Assessing Land Use Influences on the Expression of Soil Iron Hydric Indicators

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Abstract

Hydric soil features develop over frequent and prolonged saturation. This study investigated the influence of land use on the expression Fe related hydric indicators for the overarching goal of being able to delineate Prairie Pothole Region wetlands where native species have been significantly disturbed. Initial soil classification of wetland pits showed differences among the land uses. Further laboratory analysis looking at free extractable Fe (Dithionite-Fe extraction) and magnetic susceptibility showed little significant differences among the land uses. Further study is required to determine if interacting affects among other hydric indicators, including clay leaching and carbon contents, significantly differ among land uses.

Introduction

The Prairie Pothole Region spans across approximately 700 000 km^2 and is responsible for supplying the nesting grounds for over half of North America's migratory waterfowl (**Figure 1**). The rolling topography influences water redistribution and creates many temporary wetlands to form after spring snowmelt and large rain events.

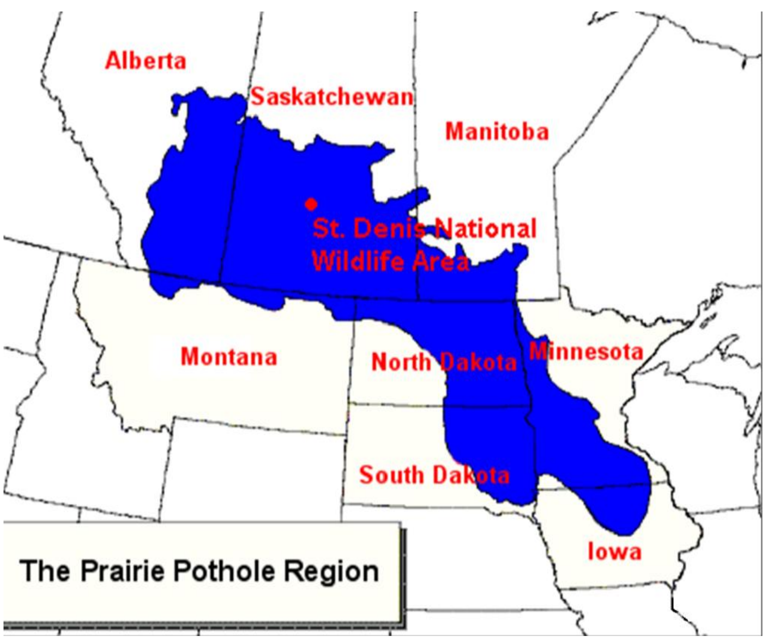

Figure 1 - Map of Prairie Pothole Region area (courtesy of US Fish and Wildlife)

Previous methods of classifying these wetlands have made use of the native species for identification of differing wetlands (Steward and Kantrud 1971). Widespread cultivation of the PPR has changed the plant communities of these areas and their native species can no longer be used to classify the wetlands. Soils develop hydric indicators through frequent saturation and this can potentially be used to differentiate wetlands in managed landscapes where native vegetation has been removed.

Hydric indicators commonly deal with the accumulation of organic matter or the reduction and translocation of Fe. Land use change can alter the hydrologic regime so it is pertinent to determine which indicators are sensitive to the change. Iron is found in soils either in a reduced or oxidized state where saturated conditions will cause the former to be dominant.

The objective of this study was to determine if land use influences the expression of Fe indicators within the soil.

Methods

Soils from St Denis Wildlife Area and surroundings were sampled in late summer 2011. Pits were excavated at both the deepest part of the wetland basin and at a reference upland area, located at the shoulder slope of the basin, usually placed approximately 10-15m from the center basin.

Three land uses from the area were sampled; cultivated (under annual cultivation), restored (taken out of cultivation and seeded to perennial grasses) and native (no cultivation in land history). Wetlands were chosen for their similar hydrologic characteristics from summer 2011 to ensure comparability amongst the wetlands. Soils were classified according to the Canadian Soils Classification System and samples were taken vertically every 10cm to a depth of 1m.

Laboratory analysis included determining magnetic susceptibility of soils at room temperature as according to de Jong et al. (2004) and a dithionite free Fe extraction (Courchesne and Turmel 2007). This study reported magnetic susceptibility as a ratio to a dithionite free Fe extraction to determine the relative rate of Fe oxidation within the soil.

Modeling and statistical tests were conducted with the R Statistics (R Development Core Team 2012). Data were assessed for normality and a log transform was applied for normalization, when necessary.

Results and Discussion

Soils of all wetland depressions were all classified out as either Chernozems or Gleysols (**Table 1**).

Table 1 - Soil classifications of sampled wetland basin and reference upland pits.

Pit location	Soil orders	Soil great groups and subgroups
Cultivated basin	4 Gleysols	4 Humic Luvic (Gleysols)
Cultivated upland	4 Chernozems	2 Calcareous Black, 1 Orthic Black and 1 Gleyed Calcareous Black (Chernozems)
Native basin	4 Chernozems, 1 Gleysol	3 Orthic Black, 1 Eluviated Black (Chernozems) and 1 Orthic (Gleysol)
Native upland	5 Chernozems	3 Orthic Black, 1 Eluviated Black and 1 Calcareous Black (Chernozems)
Restored basin	5 Gleysols, 1 Chernozem	5 Humic Luvic (Gleysols) and 1 Calcareous Black (Chernozem)
Restored upland	6 Chernozems	4 Orthic Black and 2 Calcareous (Chernozems)

Field observations showed a difference in the soil classification between the native wetlands and the other land uses (mainly Chernozems found in wetland basins as opposed to Gleysols). Soil gleying through Fe reduction and translocation and its presence is the key indicator for Gleysol classification. While the native basins were not classified as Gleysols, gleying was still present at depths below 50cm.

The soil magnetic susceptibility to dithionite extractable Fe ratio (MDR) has been plotted against depth of the wetland basin pits (**Figure 2**) and upland reference pits (**Figure 3**) for each land use.

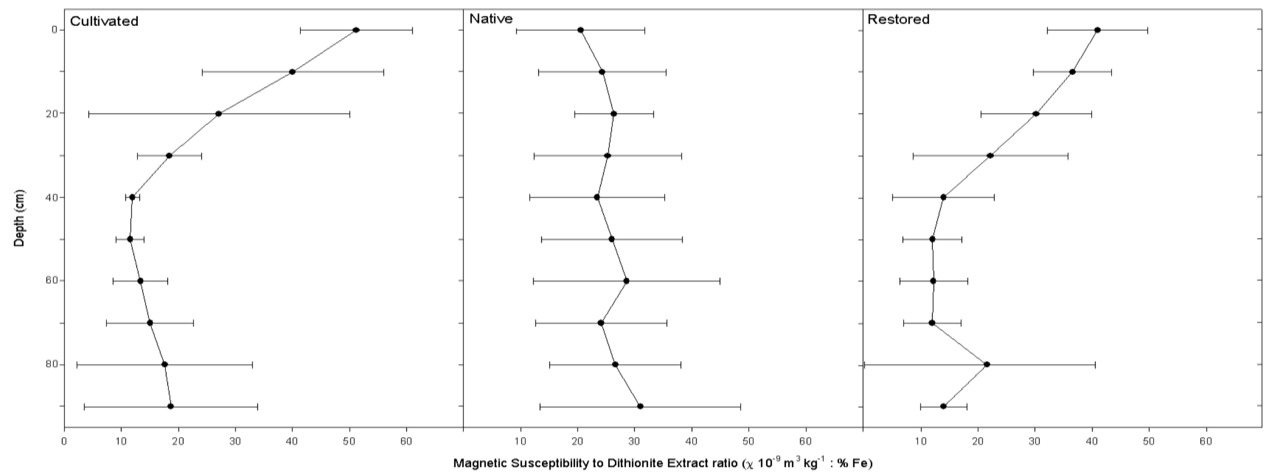

Figure 2 - Magnetic Susceptibility to Dithionite Extractable Iron Ratio (MDR) of wetland basin pits plotted against depth.

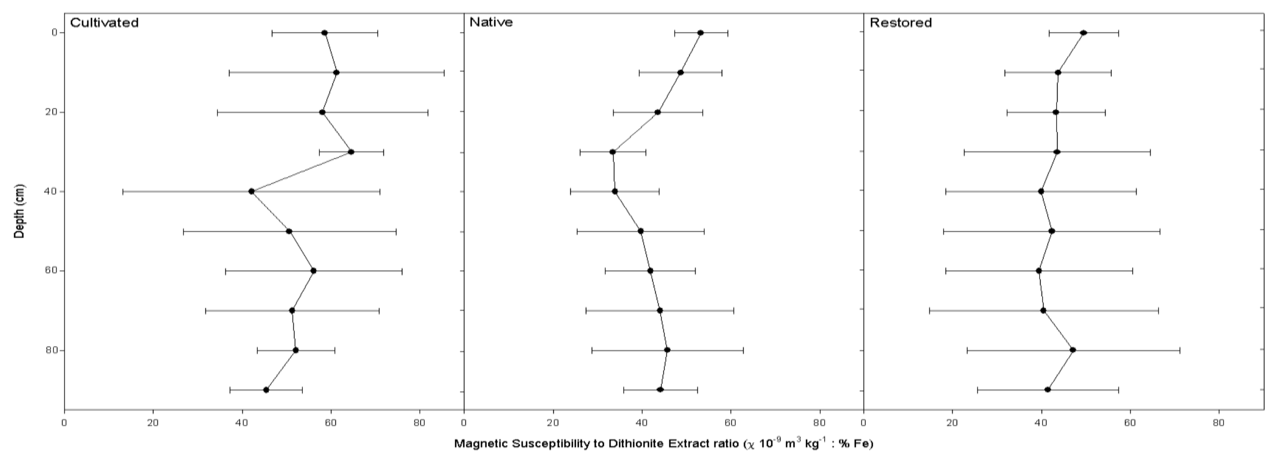

Figure 3 - Magnetic Susceptibility to Dithionite Extractable Iron Ratio (MDR) of reference upland pits plotted against depth.

Native wetland basins appear to have higher MDR values than their cultivated and restored counterparts (**Figure 2**). This may be due to soil redistribution of upper slope oxidized materials via tillage translocation in the land histories of cultivated and restored wetlands. Upper slope pits generally have high MDR values within the study, likely due to amounts of oxidized Fe, as can be seen in higher values of upland pits (**Figure 3**).

A linear mixed model (**Table 2**) was constructed using MDR as a response variable with depth and land use as fixed effects and the wetland pits included as a nested random variable. The model suggests that most of variability is significantly explained by depth ($F=41.3226$, $p=<0.0001$) with land use showing no significant relationship ($F=1.1275$, $p=0.3559$) in the expression of MDR. The interacting effects of land use and depth show less of an ability to explain the MDR variation (F=18.0685, p=<.0001) than depth alone.

Table 2- Output of general linear model with mixed effects using MDR as a response variable along with land use and depth as fixed effects. Individual pits were included as nested random variables.

Fixed factors	Degrees of freedom	Denominator degrees of freedom	F-value	p-value
(Intercept)	1	129	1311.3621	<.0001
Land use	2	12	1.1275	0.3559
Depth	1	129	41.3226	<.0001
Land use: Depth	2	2	18.0685	<.0001

An additional linear mixed model was constructed (output not shown) where both upland and wetland pits were included. Land use also had a limited explanation in the variation of MDR (F=0.8055, p=0.4586) while pit location (F=38.2184, p=<.0001) and depth (F=26.8740, p=<.0001) had strong significant influences on the MDR values.

Conclusion

The effect of land use on MDR is minimal and non-significant. While hydric features, such as Fe reduction, can develop in soils in less than 48 hours, Prairie soils rarely allow for the ideal conditions required because of their lower temperatures and basic pHs. Land use changes over the past century (wetland cultivation) and decades (wetland restoration) appear to not significantly change the oxidation status of the free Fe.

Therefore from this study, land use has no significant effects in influencing the expression of Fe based hydric indicators alone. Further analysis is required to determine if any interacting effects exist among the other hydric such indicators such clay leaching amounts and organic carbon accumulations.

References

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