Soil development of two wetland creation areas at the Olentangy River Wetland Research Park in Columbus, Ohio

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Abstract

Soil development was evaluated in two wetland creation areas at the Olentangy Wetland Research Park at The Ohio State University campus in Columbus, Ohio. Data on soil organic matter, bulk density and color were collected at permanent soil sampling stations and compared to previous soil analyses that were conducted in 1993 and 1995. Comparing this data with earlier studies, the wetlands demonstrated increases in percent organic matter at the wetland soil surface. At 0-8 cm depth, the experimental wetlands increased significantly (p=0.001) from 6.2 + 0.4% organic matter in 1995 to 10.1 + 1.2% in 2002. Bulk density at this depth did not change significantly between 1995 and 2002, however an increase (p=0.001) was detected in soils at the 8-16 cm depth (1.03 ± 0.04 g/cm3 in 1995 to 1.34 ± 0.05 g/cm3 in 2002). Soil color developed between 1995 and 2002 with all of the soils sampled reported as having a chroma of 2 or less, compared to 63% for the corresponding sampling points in 1995. Analyses were conducted to determine if soil development differed between the planted and unplanted experimental marshes or between areas closer to the wetland inflow versus further away. In both cases, no differences were detected.

Introduction

Wetland creation areas are constructed throughout the United States and are designed to provide landscape functions such as wildlife habitat, flood attenuation, and water quality enhancement (Mitsch and Gosselink, 2000). Most studies have identified the short-term (<1 to 5 years) changes that occur in soils that are inundated (Moore et al, 1992; Nairn, 1996). However, there is no consensus on how long it takes created wetlands to develop a soil composition that is comparable to natural wetland soils. Wetland soils provide the substrate for numerous biological and chemical processes and are the major source of nutrients for plants, soil fauna and microorganisms (Vepraskas and Faulkner, 2001; Collins and Kuehl, 2001). The physical conditions of the soil also affect the type and biomass of plant communities that they support (Mitsch and Gosselink, 2000) by affecting the water holding capability, substrate temperature, nutrient availability and bulk density of a given wetland (Collins and Kuehl, 2001; Mitsch and Gosselink, 2000). The accumulation of soil organic matter has been identified as an indication of the maturity of a wetland creation area because of the time required for it to develop (Nair et al., 2001; Craft, 2001). Most studies examining soils in wetland creation areas have found they are deficient in organic matter when compared to natural wetlands in comparable landscape conditions (Campbell et al., 2002; Shaffer and Ernest, 1999). A better understanding of the formation of soils in created wetlands is currently needed to assess the ability of created wetlands to provide the functions and values of their natural counterparts.

This study was an investigation of soil development at the two experimental wetland creation areas at the Olentangy River Wetland Research Park (ORW). The underlying soils in this area are within the Olentangy River floodplain and are comprised of the Ross and Eldean series, consisting of silt loam, silt clay, and clay loams (Mcloda, 1980). Both experimental marshes were constructed in 1993 and hydrated in 1994 with pumped Olentangy River water. The only difference between the two wetlands is that the western marsh (Wetland 1) was planted with native, wetland vegetation while the eastern marsh (Wetland 2) was left unplanted (Mitsch et al., 1995). The goals of this project were 1) assess the soil development of the two experimental marshes, eight years after initial inundation and 2) examine potential spatial and temporal trends in soil development within the wetlands. Given the higher productivity of biomass that has been continually reported in Wetland 2 (Mitsch et al. 2001), it was expected to have greater soil organic matter accumulation. Also, because of the higher nutrient availability in the water column at the inflows, it was expected that soil organic matter accumulation would be higher in this part of the wetlands.

Methods

Field Work and Analysis

To examine the temporal effects on soil development, a total of twelve soil sampling points were established between the two experimental wetlands. Sampling locations were determined based on previous soil work conducted in 1993 and 1995 (Nairn 1996). Using an outline of the experimental marshes, a grid system (Figure 1) was used to mark each intersection point in the field using marked PVC pipes. In 1993 (after wetland construction, but before hydration of the marshes), soil samples were collected for each

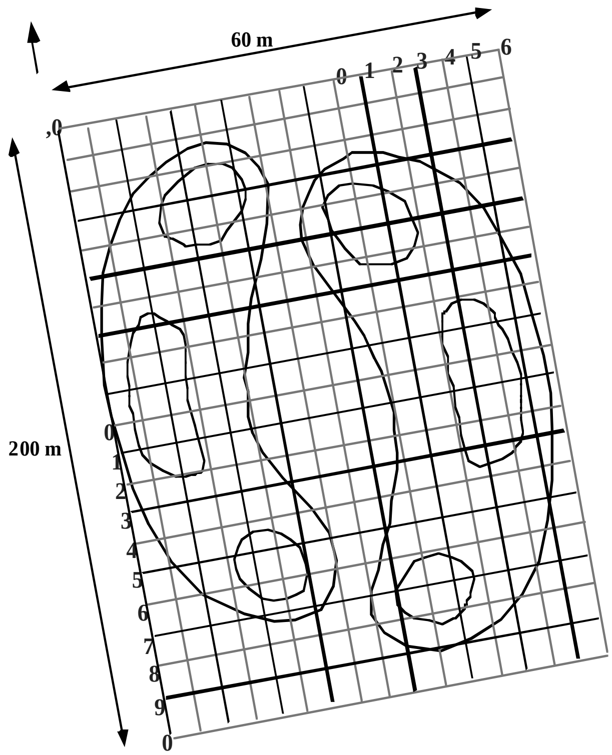

Figure 1. Soil sampling grid (10x10m) covering 3.2 ha (Nairn 1995). Soil sampling was conducted at every intersection in 1993 and at the bold line intersections (every 20m) in 1995.

intersection point at a depth of 0-8 cm and 8-16 cm (Nairn 1996). To determine the effect of hydration on soil development after one year, soil samples were collected at every other grid point and compared for several wetland soil parameters (Nairn, 1996). This study revisited twelve (six in each wetland) of the sampling points examined in 1993 and 1995.

Grid points for this study were selected based on three criteria: 1) for both wetlands, two grid points were selected at the north, central and south portions of the wetland, 2) grid points were selected close to the boardwalk to minimize traversing through the wetland, and 3) all grid points were selected at an intermediate depth of the wetlands. The locations of the grid points used in this study are provided in Figure 1. Conditions of the sampling sites did not vary considerably. All sampling points were collected in areas dominated by *Schoenoplectus tabernaemontani* Vahl. and other emergent wetland vegetation. Water conditions at the grid points varied from highly saturated soils to less than 3 cm of standing water.

For each grid point, a soil sample was collected at 0-8 cm and 8-16 cm in depth approximately 2 m east of the grid point. Standard metal soil probes were not suitable for sampling because of unavoidable compaction and the loss of soil material to standing water when the probe was extracted. As an alternative, a 16 cm+ deep soil block was carefully excavated using a garden spade shovel. Using a knife, two equal sized bricks (2 cm x 3 cm x 8 cm in length) were carefully cut from the soil block: one from the 0-8 cm depth and the other from the 8-16 cm depth. For each sample (brick), the hue, value and chroma were determined using a Musell Color Chart. Each sample was then placed in a sealed plastic bag and refrigerated until laboratory analysis.

Soil samples were collected on 27 October 2002.

Laboratory and Data Analysis

Soil samples were analyzed to determine bulk density and organic matter content as per the Nairn 1996 study. To remove water, each soil sample was stirred and oven dried at 105˚C for at least twelve hours or until constant mass was achieved. Samples were then weighed, divided by their volume, and the bulk density was determined. A subsample of each soil samples was then grinded using a material grinder and passed through a 2mm sieve. Approximately 10 g of the sieved subsample was placed in a crucible, weighed, and ignited at 550˚C for 1 hour. The post combustion material was then reweighed and the matter weight lost by ignition was divided by the pre-combustion sample weight and recorded as the percent organic matter of the soil sample.

It was determined after sampling that some grid points used in this study were not processed for soil data in 1993 or 1995. In these cases, the closest 1993/1995 sampled grid points (within 10 m in all cases) were used in its place. The Munsell Color Chart data was evaluated for all soil samples and compared to data collected in previous investigations at these wetlands. All statistical analyses were conducted using Microsoft Excel and all means are reported as ± 1 SE and significance was determined at the 0.05 percent level. Two-tailed t-tests were conducted to compare means of: 1) 1993 and 2002 data, 2) 1995 and 2002 data and 3) Wetland 1 and Wetland 2 (2002 data). In all comparisons, percent organic matter and bulk density data were separated by soil depth. A regression analysis was conducted to examine the effect of distance from inflow had on bulk density and soil organic matter. For both parameters, regression analyses were conducted using data at both depths.

Results

Munsell Color Chart

The Munsell Color Chart hue, value, and chroma for each soil sample were determined for each wetland (Table 1). For comparative purposes, the corresponding 1995 data have been provided as reported by Nairn (1996). Hue, value and chroma generally consistent among wetland soils sampled regardless of depth or wetland. The majority of soil samples exhibited a hue of 2.5Y, a value of 3 or less, and a chroma of 2 or less. All soils sampled in 2002 indicated a chroma of 2 or less, indicating hydric soils. This is in contrast to the variable soil colors observed in 1995 (Table

Table 1. Munsell Color Chart data (hue, value, chroma) for experimental wetland soil samples in 2002 (this study) and 1995 (Nairn, 1996)

Grid point	Depth	2002	1995
Wetland 1			
1,5 *	0-8	2.5Y, 3, 1	2.5Y, 3,2
	8-16	2.5Y, 3,2	10YR, 4, 2
3,15	0-8	2.5Y, 3,2	2.5Y, 3, 2
	8-16	2.5Y, 3,2	10YR, 4, 3
4,2 *	0-8	2.5Y, 3, 1	5Y, 3, 2
	8-16	2.5Y, 3, 1	2.5Y, 4, 4
4,9	0-8	10YR, 3, 1	7.5Y, 2, 0
	8-16	2.5Y, 3, 1	10Y, 3, 3
6,14	0-8	2.5Y, 4, 1	2.5Y, 2, 0
	8-16	2.5Y, 4, 1	2.5, 4, 3
6,5	0-8	2.5Y, 3, 1	2.5Y, 2, 0
	8-16	2.5Y, 3, 1	2.5, 4, 4
Wetland 2			
8,4	0-8	2.5Y, 3, 1	5Y, 2.5, 1
	8-16	2.5Y, 3, 1	10YR, 4, 4
13,6	0-8	2.5Y, 3, 1	5Y, 2.5, 1
	8-16	2.5Y, 3, 2	10YR, 4, 4
11,11	0-8	2.5Y, 3, 1	10YR, 3, 1
	8-16	2.5Y, 3, 1	10YR, 3, 2
13,15	0-8	2.5Y, 2.5, 1	10YR, 3, 1
	8-16	2.5Y, 3, 1	10YR, 4, 4
11,15	0-8	2.5Y, 3, 1	7.5, 2, 0
	8-16	2.5Y, 3, 1	10YR, 3, 2
13,17	0-8	2.5Y, 3, 2	5YR, 2.5, 1
	8-16	2.5Y, 3, 1	10YR, 4, 4

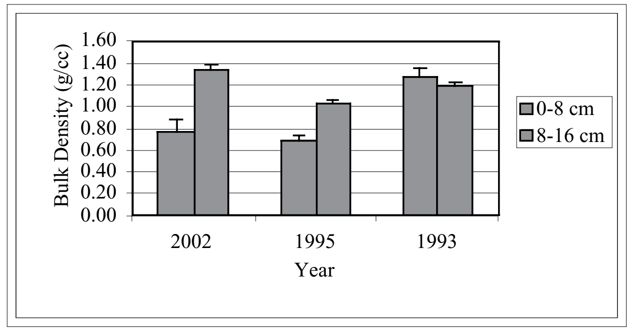

Figure 2. Mean (± SE) bulk density of experimental wetlands in 1993, 1995, and 2002 at 0-8 cm and 8-16 cm depth. 1993 and 1995 data per Nairn, 1996.

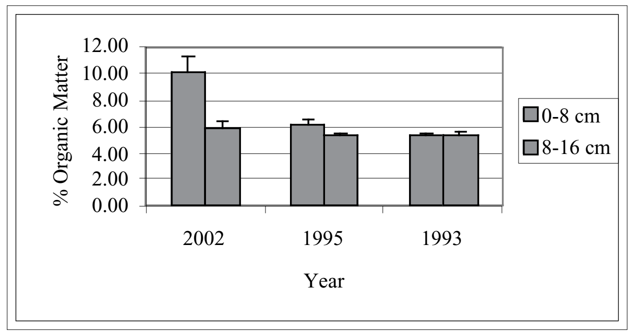

Figure 3. Mean (± SE) percent organic matter of experimental wetlands in 1993, 1995, and 2002 at 0-8 cm and 8-16 cm depth. 1993 and 1995 data per Nairn, 1996.

1) where only 15 out of 24 (63% of the samples) had a chroma less than 2.

Temporal effects on soil characteristics

The bulk density and percent organic matter were determined for each soil sample and compared to the Nairn 1993 and 1995 data (Figures 2 and 3). Between 1995 and 2002, there was no difference in bulk density of the surface soil (0-8 cm) sampled (0.77 ± 0.11 g/cm3 and 0.69 ± 0.05 g/cm3, respectively). There was however a significant increase (p=0.001) in the bulk density at the 8-16 cm depth between 1995 and 2002 (1.03 + 0.04 g/cm3 and 1.34 + 0.05 g/cm3, respectively). This was opposite to the trend compiled by Nairn (1996) where significant a decrease in bulk density was detected at both depths between 1993 and 1995. There was a significant increase in percent organic matter for soil samples at both depths between 1995 and 2002. The most substantial increase was detected at the surface where percent organic matter increased from 6.2 ± 0.4% in 1995 to 10.1 ± 1.2% in 2002 (p=0.001). The increase at the 8-16 cm depth was less substantial (from 5.4 ± 0.1% in 1995 to 6.0 ± 0.5% in 2002, p=0.022). No significant increases were detected between 1993 and 1995 for these grid points at either depth.

Spatial effects on soil characteristics

The bulk density and percent organic matter was analyzed to examine the effect of distance from the wetland inflow may have on these parameters. For both parameters, no correlations were detected between bulk density/ percent organic matter and the distance of the sample point to the inflow (Figures 4 and 5). This occurred for samples collected at 0-8 cm and 8-16 cm in depth.

Wetland 1 v. Wetland 2

The bulk density and percent organic matter data were analyzed to determine if soil progression has varied between Wetland 1 and Wetland 2. Analyzing the 1993 data collected by Nairn (1996) for the sampled grid points, no significant differences in bulk densities or percent organic matter were detected for the original 1993 soil conditions at Wetland 1 and Wetland 2 (at either depth).

After analyzing the 2002 soil sample data there was still no significant differences in bulk densities or organic matter detected between Wetland 1 and Wetland 2 at either depth (Figure 6 and 7). Mean bulk densities at 0-8 cm depth ranged from 0.71 ± 0.05 g/cm3 in Wetland 2 to 0.82 ± 0.16 g/cm3 in Wetland 1. Mean bulk densities at 8-16 cm depth ranged from 1.28 ± 0.10 g/cm3 in Wetland 1 to 1.39 ± 0.05

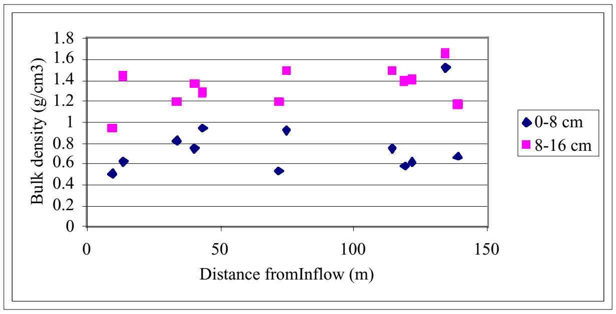

Figure 4. Scatter plot of bulk density versus distance to inflow for experimental wetland soil samples in 2002.

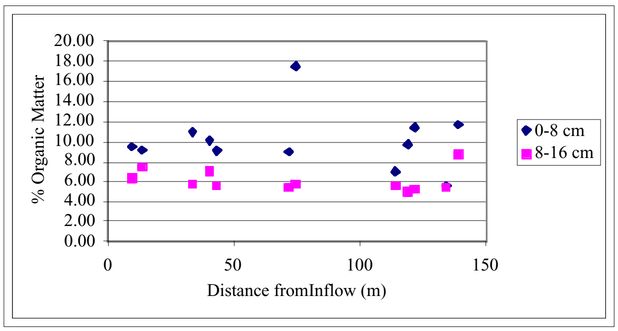

Figure 5. Scatter plot of percent organic matter versus distance to inflow for experimental wetland soil samples in 2002.

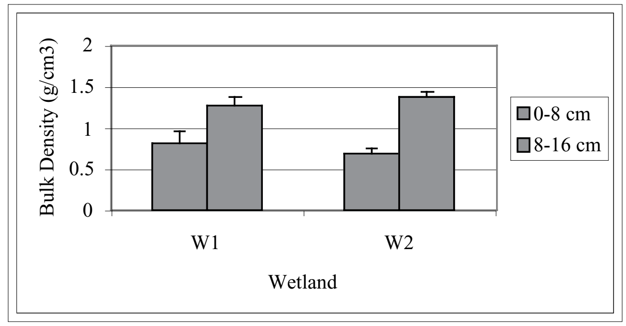

Figure 6. Mean (± SE) bulk densities of soil samples in Wetland 1 (W1) and Wetland 2 (W2) at 0-8 cm and 8-16 cm depth.

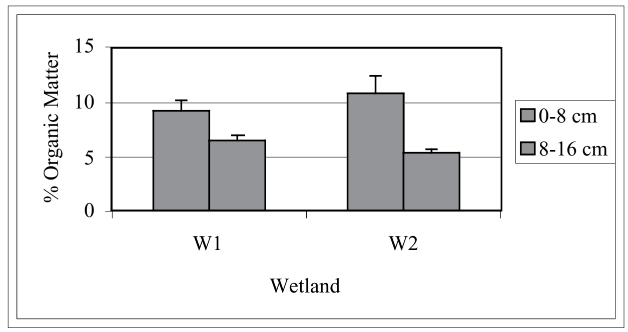

Figure 7. Mean (± SE) percent organic matter of soil samples in Wetland 1 (W1) and Wetland 2 (W2) at 0-8 cm and 8-16 cm depth.

g/cm^3 in Wetland 2. Mean percent organic matter in Wetland 1 was 9.3 ± 0.9% at 0-8 cm and 6.5 ± 0.6% at 8-16 cm. Mean percent organic matter in Wetland 2 was 10.9 ± 1.5% at 0-8 cm and 5.52 ± 0.2% at 8-16 cm.

Discussion

Based on the Munsell Color Chart data collected, there has been a very apparent transition in the colors of the experimental wetland soils sampled since 1995. These soil colors have progressed from the surface layers (0-8 cm) to the lower depths. In 1995, these sites had begun to develop low chroma numbers at the surface, but many of the lower surface soils still retained chroma that was 3+ (Table 1), presumably closer to their pre-hydration color. In an analysis of soil profiles conducted at the ORW, Glibert et. al (1999) found increasingly deeper occurrences of low chroma (2 or less) soils. The occurrence of darker color values and hues is an indication of reduced conditions and accumulation of organic matter (Mausbach and Parker, 2001).

From 1993, 1995, to 2002, there has been a substantial accumulation of organic matter at the soil surface (0-8 cm depth). The increase at the lower level was not as substantial but was still statistically significant. This increase can be explained by the obvious accumulation of detrital material after several growing seasons of wetland vegetation. The lack of significant increases between 1993 and 1995 was expected given that the productivity of macrophytes only became substantial after 1995. Prior to that, algae were the primary source of vegetative cover (Mitsch and Zhang, 2001).

Bulk density however did not show the expected trend. The 0-8 cm bulk density estimates showed a significant decrease between 1993 and 1995 with no change detected between 1995 and 2002. The most puzzling data however was the significant increase in bulk density at the 8-16 cm depth between 1995 and 2002. This was after the bulk density decreased significantly between 1993 and 1995 (Figure 4). The change in bulk density between each year was unexpected for two reasons. First, the organic matter content has risen slowly at the 8-16 cm depth during this same time. It has been well documented that organic matter is much less dense than mineral soils and its accumulation will decrease overall soil bulk density (McLatchey and Reddy, 1998). We expected an inverse relationship between the two parameters. The second unexpected factor is that bulk density would fluctuate as much as it did at the 8-16 cm depth. If factors affecting the lower soil surface bulk density are occurring (e.g., sedimentation) it is unclear why no changes would be detected at the upper layer (0-8 cm). It is important to note that the soil extraction methods used in this study were not the same as the Nairn 1996 study. Differing methodology may account for some errors.

The lack of differences in bulk density and percent organic matter between Wetland 1 and Wetland 2 was somewhat unexpected. Given the two wetlands have similar hydroperiods, the higher amount of vegetative productivity in Wetland 2 could have potentially increased organic matter being contributed to the soil surface. Wetland 2 had significantly greater productivity than Wetland 1 between 1998 and 2000 (Mitsch et al., 2001), however despite the greater productivity, no differences in either soil parameter were detected. More recently (2001+), productivity between the two wetlands has become more comparable. It is possible that the recent convergence in productivity between the two wetlands has evened the percent organic matter as well.

The lack of a correlation between the soil bulk density/ percent organic matter data and its distance to the wetland inflow source was not unexpected. There was some potential in these wetlands that the nutrient supply emanating from the inflow (pumped river water) may have been disproportionately available to vegetation closer to the inflow source that may have lead to a greater accumulation of organic matter. At the Des Plaines River Wetland Demonstration Project in northeast Illinois, Fennessy (1991) found a greater accumulation of extractable P and organic carbon in created wetland soils closer the inflows versus the outflows. Similar to the ORW, these wetlands were exposed to regularly pumped river water. Fennessy attributed this trend to the sequestration of nutrients by planktonic organisms (and their eventual subsidence into the soil surface) near the inflow. Likewise, there has been some evidence of this phenomena at the ORW (Deal and Kantz, 2001) where floating *Lemna* appear to predominate closer to the inlet in the deeper pools (not sampled during this study).

It is possible that the regular movement of water through Wetland 1 and 2 moderates the centralization of nutrients (and consequently soil organic matter accumulation) near the inflow. This phenomena may be more likely in a system that receives pulsing hydrology and nutrient inputs such as the billabong (see Kettlewell et al. in this report). The experimental marshes may be better described as steady flow systems where nutrients are likely distributed more evenly.

Conclusions

Using the data collected from previous research, some very apparent trends have been identified. The level of organic matter detected in the experimental marshes indicates that they have steadily increased in organic matter since their construction in 1993. While no differences were detected between the Wetland 1 and Wetland 2, or any spatial patterns detected it is important to remember that this is a very cursory study and that subtle trends may not be revealed until further sampling has occurred.

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