Using Phosphorus Compounds to Assess Wetland Restoration

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Abstract

Wetlands provide important ecological functions including providing wildlife habitat, hydrologic buffering of floods and drought, improvement of water quality, and nutrient cycling. Restoration practices between 2004 and 2009 have increased the number of freshwater wetlands in the United States; evaluating the success of the restoration efforts has been challenging and has focused on structure to infer function. In this study, P-NMR spectrometry was used to 'visualize' the diverse chemical compounds of soil phosphorus (P) along a topographic gradient within wetland catchments to evaluate the applicability of P compound transformation as a time-integrated index of ecosystem function in prairie wetlands. Soil P was extracted for P-NMR spectrometry using a sodium hydroxide plus EDTA extraction with a two percent hydrochloric acid pretreatment for one hour. The extraction efficiency, the ratio of total P in the soil vs. the total P in the extraction, is used as an indication of the effectiveness of the soil extraction, and the number of different P compounds present in the soil was used as an indication of wetland function. The extraction efficiencies were greatest in the wetland center (60-70%) and decreased with distance from the wetland center to 30% at the wetland edge. The number of P compounds was greatest at the edge of the wetlands and in native prairie wetlands and least in agricultural cropland wetlands. The greater number of P compounds at the wetland edge suggests that soil samples for comparative P compound evaluation should be collected near the edge of the wetland.

Introduction

1. Wetlands provide valuable ecosystem services including providing wildlife habitat, hydrologic buffering of floods and drought, improving water quality, nutrient cycling, aesthetics, and are biologically productive (*1-3*).
2. Land use practices have decreased the number and area of wetlands, and degraded wetland structure and function(*4*).
3. The United States mandates a no net loss policy regarding wetland acreage and encourages the restoration of degraded wetlands and their functions.
4. A recent wetland status and trend report for the US shows an increase in acreage of freshwater wetlands(*5*).
5. **How do we know if a wetland is restored?**
6. Structural assessment evaluates soil condition, water quality, flora, and fauna (*6, 7*). Temporal variability of these types of measurements makes them a poor choice for assessing wetland restoration.
7. Functional assessment evaluates nutrient cycling and hydrologic function(*6*), these are often assumed from structural assessments(*6*).
8. Advances in ^{31}Phoshorous Nuclear Magnetic Resonance (P-NMR) spectrometry have provided opportunities to identify soil phosphorus (P) compounds(*8*).
9. Previous work in the Carolina Bays has linked changes in P compounds to land use; however this was done with 2 samples per wetland (*7*). Previous studies use multiple cores from a single wetland for a pooled analysis.
10. The overall objective of this study is to use P compound dynamics to evaluate the effectiveness of wetland restoration in the Prairie Pothole Region.
11. The purpose of this study is to determine how P compound diversity changes along a topographic transect within wetland catchments. **Where should we collect a sample?**

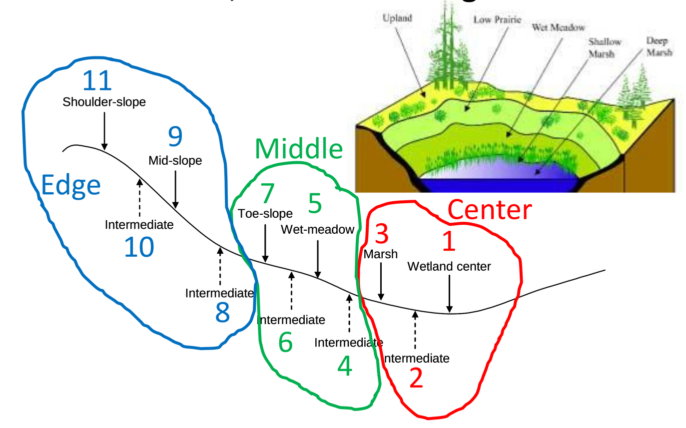
Methods

1. Soil samples were collected in the Prairie Pothole region to a depth of 15 cm.
2. Wetlands were selected within each of three land use categories: native prairie, restored wetland, and agricultural cropland. Three wetlands from each land use category including 2 different age classes of restoration were sampled.
3. Within each wetland, samples were collected across a topographical gradient from the marsh at the wetland center to the shoulder slope at the edge.
4. The samples were grouped into a center, middle and edge area within each wetland for statistical analysis.
5. **P-NMR data for 96 soil samples from 12 wetlands are presented here. In total, 268 soil samples from 36 wetlands were collected and are being analyzed.**
6. Phosphorus extraction from the soil initially followed standard procedures using sodium hydroxide and Ethylenediaminetetraacetic acid (EDTA), and then was modified to include a two percent hydrochloric acid pretreatment of one hour to improve extraction efficiencies.
7. A comparison between the soil P and the soil extract P was used as an indication of the completeness of the extraction process.
8. The number of P compounds was evaluated for use as an index of wetland function. The spectrum of P compounds of interests include: orthophosphate, orthophosphate monoesters, orthophosphate diesters, phosphonate, pyrophosphate, and polyphosphate.
9. Statistical tests included ANOVA and Tukey HSD tests.

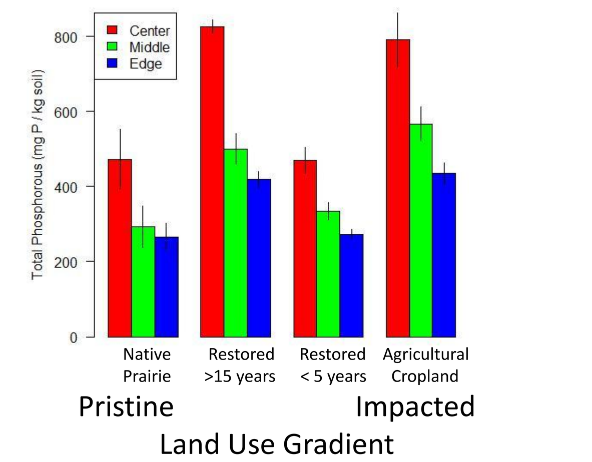
Figures

1. Wetlands within the Prairie Pothole region (yellow 3) were used for this study.

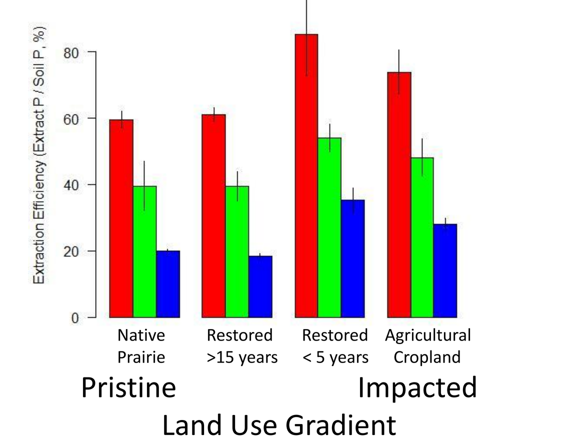
2. Idealized topographic gradient showing sample locations and sample groupings partitioning the topographic gradient into 3 areas: center, middle and edge.



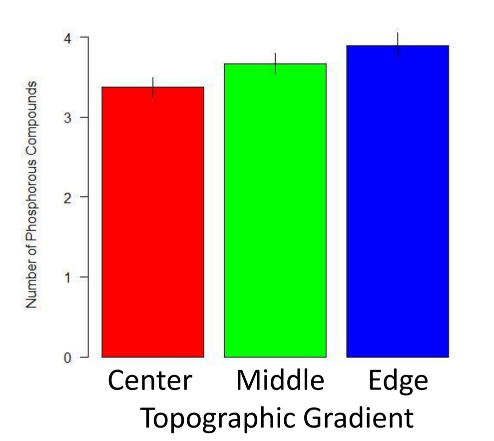
3. Soil P is significantly different across both the topographic and land use gradients



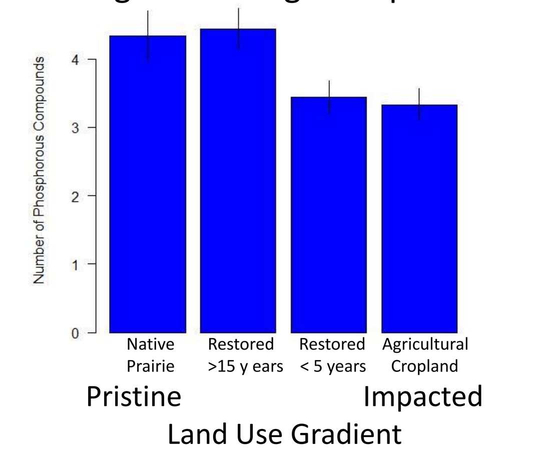
4. Extraction efficiency is significantly different across the topographic gradient, but not across the land use gradient



5. The number of P compounds is significant different across the topographic gradient

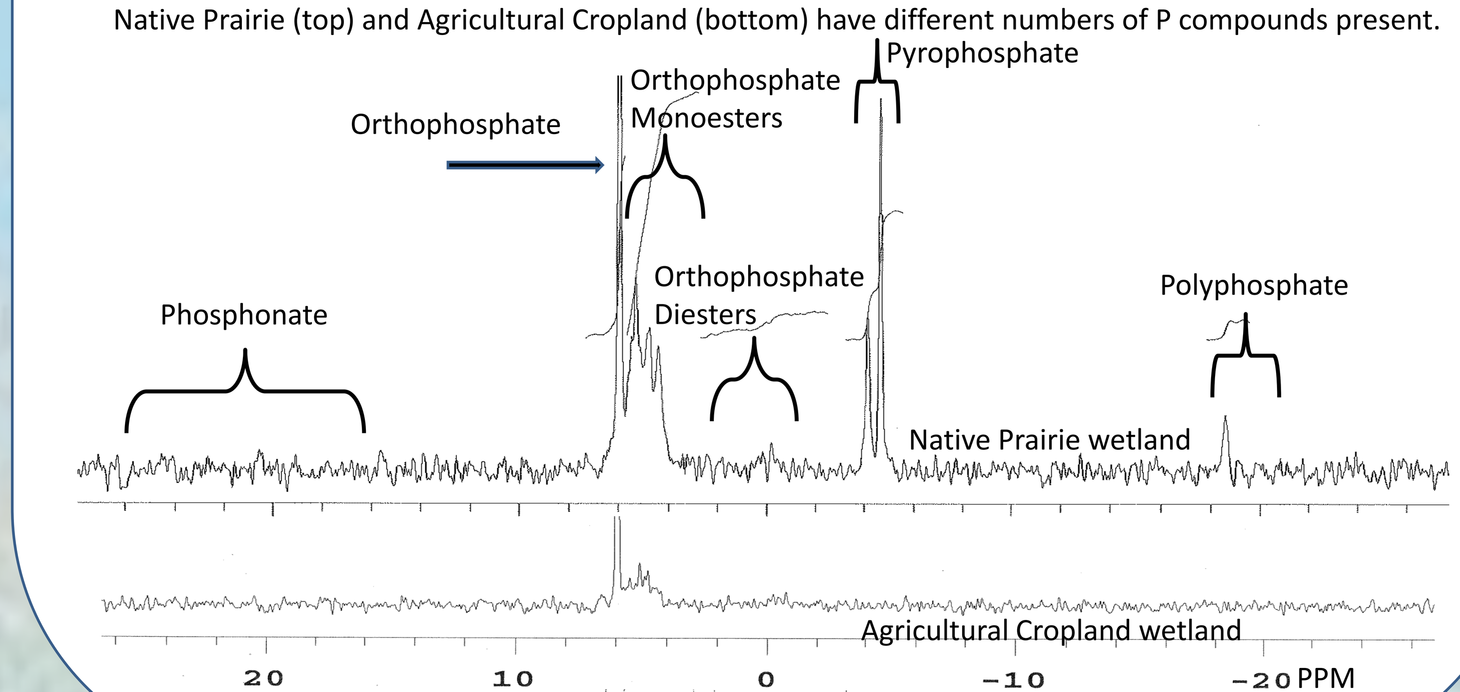


6. The number of P compounds is significantly different across the land use gradient edge samples



7. Representative P-NMR spectra showing P compounds in Edge Samples

Native Prairie (top) and Agricultural Cropland (bottom) have different numbers of P compounds present.



Results

1. Total soil P in native prairie wetlands is less than in agricultural cropland wetlands (statistically significant, $p < 0.001$), Fig3.
2. The soil P across the restoration age class is opposite to the expectation based on land use; the amount of soil P in the youngest restoration age class is similar to the native prairie, and the older restoration age classes is similar to the agricultural cropland, Fig.3.
3. Across the topographic gradient the central area of the wetlands had more soil P than the middle or edge (statistically significant, $p < 0.001$); soil moisture also followed this trend, Fig.3.
4. The extraction efficiency (the soil extract P divided by the total soil P) is statistically different across the topographic gradient ($p < 0.001$); however there is no significant difference between land use, Fig.4.
5. The number of P compounds present is statistically different across the topographic gradient (p=0.0657), Fig.5.
6. The number of P compounds across the topographic gradient is significantly different between center vs. edge samples (p=0.0519). This is primarily driven by the native prairie and restored > 15 years wetlands, Fig.5 and Fig.6.
7. The number of P compounds present in the edge samples is significantly different across the land use gradient (p=0.0163), Fig.6 and Fig.7.
8. The number of P compounds across the land use gradient is significantly different , Fig.6, for:
   i. native prairie vs. agricultural (p=0.092)
   ii. restored > 15 years vs. restored < 5 years (p=0.092)
   iii. restored > 15 years vs. agricultural (p=0.0514)

Conclusion

1. **Samples for comparative P compound evaluation should be collected near the edge of the wetland.**
2. The decreased extraction efficiencies for the edge samples are likely a result of poor extraction of orthophosphate; this does not seem to affect the number of P compounds present.
3. Future work includes concentrating the soil extract to improve the P-NMR peak recognition, comparing vegetation data to the P compound data, and comparing various basin and hydrologic classifications.

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