Report as of FY2010 for 2009OR112B: "Vegetation and Soil Processes in Restored Wetlands"

Publications

Project 2009OR112B has resulted in no reported publications as of FY2010.

Report Follows

Vegetation and Soil Processes in Restored Wetlands

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Project period: February 2009-February 2011

EXECUTIVE SUMMARY

Wetlands have been identified as critically important for provision of a number of ecosystem services such as water quality improvement, flood protection, and conservation of native plant and animal diversity (Mitsch and Gosselink 2007, Costanza et al. 1997). Wetland restoration is being considered as a watershed-scale tool for assisting in the meeting of these ecosystem services (Primovich 2008; Willamette Partnership 2008). Several recent reviews have discussed the need to incorporate information concerning provision of ecosystem services into tools that help decision makers evaluate alternative policies for land use and management (Kentula 2007). However, the most commonly used methods used to evaluate wetland functions often rely on site characteristics assumed to be associated with particular functions (such as denitrification, or other forms of nitrogen removal) in the absence of actual data concerning the level to which a particular wetland site actually performs such a function. For example, currently used hydrogeomorphic (HGM) assessments score wetlands for certain observed variables and relate these variables semi-quantitatively (on a scale from 0 to 1 relative to reference sites) to specific functions (Smith et al. 1995; Adamus and Field 2001), producing a site-level score related to estimated site quality or ability to perform functions as compared to reference sites. There is a need for research on how wetland vegetation, soil characteristics, and soil microbial communities interact in wetlands to influence processes such as denitrification, and to understand how these environments compare to agricultural fields, which may also provide some of the same ecosystem services. In addition, we need to better understand how different methods used in restoration may influence these processes.

Results of this project have assisted in advancing our understanding of vegetation and soil responses to various restoration scenarios, and will assist in the development of further research for evaluation of the ability of restored wetlands to provide ecosystem services such as conservation of native plant diversity and nitrogen removal through various soil processes such as N2O evolution and denitrification. An improved understanding of the range of values and natural variability in soil nitrogen processing is an important first step in development of benchmarks for evaluating restoration success.

We investigated relationships among wetland restoration methods, establishment of native vegetation and soil characteristics (such as soil organic matter content, soil water content) in influencing three endpoints for evaluating wetland restoration success: (1) per cent cover of native plants and plant diversity and (2) soil potential for denitrification/ N-processing as measured by denitrifying enzyme activity (DEA) at three restored wetland sites, three natural wetland sites, and three agricultural sites that were being used for crops, but resembled sites that have been restored to wetland vegetation prior to their restoration.

The project addressed issues of long-term water and watershed management with an emphasis on sustainable solutions that balance stewardship of resources with economic viability. We partnered with the USDA NRCS and the Portland Metro wetland mitigation programs to assist them in evaluating the degree to which wetlands are fulfilling their intended role. We promoted education about and implementation of sustainable practices for improved watershed management by presenting our findings at meetings, and plan to publish the project results in peer-reviewed journals such as Restoration Ecology. The results of the project will also provide materials for lectures in courses taught by the PI and co-PI.

PROJECT DESCRIPTION

Project results and benefits

The project described here was intended to result in an improved understanding of wetland vegetation and soil processes in restored wetlands as compared to natural wetlands, or the agricultural fields that are converted to wetlands through programs, and to provide baseline information for preparation of a follow-up research proposal to a funding agency such as the National Science Foundation or EPA. In addition, the project helped to build collaborative relationships as well as identifying hypotheses and research questions for follow-up proposals.

Nature and scope of project

We hypothesized that denitrification enzyme activities (DEAs) would be related to soil properties such as soil organic matter (SOM) and nitrate in soil water, and that recently restored wetlands and adjacent cropped areas would have more homogeneous soils than natural wetlands. We expected that recent restorations and cropped areas would have relatively low and less variable potential for denitrification as measured by DEAs (cf. Bruland et al. 2006). We also anticipated that native plant species might respond differently to variation in soil processes, and that both the legacy of prior use on soils of restored wetlands and feedback between vegetation and soils in these wetlands over time would influence the rate at which these restorations achieve the goals of enhancing native plant diversity and providing habitat for native species.

We addressed two project objectives with the research reported here:

1. To determine rates of DEA in wetland soils and explore the potential relationships among vegetation, soil characteristics, and soil processes such as denitrification.
2. To measure wetland site response to different restoration methods and evaluate these methods for their relative success in establishing native plant cover and native plant diversity

Both objectives have been met and both of the students whose research comprised the project have made presentations to their peers concerning their research results.

Methods, procedures, facilities

Study Region

The NRCS is currently working on several wetland restoration projects in the Tualatin River Basin near Forest Grove and in conjunction with The Nature Conservancy and other partners have established a wet prairie restoration at Gotter Prairie. We selected reference sites from wet prairie remnants in the region with the assistance of Kathy Pendergrass of the USDA NRCS, and agricultural field sites for comparison with the assistance of Portland Metro, the USDA NRCS and the US Fish and Wildlife Service. All but the Green Mountain reference site and the Westbrook agricultural field are within the Tualatin River Basin, the Green Mountain wet prairie remnant is just north of the Tualatin River Basin near Camas, Washington and the Westbrook site is just south of the Tualatin River Basin near Rickreall, Oregon

Vegetation analyses

At each study site, a set of three 10 x 10 m vegetation plots were placed within the wetland at randomly selected coordinates, with nested 1 x 1 m vegetation plots at the northwest and southeast corners of the plot. In each plot, all vascular plant species were identified and visual estimates of the per cent cover of each species as well as the portion of the plot which was bare ground or water were recorded. Verification of field identifications (especially for grass and sedge species) is being conducted in cooperation with the Dr. Richard Halse of the Oregon State University herbarium. The data were analyzed using the NMS ordination program PC-ORD, which separated the study sites into two groups, the remnant and restored sites, separated by several characteristic species with high indictor values.

In addition, at one restoration site where an experiment with different seeding treatments had been established (grass only, forbs only, grass + forbs together), three replicate 1 x 1 m plots were located in each of the three replicate treatment plots, for a total of nine 1 x 1 m plots per treatment and 27 overall, to investigate effects of seeding treatment on plot diversity. The USDA NRCS is fully-funding all aspects of the seeding treatments at the Hutchinson restoration, but has no funding dedicated to monitoring or evaluation of restoration success. Our project provided initial monitoring of the first year results of these seeding treatments with respect to species diversity, as well as data from additional sites in the region for comparison. A second year of vegetation analysis of the seeding treatment experiment plots at the Hutchinson site was completed in July 2010.

The data analyses and conclusions of these studies are presented in the Masters thesis prepared by Sara Taylor which is scheduled to be defended on June 1, 2011.

Seeding experiment results
From the results of two years of monitoring the Hutchinson wet prairie seeding experiment, we can conclude that the seeding treatment in which grasses and forbs are sown together shows the highest in native plant species abundance and species richness. Drilling grasses in first results in high native cover but lower species richness in comparison to the other treatments. Planting of forbs only results in lower diversity and higher cover of introduced species. Low species richness in the grass only treatment is most likely a result of early, rapid grass emergence that creates shading and therefore retarding forb emergence. It may also be influenced by the use of herbicides to control weeds in the grass only plots (Taylor and Santelmann forthcoming).

The results from this experiment indicate that high native plant species richness can be obtained by seeding in native grasses and forbs at one time instead of sowing in grasses and forbs one year after the other. Substantial decreases in introduced plant species cover from 2009 to 2010 were observed in all seeding treatments, which indicates that native plant species can compete successfully with introduced species for space within the wet prairie community, at least over a two-year time period. Established native perennial grasses limit space available for exotic annual seeds to germinate and limit light available to exotics reducing exotic productivity and shifting competitive interactions in favor of natives (Corbin and D'Andonio, 2004).

Comparison of Wet Prairie Remnants and Restorations

Soil sampling

Soiling sampling

Soil sampling occurred seasonally to capture the major changes in soil water content and temperature. Soils were sampled seasonally, at four dates throughout one year: in September 2009 prior to the rainy season, in November 2009 at the start of the rainy season, in February 2010 in the height of the rainy season, in April 2010 towards the end of the rainy season. Five soil samples from each plot were collected at approximately 10 m intervals, starting at about 1 m from the northwest corner of the plot. All samples were collected within 25 m of the boundary of the plot. Each sample was collected using a metal soil core (2.5 cm diameter), collecting the top 15-20 cm of soil. The five soil cores from each plot were composited into a plastic bag and refrigerated until processed. This provided three composite samples of about 500 g (wet weight) of soil from each study site at each sampling date.

Soil analyses

Each composite soil sample was measured for potential N2O and denitrification enzyme activity. Samples were also processed for extraction of DNA for analysis of the size and composition of the denitrifier community (Rich and Myrold, 2004). Analyses of these DNA extracts will be conducted by the undergraduate student over the summer of 2010. Ancillary measurements of soil water content, nitrate concentrations, and soil organic matter content were also made using standard methods.

.**Denitrification Enzyme Assays (DEAs)**
Soil (~20 g wet weight) from each sample was weighed into a 125-ml Erlenmeyer flask amended with 25 ml of a solution containing final concentration of 240 μg glucose-C ml^{-1} glucose and 40 μg KNO_3-N ml^{-1}. Flasks were sealed with rubber stoppers. The headspace of the flask was flushed with Argon gas for 1 minute. All flasks were placed onto a shaker table for 1 hour on speed 2 to allow the soils to reach room temperature and thoroughly mix with the glucose-nitrate solution. After the hour, 500-µl samples were removed from the flask via gas-tight syringes and injected into a Varian 3700 Gas Chromatograph equipped with a ^{63}Ni electron capture detector. Eight 500-µl samples were injected (once every 30 minutes). After the first three injections, 12 ml of acetylene gas was added to each flask (acetylene was added immediately after injection three so each flask had 30 minutes of exposure to acetylene before injection four).

Nitrate
Soil (~10 g) was weighed into screw top containers and 50 ml of 0.05 M K_2SO_4 was added to the containers. These were shaken for 60 minutes and the contents were poured into filter-lined funnels and filtered (Whatman #2) into small screw cap vials. An Astoria Pacific authoanalyzer was used to measure NO_3^- concentration by the cadmium reduction method.

Water content
Approximately 20 g of soil were weighed into metal tins. These tins were placed into a drying oven at 100 degrees Celsius for 24 hours. The tins were removed and re-weighed to determine the water content of each soil sample.

RESULTS

Soils analyses

Soil moisture content
Average moisture content of the soils varied among sites, with the lowest values in September (15% to 38%) and the highest values in November (25 to 46%). The Knez site was the wettest of our study sites, and samples from that site had the highest soil moisture content, ranging from 38 to 46 % (Table 1). Soils from the wet prairie remnant sites tended to have higher soil moisture content (17 to 46%) than the restorations (15 to 32%), whereas the lowest soil moisture content was found in samples from the agricultural field sites (11 to 27%).

Soil organic matter content

Soil moisture content and organic matter content tended to be highest at the wet prairie remnant sites, although the Gotter Prairie South site is quite similar to the Gotter Prairie North site. Soil organic matter and moisture content were higher in restorations than agricultural sites (Table 2); no pattern was seen in soil acidity, with all site types having an average pH of 5.8.

Rates of denitrification

Rates of N2O evolution from soil samples were available for samples from all sites collected in February and April (Figure 1 and 2 below). Technical difficulties with the analytical equipment resulted in poor quality data for the samples collected in September and November sampling periods, however, these issues were resolved soon after. Highest rates of N2O evolution were found for the Knez remnant site, the Gotter Prairie South remnant, and the Hutchinson restoration in February, and for the Green Mountain, Knez prairie remnant sites, followed closely by the Gotter Prairie Agricultural site and Hutchinson restoration site in April. The Gotter Prairie N and Lovejoy Restoration, Westbrook and Zurcher agricultural sites tended to have lower rates of N2O evolution in both sampling periods. Once data on soil organic matter content and on microbial communities are available from summer 2010 analyses, we will have the information we need to investigate the relationships among soil characteristics and nitrogen processing.

Table 1. Average soil moisture content in samples collected at project study sites

Site	% Moisture (September)	% Moisture (November)	% Moisture (February)	% Moisture (April)
Wet Prairie Remnants				
Knez	0.38	0.46	0.42	0.39
Gotter Prairie S	0.17	0.48	0.39	0.33
Green Mountain	0.26	0.42	0.45	0.36
Wet Prairie Restorations				
Hutchinson	0.20	0.32	0.31	0.25
Lovejoy	0.18	0.32	0.27	0.24
Gotter Prairie N	0.15	0.26	0.30	0.26
Agricultural Fields				
Zurcher	0.19	0.26	0.26	0.22
Westbrook	0.11	0.27	0.28	0.26
Gotter Prairie	0.18	0.25	0.25	0.18

Table 2. Soil characteristics averaged over all sampling dates for remnant, restored and agricultural sites

Site type	Site Names	% organic matter	% moisture	pH	texture class
Remnants	**Gotter Prairie South**	6.8	33.0	5.3	silty clay
	Green Mountain	13.0	36.0	5.4	clay
	Knez	9.1	39.3	6.8	clay
AVERAGE		**9.6**	**36.1**	**5.8**	
Restored	**Hutchinson**	6.9	25.1	6.2	clay
	Lovejoy	6.5	23.6	5.8	clay
	Gotter Prairie North	6.4	26.5	5.5	clay
AVERAGE		**6.6**	**25.0**	**5.8**	
Agriculture	**Zurcher**	6.4	22.3	5.9	clay
	Westbrook	3.7	25.6	6	silty clay loam
	Gotter Prairie Ag	6.0	18.1	5.4	silty clay
AVERAGE		**5.3**	**22.0**	**5.8**	

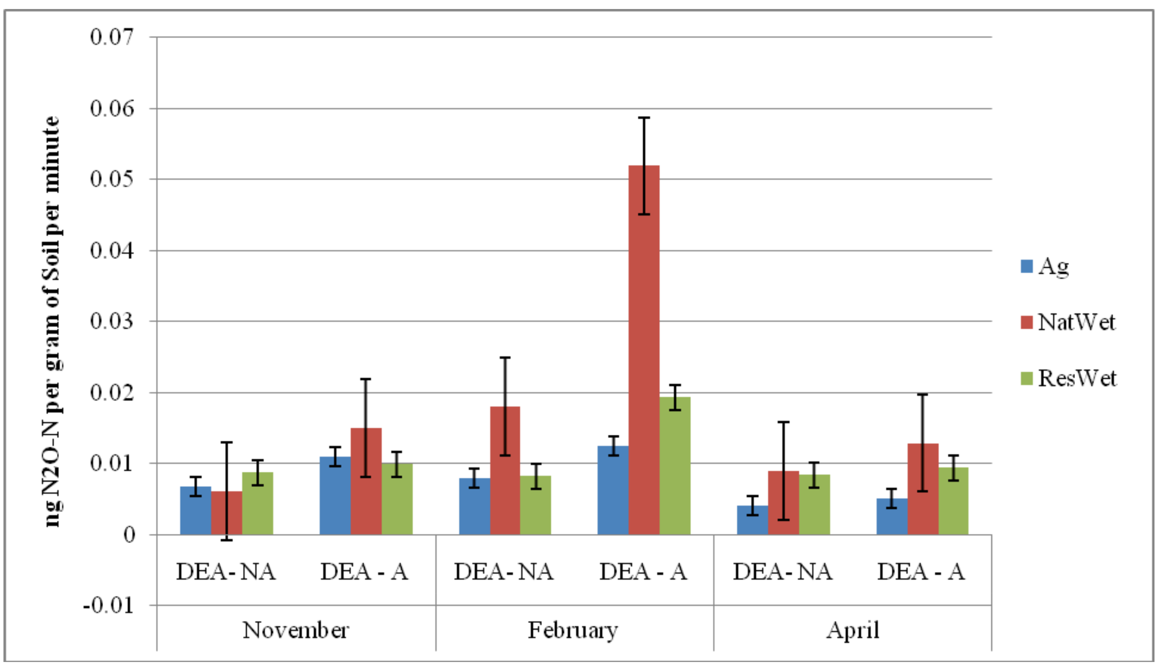
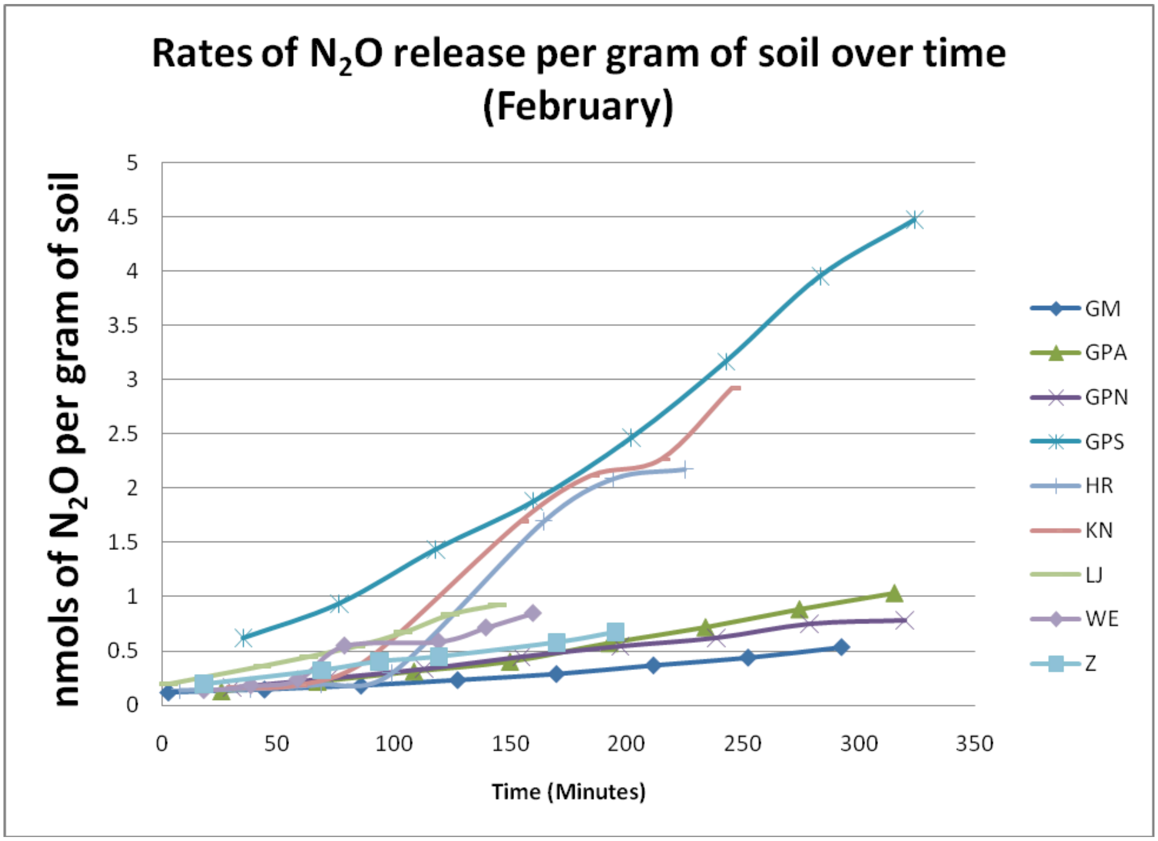
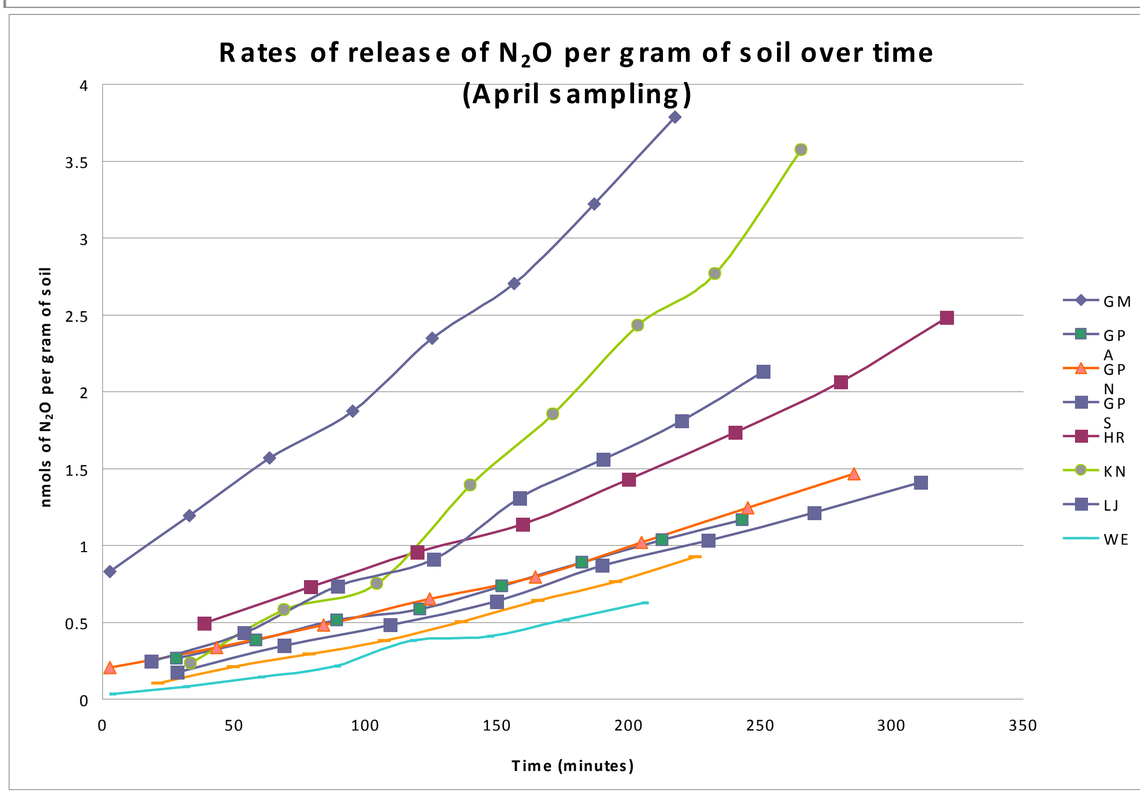


Figure 2. Denitrification rates (with and without acetylene) between agricultural (Ag), natural wetland (NatWet), and restored wetland (ResWet) sites sampled in November 2009, February 2010, and April 2010 (Figure courtesy of Betsy Leondar).

Figure 1. Rates of N2O release (A) from February and (B) April sampling periods





Vegetation analysis

Native plant cover

Comparison of the average plant cover in the remnant and restored sites revealed very little difference among sites, with the exception of the Lovejoy restoration site, which has approximately 30% more cover than the rest of the sites

Plant species richness

A total of 117 species were recorded as present in plots over all study areas; 55 were native and 62 were introduced (Table 3). Of these, 24 species were found in both remnant and restored sites (18 native and 6 introduced). A total of 44 species were unique to the remnants only (22 native 22 introduced). Plots on restored sites had a total of 49 unique species (15 native and 34 introduced). No statistically significant difference was found in native species richness between remnant and restored prairies (p-value 0.9485, N=6). This suggests that land managers have been able to restore vegetation whose native plant species richness resembles the species richness of the best intact remnant prairies within the Northern Willamette Valley Ecoregion in a relatively short period of time (8 years or less). However, a set of more than 20 native species are unique to remnant prairies, whereas species composition of restored prairies generally reflects the diversity of propagules used in establishing native vegetation.

Native species abundance and richness with environmental variables

The NMS ordination separated site types in species space (Figure 3). Remnant prairies positively associated along Axis 1 with a range of separation between negative and positive associations along Axis 2 with species most highly associated with those axes. Restored prairies negatively associated along Axis 1 with Gotter Prairie North being the center point within the ordination. Lovejoy showed slight positive associations along Axis 2 and Hutchinson showed slight negative associations along Axis 2. The NMS ordination also showed that some variables (% soil moisture and February through July flooding) were positively associated with the remnant prairie at Knez. Other positive associations were % organic matter, % sand, native species richness and abundance, years in management and perennials in the Green Mountain remnant. Lovejoy and Hutchinson had negative associations with % soil moisture and positive associations with November flooding and management categories (use of clean crops, yearly mowing and chemical application).

Highest Pearson and Kendall correlation values with species in the main matrix were: *Anthemis cotula,* an introduced, annual forb (-.744 on Axis 1); *Deschampsia cespitosa*, a native, perennial graminoid (-.764 on Axis 2); and *Veronica perigrina*, a native, annual forb (-.770 on Axis 1). A native, perennial forb, *Lomatium bradshawii*, also had a relatively high correlation with Axis 2 (.644). Highest correlations with the second matrix were: % soil moisture (.931 on Axis 1), native species richness (-.803 on Axis 2), use of clean crops (-.900 on Axis 1), February flooding (.901 on Axis 1) and November flooding (-.790 on Axis 1).

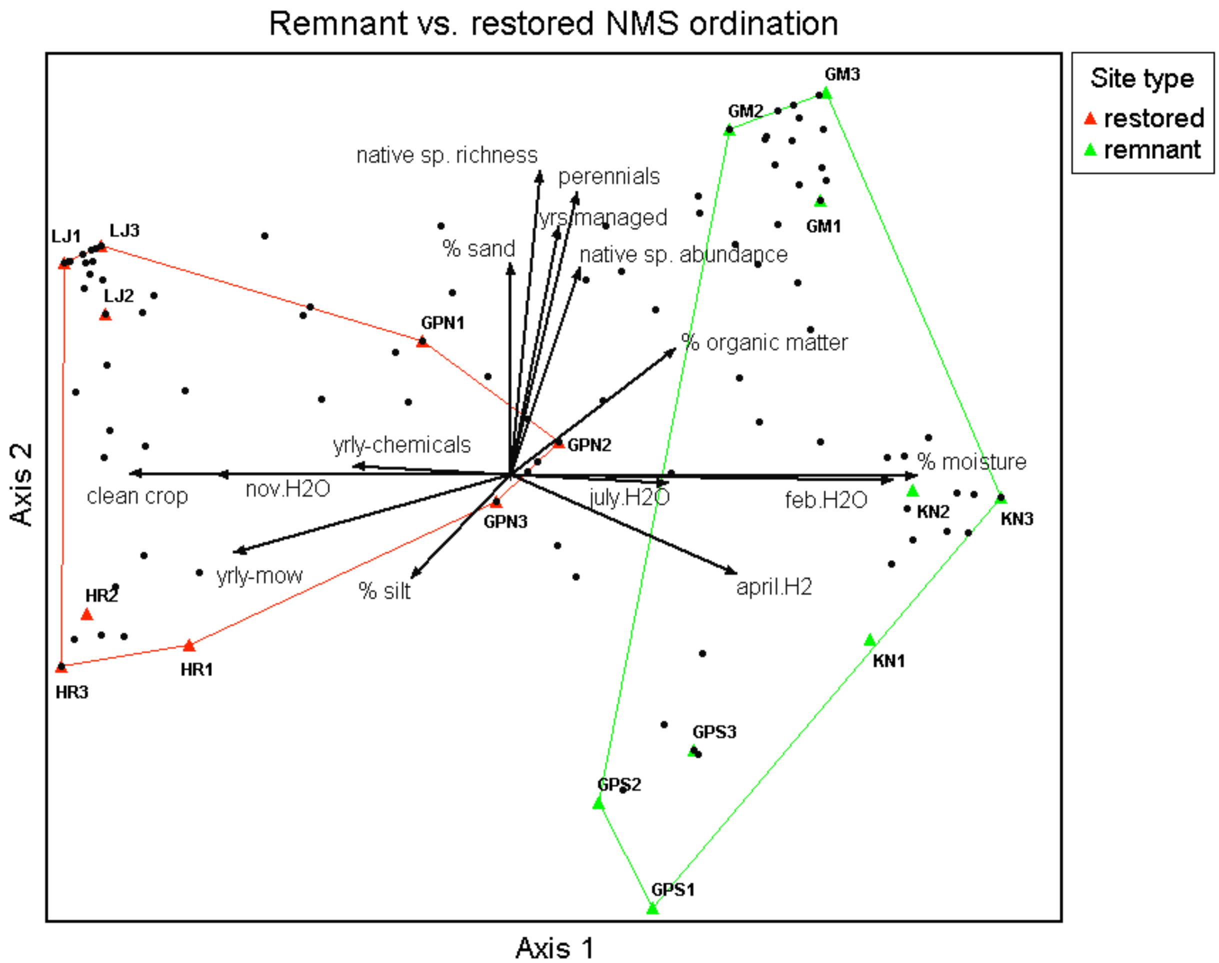


Figure 3. NMS ordination (with Sørensen's measure) of vegetation sampled at remnant (GM, GPS, KN) and restored prairies (GPN,HR,LJ) in species space with an overlaid joint plot showing strongest correlations of species traits (native, perennial, graminoid), soil categories (% moisture, % organic matter, % silt, % sand), management (flooding, use of clean crops, yearly application of chemicals, mowing and years in management) and native species diversity and abundance

Table 3. Average species richness and number of species with various plant traits in remnant and restored prairies

Site type	Project Sites	total # species	# native	# introduced	# perennial	# annual	# graminoid	# forb
remnant	Gotter Prairie S.	13	10	3	12	1	9	5
	Green Mountain	48	30	18	34	14	16	30
	Knez	23	14	9	17	6	13	12
AVERAGE		**28**	**18**	**10**	**21**	**7**	**13**	**16**
restored	Hutchinson	18	9	9	9	9	7	11
	Lovejoy	40	15	25	21	18	11	31
	Gotter Prairie N.	35	25	10	21	14	12	26
AVERAGE		**31**	**16**	**15**	**17**	**14**	**10**	**23**

CONCLUSIONS

The major findings for this study were that in many ways, restoration of wetland prairie has been successful in increasing organic matter in soils, resulting in increased moisture content in soils, and in providing high native species abundance and richness. However, a set of 20 native species were found only in remnant wet prairies. The opportunity to preserve species which are found only in wet prairie remnants is an important reason for the conservation of these rare site types in the Northern Willamette Valley. Sites associated with higher organic matter content and soil moisture and long-term management were Green Mountain (remnant) and Gotter Prairie North (restored). The restoration that has been managed for the longest period of time, Gotter Prairie North, has developed soil qualities and a plant species composition most similar to that of the remnants.

In summary, our results indicate that management practices can have a strong influence on organic matter content soils of remnants and restorations, and those differences influence soil moisture content and species composition of vegetation at the site. Time and effort expended on site management can contribute to high species richness, native abundance and abundance of perennials.

Outreach and Information Dissemination

Training potential

One graduate and one undergraduate student have benefited directly from the work in this project, which is the subject of the MS thesis for an Environmental Sciences graduate student, Sara Taylor, and an honors thesis for Elizabeth Leondar, an undergraduate in BioResource Research degree program.

Taylor presented her initial results at the student competition organized by the Oregon Chapter of the Air and Waste Management Association held on April 8th, 2010 at Portland State University. The presentation won 2nd place and received $150.

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