THE INFLUENCE OF GEOMORPHIC SETTING ON GROUND WATER DENITRIFICATION IN FORESTED RIPARIAN WETLANDS

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ABSTRACT

Riparian wetlands are potentially significant landscape features for controlling the export of ground water nitrate (NO_3^-–N), to surface waters. Variability at both the reach and watershed scales has thwarted efforts to predict watershed-scale potential for riparian ground water nitrogen removal, and to effectively manage riparian zones based on functional assessments. Removal of ground water NO_3^-–N through microbial denitrification is influenced by the presence of subsurface organic C, and by ground water flow paths that determine retention time within the riparian subsurface ecosystem. Because geomorphic setting can describe depositional features that influence ground water flow path and the occurrence of subsurface C, it has the potential to serve as an indicator for riparian ground water denitrification potential. Moreover, if riparian geomorphology relates to N removal, then watershed-scale assessments of N export could be assisted with the availability of easily mapped geomorphic settings. Glaciated regions such as the northeastern United States are often divided into three major geomorphic settings: glacial till deposits, glacial outwash, and alluvial soils. Previous research has questioned the potential for ground water denitrification within riparian wetlands situated in glacial till, based on the high frequency of surface seeps that dramatically reduce retention times. In contrast, riparian wetlands situated in glacial outwash and alluvium are frequently characterized by low gradient, deep, stratified sediments that can transmit high ground water fluxes and where retention times can be considerable. The objective of this research was to (1) compare the vertical pattern and extent of microbial ground water denitrification in riparian wetland (hydric) soils located in

glacial outwash vs. alluvial geomorphic settings, and (2) assess the potential for ground water to interact with biologically active areas of deep, stratified soils underlying riparian zones situated in glacial outwash and alluvial settings. To quantify ground water denitrification in discrete locations of riparian aquifers, we modified and evaluated an in situ method based on conservative tracers and ^{15}N-enriched nitrate (Manuscript I). We measured in situ ground water denitrification rates at three depths (65, 150, and 300 cm) within hydric soils at four riparian sites (two per setting) using a ^{15}N-enriched nitrate "push–pull" method (Manuscript II). No significant difference was found in the pattern and magnitude of denitrification when grouping sites by setting. At three sites there was no significant difference in denitrification among depths. Correlations of site characteristics with denitrification varied with depth. At 65 cm, ground water denitrification correlated with variables associated with the surface ecosystem (temperature, dissolved organic carbon). At deeper depths, rates were significantly higher closer to the stream where the subsoil often contains organically enriched deposits that indicate fluvial geomorphic processes, regardless of setting. We measured piezometric heads along a transect perpendicular to the stream, from the stream to the upland, at four riparian sites (two per setting) during a period of sustained high water table. We used a two-dimensional ground water flow model to estimate the associated piezometric surfaces, flow paths, and fluxes through the subsurface riparian ecosystem, defined as the stream to upland, to a depth of 3 m (Manuscript III). Modeling results showed that at the time when piezometric heads were measured ground water flux was substantial through the riparian subsurface ecosystem at all sites, with more complex flow paths than hypothesized, and with no apparent relationship between the geomorphic setting of these sites and the observed flow patterns. At all sites evapotranspiration (ET) dominated the hydrologic budget, ranging from 44% to 92% of the total outflux. Outflux to the stream was <10% of the total outflux at all sites. Within 10 m of the stream, where observed ground water denitrification rates were highest [Manuscript II], retention times along flow paths to the stream combined with denitrification rates resulted in the potential removal by denitrification of >10 mg L^{-1} NO_3^-–N at three of the four sites. Average annual watershed estimates that accounted for periods of low ET showed that these riparian wetlands could be transmitting about 8% of the upland recharge through ET. A nitrogen budget of the riparian wetland sites using a hypothetical development scenario in the uplands showed that three of the four sites could potentially remove or store about 25% of the upland ground water N load, with about 75% carried further downgradient to emerge lower in the watershed as either ET or baseflow. The fourth site could potentially remove or store about 90% of the upland ground water N load. Minimal N (0% to 9%) would have reached the stream. The low flux to the stream during periods of elevated evaporative demand suggests that non-hydric and till riparian areas provide much of the baseflow at this time, and argues for protection of infiltration and natural flow patterns throughout the watershed. Still unexplored is the role riparian wetlands may play when vegetation is dormant, as well as the role that root depth may have in maintaining ET during the growing season.