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Novel Danish strategies to mitigate nutrient pollution at land-water interfaces

Dominik Zak[a, b], Joachim Audet[a, b], Carl C. Hoffmann[a, b], Fatemeh Hashemi[a], Sofie G.W. van't Veen[a], Mette V. Carstensen[a], Charlotte Kjærgaard[c], Flemming Gertz[c], Brian Kronvang[a]

[a]Department of Bioscience, Aarhus University, Silkeborg, Denmark
[b]Aarhus University Centre for Water Technology, Aarhus, Denmark
[c]SEGES, Aarhus, Denmark

INTRODUCTION

Three billion people will join the global population over the next two decades, accelerating the degradation of natural resources and escalating competition for them. The water sector is particularly fragile. Along with the quantity, also water quality is alarming, with eutrophication by agricultural diffuse sources being one of main causes of aquatic ecosystem deterioration (Figure 1). In a business as usual scenario, the global demand for clean water will exceed viable resources by 40% by 2030. In Europe, an increasing demand for water and major pressure on aquatic ecosystems comes from the still-growing agricultural sector. Denmark is one of the largest contributors of agricultural nitrogen (N) discharges to the aquatic environment measured in terms of N-load per hectare. Many aquatic action plans aimed at reducing the level of N-loads from non-point sources have been implemented in Denmark since the late 1980s and have resulted in an almost 50% reduction of N-leaching from the mid-1980s to 2003 (Naturstyrelsen, 2014). Nevertheless, N-leaching is still a major concern, especially in relation to meeting the requirements for good ecological status in groundwater and coastal waters (Kronvang et al., 2005).To face these challenges a new era of targeted agro-environmental nutrient regulation has been accepted as part of the Agricultural Package adopted by the Danish Parliament in 2016. The present focus in Denmark for enacting a targeted N-mitigation policy is based on mapping of the spatial variation in groundwater and surface water N-reduction (i.e. the redox reaction where nitrate is transformed to primarily N_2 under anoxic conditions). Such a targeted N-implementation strategy is expected to be a more cost-effective approach than uniform regulation (Olesen et al., 2019). Tile drainage connecting fields to receiving waters act as subsurface highways for N and phosphorus (P) as well as suspended sediments and covers more than >50% of the Danish agricultural area. Drainage losses of nutrients contribute to estimated 45-60% of total N and 20-36% of total P losses. Hence, for a large number of recipients, drainage water nutrient loads have a major impact on water quality, and drainage filter solution may offer the benefits of a targeted measure. This calls for a paradigm shift towards a more targeted agro-environmental regulation considering local site-specific knowledge of nutrient transport and transformation in the landscape. A cost-effective mitigation strategy requires a strategy for an optimized implementation of mitigation measures targeting the major transport pathways and /or to designated watercourses and lakes in the catchments, where the environmental effects are more certain (Hashemi et al., 2018). In Denmark, a suite of new nutrient mitigation measures has been scientifically approved for use in the new collective and targeted regulation and new mitigation technologies are currently under scientific testing before they can officially be included. We will set the scene for the efforts that is currently ongoing in Denmark in this new era of regulation of agriculture for securing and improving future water quality.

Fig. 1. Natural peatlands as important kidneys in the landscape (A), but often associated with more negative associations, are almost lost in many European countries as one reason for high nutrient loads and thus eutrophication of lakes and rivers (B). Technical drainage mitigation measures such as integrated buffer zones (C) can be a viable option for farmers, however there is also an urgent need to restore large riparian wetlands as performed for the Skjern River in Denmark (D) and many other regions of Europe.

MITIGATION MEASURES

Differentiated landscape-based mitigation strategies were developed for Danish catchments for optimized implementation of variable drainage filters targeting agricultural nutrient losses. Drainage filters presented here include: 1) already approved surface-flow wetlands, pilot scales of 2) subsurface-flow wetlands and 3) integrated buffer zones and finally non-evaluated 4) saturated buffer zones and 5) controlled drainage (Figure 2). Each measure varies in its capacity to intercept water, and especially slope and soil type determine how and where the measures can be implemented. Flat landscapes (slope < 1%), for instance are suitable for implementation of controlled drainage that as a single control structure will affect a large area, however, by the progress of the technology it may soon be possible to implement controlled drainage in sloping landscapes.

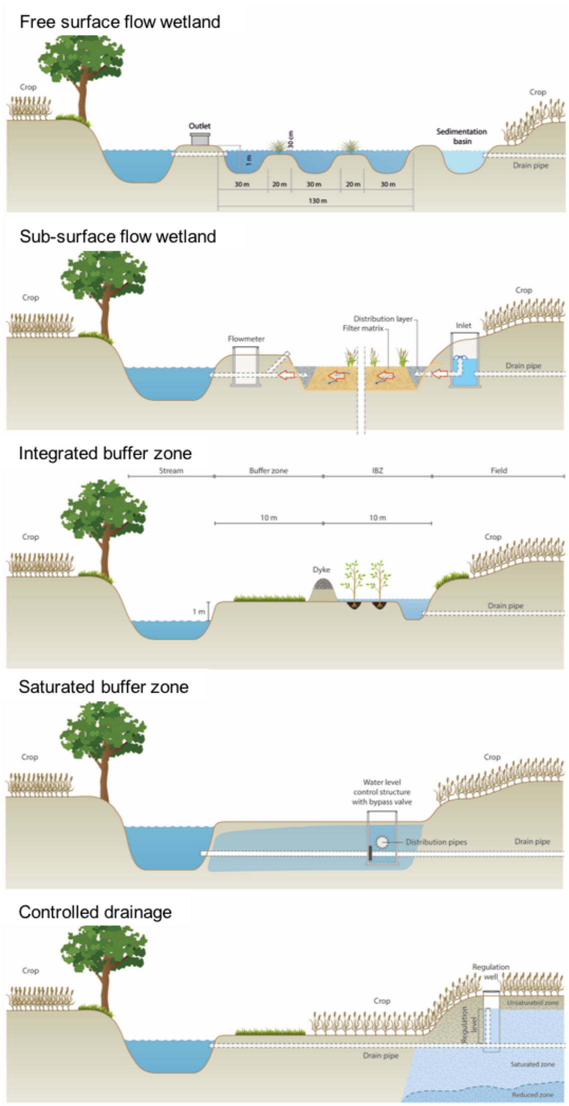

Fig. 2. Five mitigations measures approved or to be tested for their capability to retain nutrients from agricultural drain water in Denmark.

RESULTS and DISCUSSION

A comprehensive amount of monitoring studies has proved some of these facilities as valuable measures for mitigating the adverse impacts of high nutrient loading from agricultural fields on the aquatic environment. Highest nitrate removal efficiencies (ca. 90%) were achieved in subsurface-flow wetlands using wood chips as filtrating substrates. A test facility in Central Jutland treating drainage water discharge from 80 ha upland has since 2012 removed between 45 and 55 % of the TN load which amount to a removal of 0.7 – 0.8 kg N m^{-2} $year^{-1}$. In addition to high nutrient removal rates per surface area, integrated buffer zones have shown to improve wider ecosystem services that are beneficial enhancements to riparian zones (Zak et al., 2019). Results from these long-term studies should provide a good basis for discussing current limitations, future challenges and successful implementation of such edge-of-field technologies in Denmark and other countries from Northwest Europe. A cost-effective implementation of the new targeted agro-environmental regulation requires local based site-specific knowledge of the landscape, drainage structures and suitable measures, as well as a direct and trustful relation to the landowner. For that purpose, a new national program "Catchment Officer" was launched in 2017 including 22 persons on ground and a national coordination and continues capacity building. The Catchment officers facilitates site specific implementation of drain mitigation measures and play an important role as "bridge" between landowner, authorities and other stakeholders, aiming for the win-win solutions and optimizing the communication between the different actors.

CONCLUSIONS

The proper selection, design and implementation of mitigation measures plays an important role for achieving maximum pollution reduction while minimizing the costs to both farmers and government. These must be made with considering available limitation options for measure application (e.g. farm types and potential area for measure applications) and special care to optimize the supply of different ecosystem services and minimize undesirable side-effects. Some of these negative side-effects such as P release, methane emission or low oxygen content in effluent waters can be minimized by location or design of the measures (Carstensen et al., 2019), while others are more complex and need further investigation (e.g. nitrous oxide emission, loss of dissolved organic carbon). The possibilities of optimizing the ecosystem services and synergies with the surrounding landscapes of the mitigation measures is manifold, for instance biodiversity, water storage, and harvesting of biomass.

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