

Wetlands in agricultural landscapes: how to combine nutrient retention and biodiversity

J. T. A. Verhoeven

Ecology and Biodiversity, Department of Biology, Utrecht University, Padualaan 8, 3584 CH Utrecht, The Netherlands

Keywords: Riparian zones; water quality; nutrients

Riparian zones along streams and other small wetlands perform important ecosystem services in agricultural landscapes. They improve water quality by retaining nutrients from through-flowing water, sequester carbon and attenuate flood peaks at high discharge. At the same time, they have been shown to enhance biodiversity at the landscape as well as regional scale. However, there is concern about loss of biodiversity and enhanced greenhouse gas emissions where wetlands have become overloaded with nutrient-rich surface water or groundwater (Verhoeven et al. 2006). This paper identifies conditions for the best performance of riparian zones and other small wetlands in agricultural landscapes in terms of nutrient and greenhouse gas retention and biodiversity.

Agricultural activities result in diffuse pollution with nutrients, primarily nitrogen and phosphorus. The biogeochemical behaviour of these two elements is quite different and results in a range of different situations where either the one or the other is creating major problems. The way the two elements are processed by wetlands is also very different, which results in contrasting retention mechanisms and dynamics. This different behaviour of N and P requires consideration in wetland restoration initiatives. Two extreme examples are

- (1) catchments with wetlands receiving subsurface drainage water from crop fields or pastures as groundwater input. This water is often very rich in nitrate and poor in phosphates (N:P ratios > 100). N retention in the wetlands is effective and occurs as denitrification and, to a lesser extent, as storage in vegetation and soil organic matter
- (2) catchments with wetlands receiving surface runoff from crop fields and pastures where much organic fertilizer is applied. This water is rich in particulate nutrients and is high in N as well as P (N:P ratios <15). Wetland P retention is dependent on soil chemistry (presence of Fe, Ca and Al) and on sequestration in vegetation and soil organic matter.

Agricultural regions with catchments of the first category have large nitrate outputs in their streams, which creates environmental problems especially in coastal areas because their primary production is mostly N-limited. Examples of this are the coastal eutrophication in the Baltic Sea around southern Sweden (Arheimer et al. 2004) and in the Great Barrier Reef area in NE Australia (Kroon and Brodie 2009). In the Swedish region, numerous wetlands have been created to enhance nitrogen retention from groundwater before it enters the stream. Because of the high N:P ratio of the groundwater flowing into these wetlands, their P loading is quite small. This creates opportunities for a high biodiversity, as productivity in freshwater habitats is often P-limited. Such wetlands have been shown to combine nitrogen retention and biodiversity enhancement at the landscape scale very well (Thiere et al. 2009).

Catchments of the second category have a more impervious soil so that water drains mostly superficially as (sub)surface runoff. In such areas, nitrogen as well as phosphorus loadings to streams are high, and riparian zones along the streams are

important for N and P retention. Riparian zone width is an important landscape characteristic, with zones over 25 m wide showing more effective nutrient retention (Mayer et al. 2007). As such riparian zones are loaded with N as well as P, their nutrient richness increases over time, which often has a reducing effect on wetland diversity, particularly in heavily fertilized catchments.

In regions where riparian zones are restored for nutrient retention, it is important to take into account previous agricultural use of these zones. If there is a history of agricultural use, soils may contain large amounts of phosphorous, which could be released upon rewetting and lead to a very eutrophic status of the restored wetland (Ardon et al. (2010). In such cases, only N retention may still be possible, while combinations with biodiversity enhancement remain unlikely.

High nitrous oxide emissions have been identified in riparian zones used for N retention and could be a concern which would diminish the overall environmental benefit of riparian zones (Hefting et al. 2003, van den Heuvel et al. 2009). However, it has been shown that nitrous oxide emissions mainly occur at pH values lower than 4. Such conditions occur mostly in stream headwater areas only, whereas higher-order streams and their riparian zones often have higher pH values, supporting effective denitrification with low nitrous oxide emission (Van den Heuvel et al. 2011).

References

- Ardon, M., Morse, J.L., Doyle, M.W., and Bernhardt, E.S. (2010) The Water Quality Consequences of Restoring Wetland Hydrology to a Large Agricultural Watershed in the Southeastern Coastal Plain. *Ecosystems* **13** (7), 1060-1078.
- Arheimer, B., Andersson, L., Larsson, M., Lindstrom, G., Olsson, J., and Pers, B.C. (2004) Modelling diffuse nutrient flow in eutrophication control scenarios. *Water Science and Technology* **49** (3), 37-45.
- Hefting, M.M., Bobbink, R., and De Caluwe, H. (2003) Nitrous oxide emission and denitrification in chronically nitrate-loaded riparian buffer zones. *Journal of Environmental Quality* **32** (4), 1194-1203.
- Kroon, F.J. and Brodie, J. (2009) Catchment management and health of coastal ecosystems: synthesis and future research. *Marine and Freshwater Research* **60** (11), 1196-1200.
- Mayer, P.M., Reynolds, S.K., McCutchen, M.D., and Canfield, T.J. (2007) Meta-analysis of nitrogen removal in riparian buffers. *Journal of Environmental Quality* **36** (4), 1172-1180.
- Thiere, G., Milenkovski, S., Lindgren, P.E., Sahlen, G., Berglund, O., and Weisner, S.E.B. (2009) Wetland creation in agricultural landscapes: Biodiversity benefits on local and regional scales. *Biological Conservation* **142** (5), 964-973.
- van den Heuvel, R.N., Hefting, M.M., Tan, N.C.G., Jetten, M.S.M., and Verhoeven, J.T.A. (2009) N₂O emission hotspots at different spatial scales and governing factors for small scale hotspots. *Science of the Total Environment* **407** (7), 2325-2332.
- van den Heuvel, R.N., Bakker, S.E., Jetten, M.S.M., and Hefting, M.M. (2011) Decreased N₂O reduction by low soil pH causes high N₂O emissions in a riparian ecosystem. *Geobiology* **9** (3), 294-300.
- Verhoeven, J.T.A., Arheimer, B., Yin, C.Q., and Hefting, M.M. (2006) Regional and global concerns over wetlands and water quality. *Trends in Ecology & Evolution* **21** (2), 96-103.