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Effects of land cover on water table, soil moisture, evapotranspiration, and groundwater recharge: A Field observation and analysis

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Abstract

The effects of land cover on water table, soil moisture, evapotranspiration, and groundwater recharge were studied with water level measurements collected from two monitoring wells over a period of 122 days. The two wells were installed under similar conditions except that one was drilled on the east side of a creek which was covered with grass, and the other on the west side of the creek which was burned into a bare ground. Substantial differences in water level fluctuations were observed at these two wells. The water level in the east grass (EG) well was generally lower and had much less response to rainfall events than the west no-grass (WNG) well. Grass cover lowered the water table, reduced soil moisture through ET losses, and thus reduced groundwater recharge. The amount of ET by the grass estimated with a water table recession model decreased exponentially from 7.6 mm/day to zero as the water table declined from near the ground surface to 1.42 m below the ground surface in 33 days. More groundwater recharge was received on the WNG side than on the EG side following large rainfall events and by significant slow internal downward drainage which may last many days after rainfall. Because of the decreased ET and increased R, significantly more baseflow and chemical loads may be generated from a bare ground watershed compared to a vegetated watershed.
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1. Introduction

It is well recognized that land cover and land use change have significant effects on hydrological processes such as evapotranspiration (ET), soil moisture and groundwater recharge (Hillel, 1998; Rodriguez-Iturbe, 2000; Eagleson, 2002). Recent climate-soil-vegetation modeling (e.g. Rodriguez-Iturbe et al., 1999; Rodriguez-Iturbe, 2000; Laio et al., 2001; Guswa et al., 2002) suggest that given the same soil type under vegetated and bare soil conditions, vegetated soils with soil moisture losses from ET retain more infiltrating precipitation than bare soils with soil moisture loss from evaporation alone. Hence, vegetated soils would produce less groundwater recharge than bare soils.

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In application, differences in hydrological processing among land cover types can be used as strategy for reducing transport of pollutants to streams. For example, along stream corridors in agricultural watersheds, the use of perennial vegetation as a riparian buffer to scavenge excess water and nutrients from annual row crop fields has been long recognized (Pettyjohn and Correll, 1983; Hill, 1996; Correll, 1997; Cey et al., 1999; Lee et al., 2003). On a watershed scale, recent studies have suggested that adding perennial plants of substantial portions of agricultural landscapes offers promise for improving water quality (Nassauer et al, 2002; Coiner et al., 2001; Vaché et al., 2002). In the Walnut Creek watershed in Jasper County, Iowa, conversion of 33.7% of a 5217 ha watershed from row crop to native prairie has resulted in a 0.0028 mg/l per week decrease in stream nitrate concentrations (Schilling, 2002) and a measurable decrease in stream baseflow (Schilling, 2002). Randall et al. (1997) found that nitrate concentrations in drainage water from alfalfa and perennial grasses were 35 times lower than drainage water from corn and soybean fields.

One important benefit of using perennial vegetation in agricultural settings to reduce non-point source pollution loads relies on the fact that perennial cover increases evapotranspiration (ET) as compared to annual row crops. Perennial vegetation transpires throughout the spring, summer and fall, whereas substantial transpiration from row crops typically does not occur until mid-growing season. Vulnerable leaching periods occur in the spring and fall because crop uptake in Midwestern row crop production is not particularly well timed for utilizing available precipitation (Dinnes et al., 2002). Hence, maximizing water uptake by perennial vegetation in row crop fields can be used as an important nutrient control strategy for reducing nonpoint source pollution loads in the agricultural Midwest.

Historical evidence from Iowa illustrates how removal of perennial vegetation from an agricultural landscape profoundly affected stream flow characteristics and nitrate concentrations over the 20th century. Baseflow and the percentage of stream flow as baseflow significantly increased in Iowa over the second half of the 20th century, more than precipitation alone can explain (Schilling and Libra, 2003; Schilling and Zhang, 2003). Schilling and Libra (2003) hypothesized that one of the main reasons for increasing baseflow in Iowa over the 20th century was converting previously untilled land or other perennial cover crops to annual row crops. Increasing baseflow was found to be significantly related to increasing row crop intensity (Schilling, 2005). Because nitrate–nitrogen (nitrate) is primarily delivered to Iowa streams through baseflow discharge and tile drainage (Hallbertg, 1987; Schilling, 2002), changing watershed hydrology to more baseflow has the potential to deliver more nitrate to streams. In conjunction with the land use change in Iowa, a 2- and 3-fold increase in nitrate–nitrogen concentrations has been observed in the Cedar and Des Moines rivers during the 1940–2000 period (Iowa Geological Survey, 2001).

Recently, we observed the effects of land cover on a shallow groundwater table. For a 122-day period in the late summer and fall of 2003, continuous water level measurements made in two monitoring wells, one is located on bare ground and the other under dense grass cover, revealed substantial differences in water table behavior. The purposes of this paper are to present and describe the observed data, to analyze the effects of grass cover on water table, soil moisture, ET, and groundwater recharge, and to discuss the effects of grass cover on the basin-scale water cycle and nonpoint source pollution loads. Results from this study have implications for water cycle research and for utilizing perennial vegetation in agricultural watersheds for management of nutrient losses.

2. Site description and land treatment

Our study site is situated in the central portion of the Walnut Creek watershed at the Neal Smith National Wildlife Refuge (NSNWR) in Jasper County Iowa (Fig. 1). This site was chosen because it is an area of ongoing restoration efforts by the NSNWR to restore a portion of the floodplain from vegetation dominated by reed canary grass (*Phalaris arundinacea*) to a moderately diverse sedge meadow. *P. arundinacea* is an aggressive invasive species found throughout temperate North America that has been cultivated as forage grass because it is adapted to wide extremes in soil moisture (Galatowitsch et al., 1999). *P. arundinacea* thrives in wetlands with high annual or periodic fluctuations in water levels and is

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