regions. Furthermore, the use of the N-sensor and commercial livestock production are not influential which is contrary to the initial hypotheses. Moreover, it is noticeable that a strong negative influence of the characteristic "biogas plant" is found, even though the reason remains unclear in the hypotheses. If personal characteristics are considered older respondents are more willing to participate than younger ones. This is contrary to our assumptions. Furthermore, farmers with a better education are more likely to use slurry acidification.

Table 4. Factors affecting farmer's decision to participate in a stylized slurry acidification support scheme.

Variable	Coefficents (p-Value)	Marginal Effects	Willingness to Accept
	Farmer and Farm Characteristics		
Age > 35 years	2.660*** (0.000)	0.2059207	-98.216689
Agricultural education	1.603** (0.043)	0.1323042	-59.2031
Organic	24.920 (0.999)	0.735099	-920.2978
Contractor	-0.657 (0.282)	-0.052039	24.27552
Cultivated area (farm land and grassland)	0.003 (0.136)	0.0002674	-0.120150
Livestockunits per Hectare	0.425 (0.336)	0.0324668	-15.700648
Sows	-0.006*** (0.009)	-0.0004276	0.20596872
Hogs	-0.0001 (0.656)	-0.00000871	0.0040233
Dairy Cows	0.007* (0.091)	0.0005684	-0.2613953
Beef cattle	0.008** (0.022)	0.0006444	-0.29502122
Biogas	-4.483*** (0.000)	-0.2603471	165.55356
Pasture grazing	-4.90816***(0.000)	-0.2803401	181.25604
Balance	-0.157 (0.862)	-0.0124529	5.791406
Technique	0.470 (0.514)	0.0374374	-17.37520
Export	0.379 (0.696)	0.0309979	-14.010398
Commercial	-1.858 (0.111)	-0.1280745	68.604175
Successor	-0.705 (0.368)	-0.0550343	26.04285
	Policy Design Variables		
Ammonia emission reduction 20 %	0.932 (0.435)	0.0816656	-34.414955
Ammonia emission reduction 40 %	1.939* (0.090)	0.1579043	-71.605722
Ammonia emission reduction 60 %	2.506** (0.030)	0.215457	-92.53804
Cost share offered in %	0.027*** (0.000)	0.00192	-
Increase in the nitrogen accounting factor	-0.108*** (0.000)	-0.0042473	3.9895781
Reliefs on fertilizer ordinance	0.824*** (0.000)	0.0728552	-30.440323

Level of significance: * p<0,1; ** p<0,05; *** p<0,01

The strength of the influence of the attributes is shown by the marginal effects. An increase in the refund of additional costs by one percentage point increases the willingness to participate by 0.19 %-points. An increase of the nitrogen load factor that must be considered in a farmers' fertilizer plan reduces the willingness to participate stronger, namely by 0.42 %-points. The other characteristics in the Choice Sets are included as dummies and are more difficult to relate to. A larger expected emission reduction of 40 % increases the willingness to participate by 16 %-points, if a reduction of 60 % is expected, it increases acceptance by 22 % points compared to no emission reduction. By comparing the effects to those of a relief on direct incorporation, which increases acceptance by 7 %-points, it is shown, that emission reduction is more important to farmers.

The willingness to accept can be derived from the marginal effects. It shows how much of the cost share offered a farmer is willing to give up for an attribute that is positive for acceptance and how much more compensation is expected for an attribute that is viewed negatively. If farmers can assume a high emission reduction of 40 %, they would give up 72 %-points of refund of expenses. With a reduction of 60 % they would even give up 92 %-points. If, on the other hand, the amount of nitrogen that must be considered in a farmers' fertilizer plans increases by 1 %-point, they expect a 4 %-points higher refund of costs in order to show the same probability to participate. In case a relief of direct incorporation is offered, refunds could be 30 %-lower.

5 Discussion and Conclusions

The aim of this article is to determine the acceptance of farmers to use slurry acidification on fields. A large part of the participants chose to join a support scheme (89 %). A possible explanation for this high willingness to participate could be the high cost share (100 and 120 %) offered. Furthermore, farmers did not have to commit themselves to using the technique every time. This means that farmers had the opportunity to try out the technique and stay flexible. Flexibility is mentioned in a survey of farmers as a decisive factor when it comes to the willingness to participate in policy schemes that increase biodiversity (Joormann and Schmidt, 2017). Furthermore, it does not make sense to use the technique permanently. Slurry Acidification is useful if high emissions are expected due to weather conditions and other methods can no longer be used, such as direct incorporation on grassland or already grown agricultural crops. In addition, farmers should be enabled to weigh up the different advantages and disadvantages of f.e. injection and acidification (Seidel *et al.*, 2017).

Regarding possible support schemes: All characteristics used in the choice sets show a significant influence and the expected signs. In summary a higher refund of expenses, a higher reduction of emissions and a discount on the fertiliser ordinance are positive for acceptance. And, as expected, an increase in the nitrogen load factor that must be considered in fertilizer calculation lowers acceptance.

Since farmers face additional costs through slurry acidification, which will probably not be covered by additional yields or savings on mineral fertilizers (Vestergaard, 2015), a refund of the additional costs in % was offered. Schulz *et al.* (2014) and Breustedt *et al.* (2013) also find a high significance of financial support for the acceptance of second-pillar-type agricultural environmental schemes in Schleswig-Holstein and for the acceptance of provisions of "greening".

Furthermore, a political support scheme of slurry acidification would be competitive with existing subsidy programs in terms of costs: A full refund of expenses would cost 30 € / ha, if costs of approx. 1 €/m³ and an application quantity of 30 m³/ha are assumed. The subsidy would be more favorable than the subsidy of 80 € / ha that was offered in 2016 for injection and drag shoe procedures in Schleswig-Holstein (Blunk, 2016) and a subsidy for these procedures in Lower Saxony where 40 € / ha were paid (Ministry of Food, Agriculture and Consumer Protection of Lower Saxony, 2016). It is noteworthy, that a high expected emission reduction is a great motivator for farmers. For this reason, we assume that an intrinsic motivation of farmers to reduce emissions could exist. Furthermore, these results indicate that an information campaign might be a good way to gain participants with lower refunds.

Moreover, the offer of a relief of direct incorporation of slurry is beneficial for the acceptance of support schemes and might allow lower refunds. However, it is necessary to determine under German conditions which technique is preferable in terms of emission reduction on uncultivated land direct incorporation or acidification. For environmental reason the relief might only be possible if acidification reduces emissions at least as much as direct incorporation does.

In contrast to the first three characteristics, an increase in the amount of nitrogen that a farmer needs to consider in his fertilizer planning reduces the willingness to participate. Breustedt *et al.,* (2013) also find a negative influence of the tightening of existing management rules. Nevertheless, the nitrogen load factor that must be considered still offer scope to create incentives for the use of the technique. This is because a lower crediting of the additionally available nitrogen in acidified slurry result in higher yields, especially if fertilisation is below the optimum level as in Denmark (Ravnborg, 2016; Vestergaard, 2015). Therefore, this could be a major incentive in the "red areas" in Germany. They were established in 2019 and fertilisation in these areas must be 20 % below optimum (Chamber of Agriculture Lower Saxony, 2019; Mayer, 2019). However, it also has to be examined, if this is compatible with the required improvement of water quality.

Regarding a target group for the support scheme, few personal and farm characteristics are important. It is noticeable that indicators for fertilizer surpluses such as an exceed of the nitrogen balance or exporting slurry to crop farming regions are not of importance. A reason could be that there is a general interest of farmers in improving the efficiency of organic fertilizers. Still results indicate, that farms with grazing livestock or biogas plants may be less interested in participating. More suitable participants might be larger cattle farms, older farmers and those with higher education in the agricultural sector

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