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The role of vegetation and litter in the nitrogen dynamics of riparian buffer zones in Europe

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Abstract

Plant uptake and denitrification are considered to be the most important processes responsible for N retention and mitigation in riparian buffers. In many riparian buffers, however, nutrients taken up by plants remain in the system only temporarily and may be gradually released by mineralization later. Still, plants increase the residence time of nutrients considerably by reducing their mobility. We investigated the importance of plant N uptake and N immobilization in litter for N retention in riparian buffers. Nitrogen uptake in vegetation and N dynamics in litter were measured over a two-year period in a range of forested and herbaceous riparian buffers along a climatic gradient in Europe, receiving different loadings of N-enriched groundwater. Plant production, nitrogen uptake, and N retention were significantly higher in the forested buffer sites compared to the herbaceous buffer sites. However, in herbaceous buffers, periodic harvesting of herbaceous biomass contributed considerably to the N retention. No relationship between lateral N loading and plant productivity or N uptake was observed; this indicated that plant growth was not N-limited. In the winter period, decaying leaf litter had a small but significant role in N retention in a majority of the riparian ecosystems studied. Moreover, no responses to the climatic gradient were found. Generally, we

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can state that annual N retention in the vegetation and litter compartment is substantial, making up 13–99% of the total N mitigation.

Keywords: Decomposition; Immobilization; Mineralization; N retention; Plant N uptake; Riparian buffers

1. Introduction

Natural riparian zones are known to influence many aspects of stream ecosystems, including stream bank stability, water temperature, primary production, and water and nutrient inputs from terrestrial runoff (see Naiman and Decamps, 1997 for a review). In agricultural landscapes both surface runoff and subsurface runoff are major sources of sediments, nutrients and pesticides for streams. Nitrogen (as nitrate) is considered the most important and widespread water pollutant in agricultural runoff (Meybeck and Helmer, 1989; Isermann, 1990; Olsthoorn and Fong, 1998) and N removal can be highly efficient in riparian zones (Cooper, 1990; Gilliam, 1994; Hill, 1996; Mander et al., 2000). Indeed riparian zones function as buffers to reduce the quantity of diffuse pollution that reaches streams (Lowrance et al., 1984; Peterjohn and Correll, 1984; Pinay and Decamps, 1988; Osborne and Kovacic, 1993; Vought et al., 1994).

The removal of nitrogen in riparian wetlands is commonly attributed to both denitrification and plant uptake. There is, however, little agreement on the relative importance of these two processes in N removal. Most studies on nitrogen removal in riparian wetlands have focused on denitrification and nitrogen mass balances in shallow groundwater. Although there are numerous studies on plant nutrient uptake and plant biomass accumulation in riparian wetlands, few authors have attempted to quantify the net annual retention of nutrients in plant biomass and litter (Johnston, 1991). Recent experimental studies on N removal in riparian zones indicated that denitrification is probably more important than plant N uptake in the N removal of riparian zones (Verchot et al., 1997; Schade et al., 2001). This may be in accordance with expectation, because plants only temporarily retain N which returns to the available pool once mineralized, whereas denitrification permanently removes N from the soil to the atmosphere. Denitrification, however, cannot account for all inorganic N removal, suggesting that N storage in perennial plant tissue, and soil as organic matter through peat formation are potentially important processes in riparian buffers (Lowrance et al., 1984; Groffman et al., 1992; Simmons et al., 1992; Haycock and Pinay, 1993; Zhu and Ehrenfeld, 2000). Moreover, the relative importance of vegetation in N mitigation may increase with biomass harvesting, e.g. mowing or logging.

Apart from the role of vegetation in the long-term nitrogen retention in riparian buffers, plant uptake into annual tissues results in a desynchronization of nitrogen availability caused by the time lag between plant N uptake and N release by decomposition and mineralization. Additionally, immobilization of N in litter during the first stages of the decomposition requires nutrients from external sources and may temporarily reduce the amount of inorganic nitrogen in the interstitial water. Therefore, net-immobilization by decomposing litter contributes to short-term N retention in riparian zones (Berg and Staaf, 1981; Bowden, 1986). As litter decomposition predominantly begins with plant senescence in autumn, the immobilization and retention of N in the litter fraction is most important during the dormant (winter) period. This coincides with the period when the risk of nutrient losses from agricultural fields is high due to excessive rainfall and the absence of a crop (Burt and Arkell, 1987). Moreover, low temperatures in this period limit N removal by denitrification activity (Maag et al., 1997). Hence, in winter, immobilization may be more important than denitrification in the N retention in buffers.

Riparian wetlands in agricultural watersheds are subject to increasingly high nitrate inputs, which will lead to changes in species composition and nitrogen dynamics. Increased nitrogen availability is known to result in increased nitrogen cycling rates (Aerts et al., 1995; Verhoeven et al., 1996). Enhanced nitrogen cycling may reduce the importance of plant uptake and litter immobilization in the nitrogen retention