The MANAGE Database Drainage Nutrient Concentration Table: An analysis of uncontrollable factors affecting water quality

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Introduction

Successful cropping systems rely on sufficient amounts of nitrogen (N) and phosphorus (P) to sustain plant growth. However, precipitation, soil properties / hydrology, and topography are uncontrollable factors that play a major role the movement of these nutrients through the soil profile and thus significantly influence agricultural nutrient loss. Soils with sandy subsoils, high organic matter content, and preferential flow paths can lead to significant P leaching through subsurface drainage. These factors combine with the duration, intensity, and quantity of precipitation to help determine the route of nutrient transport.

The "Measured Annual Nutrient loads from AGricultural Environments" (MANAGE) database is a compilation of field-scale surface and subsurface nitrogen and phosphorus loads from agricultural landscapes across the United States and Canada. The MANAGE database is administered by the United States Department of Agriculture, Agricultural Research Service, Center for Agricultural Resources Research in Fort Collins, Colorado, and has previously been published as a database.

The **objectives** of this study were to:

- Update the MANAGE database to include agricultural subsurface drainage N and P concentrations
- Assess the variability of subsurface drainage nutrient concentrations across environments
- Use this information to produce probabilities that annual nutrient concentrations will exceed a given threshold across all environments

Methods

- Between May and December 2017, a literature review of more than 400 agricultural drainage publications yielded nutrient concentration, cropping system, crop yield, nutrient application, precipitation, and drainage data from 79 "acceptable" subsurface and surface drainage studies.
- Data were used to create a "Drain Concentration" table within MANAGE
- Acceptable literature must: 1) have been peer-reviewed; 2) be from studies performed in the United States or Canada; 3) contain at least one full year of data (multiple years were divided into separate "site-years"); 4) have a drainage area ≥0.009 ha; 5) be for "free drainage" treatments only; 6) not be a rainfall simulation or lysimeter study
- Medians of annual mean nutrient concentrations were used for spatial analysis maps due to extreme outliers skewing the means of annual mean concentrations.
- Probability of exceedance for the nutrient concentrations was calculated with the Weibull formula (eq. 1), which creates unbiased exceedance probabilities for all distributions. This was done by ranking (r) concentrations in descending order with rank one as the highest concentration in the database for a given nutrient. These rankings were divided by the total number of concentrations (n) plus one. This probability was then plotted against the corresponding concentration.

$$eq.1: \frac{r}{(n+1)}(100)$$

Results

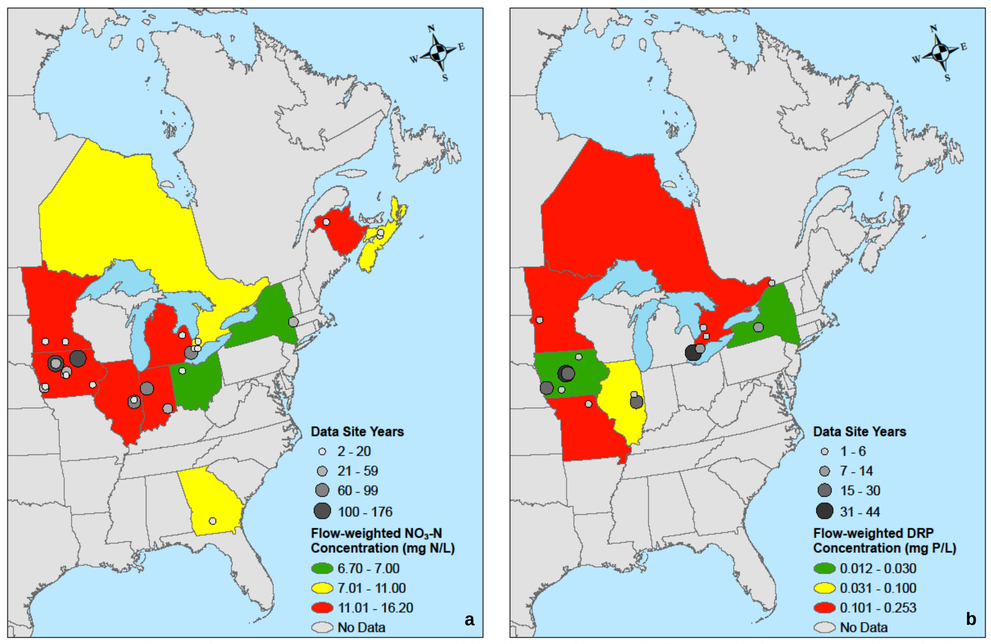

Figure 1. Location density of MANAGE Drain Concentration table subsurface drainage for flow-weighted NO_3-N (a) and Dissolved Reactive P (b) concentration site-years (gray/black dots) along with median annual flow-weighted concentrations in subsurface drainage by state/province

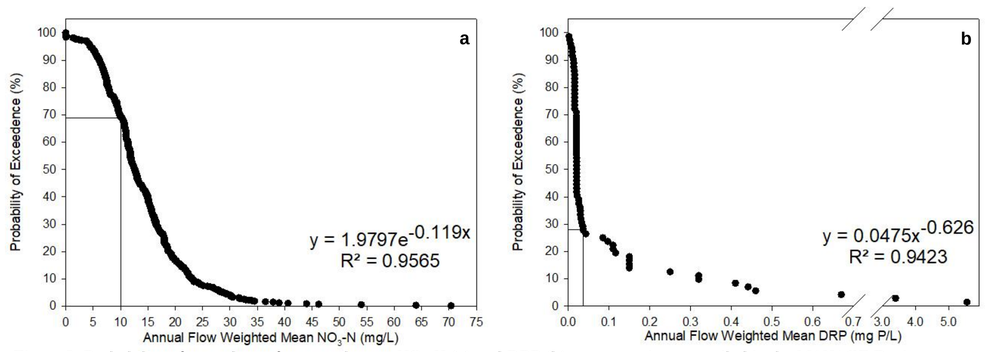

Figure 2. Probability of exceedance for annual mean NO_3-N (a) and DRP (b) concentrations compiled in the MANAGE Drain Concentration table. Vertical lines signify thresholds for the 10 mg N/L maximum allowable nitrate concentration in drinking water (USEPA 2009) (a) and the 0.375 mg P/L threshold for total P to limit algal growth in lakes and reservoirs for the Corn Belt and Northern Great Plains (USEPA 2000) (b)

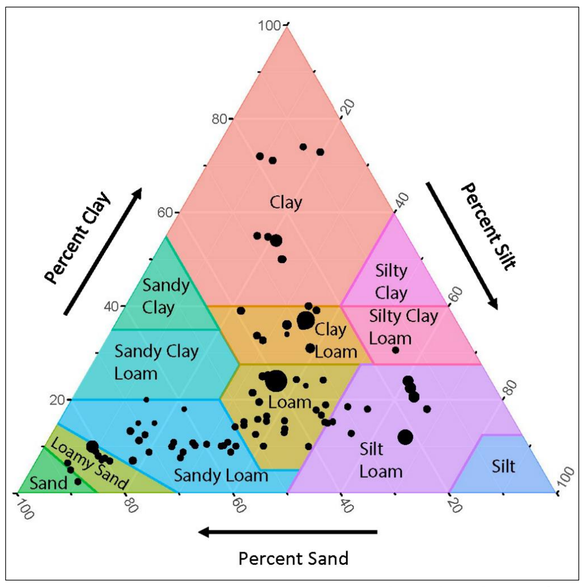

Figure 3. MANAGE Drain Concentration site-year density by soil texture for site-years with a reported percent sand, silt, and clay Dot size corresponds with the number of site-years with a given soil texture

- Medians of annual flow-weighted mean NO_3-N concentrations in subsurface drainage by state/province ranged from 6.70 to 16.20 mg N/L (figure 1a).
- The highest median annual NO_3-N concentrations were from Illinois (16.20 mg N/L; n=105), Minnesota (12.46 mg N/L; n=34), New Brunswick (12.00 mg N/L; n=10), Iowa (11.80 mg N/L; n=460), and Indiana (11.65 mg N/L; n=138).
- Medians by state/province of annual flow-weighted mean DRP concentrations in subsurface drainage ranged from 0.012 to 0.253 mg P/L (figure 1b).
- The highest median annual DRP concentrations were from Minnesota (0.253 mg P/L; n=3), Ontario (0.200 mg P/L; n=55), Missouri (0.150 mg P/L; n=4), and Illinois (0.075 mg P/L; n=30).
- There was 69% probability that a given nitrate site-year was greater than the MCL of 10 mg N/L (USEPA, 2009) (figure 2a).
- There was a relatively low (27%) probability a given site-year in the database would exceed 0.0375 mg DRP/L (figure 2b), the recommended concentration of TP to not exceed for algal growth in lakes and reservoirs within the Corn Belt and Northern Great Plains.
- The majority of site-years with a reported percent sand, silt, and clay were predominantly loam, silt loam, and clay loam soils, which corresponded with the majority of site-years being from the North American Corn Belt region (figure 3).
- The table also included sandier soils from Georgia, Nova Scotia, Quebec, and New Brunswick as well as some heavy clay Canadian soils.

Conclusions

There is an extreme need to better understand and quantify the spatial and temporal effects on nutrient transport into and out of agricultural systems. The MANAGE Drain Concentration Table provides the ability to compare multiple site-year data from many locations across the United States and Canada. This spatial analysis will aid in the experimental design of further research efforts by targeting areas that have little to no data, allowing scientists to compare research from other sites in close proximity to their own, and compare nutrient concentrations to predicted values based on all locations in the MANAGE Drain Concentration Table.

Acknowledgments

- Funding for this work was provided by the Illinois Nutrient Research and Education Council.
- MANAGE Drain Load development was previously funded by the 4R Research Fund.