Discovery, The Student Journal of Dale Bumpers College of Agricultural, Food and Life Sciences

Volume 5 Article 11

Fall 2004

Effects of vegetation removal on native soil quality in eastern Arkansas

Lorena Moreno
University of Arkansas, Fayetteville

Kristofor R. Brye
University of Arkansas, Fayetteville

Effects of vegetation removal on native soil quality in eastern Arkansas

Lorena Moreno[*] and Kristofor R. Brye[†]

ABSTRACT

Aboveground vegetation removal practices, such as cutting and baling and burning, can both positively and negatively affect a prairie ecosystem. Burning can stimulate growth and species diversity, but removing vegetation and the nutrients it contains without equal replenishment of those nutrients could cause a steady decline in available soil nutrients. The objective of this study was to evaluate the effects of vegetation removal techniques in a native tallgrass prairie in east-central Arkansas. Soil samples were collected from the top 10 cm in each soil mapping unit that existed in each of three prairie areas that differed by the amount of time since aboveground vegetation had been removed by cutting and baling (i.e., 0, 6, and 24 years). Soil samples were analyzed for bulk density, particle-size distribution, organic matter, pH, electrical conductivity (EC), and extractable nutrients. Bulk density and EC were highest in the prairie area in which vegetation removal by cutting and baling still occurs at the present, but organic matter was highest in the prairie area in which cutting and baling ceased in 1998 (i.e., 6 years prior). Soil pH was highest in the prairie area in which cutting and baling ceased in 1980 (i.e., 24 years prior). No consistent trends among the three prairie treatments existed for extractable soil nutrients. The results of this study indicate that common prairie management practices in the Grand Prairie region of east-central Arkansas significantly affect soil physical and chemical properties. Prairie management practices need to be considered carefully to insure long-term sustainability and proper ecosystem functioning.

[*] Lorena Moreno is a junior in the Department of Crop, Soil, and Environmental Sciences.

[†] Kristofor R. Brye, teacher and faculty mentor, is an assistant professor in the Department of Crop, Soil, and Environmental Sciences.

INTRODUCTION

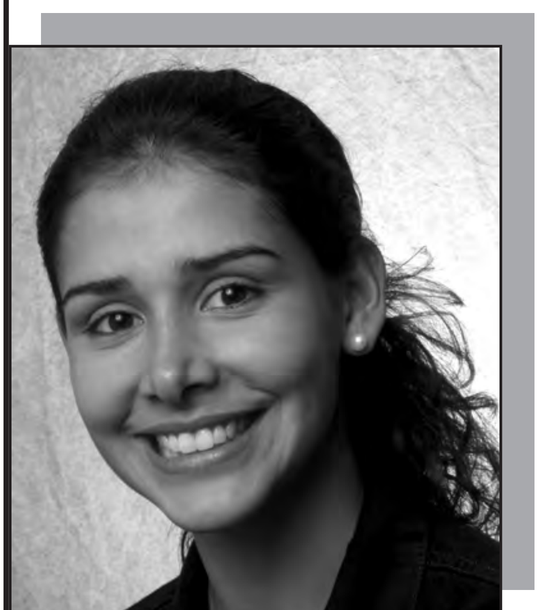
Most of the land surface in the mid-southern United States was at one time covered by tallgrass prairie (Samson and Knopf, 1994). This type of landscape also existed in east-central Arkansas in an area known as the Grand Prairie, which occupies an area of roughly 481,000 ha in five counties in east-central Arkansas. The soils underlying the Grand Prairie developed in alluvial sediments laid down by periodic flooding of the Mississippi River (Fielder et al., 1981). The establishment over geologic time of relatively drought-tolerant prairie vegetation likely influenced soil development and altered soil physical, chemical, and biological properties until relative equilibrium was achieved.

In the present, several practices are commonly conducted to manage native prairies and prairie restorations. These management practices include removal of aboveground vegetation by cutting and baling and also by burning. In the Grand Prairie region of eastern Arkansas, prairie vegetation is frequently cut, baled, and removed from the site for use as bedding for the few animal-farming operations that exist in the Delta. However, cutting and baling removes nutrients stored in the aboveground dry matter and prevents nutrient recycling to the soil. Burning aboveground prairie vegetation generally stimulates growth by promoting quicker soil warm-up, easier seedling emergence, and species diversity (Brye et al., 2002). However, as with cutting and baling, burning also prevents recycling of nutrients back to the same soil from which they were extracted in a landscape context noted for the severe fragmentation of native prairies that has occurred since the introduction and proliferation of mechanized agriculture (Brye et al., 2002).

Therefore, the objective of this study was to evaluate the effects of vegetation removal on native soil quality in the Grand Prairie region of eastern Arkansas. We hypothesized that annual removal of aboveground vegetation by cutting and/or burning has significantly slowed the accumulation of soil organic matter. More specifically, we hypothesized that the prairie area that had veg-

MEET THE STUDENT-AUTHOR

I am an international student from Bolivia. I am currently a junior in the Department of Crop, Soil, and Environmental Sciences (CSES) and am pursuing an Environmental, Soil and Water Science (ESWS) degree. I have come a long way thanks to a partnership between Bolivia and Arkansas that gave me the opportunity to come to the University of Arkansas. I have been awarded the Charles A. Stutte Memorial Scholarship and a Dale E. and Wilhemina S. Hinkle Scholarship. I also received a Dale Bumper's College Undergraduate Research Grant to conduct this research project. Throughout a year and a half I have had the pleasure to be an active member in the undergraduate Crop, Soil, and Environmental Science Club and in the International Bolivian Organization and I am currently a president in both groups. Through the CSES club, I have gained valuable experience in research, have been able to become acquainted with several faculty members, and have made many good friends. My long-term goal is to help enhance the quality of life for people in Latin America. To accomplish this goal, I am considering graduate school to learn how to educate people about environmental issues. I thank Dr. Brye for his help and constant advice. I am fortunate to be in this department and positive that I made the right choice.



Lorena Moreno

etation removal by cutting and baling cease in 1980 would have more organic matter in the top 10 cm than the other prairie areas and that soil chemical properties would generally follow the same trend as organic matter; thus the prairie area in which vegetation removal by cutting and baling ceased in 1980 would have higher extractable nutrients and EC than the prairie area that is still currently cut and baled. We hypothesized that bulk density would be lowest in the prairie area that had vegetation removal by cutting and baling cease in 1980 and highest in the prairie area that still has the aboveground vegetation removed by cutting and baling.

MATERIALS AND METHODS

Site Description

The Konecny Prairie Natural Area is a 20.2-ha tract of native tallgrass prairie in Prairie County, Arkansas, located within the region known as the Grand Prairie. The Konecny Prairie Natural Area was established in 1976 when the land was acquired by the Arkansas Natural Heritage Commission (ANHC, 2004). The Konecny Prairie resides on the Mississippi Alluvial Plain, which consists of soils that have developed in alluvial sediments laid down over geologic time by periodic flooding of the Mississippi River (Fielder et al., 1981). Vegetation within the Konecny Prairie is a mix of tall grasses—including big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), indiangrass (*Sorghastrum nutans*), and switchgrass (*Panicum virgatum*)—and numerous forbs including several coneflowers (*Echinacea* spp.), black-eyed susan (*Rudbeckia hirta*), and goldenrod (*Solidago* spp.).

The Konecny Prairie has three distinct sections that differ in the number of years since vegetation has been removed annually by cutting and baling (i.e., haying) in the Fall. Approximately 4 ha of prairie vegetation were cut and removed annually until 1980 (referred to as Prairie-1980). Approximately 10.1 ha of prairie vegetation were cut and removed annually until 1998 (referred to as Prairie-1998). Approximately 6.1 ha of the prairie still have vegetation removed annually by haying (referred to as Prairie-current). All three sections are burned in the spring on a semi-annual basis. The slope is < 1% across the entire Konecny Prairie Natural Area.

Soil Sampling Scheme

Four different silt-loam soils [i.e., the Stuttgart (Typic Natrudalf), Loring (Typic Fragiudalf), Calloway (Glossaquic Fragiudalf), and Crowley/DeWitt (Typic Albaqualf) series] are mapped within the Konecny Prairie boundaries (Fielder et al., 1981). Two sets of soil samples were collected from the 0- to 10-cm depth at 15-m intervals along a 60-m transect (i.e., at 0, 15, 30, 45, and 60 m) through each soil series mapped within each of the three prairie sections. One soil sample consisted of a 4.8-cm diameter core collected with a slide hammer, in which the sampling chamber is beveled to the outside to minimize compaction upon sampling. This soil was oven dried at 70°C for 48 hr and weighed for bulk density determination. A second set of soil samples consisted of 10, 2-cm diameter soil cores that were collected and composited from the 0- to 10-cm depth at each point along each transect, oven dried at 70°C for 48 h, and crushed and sieved to pass a 2-mm mesh screen for soil chemical property determination.

Laboratory Analyses

Soil cores collected for bulk density determination were crushed and sieved to pass a 2-mm mesh screen. Percentages of sand, silt, and clay were determined for dried, sieved soil by a standard hydrometer method (Arshad et al., 1996).

Soil pH, electrical conductivity (EC), extractable soil nutrients, and soil organic matter were determined for the dried, sieved composite soil samples. Soil pH and EC were measured with an electrode on a 1:2 (w/v) soil-to-water paste. Soil subsamples were extracted with Mehlich-3 extractant solution (Tucker, 1992) in a 1:10 (w/v) soil-to-extractant solution ratio and analyzed for extractable soil nutrients (i.e., P, K, Ca, Mg, Na, S, Fe, Mn, Zn, and Cu) by inductively coupled argon-plasma spectrophotometery. Organic matter was determined by weight-loss-on-ignition (LOI; Schulte and Hopkins, 1996).

Data Manipulations and Statistical Analysis

Extractable nutrient concentrations were multiplied by measured bulk density values to express extractable nutrients on a mass-per-land-area basis.

Analysis of variance was used to evaluate treatment differences [i.e., among the three prairie areas that had cutting and baling cease at different times (1980, 1998, and current); SAS Version 8.1, SAS Institute, Inc., Cary, N.C.]. The number of observations per sampled prairie area differed somewhat. There were 15, 20, and 10 total observations for the Prairie-1980, Prairie-1998, and Prairie-current treatments, respectively. Treatment means were separated by Fisher's least significant difference at the 5% level.

RESULTS AND DISCUSSION

Bulk density in the top 10 cm was significantly ($P < 0.05$) higher in the prairie area that still currently has vegetation cut and baled each fall than in the prairie area in which vegetation removal by cutting and baling ceased in 1980 (Table 1). This result was expected because vehicular traffic from the cutting and baling activities that still occur in the Prairie-current treatment likely has caused some degree of soil compaction whereas the Prairie-1980 treatment has had little to no vehicular traffic since 1980 to cause compaction. However, bulk density in the prairie area in which vegetation removal by cutting and baling ceased in 1998 was statistically similar to that in the other two prairie areas.

There were no consistent treatment effects on soil chemical properties in the top 10 cm (Table 1). Soil pH was significantly ($P<0.05$) higher in the Prairie-1980 treatment than in the other two prairie areas, in which soil pHs did not differ. Soil EC was significantly ($P<0.05$) higher in the Prairie-current treatment than in the other two prairie areas, in which soil EC did not differ. Extractable K, Zn, and Cu contents did not differ among prairie treatments. However, extractable P and Fe contents were significantly ($P<0.05$) higher in the Prairie-current treatment than in the other two prairie areas, in which extractable P and Fe contents did not differ. Extractable Ca and Mn contents did not differ between the Prairie-1980 and Prairie-current treatments but were significantly ($P<0.05$) higher in the Prairie-1998 treatment. Extractable S contents did not differ between the Prairie-1998 and Prairie-current treatments but were significantly ($P<0.05$) higher in the Prairie-1980 treatment. Extractable Mg and Na contents were significantly ($P<0.05$) higher in the Prairie-1980 than in the Prairie-1998 treatment.

Similar to the effects on soil chemical properties, the effects of annual removal of aboveground vegetation by cutting and baling and/or burning on soil organic matter were also inconsistent (Table 1). In the prairie area in which cutting and baling ceased in 1980 (Prairie-1980), soil organic matter by LOI averaged 4.6% in the top 10 cm. The prairie area that is still cut, baled, and burned (Prairie-current) had an average soil organic matter concentration of 4.4%, which did not differ significantly from Prairie-1980. However, soil organic matter in the top 10 cm, which averaged 5.2%, was significantly higher ($P < 0.05$) in the prairie area in which cutting and baling ceased in 1998 (Prairie-1998) than in the other two prairie areas.

The results of this study differed somewhat from our hypotheses. We expected to find the highest organic matter concentration in Prairie-1980 because vegetation removal by cutting and baling had ceased 18 years prior to that in Prairie-1998, but Prairie-1998 actually had significantly higher organic matter than the other two areas. The location of the Prairie-1998 area, which is situated between the Prairie-1980 and Prairie-current areas, may have been less impacted by fragmentation than the other two areas. The Prairie-1998 area likely received more redistributed ash after burning took place each Spring than did the other two areas; thus more organic material was likely recycled back into the Prairie-1998 area than was recycled back into the other two areas (Brye et al., 2002). In addition, woody plants were more abundant in the Prairie-1998 area than in the other two areas, which may have resulted in unequal biomass production within the three areas. Since the entire Konecny Prairie Natural Area is surrounded completely by agricultural lands, anthropogenic factors, such as drifting of applied herbicides, could have also contributed to unequal biomass production among the three areas, in particular, slightly less biomass production in the two areas, Prairie-1980 and Prairie-current, that are located on either side of the Prairie-1998 area.

Bulk density differences also differed somewhat from our hypothesis. We expected bulk density to vary inversely with soil organic matter such that the treatment with the highest organic matter would have the lowest bulk density. However, this was not the case for the treatments evaluated in this study. Overall, vegetation removal by cutting and baling followed by burning affected native soil quality in the Grand Prairie region of eastern Arkansas in a variety of ways.

LITERATURE CITED

Arkansas Natural Heritage Commission (ANHC) [Online]. 2003. Available at <http://www.naturalheritage.com/system/> (verified 3 March 2004).

Arshad, M.A., B. Lowery, and B. Grossman. 1996. Physical tests for monitoring soil quality. pp. 123-141. In J.W. Doran and A.J. Jones (eds.). Methods for assessing soil quality. SSSA Spec. Publ. 49. SSSA, Madison, Wis.

Brye, K.R., J.M. Norman, and S.T. Gower. 2002.The fate of nutrients following three- and six-year burn intervals in a restored tallgrass prairie in Wisconsin. Am. Midl. Nat. 148:28-42.

Fielder, R. T., K. J. Crader, M. A. Simon, and C. R. Wilson. 1981. Soil survey of Lonoke and Prairie Counties, Arkansas. United States Department of Agriculture, Soil Conservation Service, Washington D.C.

Samson, F., and F. Knopf. 1994. Prairie conservation in North America. BioSci. 44:418-42.

Schulte, E.E., and B.G. Hopkins. 1996. Estimation of soil organic matter by weight-loss-on-ignition. pp. 21-31. In F.R. Magdoff, M.A. Tabatabai, and E.A. Hanlon (eds.) Soil organic matter: analysis and interpretation. Soil Sci. Soc. Am., Madison, Wis.

Tucker, M.R. 1992. Determination of phosphorus by Mehlich-3 extraction. p. 6-8. In: S. J. Donohue (ed.). Soil and media diagnostic procedures for the southern region of the United States. Virginia Agricultural Experiment Station. Series Bulletin 374. Blacksburg, Va.

Table 1. Summary of soil physical and chemical properties after different years of vegetation removal followed by burning at the Konecny Prairie Natural Area in Prairie County, Ark.

Soil property	Prairie-1980[z]	Prairie-1998[y]	Prairie-current[x]
Physical properties			
Sand (%)	23.9 (1.4)a[w]	25.4 (0.9)a	21.3 (1.3)a
Silt (%)	63.1 (1.7)a	67.4 (0.8)b	67.7 (0.7)b
Clay (%)	15.1 (1.6)a	7.2 (0.9)b	11.0 (1.4)c
Bulk density (g cm^{-3})	1.04 (0.02)a	1.08 (0.01)ab	1.10 (0.02)b
Organic matter (%)	4.6 (0.1)a	5.2 (0.1)b	4.4 (0.3)a
Chemical properties			
pH	4.9 (0.1)a	4.7 (<0.1)b	4.6 (0.1)b
EC (dS m^{-1})	0.09 (<0.01)a	0.08 (<0.01)a	0.12 (<0.01)b
Extractable P (kg ha^{-1})	11.4 (0.9)a	11.5 (0.5)a	15.8 (0.8)b
Extractable K (kg ha^{-1})	64.0 (1.9)a	59.9 (2.4)a	65.1 (2.1)a
Extractable Ca (kg ha^{-1})	237 (24)a	148 (15)b	210 (22)a
Extractable Mg (kg ha^{-1})	34.9 (2.7)a	23.9 (1.8)b	28.4 (2.1)ab
Extractable S (kg ha^{-1})	32.8 (0.7)a	41.7 (1.0)b	43.6 (2.1)b
Extractable Na (kg ha^{-1})	43.5 (1.9)a	30.5 (1.8)b	36.7 (4.2)ab
Extractable Fe (kg ha^{-1})	198 (7.7)a	180 (8.7)a	236 (13)b
Extractable Mn (kg ha^{-1})	154 (12)a	122 (9.1)b	165 (7.7)a
Extractable Zn (kg ha^{-1})	0.9 (<0.1)a	0.8 (0.1)a	0.9 (0.1)a
Extractable Cu (kg ha^{-1})	1.5 (0.1)a	1.5 (<0.1)a	1.6 (0.1)a

[z] n = 15 observations per soil property for the Prairie-1980 treatment
[y] n = 20 observations per soil property for the Prairie-1998 treatment
[x] n = 10 observations per soil property for the Prairie-current treatment
[w] Different letters next to mean (" standard error) values within the same row are significantly different at the 5% level.