Report for 2004AR74B: Hydrodynamics of a Karst Soil Catena in the Ozark Plateau, USA

- Dissertations:
  - DeFauw, S.L., 2005 (in progress), Hydrodynamics of a Hillslope Assemblage in the Ozark Highlands, USA. Ph.D. Dissertation, Environmental Dynamics Program, College of Arts and Sciences, University of Arkansas, Fayetteville, Ar, xxxpp.
- Other Publications:
  - DeFauw, S.L., T.J. Sauer, K.R. Brye, M.C. Savin, P.D. Hays, and J.V. Brahana, 2005 (in press), Nitrate-N distributions and dentrification potential estimates for an agroforestry site in the Ozark Highlands, USA. In: Proceedings of the Ninth North American Agroforestry Conference, CINRAM, St. Paul, MN. xx-xx. [Invited paper]
  - DeFauw, S.L., T.J. Sauer, K.R. Brye, M.C.Savin, P.D. Hays, and J.V. Brahana, 2005 (in press), Nitrate-N distributions and dentrification potential estimates for an agroforestry site in the Ozark Highlands, USA. In: Abstracts of the Ninth North American Agroforestry Conference, 12-15 June 2005, Rochester, MN, xx-xx. [Invited abstract]
  - DeFauw, S.L., T.J. Sauer, P.D. Hays, K.R. Brye, and J.V. Brahana, 2004, Hydrodynamics of an Experimental Silvopastoral Field in the Ozark Plateau of Northwestern Arkansas, USA. In: Book of Abstracts, First World Congress of Agroforestry, 27 June-2 July 2004, Orlando, FL, USA, p. 176.
  - Thomas, A.L., S.L. DeFauw*, T.J. Sauer, and D. Brauer, 2004, Hydrologic Influences on the Growth of yound Grafted Black Walnut Trees in Arkansas, USA. In: Book of Abstracts, First World Congress of Agroforestry, 27 June-2July 2004, Orlando, FL, USA, p.213. [*presenter]
  - Sauer, T.J., S.L. DeFauw, K.R. Brye, J.V. Brahana, J.V. Skinner, W.K. Coblentz, A.L. Thomas, P.D. Hays, D.C. Moffitt, J.L. Robinson, T.A. James, D.K. Brauer, and K.A. Hickie, 2004, N and P Assimilation in a Silvopastoral System Receiving Poultry Litter or Inorganic Fertilizer. In: Book of Abstracts, First World Congress of Agroforestry, 27 June-2 July 2004, Orlando, FL, USA, p.207.

Report Follows

Problem and Research Objectives:

The dynamics of nutrient infiltration and subsurface transport and transformation in karst terrains characterized by high soil heterogeneity, multi-level permeability contrasts within the vadose zone (e.g., plowpans, fragipans, and relict chert layers), rapidly fluctuating unconfined aquifers, and preferential flow paths is very poorly understood. Despite these gaps in our knowledge of basic soil-water relations and biogeochemical processing, land application of animal manures has intensified, in this region, over the past five decades. The main objectives of this research are fivefold: (1) determine saturated and unsaturated hydraulic conductivities at the soil surface for the three soil series (Nixa, Captina, and Johnsburg) that dominate an experimental silvopastoral field on the University of Arkansas Farm; (2) estimate saturated hydraulic conductivities for various subsoil horizons penetrated by select shallow wells; (3) track fluctuations in the unconfined aquifer, throughout the year, and produce a probability map for the water table surface; (4) evaluate nutrient (NO_3-N) sources, transformations and transport, within a karst catena, using stable isotopes; and (5) examine current management practices (i.e., the timing and rate of poultry litter and commercial fertilizer applied per hectare) in light of the hydrodynamic patterns that develop in this field throughout the year (and suggest modifications that should be implemented to enhance fertilizer use efficiency).

Methodology:

Soil Water and Ground Water Monitoring and Analysis. Concentrations of nitrate-N and total P in the soil and ground waters have been regularly monitored over the past three growing seasons (March 2002 – October 2004), and include a several storm events. Water samples from porous cups and shallow wells were colorimetrically analyzed for nitrate-N using a Lachat continuous-flow ion analyzer. Ground water DOC (collected over two growing seasons, from May 2003 – October 2004) was determined using a Shimadzu TOC-V_{CSH} Analyzer.

Subsoil Hydraulic Conductivities. Saturated hydraulic conductivities for select wells were derived from bail-down data. Well recoveries were plotted in Excel. The Bouwer and Rice method (incorporating modifications from Bouwer, 1989) was used to estimate subsoil saturated hydraulic conductivities. This methodology was designed to account for the geometry of partially penetrating or fully penetrating wells in unconfined aquifers.

GIS Database. A DGPS unit was used to produce a high-resolution topographic map of the AEF. The GIS database (ArcView 3.3) incorporates topography, soils, unconfined aquifer fluctuations (including basic water quality parameters), electromagnetic induction (EMI) geophysical surveys, tree growth patterns, nitrate-N profiles, and the spatiotemporal delineation of N pools developed at the soil-karst interface of this agroecosystem. The ArcView Hydro extension was used to produce a simple model of the AEF's surface hydrology. Field-scale nitrate-N distributions for porous cup and well datasets were mapped using grid interpolation techniques (i.e., Spline method with a 1 meter cell size, weight varied 100-700 for the purpose of optimization, number of points varied from 2-4, type Tension). Change detection operations were performed on optimized grid maps using Map Calculator.

Principal Findings and Significance:

Transport and biogeochemical processing of nitrate-N in upland watersheds is poorly understood, and denitrification potential estimates for the thin soil veneers of the Ozark Highlands have yet to be documented. Since March 2001, nitrate-N distributions have been monitored from an array of 53 shallow wells (0.5-5.6 m deep) emplaced in a 4.3 ha experimental agroforestry site (receiving split-field treatment of poultry litter to the eastern half in Spring, and a comparable annual N-load from commercial fertilizer applied on the western half in Spring and Fall). The field integrates subsurface flows from a small upland catchment and, in March 2001, contained several "hot spots" with ground water nitrate-N varying from 25.0-64.5 mg/L. Late winter peaks in nitrate-N from this 6 year-old alley cropping system have steadied over the last 2 years (13.2 mg/L for mid-March 2003; 12.0 mg/L for late-February 2004). Saturated hydraulic conductivity means for 3 down-gradient wells (2.0-3.6 m) ranged from 0.83±0.17 to 1.12±0.20 m/day during baseflow conditions. High aquifer-stand hydraulic conductivity estimates were significantly lower for two out of three wells, expanding the range to 0.41±0.05 to 1.39±0.02 m/day, with the well in the lowest landscape position stemming the flow through this hillslope soil assemblage. Mean denitrification potentials, based solely on declines in nitrate-N throughout the growing season for this key ground water integration area, were 8.15±6.20 kg/ha (2002), 20.80±10.23 kg/ha (2003), and 7.11±3.65 kg/ha (2004). Cross-validation of these estimates, using dissolved organic carbon (DOC), resulted in mean denitrification potentials of 22.45±4.41 kg/ha and 16.78±3.63 kg/ha for the 2003 and 2004 growing seasons, respectively. Results of this field-to-small-watershed scale investigation provide much-needed data on key soil physical properties, transit times, and biogeochemical processes useful in the development of nutrient management strategies that adequately reflect the "N-loading capabilities" as well as seasonal vulnerabilities of a common hillslope soil assemblage in the Ozark Highlands. Data collection and analysis for the stable isotope component of this investigation is still in process and will be completed by 31 August 2005.