Data from: Leaching losses of dissolved organic carbon and nitrogen from agricultural soils in the upper US Midwest

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Abstract

Leaching losses of dissolved organic carbon (DOC) and nitrogen (DON) from agricultural systems are important to water quality and carbon and nutrient balances but are rarely reported; the few available studies suggest linkages to litter production (DOC) and nitrogen fertilization (DON). In this study we examine the leaching of DOC, DON, NO_3^-, and NH_4^+ from no-till corn (maize) and perennial bioenergy crops (switchgrass, miscanthus, native grasses, restored prairie, and poplar) grown between 2009 and 2016 in a replicated field experiment in the upper Midwest U.S. Leaching was estimated from concentrations in soil water and modeled

drainage (percolation) rates. DOC leaching rates (kg ha^{-1} yr^{-1}) and volume-weighted mean concentrations (mg L^{-1}) among cropping systems averaged 15.4 and 4.6, respectively; N fertilization had no effect and poplar lost the most DOC (21.8 and 6.9, respectively). DON leaching rates (kg ha^{-1} yr^{-1}) and volume-weighted mean concentrations (mg L^{-1}) under corn (the most heavily N-fertilized crop) averaged 4.5 and 1.0, respectively, which was higher than perennial grasses (mean: 1.5 and 0.5, respectively) and poplar (1.6 and 0.5, respectively). NO_3^- comprised the majority of total N leaching in all systems (59-92%). Average NO_3^- leaching (kg N ha^{-1} yr^{-1}) under corn (35.3) was higher than perennial grasses (5.9) and poplar (7.2). NH_4^+ concentrations in soil water from all cropping systems were relatively low (< 0.07 mg N L^{-1}). Perennial crops leached more NO_3^- in the first few years after planting, and markedly less after. Among the fertilized crops, the leached N represented 14-38% of the added N over the study period; poplar lost the greatest proportion (38%) and corn was intermediate (23%). Requiring only one third or less of the N fertilization compared to corn, perennial bioenergy crops can substantially reduce N leaching and consequent movement into aquifers and surface waters.

Methods

Leaching dataset of dissolved organic carbon (DOC) and nitrogen (DON), nitrate (NO3+) and ammonium (NH4+) were collected from 6 cropping treatments (corn, switchgrass, miscanthus, native grass mix, restored prairie and poplar) established in the Bioenergy Cropping System Experiment (BCSE) which is a part of Great Lakes Bioenergy Research Center (www.glbrc.org) and Long Termn Ecological Research (LTER) program (www.lter.kbs.msu.edu). The site is located at the W.K. Kellogg Biological Station (42.3956° N, 85.3749° W and 288 m above sea level), 25 km from Kalamazoo in southwestern Michigan, USA.

Prenart soil water samplers made of Teflon and silica (http://www.prenart.dk/soil-water-samplers/) were installed in blocks 1 and 2 of the BCSE (Fig. S1), and Eijkelkamp soil water samplers made of ceramic (http://www.eijkelkamp.com) were installed in blocks 3 and 4 (there were no soil water samplers in block 5). All samplers were installed at 1.2 m depth at a 45° angle from the soil surface, approximately 20 cm into the unconsolidated sand of the 2Bt2 and 2E/Bt horizons. Beginning in 2009, soil water was sampled at weekly to biweekly intervals during non-frozen periods (April to November) by applying 50 kPa of vacuum for 24 hours, during which water was collected in glass bottles. During the 2009 and 2010 sampling periods we obtained fewer soil water samples from blocks 1 and 2 where Prenart lysimeters were installed. We observed no consistent differences between the two sampler types in concentrations of the analytes reported here.

Depending on the volume of leachate collected, water samples were filtered using either 0.45 µm pore size, 33-mm-dia. cellulose acetate membrane filters when volumes were <50 ml, or 0.45 µm, 47-mm-dia. Supor 450 membrane filters for larger volumes. Samples were analyzed for NO_3^-, NH_4^+, total dissolved nitrogen (TDN), and DOC. The NO_3^- concentration was determined using a Dionex ICS1000 ion chromatograph system with membrane suppression and conductivity detection; the detection limit of the system was 0.006 mg NO_3^--N L^{-1}. The NH_4^+ concentration in the samples was determined using a Thermo Scientific (formerly Dionex) ICS1100 ion chromatograph system with membrane suppression and conductivity detection; the detection limit of the system was similar. The DOC and TDN concentrations were determined using a Shimadzu TOC-Vcph carbon analyzer with a total nitrogen module (TNM-1); the detection limit of the system was ~0.08 mg C L^{-1} and ~0.04 mg N L^{-1}. DON concentrations were estimated as the difference between TDN and dissolved inorganic N (NO_3^- + NH_4^+) concentrations. The NH_4^+ concentrations were only measured in the 2013-2015 crop-years, but they were always small relative to NO_3^- and thus their inclusion or lack of it was inconsequential to the DON estimation.

Leaching rates were estimated on a crop-year basis, defined as the period from planting or emergence of the crop in the year indicated through the ensuing year until the next year's planting or emergence. For each sampling point, the concentration was linearly interpolated between sampling dates during non-freezing periods (April through November). The concentrations in the unsampled winter period (December through March) were also linearly interpolated based on the preceding November and subsequent April samples.

Solute leaching (kg ha^{-1}) was calculated by multiplying the daily solute concentration in pore-water (mg L^{-1}) by the modeled daily drainage rates (m^3 ha^{-1}) from the overlying soil. The drainage rates were obtained using the SALUS (Systems Approach for Land Use Sustainability) model (Basso and Ritchie, 2015). SALUS simulates yield and environmental outcomes in response to weather, soil, management (planting dates, plant population, irrigation, nitrogen fertilizer application, tillage), and crop genetics. The SALUS water balance sub-model simulates surface run-off, saturated and unsaturated water flow, drainage, root water uptake, and evapotranspiration during growing and non-growing seasons (Basso and Ritchie, 2015). Drainage amounts and rates simulated by SALUS have been validated with measurements using large monolith lysimeters at a nearby site at KBS (Basso and Ritchie, 2005). On days when SALUS predicted no drainage, the leaching was assumed to be zero. The volume-weighted mean concentration for an entire crop-year was calculated as the sum of daily leaching (kg ha^{-1}) divided by the sum of daily drainage rates (m^3 ha^{-1}). Weather data for the model were collected at the nearby KBS LTER meteorological station (lter.kbs.msu.edu).

Usage Notes

readme files are given that describe the data table

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References

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Keywords

dissolved organic matter, nitrate, corn, grass, poplar, Biofuel

Files

2 files for this dataset

Readme_leaching_d...and_nitrogen.txt	10.07 kB	text/plain
data_table_leachi...and_nitrogen.xls	695.30 kB	application/vnd.ms-excel

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