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Effectiveness of natural riparian buffers to reduce subsurface nutrient losses to incised streams

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Perennial vegetation borders many incised, perennial streams and rivers in southern Iowa and is assumed to provide a natural riparian buffer against subsurface nutrient losses from shallow groundwater. Questions remain about the effectiveness of these systems near incised channels that cut through nutrient-rich Holocene alluvium underlying the riparian corridors. In this study, riparian groundwater nutrient concentrations were evaluated near an incised stream under four perennial land cover types common to southern Iowa with the objectives to assess how groundwater quality differed by i) distance away from an incised stream and ii) perennial land cover type. Groundwater samples were collected from riparian wells installed 1 m, 20 m and 40 m from an incised channel under four replicated land covers (cool season grass, warm season grass, woods, pasture) on six occasions across the growing season. Results indicate that channel incision lowers water tables in the near-stream zone and maintains more aerobic conditions but did not result in enhanced nitrogen mineralization or leaching to groundwater. Average concentrations of nitrate–nitrogen, phosphorus and dissolved organic carbon were 0.3 mg/l, 0.2 mg/l and 6 mg/l, respectively, with variations due mainly to land cover type and geomorphology. Study results suggest that nutrient losses from perennial buffers in the region do not greatly impact regional water N and P loads although average concentrations in riparian groundwater may exceed proposed stream nutrient criteria.

1. Introduction

Establishing perennial vegetation adjacent to a stream is considered to be an effective best management practice (BMP) to buffer aquatic ecosystems against nutrient losses from groundwater (Phillips, 1989; Schultz et al., 1995; Spruill, 2000). Such riparian buffers attenuate nitrogen through plant uptake (Lowrance, 1992), denitrification (Clement et al., 2003; Jacobs and Gilliam, 1985), and groundwater mixing (Altman and Parizek, 1995; Lowrance et al., 1997). Less well documented are effects of riparian vegetation on groundwater concentrations of phosphorus (Carlyle and Hill, 2001) and dissolved organic carbon (DOC) (Jacinthe et al., 2003).

Comparing the effectiveness of different riparian zone configurations is often complicated by variations in vegetation type and subsurface geology that occur among sites. The influence of different vegetation types on riparian buffer performance has largely centered on evaluating nutrient processing at a single vegetated site, such as forests (Lowrance, 1992; Peterjohn and Correll, 1984), grasslands (Borin and Bignon, 2002; Schoonover and Williard, 2003) or forest–grassland combinations (Addy et al., 1999; Haycock and Pinay, 1993). Mayer et al. (2005) used a meta-analysis to suggest that forest was more effective than grass in nitrogen removal effectiveness. Additional studies of riparian buffer effectiveness have focused on systems established under USDA conservation standards (Dosskey, 2001). Moreover, variations in subsurface lithology and stratigraphy often play a critical role in controlling nutrient cycling and transport in riparian zones (DeVito et al., 2000; Hill et al., 2004). Mittelstet et al. (2011) showed that groundwater phosphorus contributions to streams can be significant when riparian soils exhibit spatial variability in hydraulic conductivity and preferential flow pathways. Studies are needed to evaluate natural buffers that control for subsurface geologic variability so that effectiveness of riparian vegetation type on groundwater quality can be better quantified.

Further complicating comparisons of riparian buffer effectiveness across sites is the effect of channel incision on shallow groundwater quality (Schilling and Jacobson, 2008). Agricultural practices such as stream channelization, removal of riparian vegetation, increasing row crop production and widespread artificial drainage have caused many streams to downcut and widen into their floodplains. Incised streams are hydrologically disconnected from their floodplains, lowering the water table near the stream and creating a large unsaturated zone in the near-stream riparian zone (Hardison et al., 2009; Schilling et al., 2004). Deeper water tables near incised channels can result in a more aerobic soil profile conducive for mineralization of soil N (Groffman et al., 2002; Schilling and Jacobson, 2008).

In this study, we evaluated groundwater nutrient concentrations in riparian wells installed near an incised stream under four perennial

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land cover types common to southern Iowa. Naturally occurring remnant forests and herbaceous communities line many kilometers of incised streams in this region yet little is known about their ecological effectiveness (Knight et al., 2011). For example, in northern Missouri (the same ecoregion as much of southern Iowa), Herring et al. (2006) found that riparian land use consisted of forest (46%), cropland (29%) or grass (23%). Evaluating groundwater nutrient concentrations beneath naturally occurring perennial riparian buffers is critical since these buffers overlie nutrient-rich Holocene-age alluvium. Recent work in southern Iowa indicated that nitrogen and carbon contents can range up to 0.42% and 7.1%, respectively, and phosphorus concentrations up to 1792 mg/kg in fine-grained alluvium (Schilling et al., 2009). The ability of natural perennial buffers to control nutrient losses to streams incising through the Holocene alluvium has not been assessed.

The purpose of this study was to examine how groundwater nutrient concentrations varied in the riparian zone of an incised stream. In particular we were interested in evaluating factors that affect groundwater concentration patterns, namely i) distance away from an incised stream and ii) perennial land cover type, with our ultimate objective being to assess the effectiveness of natural riparian buffers to reduce nutrient losses to incised streams in southern Iowa. Our study follows previous work by Schilling et al. (2009) that focused on nutrient concentrations in riparian soils. Herein we test the implication posed by the earlier study that high nutrient concentrations in riparian soils will adversely impact the quality of groundwater flowing through the soils.

2. Methods and materials

2.1. Site description

The study area consists of monitoring sites located in the riparian zone of Walnut Creek, a third-order stream draining a 5218 ha watershed in Jasper County, Iowa (Fig. 1). The area is in a humid, continental region with average annual precipitation of around 750 mm. Walnut Creek watershed is located in the Southern Iowa Drift Plain landscape region of Iowa, an area characterized by steeply rolling hills and a well-developed drainage network (Prior, 1991). Most of the soils are silty clay loams, silt loams or clay loams formed in loess and pre-Illinoian till. In the floodplain of Walnut Creek, the Holocene-age alluvial

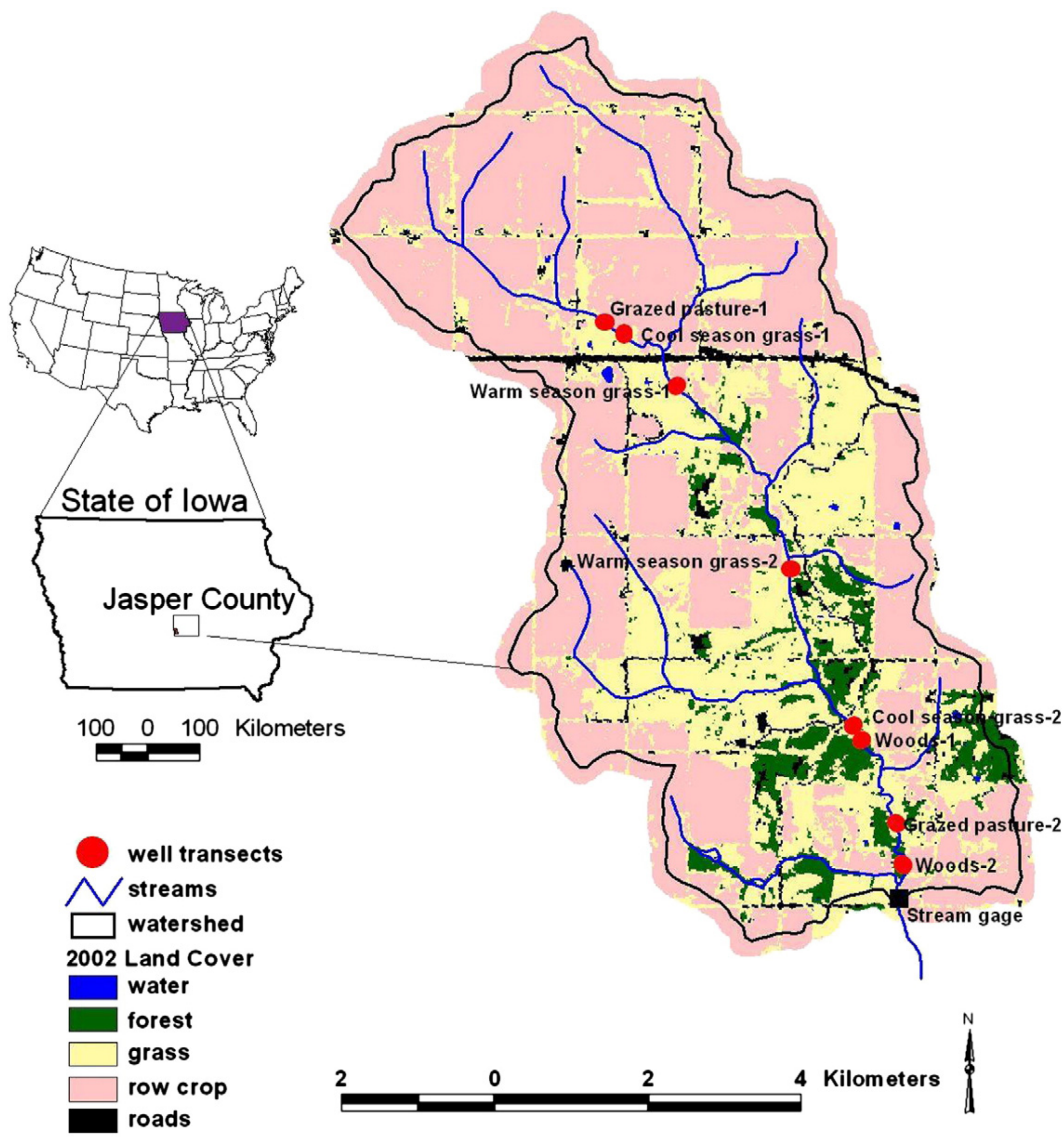

Fig. 1. Location map.