Decrease in Soil Nutrient Availability After Prescribed Fire in an Oak Savanna Ecosystem of Northern Indiana.

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Abstract

This research examined how fire affects Cation Exchange Capacity (CEC) in post fire soil samples. CEC is an important soil characteristic that helps to describe soil fertility. Thirty pre burn samples and 229 post burn samples were collected during the spring burn season from Hoosier Prairie Nature Preserve. Samples were processed and analyzed to identify and quantify major individual cations and total CEC. CEC and individual cation concentrations, excluding Al and Na, were found to show an overall declining trend after the April 23, 2003 burn. There was a solitary increase around sampling round 4 (May 2, 2003). This increase might be attributed to the incorporation of ash in to the soil by a precipitation event. After round 4, the values again declined throughout the sampling. The overall decline in CEC was attributed to the removal of organic exchange sites which were present during the pre burn sampling round. Various factors may have resulted in the overall decline of cation concentrations: nutrient exportation (convective transportation, percolation, or wind erosion), removal of exchange sites, differing vegetation types, or lag time between burns. Although the overall cation and CEC values decline and data does not show any conclusive results for the decline, it does illustrate the need for continuing research. With further research, many of the variables which affect soils and vegetation after prescribed or natural fires can be managed to enhance the natural ecosystem.

Introduction

The objectives of this study were to determine the effect of prescribed fire on cations in an oak savanna. Specifically, this study examined the overall change in CEC and individual cations over the course of 23 days after a prescribed fire had occurred. The research tested the following questions:

- *What effect does prescribed fire have on the overall CEC?*
  CEC was measured and analyzed over the course of the 23-day study to reveal whether prescribed fires have a significant effect on overall site CEC.

- *What is the effect of prescribed fire on individual cations?*
  This was tested by determining the concentration of cations in pre burn soil samples and comparing the data to post burn soil samples. The hypothesis was that with the combustion of aboveground biomass, individual cations would increase after the fire.

- *What is the temporal effect of the nutrient release?*
  Data from eight rounds of sampling was compared to determine the temporal effect of the release over the 23-day time period.

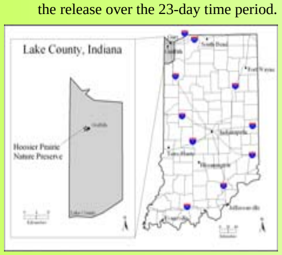

Figure 1: Location of study site.

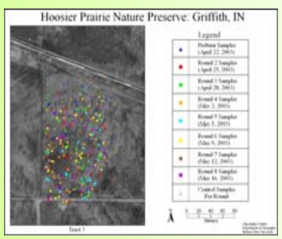

Figure 2: Randomly located sample points.

Hoosier Prairie Nature Preserve (Figure 1) is located near the city of Griffith in Lake County, Indiana. The nature preserve is one of the largest unspoiled remnants of the sand prairies that used to be prevalent in Northwestern Indiana. The dominant vegetation types found at Hoosier Prairie are sedge meadows, black oak savannas, wet prairies, and mesic sand prairies. The central portion of this 440-acre preserve will be subjected to prescribed burns during the course of the study (IDNR – NP, 1999).

Methods

Sample Site Selection

Samples were taken from Hoosier Prairie during the spring burn season of 2003. The site had both pre fire and post fire rounds of sampling. A combined total of 270 samples were taken from randomly selected locations (Figure 2). Thirty samples were extracted from the pre burn sampling locations and another seven rounds of up to 38 samples were collected from after the burn at three-day intervals. From 4-7 (totaling 37 samples) randomly located samples were collected from the control site (unburned) at the same time interval as the burned site.

Field Methods

A Garmin 12 GPS unit, with an accuracy of 5-15 meters (Rizos, 2002), was utilized to locate the sampling sites in the field. The soil samples were extracted using an Oakfield 12" soil sampling tube with a ¾" diameter at a depth of 5cm. The sampling probe was washed prior to taking each sample in a non-phosphate detergent solution to assure no cross contamination occurred between samples. Each sample was then be placed in a plastic sample canister and stored in a cooler for transportation to the laboratory.

Laboratory Methods

The samples were transported to the Indiana State University, Chemistry Laboratory for analysis. Under the supervision of Dr. Stephen F. Wolf, each sample was processed for the identification and quantification of major individual cations, as well as, the sum CEC using a compulsive exchange method. Determination of CEC by Barium Chloride Dihydrate ($BaCl_2$-$2H_2O$) compulsive exchange (Gillman and Sumpter, 1986) was used because it is the method recommended by the Soil Science Society of America for its accuracy and repeatability.

Results

The results of the analysis of variance showed there was no significant difference in the CEC of the burned sites when compared to the pre burn samples over the course of the 4-week sample period. Analysis of the individual cations used in the formula for CEC (Mg, Al, K, and Ca) again showed no significant difference when compared to the pre burn totals. Na also showed no significant difference when compared with pre burn totals. Further comparative analysis (t-Test) showed no significant

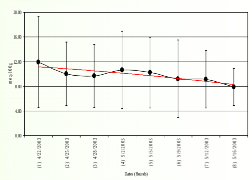

Figure 3: Mean Data Plot for CEC.

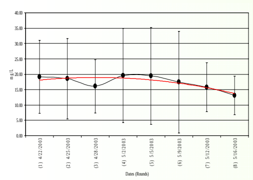

Figure 4: Mean Data Plot for Mg.

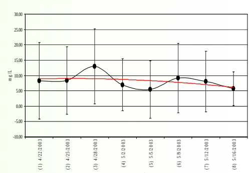

Figure 5: Mean Data Plot for Al.

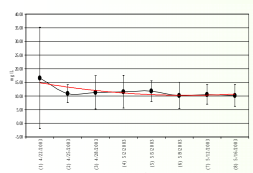

Figure 6: Mean Data Plot for K.

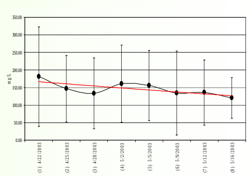

Figure 7: Mean Data Plot for Ca.

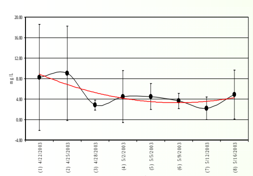

Figure 8: Mean Data Plot for Na.

difference between burn and control samples of CEC in the same rounds. Some significant results were found when comparing individual cations to the control samples in the same rounds.

In round three, the measured amount of Mg from the burn samples was significantly lower than control samples of round three ($t=1.92$, $p=0.06$). Ca from the burned samples also showed a significantly lower amount in round two ($t=-1.49$, $p=0.10$). Analysis of Al showed the only significant increase. In rounds two ($t=2.87$, $p=0.004$), three ($t=1.83$, $p=0.07$), and eight ($t=1.52$, $p=0.08$), Al was significantly greater when compared to the control samples of each respective round.

The mean data for CEC, Mg, Al, K, Ca, and their control samples were plotted to visualize the change in their quantity over the course of the study. Each of these mean values varies around a declining trend from the beginning to the end of the sample period (Figures 3-7). Bars showing variance at one standard deviation were plotted.

The mean data for Al (Figure 5) were the only values which showed a steady increase. Mean values increased significantly (to the control) from the preburn totals of 8.27 mg/L to a value of 12.96 mg/L in round three. Round eight also showed a significant increase when compared to control samples.

Discussion

Translocation of nutrients is one possible reason for the overall decrease in cations from preburn totals. Some heat tolerant nutrients (Mg, Ca, and K) become highly concentrated in post fire ash deposits (Macadam, 1989). During prescribed fires, the ash can be carried offsite by convection currents and large clouds of smoke (McNabb and Cromack, 1990).

Percolation of nutrients through the soil is another way overall cation concentrations could be lower in post burn soil samples. Unused, soluble cations can be washed through the soil by precipitation instead of remaining for later uptake by plants (Debano et. al., 1989). The mean data values for Mg (Figure 4), K (Figure 6), and Ca (Figure 7) show declining trends after sampling round 4. This corresponds with the first precipitation event during the study. Precipitation events continue through the middle dates of the research, and cation concentrations continue to show an overall declining trend after round four.

The most likely reason for the overall decline in CEC after the prescribed fire is the loss of exchange sites. Besides the removal of ash by convective currents, fire intensity does not typically alter the cations or mineral soil. However, when fire consumes OM on the surface, exchange sites are effectively removed (McKay, 1998). OM can be completely volatized with temperatures in excess of 930˚F (Wells et al., 1979). With the removal of these sites, the overall CEC would decrease. All of the sampling rounds analyzed after the burn show a steady decline in CEC.

The mean data plot for Al (Figure 5) shows a significant increase in round two (when compared to the control) followed by a steady decline with another increase in round six before the steady decline through round eight. A possible explanation for this trend could be related to soil structure and cation bonding. Al holds a higher positive charge (+3) than other cations analyzed in the study (Mg^{2+}, Ca^{2+}, K^+, and Na^+). Since Al makes up the majority of a soil's clay structure, this stronger positive charge would help Al stay attracted to clay fractions or other remaining exchange sites (Brady and Weil, 1998).

Conclusion

Prescribed fires had an overall negative effect on the CEC of Hoosier Prairie Nature Preserve. The sample values decreased steadily to a low of 7.9 meq/100g in round eight from the pre burn sample value of 11.94 meq/100g, with one slight increase (+1 meq/100g) in the fourth round. The majority of this decline can possibly be explained by the loss of organic exchange sites which were present before the burn.

The overall concentrations of cations, with the exception of Na (Figure 8) and Al (Figure 5), also showed a similar trend to the CEC (Figure 3). The overall totals declined until round four where some slight increases could be found. After round four, the concentrations again showed a negative trend throughout the rest of the sampling. The slight increase corresponded to the first precipitation event, although there was precipitation throughout the rest of sampling, and declining concentrations continued after round five.

The methods used in this research offer opportunities to environmental managers to examine related issues on their fire managed areas. A tenuous relationship exists between prescribed fires, local vegetation, and the underlying soil layers. Not all outcomes can be predetermined without first developing base knowledge about how various factors will be affected by fire and how those factors interact with the surrounding environment.

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