Edge of Field Denitrification Practices

Why Edge of Field is Essential to Stop Agriculture Runoff Pollution

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1.0 Introduction

Nutrient pollution has become one of the most dangerous sources of water pollution in the world—contributing to downstream ecosystem failure and incurable waterborne diseases. In rural and impoverished communities in the United States and worldwide, preventing this type of pollution is essential to quality healthcare and water-resource economies. In the United States, nitrogen and phosphorous abatement techniques are unable to reduce the pollutants to the 40% reduction standard set by environmental economists while maintaining feasibility. To reduce water pollutants, the literature suggests that a restoration policy using site-targeted wetland creation is the most cost-effective solution in the long run.

While targeted wetland creation is the most feasible solution, the policy can be applied in more areas for less cost by improving the targeting and construction of these systems. With better restoration site-targeting and improved wetland construction, policymakers can improve surface and groundwater quality for the general public and the most disadvantaged communities.

2.0 Supplementing In-Field Practices

Eutrophic “dead zones” have historically been prevented using expensive techniques. Some examples of expensive techniques are physical methods such as mechanical cleanup, ultrasonic disturbance, ultraviolet irradiation, and chemical treatment such as algicides that contain heavy metal compounds (Hu & Hong, 2008).

Adapting farming techniques is a simple way to reduce pollutants entering a stream by surface runoff using no-till farming or cover crops. While new farming techniques reduce a large sum of pollutants entering waterways, 80% of farms in the U.S. Midwest are unable to use all new techniques to the best of their ability because of soil or elevation restrictions. Because so few farms can utilize these techniques, it would only reduce an estimated 5% of nitrates in streams if applied on all ideal farmland according to an interview with Dan Jaynes, a soil scientist with USDA’s Agricultural Research Service (*New Tool Cheaply, Efficiently Captures Nitrates*, 2015). Many techniques available to farmers still fall short of decreasing nitrogen, and have efficiencies ranging from 4%-77% nitrate removal on the individual farm (Groh 2018), providing evidence that other methods beyond producer-driven techniques must be studied.

The total nitrate reduction failure in buffer zones can be attributed to the soil composition, slow biological processes, elevation, and runoff from dying vegetation (Noij et al., 2012; Satchithanantham et al., 2019). Thus, techniques that increase the absorption of nutrients through a microbiome and plants’ biological processes are extremely effective in mitigating the risk of dead zones (Akratos & Tsihrintzis, 2007). If natural processes upstream denitrify equal to the rate nitrates are being added to the system, rivers will never exceed the total maximum daily load (TMDL) that creates eutrophication and dead zones.

3.0 Economic Reasons for Edge of Field

To target areas producing the most considerable marginal damage while keeping marginal costs low, economists must redesign the targeting system for wetland restoration and land retirement. Several economists have recently examined wetlands and have thus designed studies on wetlands and buffer zone differences. Jones et al. (2013) assert in their article on agriculture greenhouse gas mitigation that previous works focused on the wetland systems because they are more effective at higher altitude systems (Jones et al., 2013). Edge of field Practices must react to local soils and nutrient loads. For regional planning, we distinguish by rural areas, urban development, and agricultural use.

To designate these areas, economists Wu and Irwin (2008) point to previous policy proposals aimed at reducing urban sprawl to maintain the natural ecosystems that exist around them. Urban growth boundaries (UGB) and buffer zones intend to keep the ecosystems in rural areas as large and untouched as possible to reduce the costs needed to repair damaged or destroyed wetlands. The policies in place have had mixed levels of efficiency in reducing nutrient loads in ponds because the marginal cost is not easily calculated (Wu & Irwin, 2008). With steep recurring costs due to negative feedback loops (climate change, soil degradation, urban expansion), the fixed costs to install buffers are becoming more efficient in the long run compared to transaction costs to keep rezoning urban growth boundaries.

However, buffer zones and land retirement cannot be reversed without releasing the nutrients, creating widespread damage. The most economically feasible approach is to use a variety of edge of field practices depending on the resource concern.

4.0 Proposed Solutions

a. Hybrid Wetlands

Further research into wetlands hybridization will allow a closer look at ways to stop sediment from entering the watersheds with pollutants. When a wetland has a large increase in sediment, suspended sediment can accelerate nitrous oxide emissions; sedimentation will also decrease water depth leading to less water that can be absorbed by the rhizomes of wetland plants such as cattails or reeds (Zhou et al., 2019).

Hybrid wetlands prevent sediment less from farms as well as capture nutrients such as nitrate and phosphorus. Nitrate is more difficult to reduce in aquatic ecosystems, but a hybrid wetland which incorporates aerobic and anaerobic environments can achieve higher denitrification. The following chart highlights five researchers who tested nutrient reduction levels within hybrid wetland systems.

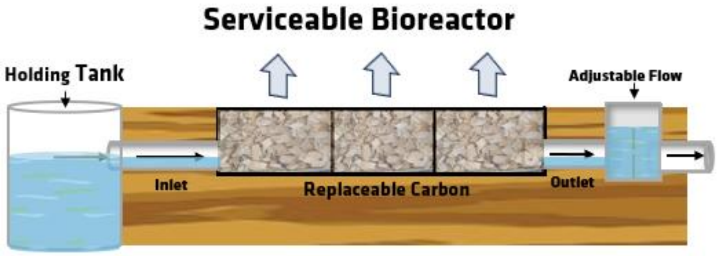
Hybrid Wetland Applications

Researcher	Chemical Reduced	Percent Reduction
Ávila	NO3	60-70%
Saeed	NO3	97%
Politeo	Total N	58-90%
Wang	NO3	89.78%
Zheng	Total N	58%

Hybrid wetlands present the greatest opportunity to reduce nitrates in aquatic ecosystems because pre-pollutant control has an extremely varied effectiveness and post-pollutant control practices are incredibly costly. Nitrate reduction in hybrid wetlands is above 50% removal with many systems seeing between 60% and 70% reduction as shown by Ávila et al. (2017). Some systems have even achieved as much as 97% total nitrate reduction such as the system of Saeed et al. (2019). With nitrate reduction rates higher and with less variation than the current targeting model, hybrid wetlands are more economically and ecologically efficient.

b. Enhanced Denitrifying Bioreactors

Denitrifying bioreactors are engineered structures designed to remove excess nitrate from agricultural drainage water or other nitrogen-rich sources before they enter rivers, lakes, or oceans. The bioreactors function as subsurface, anaerobic environments where denitrification, a natural biological process, occurs. During denitrification, nitrate is transformed into harmless nitrogen gas (N2), which is released into the atmosphere, thus preventing it from contaminating water bodies.



The conventional approach to denitrifying bioreactors involved the initial loading of a substantial amount of carbon source to provide sufficient food for denitrifying bacteria. However, this approach has certain limitations. It could lead to inefficient use of carbon, potential clogging of the bioreactor due to excessive biomass growth, and inconsistent performance over time. Clear Water has now discovered that a more sustainable and effective strategy involves the gradual addition of carbon sources to the bioreactors in solid form using a containerized injector.

c. Large Wetlands

Wetlands act as nature's water purifiers, absorbing excess nutrients and mitigating the impacts of fertilizer runoff. Some of the benefits of wetlands as a standalone practice are:

- Nutrient Removal: Wetlands act as nutrient sponges, efficiently trapping and metabolizing excess nitrogen and phosphorus from fertilizer runoff. This natural filtration system helps prevent nutrient pollution from reaching nearby water bodies.
- Improved Water Quality: By intercepting and absorbing nutrients, wetlands improve water quality in the surrounding areas. Cleaner water benefits aquatic life and provides a healthier habitat for plants and animals.
- Biodiversity Support: Wetlands provide a diverse range of habitats, attracting various plant and animal species. The creation of wetlands can help support biodiversity and create important wildlife corridors.

- Erosion Control: Wetland vegetation and soil structures help stabilize shorelines and mitigate the impact of erosion, reducing sediment transport and nutrient loss downstream.

d. (Saturated) Buffers

Saturated buffers are vegetated areas designed to intercept and treat tile drainage water. As opposed to a standard vegetated buffer, they use a water-level-control structure to increase and decrease the water level within the buffer without damaging the field. While only effective in some soils, they are an inexpensive method to reduce nutrient runoff on the field edge.

If incorporating **biochar** into these buffers, the ability to retain nutrients and filter water is further improved. Biochar acts as a reservoir for nutrients, preventing excessive leaching and reducing the risk of nutrient-laden runoff reaching nearby streams and rivers.

5.0 Future Direction / Long-Term Focus

The future direction of conservation practices used to reduce nutrient pollution lies in the preferences of farmers and the goals of cites, counties, and Soil and Water Conservation Districts. The direction is shifting more toward edge-of-field practices because in-field practices have not removed the resource concern on their own.

The long-term focus of constructed denitrifying practices is to prove efficacy in as many landscapes as possible. The requirement for environmental engineers to design them makes these practices more difficult to scale quickly and more costly to produce. For practices to be effective, they must take the site characteristics into consideration and design them for the flow rates off the field. Organizations that operationalize these practices must do so with careful consideration and input from their stakeholders.

6.0 Conclusion/Key Takeaways

Several conservation practices exist with the ability to reduce nitrate and phosphorus runoff from farm fields.

The question of what will work for most applications comes down to the local watershed and needs of the community. For anyone planning to reduce nutrient pollution, a plan that integrates in-field management with edge-of-field conservation will be the best path toward reduction goals.

Monitoring of nutrient runoff and the implementation of these practices with skilled engineering creates the opportunity to finally prevent dead zones, human health risks, and economic damages.

Appendices

Appendix A – Scenarios

Common scenarios for conservation practices include:

1. A County Environmental Services professional notices many feedlots that are noncompliant with the amount of their manure application. At the same time, the feedlot operator plans to implement a conservation practice to reduce manure pollution to surface water.
2. A farmer has a high water table, so they decide to put in drain-tile in order to avoid crop damage - creating more subsurface nutrient runoff. As a result, city lakes downstream have to increase water treatments to prevent algae blooms unless the farmer implements a conservation practice along with the drainage tile.
3. A County Parks Department notices that algae blooms have increased in parks with farms nearby. At the same time, nearby farmers notice their wells are testing high for nitrates.

Appendix B – Options

Some optional steps include:

1. assessment of total nutrient pollution to waterways on farms and local communities
2. meeting with professional engineers and conservation planners for local denitrification projects
3. collaboration with local communities and organizations on long-term strategy
4. application of conservation practices on high runoff potential farms/feedlots

Appendix C – References

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