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At-grade stabilization structure impact on surface water quality of an agricultural watershed

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ABSTRACT

Decades of farming and fertilization of farm land in the unglaciated/Driftless Area (DA) of southwestern Wisconsin have resulted in the build-up of P and to some extent, N, in soils. This build-up, combined with steep topography and upper and lower elevation farming (tiered farming), exacerbates problems associated with runoff and nutrient transport in these landscapes. Use of an at-grade stabilization structure (AGSS) as an additional conservation practice to contour strip cropping and no-tillage, proved to be successful in reducing organic and sediment bound N and P within an agricultural watershed located in the DA. The research site was designed as a paired watershed study, in which monitoring stations were installed on the perennial streams draining both control and treatment watersheds. Linear mixed effects statistics were used to determine significant changes in nutrient concentrations before and after installation of an AGSS. Results indicate a significant reduction in storm event total P (TP) concentrations ($P = 0.01$) within the agricultural watershed after installation of the AGSS, but not total dissolved P ($P = 0.23$). This indicates that the reduction in P concentration is that of the particulate form. Storm event organic N concentrations were also significantly reduced ($P = 0.03$) after the AGSS was installed. We conclude that AGSS was successful in reducing the organic and sediment bound N and P concentrations in runoff waters thus reducing their delivery to nearby surface waters.

1. Introduction

Agriculturally derived nonpoint source pollution is the primary cause of impairments to rivers and streams in the United States this is largely due to eutrophication (USEPA, 2010). Eutrophication occurs when excessive amounts of nutrients are introduced into surface waters leading to increased plant and algal growth. This increased growth reduces dissolved oxygen levels in waters receiving runoff and sediment, which can negatively impact aquatic ecosystems.

Phosphorus is the nutrient mainly limiting eutrophication in freshwater systems, while N is mainly limiting in most saltwater systems (Sharpley et al., 1994; Correll, 1998). However, given complex nutrient cycling and plant uptake pathways within aquatic systems, as well as the spatial and temporal variability of such pathways, both N and P can be important in impairment in both types of ecosystems (Dodds and Welch, 2000). Nitrate is a form of N that is readily available for plant uptake and can also threaten both human and animal health. For drinking water, the NO_3 form of N has been known to cause methemo-globinemia in infants as well as have toxic effects on livestock (Sandstedt, 1990; Amdur et al., 1991). For this reason, the USEPA has set the drinking water standard for NO_3 (as N) at 10 mg L^{-1} (USEPA, 2009). Nitrate-N levels between 40 and 100 mg L^{-1} in waters being consumed by livestock can also cause adverse effects (Sandstedt, 1990). Ammonium-N concentrations of 0.5 and 2.5 mg L^{-1} have been reported to be harmful to

Abbreviations: DA, unglaciated/Driftless Area; AGSS, at-grade stabilization structure; TP, total phosphorus; DP, dissolved phosphorus; PP, particulate phosphorus; TN, total nitrogen; TKN, total Kjeldahl N; TDP, total dissolved P; NW, north watershed; SW, south watershed; LME, linear mixed effects; CRP, conservation reserve program; CREP, conservation reserve enhancement program.

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both humans and aquatic organisms, respectively (USEPA, 1973; Russo, 1985; Miltner and Rankin, 1998).

Total P (TP), with respect to agricultural runoff, can be separated into dissolved and particulate components. Dissolved P (DP) primarily comprises inorganic PO_4 salts that can readily be taken up and utilized by algae (Walton and Lee, 1972). Particulate P (PP) includes that attached to soil particles and organic matter and is the dominant P component in agricultural runoff. About 75–90% of TP in conventional agricultural runoff is in the PP form (Sharpley et al., 1994). Even though PP is not immediately available for plant uptake, it acts as a long-term source within sediment, although the bioavailability of PP has been shown to be quite variable (e.g., 10–90%; Sharpley et al., 1992). Total P concentrations in agricultural runoff have been shown to decrease with increased conservation and less intensive agricultural practices; however, bioavailable components of phosphorus (DP and bioavailable PP) were shown to represent a much greater proportion of the TP under increased conservation practices (Sharpley et al., 1992). However, it should be noted that the particulate forms of any nutrient in freshwater systems represent a complex continuum of organic particles, microorgansims, and sorbed inorganic ions and that suspended sediment itself can be aggregated (Droppo, 2001).

Particulate N and P tend to be dominant form of these nutrients in runoff from agricultural landscapes. Sharpley et al. (1987) concluded that 75% of the TP and 64% of the TN in runoff from rural areas are in the particulate form. Also, the U.S. Department of Agriculture (USDA, 1989) reported that roughly 80% of the TP and 73% of the TKN in runoff from agricultural areas is attributed to eroded sediment. These particulate transported nutrients are of particular concern for the unglaciated/Driftless Area (DA) of Wisconsin given this area's steep topography and susceptibility to runoff and erosion. This combined with agriculture being the primary land use within the DA, only exacerbates the problems associated with the transport of particulate N and P to surface waters. Total suspended sediment and TP loadings to DA streams were as high as 353.8 Mg km^{-2} yr^{-1} and 693.5 kg km^{-2} yr^{-1}, respectively, and as much as 95% of annual TSS and 87% of the annual TP loadings were attributed to storm runoff events (Corsi et al., 1997).

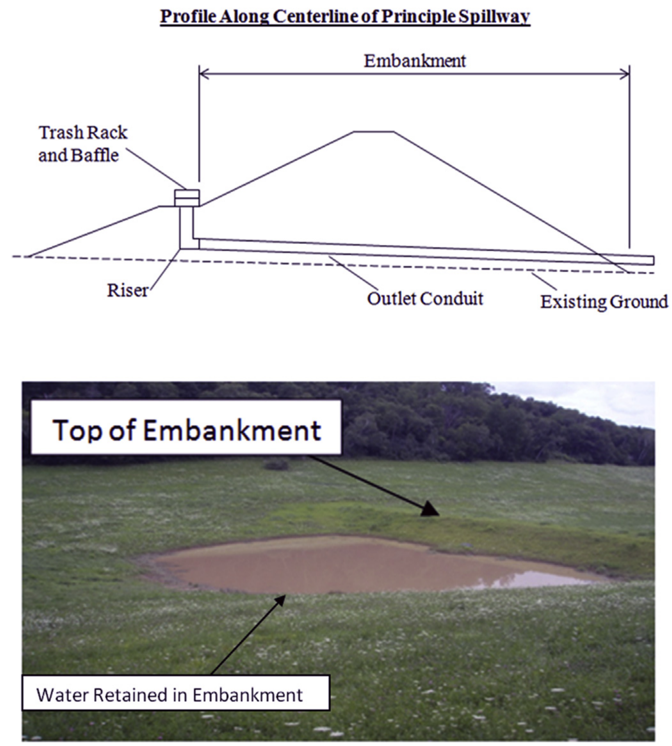

Fig. 2. Cross-sectional view and picture of the at-grade stabilization structure embankment that was installed in the north watershed (USDA NRCS, 2005; Minks et al., 2012).

An at-grade stabilization structure (AGSS) can be effective in reducing the amount of suspended sediment being transported to surface waters of the DA (Minks et al., 2012). These structures consist of a large embankment that is designed to retain storm runoff long enough for transported sediments to settle (Fig. 2). In addition, they also serve as a sink in which these transported sediments can be stored for a specified period. In this fashion, it is very similar in function to sedimentation basins and detention

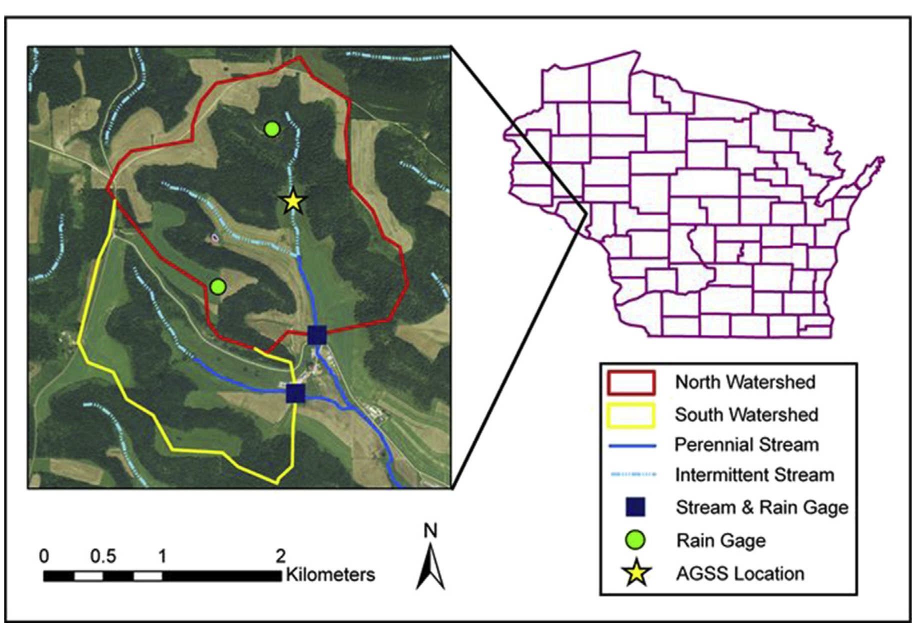

Fig. 1. Location of north and south Travers Valley Creek Watersheds as well as stream and rain gages (Minks et al., 2012).