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Soil organic carbon and mineralization rates at the Woolsey Wet Prairie mitigation site in Fayetteville, Arkansas

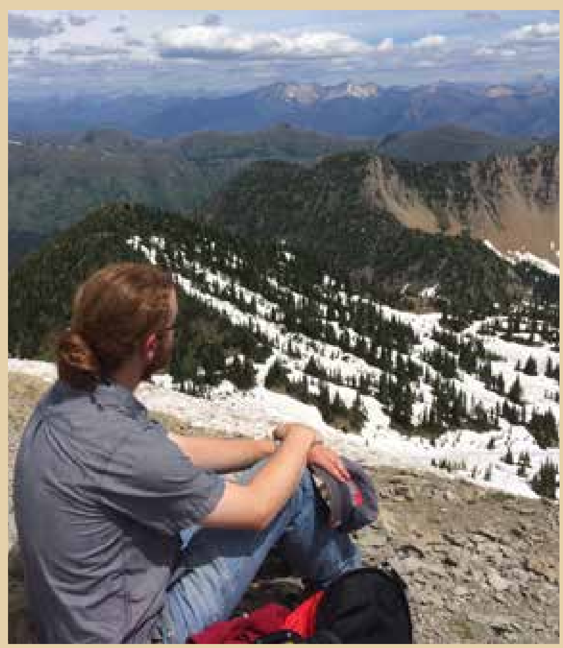
Meet the Student-Author

Zachary Tipton

I am a native of Fayetteville, Arkansas and graduated from Fayetteville High School in 2009. In May 2018, I graduated cum laude from the Dale Bumpers College of Agricultural, Food and Life Sciences with a major in Environmental, Soil and Water Science and minors in Chinese and Statistics. Generous funding was provided by the Honors College to present this research at an undergraduate oral paper competition during the ASA, CSSA, SSSA conference in Tampa, Florida.

As a non-traditional student, I faced many challenges to my education. But through the kindness, passion, and support from the Bumpers faculty, I quickly found my second home. During my time at the University of Arkansas, I was awarded several scholarships from the Honors College to study abroad in China, Taiwan, and Belgium.

This project would not have been possible without the guidance and patience of my advisors Dr. Lisa Wood and Dr. Mary Savin. Big thanks to Dr. Benjamin Runkle for his input and generosity in letting me borrow the LICOR LI-8100 for the duration of the study. Warmest gratitude and love to my wife Yujie for not only her emotional support but also the amazing amount of help she provided with SAS programming and statistical analysis. I would like to thank the Bumpers College for providing funding for this research. I would also like to thank the stewards of the Woolsey Wet Prairie for allowing this research to be conducted on the site.



Zachary at Glacier National Park during a summer 2017 program studying Ecology at the Flathead Lake Biological Research Station with the University of Montana.

Research at a Glance

- Wetlands can store large amounts of carbon and by storing carbon dioxide, can potentially help reduce the negative effects of high carbon dioxide levels in the atmosphere.
- At our study site, fire is used as a management tool to control the spread of invasive species, which might have negative effects by removing available food for plants, and cause soils to release large amounts of carbon dioxide into the air.
- Based on our study, the low-intensity fire management did not negatively affect the organic matter available for plant uptake nor significantly increase the amount of carbon dioxide released from the soil.

Soil organic carbon and mineralization rates at the Woolsey Wet Prairie mitigation site in Fayetteville, Arkansas

Zachary Tipton, Lisa S. Wood†, Mary C. Savin§, and Benjamin R.K. Runkle‡*

Abstract

Atmospheric carbon dioxide (CO_2) levels are rapidly increasing, surpassing 400 ppm in 2013 from a pre-industrial revolution level of around 280 ppm. Researchers have been looking at methods to reduce CO_2 levels in the atmosphere, including promoting carbon sequestration in soils. Carbon sequestration is the process where CO_2 is naturally or artificially transferred out of the atmosphere and stored in the ocean, plant biomass, soils, and geologic formations. Seemingly contradictory to the notion of carbon sequestration is the use of fire as a management treatment for the restoration of native prairie grass ecosystems. Fire combusts plant biomass and produces CO_2 as one of its products, potentially leading to increased atmospheric CO_2 concentrations. The first objective of this research was to determine particulate (easily broken down) and total (easily broken down plus stable) soil organic matter content and CO_2 respiration (output) in Woolsey Wet Prairie Sanctuary (WWPS) soil that has been restored and managed with annual burning for 10 years compared to soil from non-restored adjacent fields growing tall fescue. The first objective was accomplished by taking soil samples and CO_2 respiration measurements before the 2017 annual prescribed burn. The second objective was to determine short-term impacts of the prescribed burn on soil carbon release and storage. The second objective was accomplished by comparing CO_2 respiration before the fire management in the spring, then comparing to CO_2 respiration 2, 7, 16, and 29 days post-treatment, and collecting soil samples. Soil samples were taken before the prescribed burn, two weeks after the burn, and two months after the burn to compare short-term changes in particulate organic matter (easily broken down; POM) and stable organic matter (OM). Results indicated high productivity in the wetland low-lying areas with statistically greater levels of POM and OM compared to the other sample sites. Additionally, there was no statistically significant change measured in POM following the annual prescribed burn at any sample site, or a statistically significant increase in CO_2 respiration. The results indicate that the managed wetland area is functioning as a highly productive carbon sink.

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Introduction

Carbon Cycling

Continued use of fossil fuels as an energy source plays a role in global warming, so an understanding of the carbon cycle and promoting carbon storage in soil is important to the goal of reducing atmospheric carbon dioxide (CO_2) levels (Stout et al., 2016). Soils store roughly three times more carbon than the atmosphere by capturing plant and animal matter residues, which break down and transform into soil organic matter (SOM) (Ontl and Schulte, 2012). Soil CO_2 is produced by plant root respiration, soil microorganisms around the rhizosphere (a roughly 1-mm thick area of high activity around plant roots), and microorganisms in the soil metabolizing organic matter, including particulate organic matter (POM), a fraction of soil organic matter comprising a readily available source of nutrients. The ease of breakdown of total SOM varies across different pools from readily decomposed POM to stable humus. The SOM is beneficial to plant growth by improving soil structure, which also protects against erosion, providing micro and macronutrients to plants, and helps retain water (Murphy, 2015). Carbon sequestration in SOM has the potential to reduce the levels of atmospheric CO_2 and mitigate the negative effects of global warming (Lal, 2004; Post et al., 2004). Carbon sequestration in plant biomass is beneficial; however, burning biomass and thus releasing carbon as CO_2 is promoted as a tool for prairie management to reduce invasive species and promote native seed germination (Rook et al., 2011).

Fire as a Management and Restoration Tool

Before major European settlement, large areas of northern Arkansas consisted of tallgrass prairie that were naturally sustained by fire (Brye et al., 2008). Various intensities of fire happen naturally depending on the amount of biomass (fuel) available. Prairie ecosystems evolved under a frequent, low-intensity, natural fire cycle. Due to human interference in this fire cycle, prairie ecosystems have been deprived of fire, which has led to problems such as domination of the habitat by invasive species, which can cause total ecosystem shifts (Docherty et al., 2011). Fire can be used as a management tool in ecosystem restoration by burning invasive plants, providing bare mineral soil and sunlight to native seeds for germination. Efforts are ongoing to promote using fire as a management tool to restore native tallgrass prairies. Low-intensity burning can be beneficial, by increasing nutrient availability and decreasing threats from pathogens (Neary et al., 1999). Conversely, high-intensity fires can cause severe disturbances, such as disruption of microbial communities and loss of nutrients (Neary et al., 1999).

A successful example of species restoration in tallgrass prairie is the Woolsey Wet Prairie Sanctuary (WWPS), located in Fayetteville, Arkansas. Designed by ecologists from Environmental Consulting Operations, Inc. (ECO, Benton, Ark.) and engineers from McGoodwin, Williams, and Yates Consulting Engineers, Inc. (Fayetteville, Ark.), the 46-acre WWPS was established as a wetland mitigation project following the construction of a regional wastewater treatment facility in 2006 (ECO, Inc, 2018). Engineers and city planners created a mosaic ecosystem area using earthen berms to include basin wetlands, open water, marsh, and forested wetland areas. The berms and non-wetland areas were restored in native prairie grass and forb species. The soil type is characterized by a somewhat poorly drained mound/intermound system with mounds being microtopological features with a higher elevation than the surrounding area and adjacent intermounds, low points of elevation between mounds. The mount/intermound systems are of unique interest because of their symmetric properties; many hypotheses have been published as to the origin of prairie mounds, one such hypothesis is that the mounds developed from accumulation of wind-blown deposits and are at a state of "environmental equilibrium" with grasses protecting mounds from erosion and soil organisms seeking slightly elevated soil to reside in dryer conditions (Allgood and Gray, 1974). Environmental consultants with ECO, Inc., use a prescribed burn treatment to remove invasive grasses and emergent woody vegetation annually in the spring around mid-March (ECO, Inc., 2018).

The prescribed fire utilized on WWPS is a low-intensity, quickly moving fire. Burning in the spring kills primarily cool-season invasive grasses prior to emergence of warm-season grasses and creates a mineral bed in which native plants thrive (ECO, Inc, 2018). The approach and management plan have been successful in restoring aboveground biodiversity. Enhancing carbon storage in the soils and burning of OM to promote prairie restoration appear to be contradictory in terms of soil carbon management. However, aboveground biomass in tallgrass prairie systems can be significantly increased for up to two years after a low-intensity fire, resulting in greater amounts of carbon storage in plant residues than in unburned test plots (Docherty et al., 2011).

Research Questions

Restoration of aboveground biodiversity has been successful at WWPS, but the effect of management on soil carbon has not been studied at this site. Thus, we used this site to research the following questions:

1. How has restoration, including fire management, influenced soil CO_2 respiration and carbon storage after 10 years of prairie restoration management.

2. What is the immediate versus short-term temporal impact of the 2017 annual prescribed burn on soil carbon release and storage?

Objectives

The objectives of this research were to:

1. Determine particulate organic matter (easy to break down, POM) and SOM (easy to break down plus stable) content and CO_2 respiration rates on soil from WWPS that has been restored and managed with annual burning for 10 years compared to soil from an adjacent field that is non-restored and in which tall fescue is growing.
2. Determine immediate versus temporal impacts of burning on POM content and CO_2 respiration rates starting from two days after the 2017 annual burn treatment to two months post-burn WWPS compared to soil from an adjacent field in which tall fescue is growing.

Materials and Methods

Study Site

Two treatment sites were selected for the study, one being a section of the berm and wetland which was burned as the treatment, and the other being an adjacent fescue mound/intermound system that was not burned. The wetland soil type was anthropogenic in nature, being a blend of the primary soil type for the area that was heavily disrupted during the creation of the WWPS, while the fescue area had a Taloka complex, mounded soil type as mapped by the WEB Soil Survey (USDA, 2018).

In the fescue unburned control area, four transects were established and samples were taken on representative mounds and adjacent intermounds (Fig. 1). For the wetland area, sample sites were selected along the main trails between the fescue control area and parking lot. Four samples were collected immediately adjacent to the trail but on top of the constructed berm areas. Four samples were collected downslope of the berm sample sites in the wetland cells themselves. It is important to note that while designations are assigned to landscape positions for both treatment areas, landscape positions cannot be assumed to be at the same elevation at all sample sites.

Timeline

Samples were collected between 10 February and 18 May 2017. The first CO_2 respiration measures occurred on 22 February. The prescribed burn was conducted on 25 February, and CO_2 respiration samples were measured on 27 February, 4 March, 13 March, and 26 March. Soil samples were collected adjacent to locations of soil respiration measurements on 10 February, 12 March, and 18 May.

Bulk Density

Soil bulk density, which can indicate the degree of soil compaction, was determined by using one 5-cm diameter,

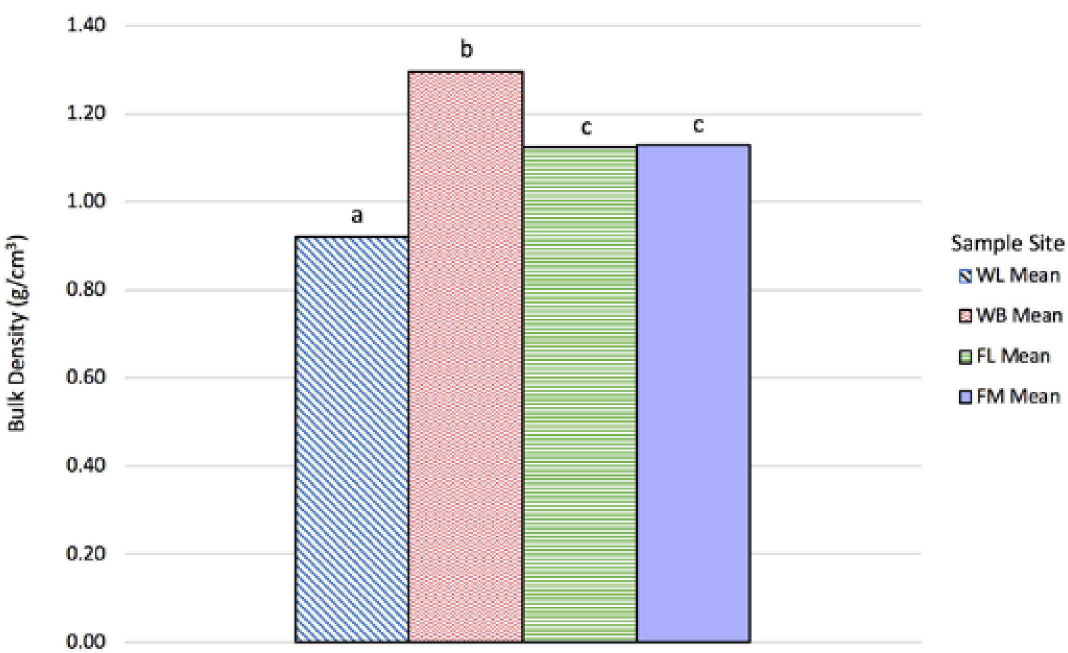

Fig. 1. Bulk density (g/cm³) of soil in the Woolsey Wet Prairie Sanctuary wetland low (WL), wetland berm (WB), and adjacent fescue field intermounds (FL) and mounds (FM) in Fayetteville, Arkansas from 10 February, 12 March, and 18 May 2017. Bulk density did not change with time and samples were averaged together (n = 12). Means with the same letters are not statistically different (α = 0.05).

5-cm long soil core to collect soil at each site (4 replications each in Wetland Low, Wetland Berm, Fescue Low, and Fescue Mound) on 10 February, 12 March, and 18 May for a total of 48 soil samples. The known volume of the soil was removed from the soil core and dried in a pre-weighed container at 55 °C for 5–7 days until a constant weight was reached. The dry soil weight was measured and subtracted from the container weight to calculate bulk density (dry soil mass divided by total soil volume).

Soil Organic Matter (SOM)

Oven-dry soil (from the determination of bulk density) was ground with a mortar and pestle and passed through a 2-mm sieve. Ten grams of soil was transferred into a pre-weighed crucible (small ceramic bowl). Crucibles were placed in an oven at 55 °C for 5 days. After five days, the samples were removed from the oven and weighed again. Crucibles were then placed into a muffle furnace and combusted at 450 °C for 8 hours. Crucibles were weighed again, and percent organic matter was calculated using the following equation: %OM = ([oven-dry soil (g) after 5 days at 55 °C – ash weight (g) after being combusted in the muffle furnace] / [oven-dry soil (g) after 5 days at 55 °C]) * 100%.

Particulate Organic Matter

Oven-dry soil was ground with a mortar and pestle and passed through a 2-mm sieve. Particulate organic matter, or sand-sized fraction (SSF) between 0.053-mm and 2-mm, was determined using the oven-dried soil. Sieved soil (25 g) was transferred to a 250-mL bottle and mixed with an aqueous solution of 5 g sodium hexametaphosphate ($(NaPO_3)_6$) and 100 mL ultrapure water. After being shaken for 16 hours, the solution was poured through a 53-µm sieve and rinsed with deionized water. The retained fraction was dried overnight in a pre-weighed container at 55 °C and again weighed. The oven-dry weight of the SSF was divided by 25 g to determine the SSF fraction relative to total soil weight. After weighing, dried SSF samples were transferred into pre-weighed crucibles, re-weighed, and combusted in a muffle furnace at 450 °C for 8 hours. Samples were cooled in a desiccator and the weight of the crucible and ash was determined and used to calculate percent organic matter in the SSF. The SSF fraction was multiplied by %POM in the SSF to determine %POM. The %POM was divided by %SOM determined in the previous section to calculate %POM as part of the total soil organic matter.

Carbon Mineralization

In-situ respiration (CO_2 output), or CO_2 flux, was determined using a LI-COR LI-8100A automated soil gas flux system (LI-COR, Lincoln, Nebraska, U.S.). A 20-cm diameter survey chamber was fitted over a 20-cm diameter PVC soil collar which was installed 2–5 cm into the soil surface to create a seal. Individual collars were installed at least 24 hours prior to CO_2 flux measurements to allow the soil to normalize after the disturbance. Additionally, plant matter on the soil surface within the soil collars was cut and removed 24 hours before measuring soil flux. Flux was calculated by an infrared analyzer located in the survey chamber. The rate of CO_2 being released from the soil into the survey chamber was used to model CO_2 diffusing into the air outside of the chamber. Soil temperature and moisture were determined by inserting a temperature probe (Omega Soil Temperature Probe 6000-09TC; LI-COR, Lincoln, Nebraska) and theta probe (Delta-T ML2 ThetaProbe; LI-COR), respectively, into the soil adjacent to the survey chamber. The soil surface area within the 20-cm soil collar was 317.8 cm^2. The temperature probe was inserted 15.24 cm into the soil, while the theta probe was inserted 6 cm into the soil. The headspace between the soil surface and top of the soil collar was measured in five locations around the inside of the collar, averaged, and entered into the LI-8100A measurement software as chamber offset in centimeters to calculate chamber volume. The LI-8100A device was set with a one-minute pre-purge time in between measurements to allow normalization of gasses, while the observation time was set for two minutes. Three measurements were collected, one minute apart, at each site. Soil flux rates were reported by the LI-8100A in µmol CO_2 m^{-2} s^{-1}. The average flux was calculated for the three measurements of exponential flux for each sample site. Flux was adjusted using an assumed Q_{10} temperature coefficient of 1.4.

Data Analysis

Preliminary organization of data and graphs was conducted in Excel 2016 (Microsoft Corp., Redmond, Washington). Statistical analysis was performed using SPSS Statistics 24.0.0.2 (IBM Corp., Armonk, New York) and SAS 9.4 (SAS Institute, Inc., Cary, North Carolina). Repeated measures analysis of variance (ANOVA) were run individually for each dependent variable (bulk density, OM, POM, temperature, water content, and flux) to determine significance with $\alpha = 0.05$ of values within and across groups. Statistical analysis was performed to determine if measurements changed with time, followed by ANOVAs comparing means across the two treatment sites (fescue, wetland) and four microtopography levels (Wetland Low, Wetland Berm, Fescue Low, and Fescue Mound). Respiration was compared to soil moisture content and soil temperature recorded at the time of CO_2 respiration sampling to determine if those parameters could explain variation in soil respiration.

Results and Discussion

Three parameters (bulk density, SOM, and POM) did not change with time (all $P > 0.05$), so data from the different dates were combined. The bulk density in the Wetland Low treatment was 0.917 g/cm^3, the Fescue Low and Fescue Mound treatments were both 1.13 g/cm^3, and the Wetland Berm treatment was 1.295 g/cm^3. Bulk density in the Wetland Berm was greater than all other treatments, and the bulk density of the Wetland Low was less than in Wetland Berm, Fescue Low, and Fescue Mound treatments ($P < 0.05$). The bulk density in Fescue Low and Fescue Mound values did not differ from each other ($P > 0.05$) (Fig. 1).

Soil OM values were Wetland Low at 8.94%, Wetland Berm at 5.34%, Fescue Low at 6.4% and Fescue Mound at 6.19%. The Wetland Low values were greater than the other three sites ($P < 0.05$), and the values for the Wetland Berm, Fescue Low and Fescue Mound sites did not differ ($P > 0.05$) (Fig. 2).

Particulate OM values ranged from 46.6% for the Wetland Low site, to 25.58% for the Wetland Berm site, with Fescue Low and Fescue Mound being 29.18% and 34.49%, respectively. The Wetland Low values were greater than the other treatments ($P < 0.05$) and no difference was found among the other three sites ($P > 0.05$) (Fig. 3).

Soil CO_2 respiration fluxes did change with time. The Wetland Low and Wetland Berm CO_2 respiration measurements did not differ between 22 February (pre-burn) and 27 February (2 days after the burn); however, Fescue Low and Fescue Mound measurements decreased between these time intervals (Fig. 4; $P < 0.05$). Respiration in Wetland Low did not differ across any of the time intervals, while respiration in Wetland Berm increased from 13 March to 26 March ($P < 0.05$). For Fescue Low, respiration decreased between 22 February and 27 February ($P < 0.05$). For Fescue Mound, respiration fluxes decreased from 22 February to 27 February and between 4 March and 13 March ($P < 0.05$).

For 22 February pre-burn CO_2 respiration measurements, Wetland Low and Wetland Berm did not differ, and Fescue Low and Fescue Mound did not differ (Fig. 4). Both Wetland Low and Wetland Berm CO_2 respiration fluxes were lower than Fescue Low and Fescue Mound measurements ($P < 0.05$). On February 27, two days following the burn, CO_2 respiration measurements among the four sites did not differ. On 4 March, CO_2 respiration at the Wetland Berm site was lower compared to Fescue Low and Fescue Mound but did not differ from Wetland Low ($P < 0.05$), while Wetland Low, Fescue Low, and Fescue Mound did not differ from each other. On 13 March, respiration in Wetland Berm was greater than the two fescue sites, and on 26 March, respiration was greater in Wetland Berm than Wetland Low and Fescue Low ($P < 0.05$), while the

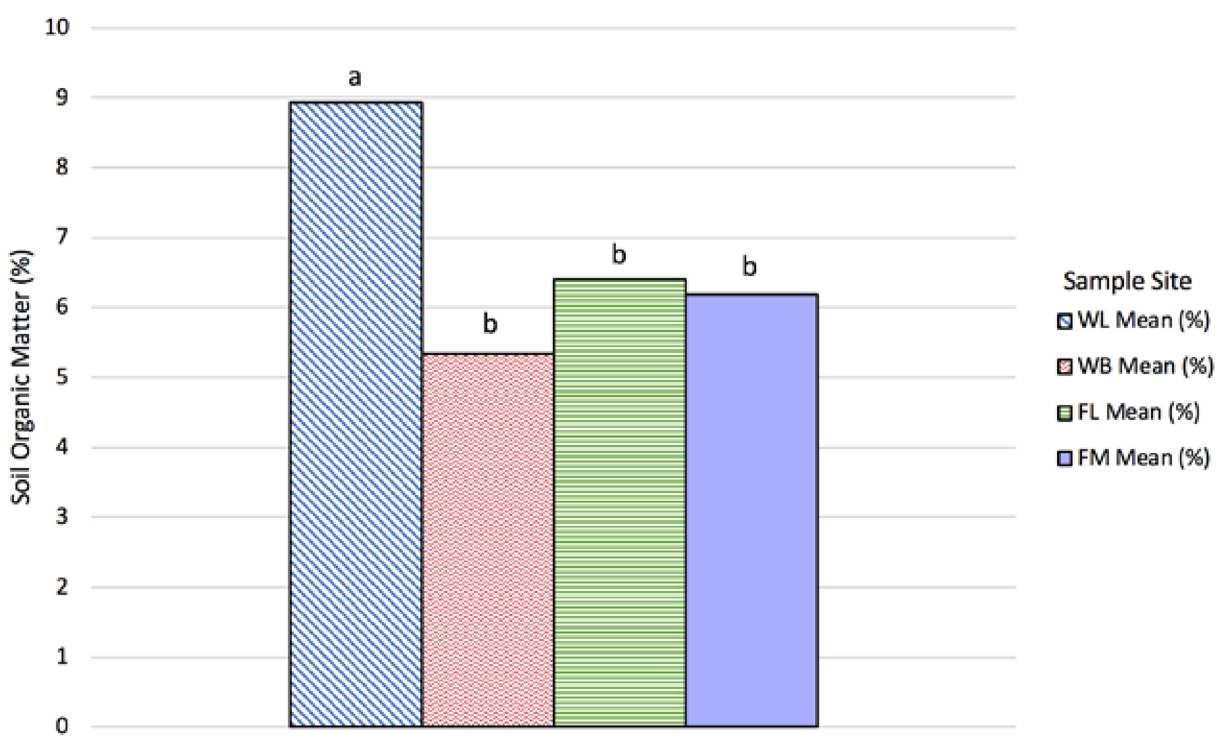

Fig. 2. Soil organic matter (%) of soil in the Woolsey Wet Prairie Sanctuary wetland low (WL), wetland berm (WB) and adjacent fescue field intermounds (FL) and mounds (FM) in Fayetteville, Arkansas from 10 February to 18 May 2017. Means with the same letters are not statistically different (α = 0.05). Organic matter did not significantly change over time and values across dates are averaged together (n = 12).

other three sites did not differ from each other (Wetland Low, Fescue Low, Fescue Mound; $P > 0.05$). On the dates following 4 March, there were several major rain events (data not shown), resulting in a corresponding decrease in soil temperature (Fig. 5), increase in soil water content (Fig. 6), and decrease in CO_2 flux in Wetland Mound on 13 March (Fig. 4). Precipitation events in March resulted in increased soil water content at all sites on 13 March compared to 4 March 4 and wetter soil in the lower elevation sites on 13 and 26 March (Fescue Low, Wetland Low, Fig. 6). Respiration increased in the higher elevation Wetland Berm (Fig. 4) between 13 and 26 March concurrent with warmer soil temperatures, even though the soil temperature did not increase significantly in the Wetland Berm (Fig. 5).

The temperature of Wetland Low was greater on 26 March from 13 March, Wetland Berm greater on 27 February from 22 February and lower on 13 March from 4 March. Additionally, Fescue Low was greater on 27 February from 22 February, lower on 13 March from 4 March, and higher on 26 March from 13 March, while Fescue Mound was lower on 13 March from 4 March, and higher on 26 March from 13 March (Fig. 5, $P < 0.05$). Regarding within-date statistical variation, differences were only measured on 27 February with Wetland Low having a higher temperature compared to Fescue Low, while Wetland Berm and Fescue Mound did not differ from the other two sample sites (Fig. 5, $P < 0.05$). No other dates showed within-date statistical differences among the four sample sites.

Soil water content was lower in Wetland Low on 27 February than 22 February and increased on 13 March from 4 March. Soil water content in Wetland Berm was greater on 13 March than 4 March; Fescue Low was lower on 27 February than 22 February and higher on 13 March than 4 March, while water content in Fescue Mound was higher on 13 March than 4 March (Fig. 6, $P < 0.05$). Regarding within-date statistical variation, on 22 February, Wetland Low had a greater soil water content than Wetland Berm and Fescue Mound which did not differ, while Fescue Low was not different from the other three sample sites. On 13 and 26 March, soil water content in Wetland Low and Fescue Low did not differ, and were higher than Wetland Berm and Fescue Mound which did not differ from each other. No statistical variation was observed on 27 February and 4 March (Fig. 6, $P < 0.05$).

The first objective was to determine POM and SOM content and compare CO_2 respiration from WWPS soil that has been restored and managed with annual burning for 10 years compared to non-restored adjacent field soil

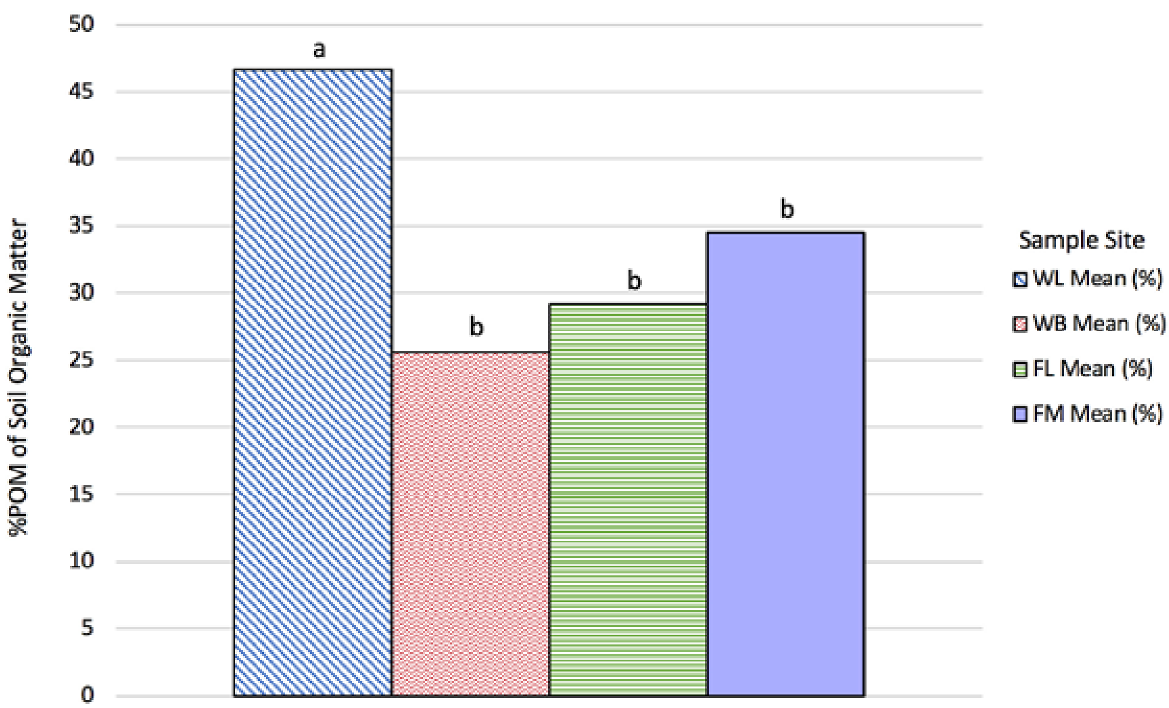

Fig. 3. Particulate organic matter as a percentage of the soil organic matter (%) in the Woolsey Wet Prairie Sanctuary wetland low (WL), wetland berm (WB), and adjacent fescue field intermounds (FL) and mounds (FM) in Fayetteville, Arkansas on 10 February, 12 March, and 18 May 2017. On each date, means with the same letters are not statistically different (α = 0.05). Particulate organic matter did not significantly change over time and values across dates are averaged together (n = 12).

growing tall fescue. This was accomplished by analyzing pre-burn data measured from the treatment and control areas. Soil POM is beneficial to soil functioning by providing a food source for microorganisms, promoting soil aggregation, and can be considered as an initial catalyst to C sequestration (Kravchenko et al., 2014). The results of this study suggest the Wetland Low to be highly productive with soil aggregation (low bulk density) and metabolic conversion of POM into more stable forms of SOM (greater measured OM levels). Decomposition of organic matter in soils releases CO_2 into the atmosphere (Keiluweit et al., 2017); however, pre-burn flux values were measured as lower in the wetland area than in the fescue fields. The sample sites chosen for Wetland Low and Fescue Low were at the lowest point of the landscape, and after rain events soil collars had to be retrieved from underwater and relocated to above the water line. Keiluweit et al. (2017) reported that while mineralization occurs during anaerobic conditions, mineralization rates decrease by 60–95% compared to aerobic conditions. Anaerobic conditions are typical for a wetland system.

The second objective was to determine immediate versus temporal impacts of burning on POM content and C mineralization rates on wetland (burned) soil. Since there was no measured change in POM before the burn, 15 days, and 83 days after the burn, it appears from these samples that there was no change in POM immediately following the burn. Regarding flux, measurements taken 2 days after the burn all decreased from pre-burn levels and did not differ from each other regardless of microtopography. It is possible that the heat from the fire and increased solar radiation resulting from the removal of surface biomass disrupted the microbiological functions in the wetland area as soil temperature in Wetland Low increased significantly 2 days after the burn compared to Fescue Low. However, flux measurements from the fescue areas were not different from the wetland 2 days after the burn, suggesting that biological functions were not altered by the prescribed fire. Additionally, major disruptions to proteins and plant tissue occur around 40–70 °C (Neary et al., 1999). Reports from the prescribed fire indicate that the fire moved very quickly through the system at a low intensity and, after the burn was completed, the ground was cool enough to walk on. Fire can have a wide range of effects on the soil system depending on intensity and duration of the fire, with duration being the main factor in how much damage a soil system receives belowground (Neary et al., 1999). Low-intensity fire events typically do not burn hotter than 100

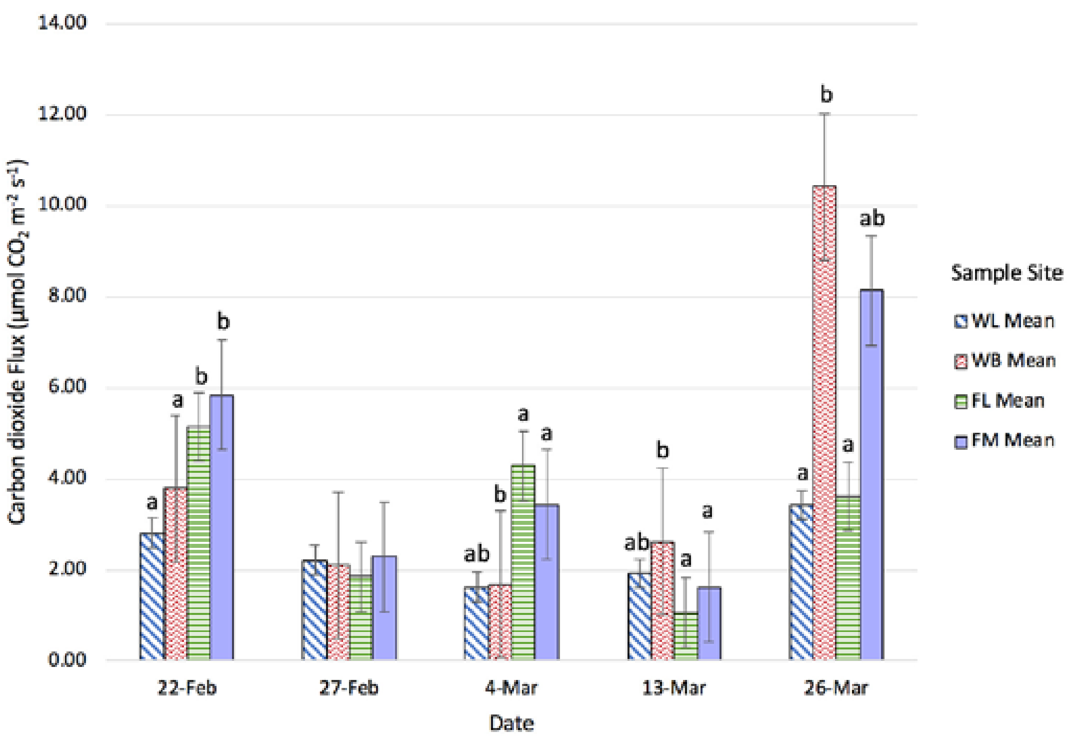

Fig. 4. Carbon respiration measurements (μmol CO_2 m^{-2} s^{-1}) of soil in the Woolsey Wet Prairie Sanctuary wetland low (WL), wetland berm (WB), and adjacent fescue field intermounds (FL) and mounds (FM) in Fayetteville, Arkansas on 22 February, 27 February, 4 March, 13 March, and 26 March 2017 (n = 12). On each date, means with the same letters are not statistically different (α = 0.05). Statistical differences among treatments were not observed on 27 February. Dates within one sample location with flux statistically different from the previous date are indicated by (*).

°C at the surface and 50 °C at 5 cm below the soil surface (Neary at al., 1999). These types of low-intensity fire can break down nutrients into forms for plant and microbial consumption, thin overcrowded biomes, and are popular as an ecological restoration practice (Neary et al., 1999). The annual burning schedule at the WWPS limits large amounts of fuel loading, thus limits the intensity of fires and damage to the soil system.

Besides the expected variability in flux measurements, there were several potential sources of measurement error. First, the PVC soil collars had to be moved twice. The pre-burn collars were removed after initial measurements, so they were not damaged by the prescribed fire treatment. Additionally, the Wetland Low and Fescue Low collars had to be relocated to slightly higher elevation on 12 March because they were completely submerged after a rainstorm. A second potential source of analysis error is that soil temperature readings were taken at 15 cm, while the PVC soil collars used for collecting the LI-8100A CO_2 respiration measurements were inserted shallowly into the soil at a depth of 2–5 cm. This may have resulted in improper analysis of the effect of temperature on flux as the temperatures measured were not exactly at the same depth as much of the microbial activity. In a study by Zhou et al. (2013), nearly twice the microbial biomass resided at a 0–10 cm soil depth compared to 10–20 cm in a grassland. Additionally at the 0–10 cm soil depth, the microbial community was more responsive (increasing respiration) to temperature and moisture changes. Future studies should include soil texture analysis of the wetland area to measure the texture as a result of anthropogenic mixture. Additionally, C:N measurements might allow researchers to gain more insight regarding total ecosystem health.

Based on the measurements of this study, the Wetland Low area is functioning as a highly productive carbon sink with greater carbon retention in organic matter and lower CO_2 respiration. Organic matter (POM and SOM) and respiration measurements in the spring before and after an annual prescribed burn did not indicate that fire management is detrimental to carbon sequestration; therefore, prescribed annual fire appears to be a positive influence on soil carbon storage at the WWPS.

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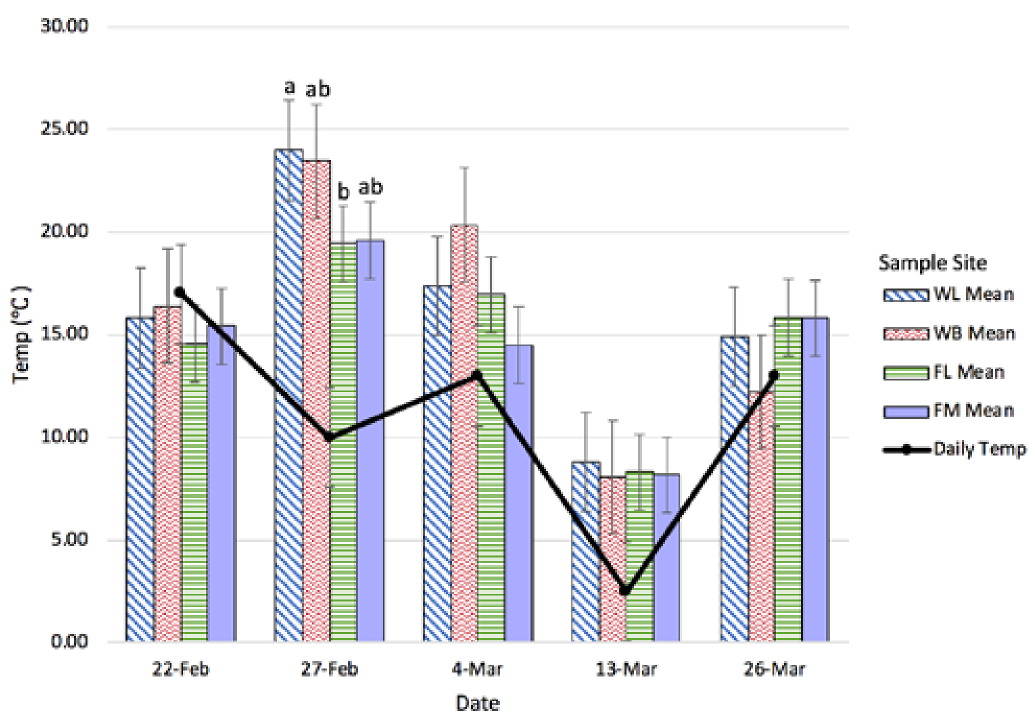

Fig. 5. Soil temperature measurements (°C) of soil in the Woolsey Wet Prairie Sanctuary wetland low (WL), wetland berm (WB), and adjacent fescue field intermounds (FL) and mounds (FM) in Fayetteville, Arkansas on 22 February, 27 February, 4 March, 13 March, and 26 March 2017 (n = 4). On each date, means with the same letters are not statistically different (α = 0.05). Statistical differences were only observed on 27 February. Dates within one sampling location with temperature statistically different from the previous date are indicated by (*).

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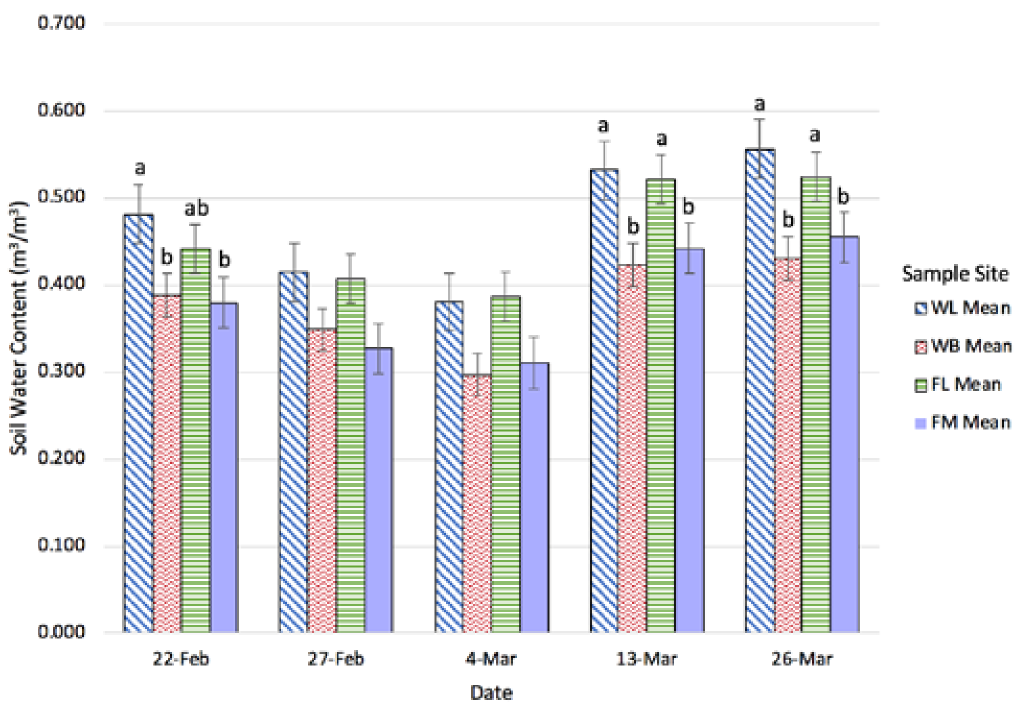

Fig. 6. Soil water content measurements (m^3/m^3) of soil in the Woolsey Wet Prairie Sanctuary wetland low (WL), wetland berm (WB), and adjacent fescue field intermounds (FL) and mounds (FM) in Fayetteville, Arkansas on 22 February, 27 February, 4 March, 13 March, and 26 March 2017 (n = 4). On each date, means with the same letters are not statistically different (α = 0.05). Statistical differences were not observed on 27 February or 4 March. Dates within one sampling location with soil water content statistically different from the previous date are indicated by (*).