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# Adoption of voluntary water-pollution reduction technologies and water quality perception among Danish farmers

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ABSTRACT

The adoption of voluntary nutrient reduction technologies among Danish farmers is relatively low despite the introduction of a number of incentives to do so. With data from 267 farmers, this study analyzes the level of adoption of these technologies and the farmers' perception of water quality, existing regulatory measures and their implementation strategies. In general, farmers perceive the water quality to be above average and indicate a strong opposition to penalties for non-compliance. Results of two ordered probit models on adoption and perception show a significant importance of farm and soil types, farm size and slopes and information availability. These findings point to the need for increased information dissemination on water quality requirements both at national and regional levels and technical and institutional support for the existing and future incentives.

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## 1. Introduction

### 1.1. Nutrient reduction plans

For over 25 years, Denmark has implemented different approaches to the reduction of nitrogen and phosphorous discharges from agricultural farms. These initiatives, which range from the initial Action Plan for the Aquatic Environment (APAE) in 1987 to the broader Green Growth Agreement in 2009, have mainly been implemented using a national-wide approach as opposed to the designation of vulnerable zones adopted in other EU countries (Smith et al., 2007a). The first APAE, effective in 1987 was followed shortly by APAE II which was implemented in 1998 with the aim of reducing Nitrogen (N) and Phosphorus (P) losses to the aquatic environment by 50% and 80% respectively.

The third APAE became effective in 2004 and further targeted N and P reduction by 13% and 50%, respectively, by 2015. An evaluation of the plan in 2008 indicated that only an insignificant decrease in nitrate leaching had been achieved between 2003 and 2007, thus leading to the launch of the Green Growth Agreement (GGA, 2009–2015). The aim of GGA was to integrate activities aimed at implementing and achieving the requirements of the Water Framework Directive (WFD), deal with the problems encountered in APAE III as well as ensure a balance between nature, environment and agricultural development. The targets of the GGA are to reduce nitrogen and phosphorous leaching to coastal waters by 19,000 tonnes and 210 tonnes respectively (Danish Ministry of Environment, 2009).

The GGA, aims to ensure environmentally friendly agricultural production by e.g., ensuring sustainable use of resources, stimulating green energy production and promoting market based organic production. The implementation of these initiatives is largely through various government-funded interventions such as the promotion of biogas production, perennial crop production, organic production and the establishment of wetlands. In addition, the compulsory measures developed in the previous action plans are still effective. There are, however, a few exceptions if the producers adopt some of the measures proposed under the GGA although there are no clear guidelines on the exemptions. Table 1 summarizes the nutrient reduction measures in the Danish context (Balticdeal, 2011).

Despite the incentives given under the GGA, the adoption and implementation of the proposed measures has been relatively low. This aspect is clearly evident with over 90% of the Danish farms still practicing conventional farming (Statistics Denmark, 2014). Additionally fewer than 100 applications for the construction of biogas plants have been submitted for funding (Jacobsen et al., 2013), while the production of perennial energy crops currently stands at 4000 ha (Ministry of Food, Agriculture and Fisheries, 2008). The construction of wetlands is also very low with less than 20 wetlands covering approximately 130 ha being fully established (supremtech.dk). The area of wetlands is quite small compared to

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**Table 1**
Summary of nutrient reduction measures in Denmark.

| General Measure | Description of specific measures | Obligatory by law | Subsidized through agri-environmental scheme |
|---|---|---|---|
| Non-season plant cover | - Planting of cover crops in winter | √ | |
| | - Growing of Catch crop | √ | |
| | - Setting aside of buffer zones | √ | Future possibility |
| | - Cultivation of permanent grass | | √ |
| Tillage | - No tillage in Autumn before spring sown crops | √ | |
| Fertilization | - Compulsory fertilizer plans and accounts | √ | |
| | - Maximum Nitrogen quotas at farm level (calculation of quotas based on crops, soil types, etc., and minimum use of Nitrogen in animal manure) | √ | |
| Manure/slurry management | - Restrictions on application times and techniques for solid and liquid manure | √ (On bare soils and grasslands) | |
| | - Separation of liquid–solid manure/slurry | | √ |
| | - Acidification of manure/slurry | | √ |
| | - Establishment of manure/slurry storage facilities | √ | |
| | - Biogas production | | √ |
| Run-off water treatment | - Wetlands and sedimentation ponds | √ (in some regions) | |
| Production system | - Maximum livestock units (Lu) per ha (1.7 Lu/ha for dairy cows and 1.4 Lu/ha[a] for other livestock) | √ | |
| | - Maximum Phosphorous amounts in livestock feeds | √ | |
| | - Extensive farming in sensitive areas | √ | |
| | - Organic production | | √ |

Adapted from http://www.balticdeal.eu/news/new-measures-in-denmark/ (accessed 30.03.14

[a] 1 cow = 1.33 Lu, 36 pigs @ 32–107 kg = 1 Lu, 200 piglets @ 7.2–32 kg = 1 Lu, 4.3 sows = 1 Lu and 2900 chicken @ 40 days = 1 Lu.

the stated potential of 15,000 ha and the increasing demand for more targeted nitrogen and phosphorous reduction measures in Denmark (Balticdeal, 2011; Hoffmann et al., 2011).

Although the low pace of adoption of all these technologies (specifically the constructed wetlands) may be attributed to the fact that their actual effectiveness and/or profitability has not yet been fully established, the phenomenon is not unique to Denmark. Similar low adoption rates of best management practices (BMPs) have been observed in other countries, despite farmers having full information regarding the performance and profitability of these environmental measures (Smith et al., 2007a). This phenomenon therefore calls for a critical assessment of factors influencing the adoption of voluntary pollution mitigating technologies, farmers' attitudes and perceptions of the quality of surface water, the various nutrient reduction measures and their impact on water quality and the relationship between technology adoption and water quality perception. It is expected that this knowledge and understanding will help policy makers formulate strategies for implementing environmental measures that reduce pollution from agricultural activities.

Currently in Denmark, the construction of wetlands is still at a preliminary stage in the form of pilot projects to test the technique and its effects (Ministry of Food, Agriculture and Fisheries, 2012). The initiative is supported through the Danish rural development fund for non-productive investment in agriculture and grants for investment in "new green technologies" under the GGA (Minivådområder, 2012). Constructed wetlands (CWs) are however seen as a more targeted and cost effective option in the reduction of N and P pollution from agricultural fields (Kjærgaard et al., 2012). Consequently, given the expected potential of the technology and the projected capacity of one hectare of wetland to remove 480–1380 kg N per year (Kjærgaard and Hoffmann, 2013), this measure, if properly implemented could effectively replace some of the existing mandatory measures that have direct negative effects on the productivity and profitability of farms.

In order to identify the best strategy for policy makers to incorporate CWs as a nutrient reduction measure and encourage farmers to adopt them, it is paramount to first establish the farmers' level of adoption of voluntary technologies, their attitudes and perception regarding the current surface water quality, their perceived effectiveness of the existing regulatory nutrients mitigation measures and their preference for various government strategies for implementing the pollution reduction measures. These four aspects and their interrelations are analyzed in this article.

### 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 them being conducted in the US (Lichtenberg and Lessley, 1992; Ryan et al., 2003; Morton, 2007; Popp et al., 2007; Kaplowitz and Witter, 2008; Hu and Morton, 2011; Savage and Ribaudo, 2013). Bratt (2002), analyzes Swedish farmers' choices for management practices aimed at reducing nutrient pollution at the catchment level, while Sang (2008) studies farmers' preference for catchment management practices in Scotland. Other studies have been carried out in developing countries (Nguyen et al., 2006; Mojo et al., 2010; Perez-Espejo et al., 2011). Some of these studies have focused on catchment level analysis while others have primarily targeted areas designated as Nitrate Vulnerable Zones (NVZs). Macgregor and Warren (2006) assess arable farmers' perspectives about the causes of water pollution in two NVZs in Scotland, while Barnes et al. (2009) analyze perceptions about NVZs regulations among farmers with different farm typologies in all the four Scottish NVZs. In general, most of these studies find that farmers acknowledge the existence of water quality problems with agricultural production being a possible source. However, they seem to point out that most farmers do not agree that water pollution results from their own farms. The studies also reveal that farmers are generally opposed to the

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