Nitrogen and phosphorus load reduction approach within safe ecological boundaries for the Nordic-Baltic region
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POLICY BRIEF NO. 1

NORDBALT ECOSAFE

Methane versus Multifunctionality

Evaluating Benefits and Tradeoffs of Constructed Ponds and Wetlands in Agricultural Areas

Recommendations

- Continue to support the creation and maintenance of ponds and wetlands in agricultural areas
- Recognize that constructed ponds and wetlands can provide multiple benefits, but that these benefits can be hard to quantify
- Include greenhouse gas emissions in the total cost estimates for constructed ponds and wetlands
- Continue to build the knowledge needed to quantify and communicate pond and wetland multifunctionality

Ponds and wetlands in agricultural areas have many functions. They retain nutrients, helping to limit downstream eutrophication in the Baltic and North Seas. They can store large amounts of carbon in their sediments, helping to offset emissions. They can be biodiversity hotspots, providing necessary habitat for birds and other organisms. They provide recreational opportunities. They can provide water in times of drought and can help to control flooding by mitigating some of the effects of more intensive rainstorms. However, they can also emit greenhouse gases.

Constructed ponds and wetlands are a key component of resilient agricultural areas. Relative to their small size, they can have disproportionate effects on the surrounding landscape. They can mitigate or buffer some of the undesirable effects of human activity on the environment by reproducing the behaviour of natural waterbodies. Unlike natural waterbodies, they can be designed, built and operated to achieve specific benefits related to mitigating the effects of floods and droughts, controlling nutrient runoff, reducing greenhouse gas emissions and ameliorating unhealthy living environments.

A sustainable pathway can serve both water ecology, economy and our welfare. Further development of a sustainable bioeconomy pathway into practical policy is therefore highly recommended.

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Background

Depending on location, design, maintenance and management an individual waterbody can be more or less effective at providing specific benefits. For example, ponds for drought mitigation should be designed and located differently than those targeting flood control. Similarly, the ability to control nutrient runoff or promote biodiversity depends on the way in which a waterbody is designed and constructed and where it is located. For nutrient runoff, location in the catchment (e.g., situated downstream or in an agricultural area) should be considered while for biodiversity, proximity to other waterbodies and the potential for dispersal can be important factors.

Typically, the financial costs of creating and maintaining ponds and wetlands can be estimated with a high degree of accuracy and a number of programs exist for reimbursing these costs in different European countries. However, quantifying the benefits provided by these waterbodies is more complicated. Some individual benefits related to, for example, retention of nitrogen and phosphorus can be quantified in a straightforward manner and it is possible to rank waterbodies in terms of their effectiveness at removing a single nutrient. However, ranking the co-benefits associated with removal of both nitrogen and phosphorus is not straight forward.

Standard river water quality monitoring programs of the kind used for HELCOM and OSPAR reporting do not clearly show the effects of agricultural measures such as constructed wetlands on nutrient removal. There are a number of possible reasons for this. First, it is possible that individual wetlands are not retaining nutrients as efficiently as might be expected. Second, it is quite likely that water quality monitoring programs at the river mouth are not able to detect the effects of green infrastructure on nutrient concentrations. Finally, it is possible that the monitoring time

Photo: Michael Peacock

Sustainability depends on the creation of new knowledge about benefits and tradeoffs of societal actions. Efforts to improve water quality and reduce eutrophication may increase greenhouse gas emissions.

series are not long enough to show a clear effect. Routine water quality monitoring programs based on monthly spot sampling are good at detecting the effects of major “grey infrastructure” interventions such as new wastewater treatment facilities but are less effective at documenting improvements in water quality associated with measures in agricultural areas.

When evaluating multifunctionality, benefits related to multiple factors including recreation, water quantity, water quality, biodiversity and climate regulation must be assessed. These benefits are not straightforward to measure or compare and must be balanced against drawbacks related to factors such as nuisance insects, greenhouse gas emissions and loss of productive land. Costs for the latter can be estimated as ongoing reductions in farm income associated with conversion of productive land and can be accounted for as part of the maintenance costs for a waterbody.

Ponds and wetlands cannot be considered in isolation but should be seen as part of a larger “wetlandscape” (Hambäck et al. 2022) consisting of multiple waterbodies and their connections. Where a body of water is located is relevant to the manner in which it functions. The impact of ponds and wetlands on societal and ecosystem wellbeing should be evaluated at multiple spatial scales. Benefits and drawbacks can be evaluated at local (individual waterbody), catchment and administrative (e.g., municipality or county) scales as effectiveness of ecosystem service delivery is dependent on where the waterbody is located.

There are always tradeoffs associated with the design and placement of constructed ponds and wetlands. Better delivery of one class of ecosystem service (e.g., nutrient retention) can lead to less effective delivery of other services (e.g., climate regulation). There is no single best solution. There is always more than one way to evaluate the ecosystem services and tradeoffs provided by any waterbody depending on multifunctionality, local and catchment-scale effects and the type of tradeoffs encountered.

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Ponds, wetlands and other small artificial waterbodies are a complement to, not a replacement for traditional “grey” infrastructure. The flow mitigation possibilities of artificial ponds and wetlands cannot replace the need for dams and other flood control infrastructure such as urban storm drainage. Nor can they replace water treatment facilities.

Floods and droughts can be caused by large-scale changes in weather patterns as well as by local land management decisions. Small waterbodies can mitigate the negative effects of small to medium size floods and droughts, especially those related to urban land management but are not likely to provide any relief from the most extreme hydrological events.

Natural and artificial waterbodies contribute to biodiversity. This can be beneficial, for example ponds and wetlands can provide bird habitat, but can also be detrimental if they lead to higher numbers of mosquitoes and biting insects.

People like ponds. The aesthetic and societal benefits of well-designed and well maintained ponds and wetlands are a key part of their contribution to resilient landscapes. Ponds and wetlands offer recreational opportunities including bird watching, walking, and in some cases, skating and hunting.

Climate Impacts

Carbon accounting is becoming increasingly common for all types of infrastructure and the tools to support accounting are becoming increasingly sophisticated. These tools could also be applied to constructed ponds and wetlands. The IPCC has developed emission factors for greenhouse gas production (see Wetlands International 2023). Emissions factors are quantitative estimates of the amount of greenhouse gases released annually per unit area of a constructed wetland. Today, these factors only exist for methane and are in need of regional refinement. However, they provide a starting point for estimating the climate impacts of ponds and wetlands.

There are three main greenhouse gases emitted by ponds and wetlands: CO2, N2O and methane. Both N2O and methane are more potent

Photo: Michael Peacock

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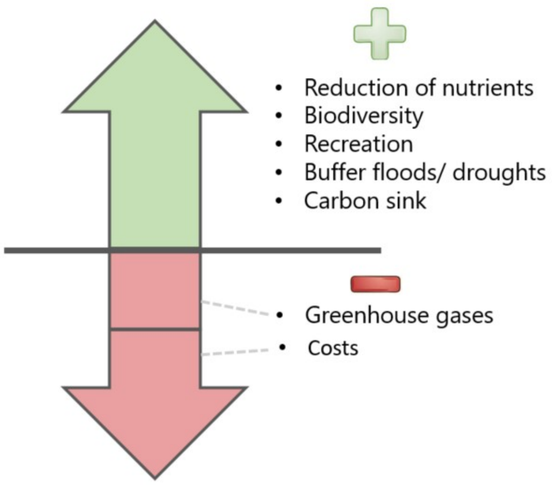

greenhouse gases than CO2. Kilogram for kilogram, these gases have a stronger climate impact than CO2. However, not all agricultural waterbodies emit each of these three gases. Some waterbodies are net greenhouse gas sinks, that is to say they take up more greenhouse gases than they emit.

In a landscape perspective, ponds and wetlands are greenhouse gas hotspots. However, much of the CO_2 and N_2O they emit would be emitted elsewhere in the landscape if the waterbody did not exist. CO_2 is emitted from soils, lakes and rivers while N_2O can be emitted anywhere there are high concentrations of nitrogen. Methane is the exception, as it is emitted disproportionately from small waterbodies.

Measuring methane emissions is more difficult than for other greenhouse gases as much of it is emitted as bubbles, which are easy to see but hard to quantify. Methane emissions are controlled by two groups of microbes. One group, methanogens, produce methane and are common in sediments. The other group, methanotrophs, are found in the water column and consume methane. Understanding the interactions between these two groups of microbes and their impact on methane emissions is an important new area of research.

As well as emitting greenhouse gases, ponds and wetlands sequester carbon in their sediments. Depending on the way in which the waterbodies are managed, sediment carbon can be retained for long periods of time, offsetting some of the negative effects of greenhouse gas emissions.

A changing climate may reduce the effectiveness of small artificial waterbodies for providing ecosystem benefits. Specifically, the interactions of drought and nutrient loading may cause significant loss of biodiversity and reduce aesthetic benefits due to increased algal growth and potentially contribute to increased greenhouse gas emissions. However, an increase in the frequency of hydrological extremes, both floods and droughts, only increases the need for ponds and wetlands in agricultural areas.

Further Reading

Hambäck et al. 2023. Tradeoffs and synergies in wetland multifunctionality: A scaling issue. Science of the Total Environment, 862, p.160746.

Peacock et al. 2021. Small artificial waterbodies are widespread and persistent emitters of methane and carbon dioxide. Global Change Biology, 27(20), pp.5109-5123.

Wetlands International. 2023. Wetlands and Methane: Key Messages 6 pp. https://www.wetlands.org/publications/wetlands-and-methane/

Zak et al. 2019. An assessment of the multifuntionality of integrated buffer zones in northwestern Europe, JEQ 48: 362-375.

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Summary

- Constructed ponds and wetlands contribute to a resilient agricultural landscape through flood and drought mitigation, nutrient retention, support for biodiversity, carbon storage and more recreation opportunities.
- Monetary costs for construction and operation of constructed wetlands can be determined with a high level of accuracy. However, the range of benefits provided by ponds and wetlands is harder to quantify.
- Most constructed ponds and wetlands in agricultural areas are net emitters of greenhouse gases. These emissions should be included in cost estimates.
- Benefits (and possible drawbacks) of agricultural ponds and constructed wetlands should be evaluated at local, catchment, administrative and global scales.
- Further work is needed to understand why individual wetlands function in the way they do. Better process understanding of nutrient retention, greenhouse gas production and hydrological functioning are key research questions, as is work to make the connection between biodiversity and wetland properties more explicit.
- Monitoring programmes must be revised and improved so as to be able to better detect the impacts of constructed wetlands on water quality.

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The NORDBALT-ECOSAFE consortium will develop and demonstrate innovative methods and establish best practices to improve current river basin management and governance by reaching the following major aims: i) setting ecologically safe nutrient boundaries in different types of water bodies; ii) improving monitoring of nutrient concentrations by comparing benefits of novel high-frequency online sensors with traditional monitoring; iii) establishing nutrient loading tipping points for carbon sequestration and emissions in water bodies; iv) establishing a harmonised river basin modelling tool for precise estimation of nutrient sources, pathways and transport; v) demonstrating novel Nature Based Solutions (NBSs) and Mitigation Measures (MMs) for reaching the required nutrient load reductions; and vi) developing advanced solutions supporting regional governance

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