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Vertical distribution of total carbon, nitrogen and phosphorus in riparian soils of Walnut Creek, southern Iowa

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ABSTRACT

Subsurface lithology plays an important role in many riparian zone processes, but few studies have examined how sediment nutrient concentrations vary with depth. In this study, we evaluated concentrations of nutrients (N, C and P) with depth in a riparian zone of the glaciated Midwest. A total of 146 sediment samples were collected from 24 cores that extended to a maximum depth of 3.6 m at eight sites in the riparian zone of Walnut Creek. Subsurface deposits were predominantly silt loam, becoming coarser and more variable with depth. Nitrogen and carbon content ranged from <0.01 to 0.42% and <0.01 to 7.08%, respectively, and exhibited a strong trend of decreasing nutrient content with depth. In contrast, P concentrations averaged 574 mg/kg and did not vary systematically. Systematic variations in texture and nutrient content with depth largely corresponded to stratigraphic differentiation among the Camp Creek, Roberts Creek and Gunder members of the regionally recognized Holocene-age DeForest Formation. Variations in subsurface nutrient content were not found to be significantly related to present land cover, but land cover may have influenced nutrient content at the time of original sediment accumulation. Subsurface lithology and stratigraphy should be considered an important component in riparian zone studies where nutrient losses to streams via streambank erosion or groundwater discharge are assessed.

1. Introduction

Recent attention has focused on the important role that subsurface lithology and stratigraphy play in controlling many riparian zone processes. Soil and geotechnical properties are important considerations in relation to streambank stability and mass failure (Wilson et al., 2007; Simon and Rinaldi, 2006, Fox et al., 2007). Mobilization and transport of phosphorus from streambanks can contribute to eutrophication of surface waters (Sharpley et al., 2003; Laubel et al., 2003; Zaimes et al., 2008a,b). Zaimes et al. (2008b) recently observed that more than 100 kg/year of phosphorus was eroded per kilometer of stream bank length in several Iowa agricultural regions. Subsurface variations in soil texture, organic matter content, denitrification potential, and other physical and chemical properties affect dynamics of dissolved organic carbon cycling (Jacinthe et al., 2003), nitrate removal (Hill et al., 2004, DeVito et al., 2000) and phosphate concentrations in riparian groundwater (Carlyle and Hill, 2001; Schilling and Jacobson, 2008).

Despite the increasing recognition of subsurface lithology, the vertical distribution of C, N and P have rarely been documented in riparian zone studies. Soil quality investigations were extended to 35 cm in a riparian buffer zone study (Marquez et al., 1999). Other studies have focused on variations in the surface C and N pool (Homann et al., 2007), while the vertical distribution of organic C in soil is poorly understood (Jobbágy and Jackson, 2000). Nutrient concentrations are rarely evaluated at depths beyond 1 m, with typical depths less than about 20 cm. Variations in surface and shallow C have mainly focused on the effects of vegetation, climate and soil texture (e.g., Burke et al., 1989; Honeycutt et al., 1990; Hassink et al., 1993; Percival et al., 2000; Miller et al., 2004). Given the proximity of riparian zones to streams and the influence of lithology on biogeochemical processes, there is a need to examine nutrient concentrations deeper in the soil profile of riparian zones.

This study expands on Schilling and Jacobson's (2008) in Walnut Creek watershed by conducting nutrient and textural analyses on sediment cores that extended to depths of 3 m in the riparian zone of a small rural stream in southern Iowa. Previous work included only

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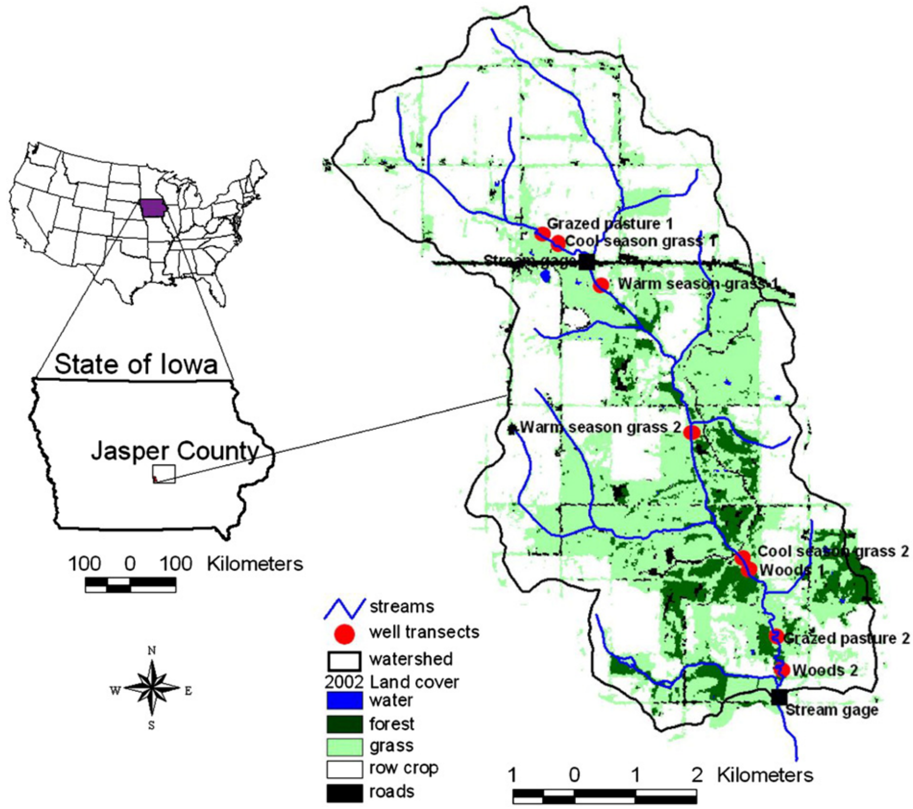

Fig. 1. Location of Walnut Creek and sampling sites.

limited sediment analyses at a single monitoring transect. Herein we report on nutrient concentrations (N, C and P) measured in subsurface sediments at several riparian zone sites in the watershed and assess the effects of four general land cover classifications and lithostratigraphic properties of alluvium on deep nutrient profiles. Because stratigraphic and land cover conditions encountered in the Walnut Creek riparian zone are similar to conditions observed elsewhere in the Midcontinent of the United States, study results are applicable regionally. Our study objectives were to: 1) evaluate how concentrations of nutrients (N, C and P) varied with depth and land cover in the riparian zone of Walnut Creek; and 2) interpret the nutrient variations within the context of the lithostratigraphic framework developed for Holocene alluvium in the Upper Midwest. We hypothesized that variations in subsurface soil nutrient concentrations were better explained by the legacy of historical sediment deposition than current land cover.

2. Methods and materials

2.1. Site description

The 5218 ha Walnut Creek watershed is located in the Southern Iowa Drift Plain region of Iowa, an area characterized by steeply rolling hills and a well-developed drainage network (Prior, 1991). The Neal Smith National Wildlife Refuge (NSNWR) is located in the central portion of the Walnut Creek watershed (Fig. 1). Since 1995, large portions of the watershed have been restored from row crop agriculture to native prairie and savanna at the NSNWR by the United States Fish and Wildlife Service. As of 2005, 1224 ha have been planted in native prairie representing 23.5% of the watershed (Schilling and Spooner, 2006).

Walnut Creek is incised in the floodplain to a depth of approximately 3 m, with width-depth ratios generally ranging between 3 and 4 (Schilling and Wolter, 2000). Stream sinuosity is approximately 1.2, suggesting that much of Walnut Creek was channelized in the past. Discharge in Walnut Creek tends to be very flashy, responding rapidly to precipitation events and snowmelt. Between 1996 and 2005, stream discharge at the downstream gaging station ranged from a high of 13.9 m^3/s to a low of 0.002 m^3/s (Schilling et al., 2006).

The alluvial stratigraphy in Walnut Creek watershed is characteristic of many other valleys across Iowa and in loess-mantled areas of the Midwest (Bettis, 1990; Mandel and Bettis, 1992; Bettis and Autin, 1997). The majority of alluvial fill in these valleys is Holocene in age collectively called the DeForest Formation (equivalent to the Cahokia Alluvium of Illinois; Bettis, 1990; Bettis et al., 1992). The formation is divided into four members based on lithologic properties (texture, color, bedding structures and pedogenic alterations) and landscape associations and includes the Camp Creek, Roberts Creek, Gunder and Corrington members (Bettis, 1990; Bettis et al., 1992). The Corrington Member is typically only observed in major river valleys and was not present in our study area. The three alluvial units found in small tributary valleys (Camp Creek, Roberts Creek, Gunder members) were each deposited during a restricted time range during the Holocene, with the Gunder Member deposited between about 10,500 and about 4500 radiocarbon-years B.P., the Roberts Creek Member from 3500 to about 500 B.P. and the Camp Creek Member from about 400 B.P. to present (Bettis et al., 1992). While texture of each member varies as source materials change, the fills are dominantly silty, loamy and clayey, and buried organic matter is often preserved. Regionally, the Roberts Creek Member has been found to consistently contain a higher content of organic carbon than the Gunder Member (Bettis et al., 1992).

The riparian zone of Walnut Creek contains four major perennial land cover types and two replicates of each type were targeted for investigation in this study (total of eight sites; Fig. 1). Dominant vegetation at the two cool season grass sites consisted of *Phalaris arundinacea* L. (reed canary grass), an invasive forage grass adapted to wide extremes in soil moisture (Galatowitsch et al., 1999). The two