Danish farmers' perception of water quality, nutrient reduction measures and their implementation strategy

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Abstract

Implementation of voluntary nutrient reduction technologies among Danish farms is relatively low despite the introduction of a number of incentives on such technologies. With data from 267 farmers, this study analyzed the level of uptake of these technologies and the farmers' perception of water quality, existing regulatory measures and their implementation strategies. In general, farmers perceived; the water quality to be above average and indicated a strong non-support for penalties on non-compliance. Results of two ordered probit models on adoption and perception showed a significant importance of factors such as farm and soil types, farm size and slopes and information availability. These findings give a direction to policy makers and other stakeholders on the need to increase information dissemination on; water quality requirements both at national and regional levels and availability and procedures of financial, technical and institutional support for the existing and future incentives. Ultimately, tailor-made incentives could be designed based on farm structure and physical characteristics so as to improve the pace of adoption of the technologies thereby reducing water pollution from farms substantially.
Keywords: agricultural water pollution, Denmark, agri-environmental measures, recipient water bodies, ordered probit.

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1 Introduction

1.1 Nutrient reduction plans

For over the last 25 years, Denmark has implemented different approaches towards reduction of nitrogen and phosphorous discharges from agricultural farms. These initiatives range from the initial Action Plan for Aquatic Environment (APAE) in 1987 to the broader Green Growth Agreement (GGA) in 2009. The initiatives have mainly been implemented in a territorial approach as opposed to the designation of vulnerable zones adopted in other EU countries [1], with former initiatives being compulsory most of the latter initiatives being voluntary. The first APEA, effective in 1987 was followed shortly by APAE II, which was effected in 1998 with an aim of reducing Nitrogen and Phosphorus losses to aquatic environment by 50% and 80% respectively. The third APAE became effective in 2004 targeting further N and P reduction by 13% and 50%, respectively by 2015.

In 2009, the GGA (2009–2015) was launched. This was aimed at integrating activities in the implementation of the Water Framework Directive, dealing with the problems encountered in APAE III and ensuring a balance between nature, environment and agricultural development. The targets under the GGA are reduction of 19,000 tonnes of nitrogen to coastal water and 210 tonnes of phosphorous [2].

The initiatives under the GGA include government-supported interventions on biogas production, perennial crop production, organic production and implementation of wetlands. However, the compulsory nutrients pollution reduction measures developed in the previous action plans are still effective. Despite the incentives given under the GGA, the adoption and implementation of the proposed measures has been relatively low [3–5] a phenomenon worth investigation.

In the current Danish context, constructed wetlands are seen as a more targeted and cost effective option in the reduction of N and P pollution from agricultural fields [6]. Consequently, given the expected level of the technology’s potential and the projected capacity of one hectare of wetland to remove 480–1380 Kg N per year [7] this measure if properly implemented could effectively reduce agricultural non-point water pollution. To establish the best strategy that policy makers could adopt in the implementation of constructed wetlands as a nutrient reduction measure, it is paramount to first establish the farmers’ level of adoption of voluntary technologies, their attitudes and perception on the current surface water quality, the perceived impacts of the existing regulatory nutrients mitigation measures and their preferred mode of implementation of the pollution reduction measures. The objective of this paper is to investigate the four aspects and assess the relations among them.

1.2 Previous studies and conceptual model

Studies on farmers’ perception of water quality and pollution reduction measures and adoption of associated BMPs have been conducted over the last few decades with most of these studies conducted in the US [8–11]. Bratt [12], analyzes the Swedish farmers' choices for management practices aimed at reducing nutrient pollution at a catchment level, while Sang [13], studies farmers' preference for catchment management practices in Scotland. These two studies have focused on catchment level analysis whereas others have primarily targeted areas designated as Nitrate Vulnerable Zones (NVZs) [14, 15].

In Denmark, only a few studies on farmers' perceptions on water quality and pollution reduction measures have been conducted [1, 16, 17]. Although the first study deals with a broader issue, producers' perspectives are not clearly captured since farmers do not form part of the respondents. The other two studies incorporate the farmers' perspectives but cover a single locality and pesticide pollution respectively. The current study however focuses on nutrients pollution and targets farmers within different catchment areas.

Different approaches have been used in perception and adoption studies. Adoptions of conservation technologies have mainly been based on the initial work of Ervin and Ervin [18], and Just and Zilberman [19], which base adoption on the expected utility. More studies have followed over the years and summaries of factors influencing adoption reported by Kabii and Horwitz [20] and Knowler and Bradshaw [21]. Behavioural approaches based on the theory of reasoned action and theory of planned behaviour [22, 23] have also been employed in many studies [24]. The current study follows the conceptual framework on the decision making process in the adoption of agricultural technologies [18]. The framework covers both adoption and perception aspects.

2 Materials and methods

2.1 Data

The survey data was collected between March and June 2013 among Danish farmers in Funen, Jutland and Zealand using an online questionnaire. A total of 626 farmers accessed the questionnaire link and responses were received from 368 farmers of which 267 were dully completed.

Utilizing complete cases data, the analysis was conducted in two stages; Initial descriptive analysis of the general respondents' perception on water quality, attitudes on effects of pollution reduction measures and the preferred mode of nutrients mitigation measures implementation strategies. Secondly, the factors influencing the farmers' adoption of voluntary nutrient reduction measures and their perception of water quality were analyzed by fitting the models presented under the model specification section.

2.2 Model specification

Two sets of equations are specified to represent the perception and the adoption stages. It is anticipated that the formation of farmers perception might be been influenced by their level of adoption of voluntary technologies. Farmers with voluntary implemented technologies would therefore be expected to perceive the water quality being high and vice versa. The equations representing the current adoption

$$Y_{1i}^{*} = \sum \beta_j X_{ji} + \varepsilon_{1i}, \qquad i = 1,2 \ldots\ldots n \tag{1}$$

and perception

$$Y_{2i}^{*} = \sum \beta_j X_{ji} + Y_i^{*} \; Y_i + \varepsilon_{2i}, \qquad i = 1,2 \ldots\ldots n \tag{2}$$

where Y_{1i}^{*} and Y_{2i}^{*} are unobserved but what we observe is a form of censoring such that

$$Y_j \begin{cases} 0 \text{ if } Y_{ji}^{*} \leq \mu_{j1} \\ 1 \text{ if } \mu_{11} < Y_{ji}^{*} \leq \mu_{j2}, \\ \ldots\ldots\ldots\ldots \\ j \text{ if } \mu_{jj} < Y_{ji}^{*} \end{cases} \tag{3}$$

X'_{ji}'s are vectors of the observed explanatory variables, β_j 's are the parameters to be estimated corresponding to the X 's, ε_{1i} and ε_{2i} are error terms (assumed to be normally distributed, N (0,1)) , the μ's are the unknown threshold parameters and Y_i^{*} Y_i are the predicted probabilities obtained from the adoption model estimation [25].

The first equation is specified as an ordered probit with the dependent variable (Techadopt). This variable takes three possible values indicating the number of voluntary technologies already adopted by the farmer such that: 0 = none, 1 = one, 2 = more than one.

The second equation is also estimated as specified as an ordered probit with the dependent variable "perceived water quality" (Wqltypercp) taking 4 possible in an ordinal format; 1 = low, 2 = moderate, 3 = good and 4 = very good. Due to the low frequency of "none" and "low" categories in the original dataset, the observations in the two groups are aggregated to "low" category). The choice of independent variables is based on the perception and adoption literature and are broadly classified into four; physical, personal and attitudinal, economic and institutional factors (Appendix 1).

3 Results and discussion

3.1 Descriptive results

The average age of the respondents in the study is 51years whereas the average farm size is 143 hectares. The average distance of the surveyed farms from their nearest recipient water bodies is 14 km with approximately 67% of the farms being within this distance. The sample statistics on the different farm types are in line with those of the population with over 90% of the respondents being involved in crop production. Organic and full time farmers accounts for 9% and 72% of the respondents respectively. On the soil types, approximately 50% of the respondents indicate having proportions of sand soils in their farms while 70%, 35% and 25%

indicate the presence of clayey-sand sandy-clay and heavy-clay soils, respectively. Medium farm slopes (6–12 degrees) are reported by majority of the respondents at 56%.

A summary on adoption and implementation of nutrients reduction technologies indicate a current employment of one or more technologies by 65% of the respondents. Natural wetlands, permanent grass cultivation and precision farming technologies are the most voluntarily adopted pollution reduction technologies whereas farmers with future plans to adopt precision agriculture, natural and constructed wetlands approximate 49%, 39% and 34% of the respondents, respectively.

3.2 Perception of water quality and effect of regulation removal

Based on the five likert point scale, 63% of the respondents perceive the water quality in the water bodies closest to their farms as being above average whereas a smaller percentage (3%) perceive the quality to be low (Table 1). Farmers' perceptions on the anticipated level of negative effect on water quality in the recipient water body in case the existing regulations on some of the farm activities were removed vary greatly. However, most of the farmers (over 50%) perceive the effect to be low or moderate in all the six scenarios presented to them as shown in Table 2. A relatively higher percentage of respondents (20%) indicate that removal of regulation on cover crops and winter crops could have a higher negative effect on the water quality.

Table 1: Perception of water quality in the nearest recipient water body.

Variable	Description	Frequency (%)				
		None	Low	Moderate	Good	Very good
Water quality	Perceived water quality in the nearest water body	5.99	3.37	27.34	36.33	26.97

Table 2: Perception of the effect of regulation removal on water quality.

Variable	Description: regulation removal on:-	Frequency (%)			
		None	Low	Moderate	High
Slurry	Manure/slurry separation, spreading and management	3.00	53.56	37.08	6.37
P-feed	Use of high phosphorous quantity in animal feeds	10.49	34.83	41.57	13.11
N-fertilizer	Use nitrogen fertilizers	7.49	57.30	32.21	3.00
Pesticides	Spraying of pesticides	4.49	53.56	33.33	8.61
wwcrop	Cultivation of winter crop/catch crops	4.87	37.08	38.20	19.85
animalU	Large animal units	5.99	37.45	48.69	7.87

Descriptive analysis of the farmers' subjective choice of strategies for the implementation of nutrients reduction measures shows the respondents being more supportive of the "voluntary", "subsidy" and "information dissemination" options at 76%, 55% and 67% respectively. A further comparison of respondents' level of support for implementation strategy with their current level of adoption of voluntary technologies shows respondents who have adopted at least one voluntary technology being largely in favour of “voluntary” and “information dissemination” strategies at 62% and 55% respectively. Likewise, 52% of these respondents indicate non-support for use of fines on non-compliance with the set pollution reduction regulations. The overall summary is presented in Table 3.

Table 3: Support/non-support for pollution mitigation implementation strategies.

Variable	Description	Frequency (%)		
	Level of support for:	No support	Indifferent	Support
Regulation	Fines and penalties for non-compliance	64.04	18.73	17.23
Zone	Specific rules for sensitive areas	22.10	35.21	42.70
Voluntary	Use of voluntary programs	7.49	16.85	75.66
Subsidy	Use of subsidies	13.86	31.09	55.06
Information	Information dissemination	7.49	25.47	67.04

3.3 Empirical results

The adoption of voluntary nutrients reduction technologies is significantly explained by the variables on farm slope, farmers’ age, farmers’ attitude on subsidy, farm size and farmers awareness of the existence of the constructed wetland funds. In the perception model, the physical factors are largely significant with all the variables under this classification being significant except for the distance variable. Overall, the significant variables in the perception model include soil types, farm slope, fulltime farm type and farmers’ subjective reception of information on good ecological status. All the significant variables in both models display the hypothesized direction in their relationship with the dependent variables. However, the predicted adoption variable, which was expected to significantly influence farmers’ perception on water quality has an insignificant effect on perception model. The empirical results showing the estimations’ coefficients and marginal effects are summarized in Tables 4 and 5.

Table 4: Results of the adoption model (ordered probit).

Variables	Coefficient	Std. Err.	Average marginal effects		
			$\Pr(Y_i=0)$	$\Pr(Y_i=1)$	$\Pr(Y_i=2)$
Mid-steep slope	0.293*	0.160	-0.099	0.027	0.071
Age	0.016**	0.008	-0.005	0.001	0.004
Farm size	0.003***	0.001	-0.001	0.000	0.001
Cw funds	-0.347**	0.156	0.114	-0.024	-0.090
μ_1	0.650	0.636			
μ_2	2.047	0.645			
No. of observations	267				
Log likelihood	-257.123				
LR χ^2 (26 d.f.)	41.44**				
R^2	0.075				

Table 5: Results of the perception model (ordered probit).

Variable	Coefficient	Std. Err.	Average marginal effects			
			$Pr(Y_i=1)$	$Pr(Y_i=2)$	$Pr(Y_i=3)$	$Pr(Y_i=4)$
Sand	-0.248*	0.149	0.037	0.047	-0.010	-0.074
Heavy-clay	0.289*	0.167	-0.039	-0.056	0.007	0.089
Mid-steep slope	-0.298*	0.175	0.039	0.060	-0.005	-0.094
Steep slope	-0.955***	0.286	0.185	0.1500	-0.092	-0.243
Farmtype3	-0.355*	0.184	0.048	0.068	-0.007	-0.110
GES info	0.407**	0.176	-0.054	-0.081	0.006	0.128
μ_1	-0.759	0.719				
μ_2	0.334	0.717				
μ_3	1.394	0.719				
No. of observations	267					
Log likelihood	-320.235					
LR χ^2 (26 d.f.)	52.44***					
R^2	0.076					

4 Discussion

Adoption of one or more voluntary agri-environmental technologies is seen to be highly related to farm size (Table 4). This corresponds to other adoption studies [26, 27] where farmers with larger farms are more likely to adopt technologies and schemes that may leave out part of the farms out of production. Older farmers are more likely to adopt more technologies, a finding which contrasts other adoption studies [26, 28]. These studies cite risks and costs as the main factor for low adoption among older farmers and younger farmers, respectively. The widely adopted technologies in this study (natural wetlands and permanent grass cultivation) could however be associated with low risks. Farmers with mid-steep sloped farms have a 0.071 probability of implementing more technologies compared to those with farms on a flat elevation. Unexpectedly, the farmers indicating unawareness of funds for construction of wetlands show a higher adoption rate. This could indicate a strong individual motivation in adoption of the technology, and could be supported through increased information dissemination of the existing incentives associated with adoption of agri-environmental technologies [9]. Additionally, respondents supporting use of subsidies as a strategy for implementing nutrient reduction measures are more likely to adopt more than two technologies by 0.099.

The results of perceived water quality in the descriptive analysis closely follow the reported quality of water in Danish coastal and inland bathing sites in 2012 [29] with only 3.1% of the sampled sites being rated poor. The perception of farmers on the would-be effect on water quality in the event that the regulations are relaxed also rhyme with previous studies in water quality management [11, 15]. The outcome of the perception model shows respondents with portions of sandy soil in their farms being less likely to perceive high water quality and vice-versa for respondents with farms with heavy-clay portions. These results are in line with Schjønning *et al.* [30], who report that clay content in the soil increases water infiltration into the soils thereby reducing the level of surface run-off. The analysis consequently shows farmers with mid-steep and steep sloped farms being more likely to perceive low water quality. The overall general significance of the physical factors in the perception model could be an implication of farmers' intrinsic awareness of the different soil properties and farm slopes and their influence on agricultural discharge movement and nutrients transportation through the runoff. This awareness could have further played a key role in forming their attitudes on water quality. Farm characteristics such as slope and soil type and structure have been cited as key factors contributing to diffuse water pollution [31].

The dummy variable for fulltime farmers indicates a negative relationship this variable and farmers perception of water quality. The full-time farmers could be innately aware of the intensity of their farming activities and the likelihood of such activities leading to pollution of water bodies by discharges from the farms.

The positive and significance variable on the variable farmers' subjective reception of information on good ecological status (GES) means farmers with information are more likely to perceiving the water quality being high. Unpredictably, only 30% of the respondents indicate having received this information. This is an indication of an information gap which could be as a result of centralized system in Denmark [32]. This calls for improvement of information dissemination processes [16].

The predicted variable on adoption of voluntary nutrient reduction technologies shows an insignificant relationship with perception. This difference with the priori may have resulted from the fact that some of the technologies adopted by the farmers have multiple benefits thus yielding different utilities to the adopters. Practicing precision farming is one such example where farmers may employ site specific fertilizer and pesticide applications thereby reducing the variable production costs in addition to reduction of excess nutrient that may end up in farm discharge.

5 Conclusions and policy implications

Understanding farmers' decisions on adoption of voluntary nutrients pollution mitigating technologies and their inherent attitudes and perceptions regarding water quality and the existing regulatory measures are key starting points to consider when designing and providing options for farmers to implement measures that reduce pollution from agricultural fields. This study has analyzed these aspects in the pursuit of identifying the critical aspects to be considered in the future design of implementing the constructed wetland measure among the Danish farmers.

The study finds that majority of the farmers perceive the quality of water in the fjords and lakes draining from their farms to be above average. Consequently, the farmers feel that changes that would lead to removal of the regulatory measures would have little or no impact in lowering the water quality. This perception may however be misinformed since majority of the farmers have not had access to full information on the underlying stipulations and requirements of "good ecological status" under the water framework directive. The study also finds that farmers have a general negative attitude towards regulatory nutrient reduction measures despite a relatively large number of these farmers having implemented voluntary environmental measures. Adoption of voluntary technologies is influenced by farmers' age and farm size among other factors. Additionally, other factors such as farm type, soil types, farm slope and awareness of GES requirements are seen to play a key role influencing farmers' perceptions and need to be fully considered in the implementation design of the more targeted pollution reduction measures.

To bridge the identified information gap, a collaborative effort between policy makers and the various stakeholders to decentralize information should be pursued. This will ensure a smooth and efficient flow of information thereby improving on measure compliance and water quality target achievements. Whereas the regulatory measures still remain in place, designing of tailor-made incentives based on farm structure and physical characteristics would greatly improve the pace of adoption of the technologies thereby reducing water pollution substantially.

Appendix 1: Description of variables (N = 267)

Dependant variables	Variable description	**Mean**	**Std. Dev.**	**Expected sign**	
				Techadopt	Wqltypercp
Techadopt	Voluntary technologies adoption level	0.899	0.850		
Wqltyperc	Perceived water quality	3.750	1.076		
Explanatory variables					
Exogenous water quality variables/physical factors					
Distance	If farm is located less than 14 km (average sample distance) from the nearest recipient water body (0=no, 1=yes)	0.374	0.485	+	+
Sand	Sandy soil type dummy (0=no, 1=yes)	0.494	0.501	+	-
Heavy-clay	Heavy clay soil type dummy (0=no, 1=yes)	0.259	0.439	-	+
Slope	Slope of respondent's farm: categorical variable (3 levels: 1=Flat, 2=Mid-steep, 3=Steep)	1.719	0.594	+/-	+/-
Fjord	Recipient water body closest to the respondents farm (1=Hjarbæk, 2=Kattagat, 3=Limfjorden,4=Mariager 5=Others)	3.382	1.129	+/-	na
Pipedrain	If the farm is drained through pipes (0=no, 1=yes)	0.813	0.391	+/-	na
Personal and attitudinal factors					
Age	Farmer's age (year)	51.430	10.005	+/-	+/-
Regulation	Farmers attitude on fines and penalties for non-compliance as a nutrient reduction strategy (3 categories: 1=Non-support, 2=Indifferent, 3=Support)	1.532	0.772	-	+/-
Subsidy	Farmers attitude on subsidy support as a nutrient reduction strategy (3 categories: 1=Non-support, 2=Indifferent, 3=Support)	2.411	0.722	+	+/-

Appendix 1 Continued.

Dependant variables	Variable description	Mean	Std. Dev.	Expected sign	
Voluntary	Farmers' attitude on voluntary option as a nutrient reduction strategy (3 categories; 1=Non-support, 2=Indifferent, 3=Support)	2.862	0.606	+	+/-
N fertilizer	Perceived effect on water quality if regulation on fertilizer usage is removed (1=none, 2=low, 3=moderate, 4=high)	2.307	0.651	na	+/-
Animal unit	Perceived effect on water quality if regulation on animal unit is removed (1=none, 2=low, 3=moderate, 4=high)	2.582	0.723	na	+/-
Economic factors					
Farm type 1	Farm types (1=crop, 2=crop/cattle, 3=crop/pig; 4=others)	2.207	0.944	+/-	na
Farm size	Size of the farm (hectares)	143.440	119.452	+	-
Farm type 3	Full time farm-type dummy (0=no, 1=yes)	0.723	0.448	-	+
Logtuover	Log of turnover averaged over farm-size	0.227	0.338	+	na
Institutional factors					
GES info	Subjective farmers reception of information on ecological status information (dummy: 0=no, 1=yes)	0.300	0.459	+	+
NP info	Subjective farmers reception of information on Nitrogen and Phosphorous reduction measures (dummy: 0=no, 1=yes)	0.333	0.472	+	+
Cw funds	Farmers awareness of the constructed wetlands funding	0.667	0.472	+/-	na

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