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Soil Health After Intense Ponderosa Pine Forest Fire in North Central Nebraska

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SOIL HEALTH AFTER INTENSE PONDEROSA PINE FOREST FIRE IN NORTH CENTRAL NEBRASKA

by

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ABSTRACT

In late July 2012, the Region 24 Complex fire consumed over 76, 000 acres of north central Nebraska. This area consists of ponderosa pine forest with high densities of eastern redcedar, deciduous hardwood forest, and Sandhills prairie. This incredible event provided an occasion to examine the effect of the fire on soil nitrification and soil erosion at The Nature Conservancy's Niobrara Valley Preserve. Eighteen $900m^2$ plots were established in regions chosen for their topographic location (footslope, midslope, and ridgetop), forest density, and directional slope (north vs. south facing slope). Each plot was split into nine subplots with 25 erosion pins installed in the center subplot. These pins displayed soil activity per month. Soil samples were taken in all subplots, except in the center subplot where erosion pins were installed. Erosion data was highly variable, but a correlation was shown between tree density and soil activity. Each soil sample was comprised of three soil core samples (15cm) randomly selected in each subplot. Using KCl extraction, results showed that high nitrate and ammonia rates correlate with slope, soil pH, and tree density. The available soil nitrogen was shown to increase with basal area of eastern redcedar, indicating that ladder fuels like cedar add to the intensity of the fire and therefore the lasting impacts on the area's resources. A mini-disk infiltrometer was used to test for soil hydraulic conductivity and hydrophobicity. The results

indicated that further testing of the soil profile was needed to evaluate hydrophobicity, but soils within areas of higher densities of trees were indicating hydrophobic characteristics. Further research is needed to understand the complete relationship between the soil health and the wildfire, especially when it comes to eastern redcedar encroachment on these ecosystems.

PREFACE

This research would not have been possible without the collaboration and support of the Nature Conservancy, the Nebraska Environmental Trust, the Center for Grassland Studies, Nebraska Forest Service, School of Natural Resources, and the University of Nebraska-Lincoln. Furthermore, I would like to thank Dean Steve Waller, Kent Fricke, Jack Arterburn, McKinzie Peterson, Laura Snell, Cameron Oden, and Dr. Mark Kuzila for the opportunity and support to conduct this research.

INTRODUCTION

In the Great Plains, fire intensity and wildfire acres have been increasing due to years of fire suppression, fuel build up, and extreme weather conditions. Recent wildfires are making a large impact on Great Plains' ecosystems, including the natural resources that make up these ecosystems. The Colorado Hayman fire of 2002 demonstrated how fuel accumulation and fire suppression can lead to increased fire severity, which can kill a forest ecosystem by crown fire and lethal scorching (Romme et al. 2003). Crown fires are extreme wildfires that due to ladder fuels and high fuel load have spread into the canopy of a forest and burns with such intensity that there is a low survival rate for flora and fauna (Crown Fire 2007). Besides crown fires, fire intensity and fire severity are important fire components. Fire intensity (Table 1) is defined as the amount of heat energy released during a fire, not to be mistaken with fire severity, which is the

fire's effect on the environment (Romme et al. 2003). The Hayman fire demonstrated the need to study the effects and increasing intensities of wildfire in other areas of the Great Plains.

In the Great Plains, Nebraska has shown a dramatic increase in wildfire acres burned over the last 50 years (Figure 1). Tom Tabor, a horticulturist with Nebraska Game and Parks, stated that, "One of the worst effects of fire is the exposure of the forest floor to erosion, leaching and other deterioration that may cause damage in the watershed. Streams that once flowed cool and clean often become shallow, sluggish and choked with silt washed in from the floor of a burned-out fire (Tabor 1993)." With increased wildfire in Nebraska, effects such as these are expected. In late July 2012, the Region 24 Complex fire consumed 76, 242 acres of north central Nebraska. The Region 24 Complex fire started on Friday, July 20th south of Norden, NE along Fairfield Creek when lightning struck a tree. The fire raged for several days in the various ecosystems that cover north central Nebraska. In the woodland and forest ecosystems, the wildfire moved into the canopy due to high densities of ladder fuels, high temperature, low humidity, and high winds. After consuming tens of thousands of acres and several homes, it was contained on July 30th, when the Rocky Mountain Incident Management Team transitioned the incident back to the local authorities (Region 24 Complex 2012).

This incredible wildfire event provided an occasion to examine the effect of the fire on soil health and soil erosion at The Nature Conservancy's Niobrara Valley Preserve. Around 30,000 acres of the Niobrara Valley Preserve was burned, with the majority of severe fire in the ponderosa pine woodland and deciduous hardwood forest (Figure 2). Due to the severity of the fire in the woodlands and forest, soil health is an issue when it comes to future management plans for the Nature Conservancy. This area of Nebraska consists of ponderosa pine woodland with high densities of eastern redcedar, deciduous hardwood forest, mixed grass prairie, and

Sandhills prairie. These ecosystems interact in a unique way along the Niobrara River, causing this area to be known as the biological crossroads of Nebraska (Figure 3). Gerry Steinauer, a community ecologist with Nebraska Game and Parks, states that this area is, "a unique combination of geographic, geologic, and hydrologic conditions, three distinct woodland communities survive…far from their main ranges to the north, east, and west. (Steinauer 1993)." Steinauer furthers states that this area's eastern deciduous forest and pine forests are unique and actually depend on fire as a natural stimuli in their system (Steinauer 1993). These areas of woodland and forest are key in providing a "zone of habitat overlap" in which islands of woodland bridge the eastern deciduous forests with western pine forests in a sea of grasslands (Steinauer 1993). Also, to be noted is the presence of eastern redcedar (*Juniperus virginiana*) in this region's woodlands and its increasing density (Figure 4). The high density of eastern redcedar on the preserve is a major factor contributing to fire intensity and severity.

As previously mentioned, the Hayman fire showcased how fire intensity and severity has a powerful influence on the health of the soil and watershed dynamics (Lewis, Wu, & Robichaud 2005). The soil dynamics can change greatly after a severe wildfire with altered soil nitrification and soil nutrient content impacting the post-fire response of vegetation (Esque et. al. 2010). Intense crown fires can alter the immobile ammonium (NH_4^+) in the soil and convert it to a mobile form, nitrate (NO_3^-), which readily leaches into the soil and ground water (Turner et al. 2007). Studies have shown that a pulse of readily available nitrate after intense crown fires can favor invasive plants rather than native plant species due to the competiveness of invasive species and the exposed soils (Esque et. al. 2010). Besides nitrogen, other nutrients can become more available during and after fires. This can greatly influence the biota response and alter ecosystem recovery.

Soil erosion is also an issue after severe wildfire. Intense wildfire, such as the one in north-central Nebraska, can lead to a decrease in vegetation and ground cover leaving the topsoil exposed. This can encourage severe soil erosion due to lack of vegetative cover and altered soil moisture after a fire (Shakesby et. al. 2003). The severity of soil erosion is dependent on soil type, slope, and aspect. The steeper the slope, the more likely it is for erosion to occur after a wildfire. The direction the slope faces is also important, as south facing slopes often burn faster or hotter due to longer exposure to the sun which can dry out vegetation. Soil hydrophobicity can also occur after an intense wildfire, such as in the Hayman wildfire, as extremely high temperatures interact with organic compounds to change soils chemically and repel water (Lewis, Wu, & Robichaud 2005). According to a study on soil water repellency after the Hayman fire, the "highly burned sites had the strongest water repellency (Lewis, Wu, & Robichaud 2005)."

The recovery time for an area after an intense wildfire may determine the future of an area's ecosystems. Due to the high mortality of ponderosa pine in the preserve's woodland (around 95%), there may be a post-fire conversion from woodland to open grassland or savanna. High densities of eastern redcedar and other juniper species are known to increase the intensity of wildfires in forests and woodland areas, as eastern redcedar and other junipers are highly aggressive and disperse well (Ganguli et. al. 2008). Understanding the correlation between fire intensity and eastern redcedar density is critical for the Nature Conservancy's future management plans at the Niobrara Valley Preserve.

Besides researching soil properties and correlating woodland density, I took digital imagery and timelapse photography throughout the length of the project to document erosion and

the overall effect of the fire. These images were able to help capture the story and illustrate the importance of the research for future management of the preserve.

MATERIALS AND METHODS

Study sites and sampling design

Eighteen plots were established on the Nature Conservancy's Niobrara Valley Preserve in woodland areas burned in 2012. These plots were chosen for their topographic location (footslope, midslope, and ridgetop), forest density, and aspect (north vs. south facing slope). The ecology of the plots ranged in tree density from open prairie to dense pines with redcedar understory. Plots 1 through 8 were established in December 2012, with the remaining plots established in the summer of 2013. Fifteen of the eighteen plots were located on the north side of the Niobrara River in ponderosa woodland and grasslands (Figure 5). Plots 1 through 11 and 15 through 18 are generally on south facing slopes in mostly heavily wooded areas. Plots 3, 4, and 18 are the exceptions, as they are located in grassland with sparse, scattered trees. The remaining plots (plots 12 through 14) were located on the south side of the Niobrara in the deciduous forest. Plots 12 and 13 were north facing slope with plot 14 on a west facing slope. Slope and aspect played a key factor in establishing plots, as the fire's impact changed with topography.

Each plot was 900m^2 with nine 100m^2 subplots. In June 2013, the species and diameter of all trees in the plots was recorded. These data were used to calculate tree density on a per hectare basis and basal area (m^2 per ha), which represents the amount of wood in a stand. In intensely burned plots, the density and basal area estimates were based on standing or fallen dead tree because no pre-fire stand data was available. Although these estimates are somewhat inaccurate, they nevertheless indicate the broad range in stand density represented in our plots. The center subplot (subplot 5) had 25 erosion pins installed. Erosion pins were made by driving

5 foot long pieces of metal conduit two feet into the ground. The erosion pins were set up 1m inside the subplot and were placed 2m apart from each other. Erosion pins were numbered from left to right; with the northwestern most pin being erosion pin 1 and the northeastern pin being erosion pin 5 (Figure 6).

At each plot, soil movement (erosion and deposition) was monitored, soil samples were taken, and soil infiltration was measured.

Measurements and Data Collection

Erosion pins were measured monthly from May to September 2013. Initial measurements vary due to the time when the plot was established. Measurements were taken with a meter stick on the upslope side of the erosion pin and recorded on data sheets. Plot topography, slope, and aspect were documented at each site. In this thesis, only the net changes in the soil surface from May to September are reported.

A mini-disk infiltrometer was used to measure soil infiltration in late July. A mini-disk infiltrometer is a portable device that measures water infiltration into a substance (Decagon Devices Inc., 1998). It determines the infiltration rate which then helps determine the mean conductivity of the soil, therefore showcasing if the soil has hydrophobic characteristics. Three of the nine subplots were randomly chosen to measure soil infiltration. The center subplot was ignored due to erosion pins. Two measurements of 15 minutes in duration were conducted at each site. Because soil texture was generally sandy loam, the suction rate on the mini-disk infiltrometer was set at a standard of 5 for all measurements. If the two infiltrometer data sets collected in a subplot varied largely, a third or sometimes fourth measurement was conducted.

Soil samples were taken from each subplot, except for the center subplot where the soil erosion pins were located. Samples were taken with a hand probe that was 1.8cm in diameter to

a depth of 15cm. Three random locations were chosen in each subplot, yielding a total of 24 soil samples taken from each plot and a total of 144 soil samples taken for the study. The three subplot samples were then placed in a bag to be homogenized and then placed in a cooler. All soil samples were refrigerated until analyzed approximately 14 days later. In the lab, roughly 15-20 grams of moist soil from each sample was placed in 50 ml of 1 molar KCl, shaken for 30 minutes and then placed in a cooler overnight. Vials with KCl were weighed before and after soil was added was calculate the amount of soil extracted. The next day, 20ml of the clear solution was pipetted into small vials, which were frozen until analyzed for nitrate and ammonium on a two-track autoanalyzer in the Ecosystems Analysis Laboratory (School of Biological Sciences, University of Nebraska – Lincoln). At the same time soils were placed in KCl, soil from each sample was analyzed for gravimetric soil moisture content, which was used to calculate the weight of dry soil extracted for each sample. The remainder of the soil from each subplot was air dried and passed through a 2mm sieve prior to analysis for soil pH, base cations, organic matter, texture and available phosphorus (Ward Laboratories, Kearney, NE). These analyses were done once for each of the 18 large plots using a composite soil sample from subplots in that plot.

RESULTS

Soil Survey Information

The dominant soil map units at the study sites are Longpine-Ronson-Duda and Mariaville-Keota. The soils in these unites are generally sandy loam texture throughout and are located on slopes that range from 11% to 70%. The soil map and legend are found on Figure 7 and Table 2, respectively. The soil survey is consistent with actual textural determinations on

the soils by Ward Laboratories: soils in 3 plots were classified as sand, 1 plot as loam, 8 plots as loamy sand, and 6 plots as sandy loam.

Erosion Pin Data

Digital images demonstrated large quantities of erosion occurring across the fire-affected landscape, while erosion pin data were only moderately successful in showing the extent of erosion (Figure 8). Erosion pin data was highly variable; however it did indicate removal of soil from the slopes and deposition down slope (Figure 9). In order to evaluate erosion data (May 2013 - Sept. 2013), absolute values were used to demonstrate soil movement activity. This records change in the height of the soil surface whether that change was deposition or removal. Little removal or deposition happened in stands with low stand density (i.e. grassland and open savanna), whereas when pre-fire tree density was high there was increased erosion or deposition (Figure 9). Topographic position also affected soil movement with removal in midslope plots and deposition in footslope plots. Plot 15 was at the bottom of a valley and had deposition occurring, while plot 1 was on a steep midslope and had erosion occurring (Figure 9). The three grassland plots (plots 3, 4, & 18) showed little erosion (Figure 9).

Soil Hydrophobicity

The infiltrometer measured the infiltration rate of water into the soil. From that information soil hydraulic conductivity was determined. Soil hydraulic conductivity measures the rate of water movement through a soil. The results of the infiltrometer compared to the pre-fire basal area of eastern redcedar in a plot demonstrated that the amount of ladder fuels like eastern redcedar decreased post-fire soil conductivity (Figure 10). Plots 1 and 6 had a high amount of eastern redcedar and had lower soil conductivity, showing that there was a correlation between eastern redcedar and hydrophobicity (Figure 10). Plot 11, while having a low basal area

of eastern redcedar, was located on a ridge top indicating that topography also may have played a role.

Soil Analysis

Available soil nitrogen (the sum of nitrate and ammonium) was high in all plots except the three open grassland plots (Figure 11). These data were taken one year after the July 2012 fire. A dozen subplots had soil nitrate concentrations greater than 40 ppm, values considered quite high in fertilized agricultural fields. Available soil nitrogen was high in all plots except the three open grassland plots (plots 3, 4, and 18), but it was very high (e.g. greater than 15 ppm) in the plots with the densest stands of pine and redcedar where the fire was most intense.

The ratio of nitrate to ($NO_3^- + NH_4^+$) is an index of nitrification, in other words, the proportion of available nitrogen converted from ammonium to nitrate (Figure 12). In pine-dominated plots, nitrification appeared to be inhibited and was associated with low pH (Figure 13). The deciduous forest plots on the south shore had higher pH and nitrification was high, suggesting that significant post-fire nitrate leaching has most likely occurred (Figure 14).

DISCUSSION

The results brought to light the impact of forest density and how that can greatly alter fire behavior and lead to problems for soil health. Together, the erosion results, the soil nutrient results, and the hydrophobicity results (although limited) indicate that soils have been strongly affected by the fire in areas with dense pre-fire stands of pine and redcedar. These soils have not recovered 12 months after the fire. In contrast, soils in post-fire grassland plots showed relatively low, and presumably normal, levels of available nitrogen, and minimal erosion and hydrophobicity. While erosion pin data was variable, digital images captured displayed large amounts of soil erosion (Figure 8). More erosion occurred in areas that had higher densities of

trees, which one can almost assume that those plots also had high densities of eastern redcedar (Figure 9). Soil deposition also increased in areas with high densities of eastern redcedar, which leads to the idea that the steeper slopes eroded more and deposited runoff onto lower sloped plots (Figure 9). This makes logical sense as literature often states that eastern redcedar can influence the intensity of a wildfire by creating ladder fuels to the canopy (Ganguli, A.C. et al. 2008). The preserve has a problem with eastern redcedar encroachment, which led to the intensity of the fire and therefore, soil issues such as nitrification and erosion.

While the soil conductivity was altered by the intensity of the fire, these results should be considered preliminary. However, we can infer that those plots with higher densities of eastern redcedar burned hotter, leading to possible hydrophobicity and therefore displaying lower soil conductivity (Figure 10). Lewis, Wu, & Robichaud (2005) suggested that mini-disk infiltrometer measurements do not capture the entire impact fire on soils because they are only taken on the surface and do not penetrate deep into the soil profile. This leads to the idea that areas with higher fire intensity (meaning higher tree density and basal area) most likely have a deeper water repellant layer than our measurements could detect. Further examination of soil cores might be able to show these deeper impacts of hydrophobic soils.

The effect of fire intensity on soil nitrogen availability and nitrification was a strong result. Grassland plots did not burn as intensely, and nitrogen dynamics in their soils were not altered as they were in the pine / redcedar woodland and the deciduous forest. Again, stand density played a huge factor in fire intensity and therefore, available soil nitrogen (Figure 11). The extremely high levels of nitrate found leads to the assumption that a large nitrification movement was occurring and possibly leaching into the Niobrara River with the erosion. While these results were fascinating, it is difficult to assume that these available nitrogen levels were

solely based on the fire. Without data collection before the fire, one cannot say for certain if the cause of all this nitrification is due to the wildfire exclusively. The basal area correlation with pH is also something that is hard to evaluate without having previous data. Literature states that, "soil pH typically increases immediately after fire, then declines back to pre-fire levels over a period of months, years, or decades (Binkley & Fisher 2013)." Without a time series of pre- and post-fire data, it is hard to determine if this study captured this pulse of high pH or if the data missed this pulse. Deciduous forests are also known to have higher pH levels than ponderosa pine forests (Binkley & Fisher 2013). This may sway some of the results, but not greatly. Other studies have also shown that the concentration of soil ammonium generally increases greatly after fire due to soil heating and ash content in the soil (Binkley & Fisher 2013). While the results show that ammonium levels were greater in the ponderosa pine woodland plots, there was not a great correlation between basal area and levels of ammonium (Figure 13 & 14). This means that the relationship between higher densities of redcedar in the plot and the ammonium levels did not reflect the entire story of fire intensity in the area. Nitrification could also have occurred before our samples were taken, which could explain the lack ammonium. "Pulses of ammonium and nitrate availability are ephemeral, often lasting a few growing seasons or less (Binkley & Fisher 2013)." The available nitrogen found after a fire also depends upon the quantity of nitrogen lost in the fire (Binkley & Fisher 2013), which was not quantified in this study.

SUMMARY AND CONCLUSIONS

The impacts of wildfire on soil health in north-central Nebraska is expected to increase as fire intensity and acres consumed by wildfire continue to increase. Soils are the foundation of every ecosystem, with flora and fauna depending on healthy soil to survive. It is important and critical to study the effects of intense fire on soil health, as damaged soil impacts every

ecosystem. By exploring post-fire soil erosion (erosion pins), nutrient levels (soil samples), and soil water infiltration (mini-disk infiltrometer), this study was able to explore the soil health after an intense wildfire. Data indicates that many of the woodland soils were altered by the wildfire and that eastern redcedar density played a major factor in affecting soil health. Furthermore, examining soil dynamics in different habitats will help predict the future recovery of this landscape, especially as eastern redcedar increases in area. The future for these ecosystems is uncertain. The ponderosa pine woodland will have a difficult recovery, as the pressures of invasive species like eastern redcedar and inadequate seed source prove to be a challenge. Management strategies must be determined to protect surrounding pine trees and rid the area of eastern redcedar. The question lies in how the ponderosa pine woodland will recover and if management practices will encourage woodland or grassland ecosystems on those steep northern slopes. Future research questions include: How will these post -fire soils affect the recovery of ponderosa pine, eastern redcedar, and grassland? And how will eastern redcedar influence the recovery of the northern slopes? Research will begin the summer of 2014 to address these questions.

TABLES AND FIGURES

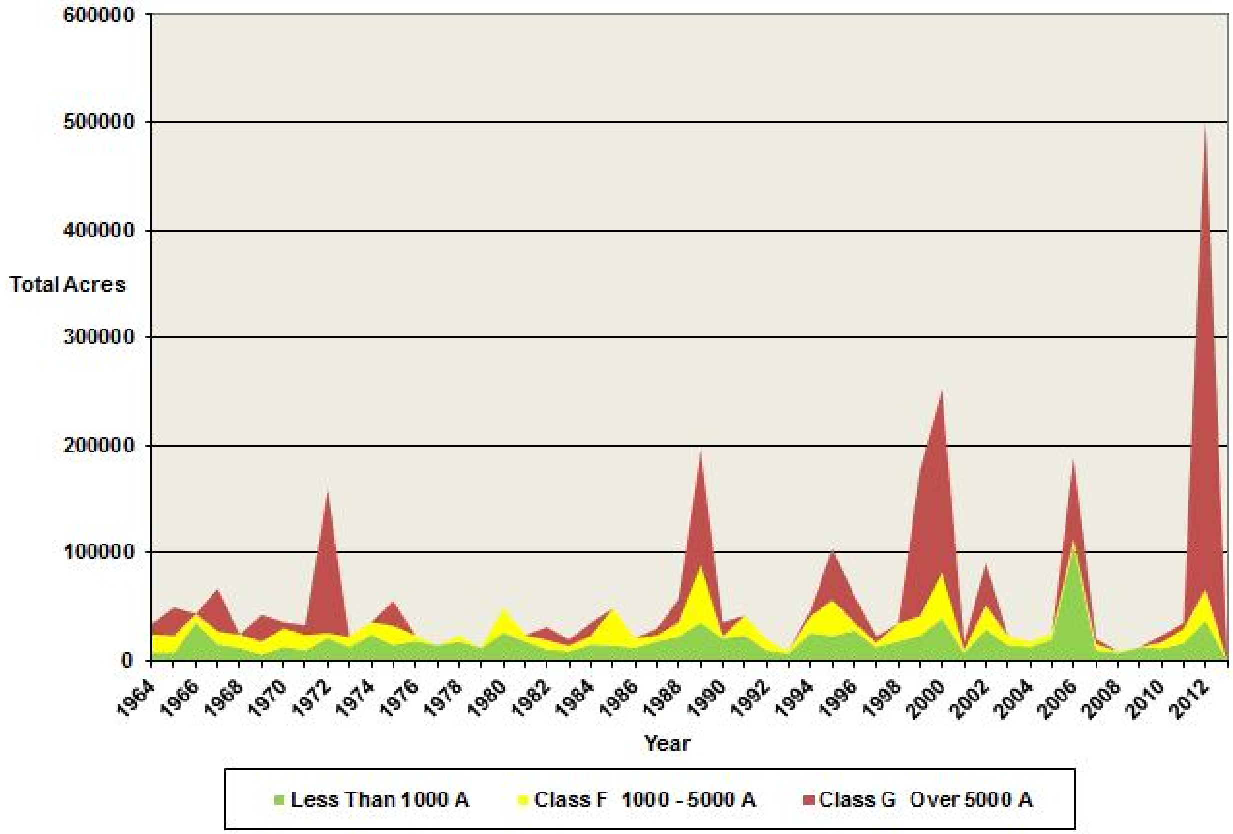

Figure 1: Nebraska Wildfire Acres Burned 1964-2012 (Source: Nebraska Forest Service 2012).

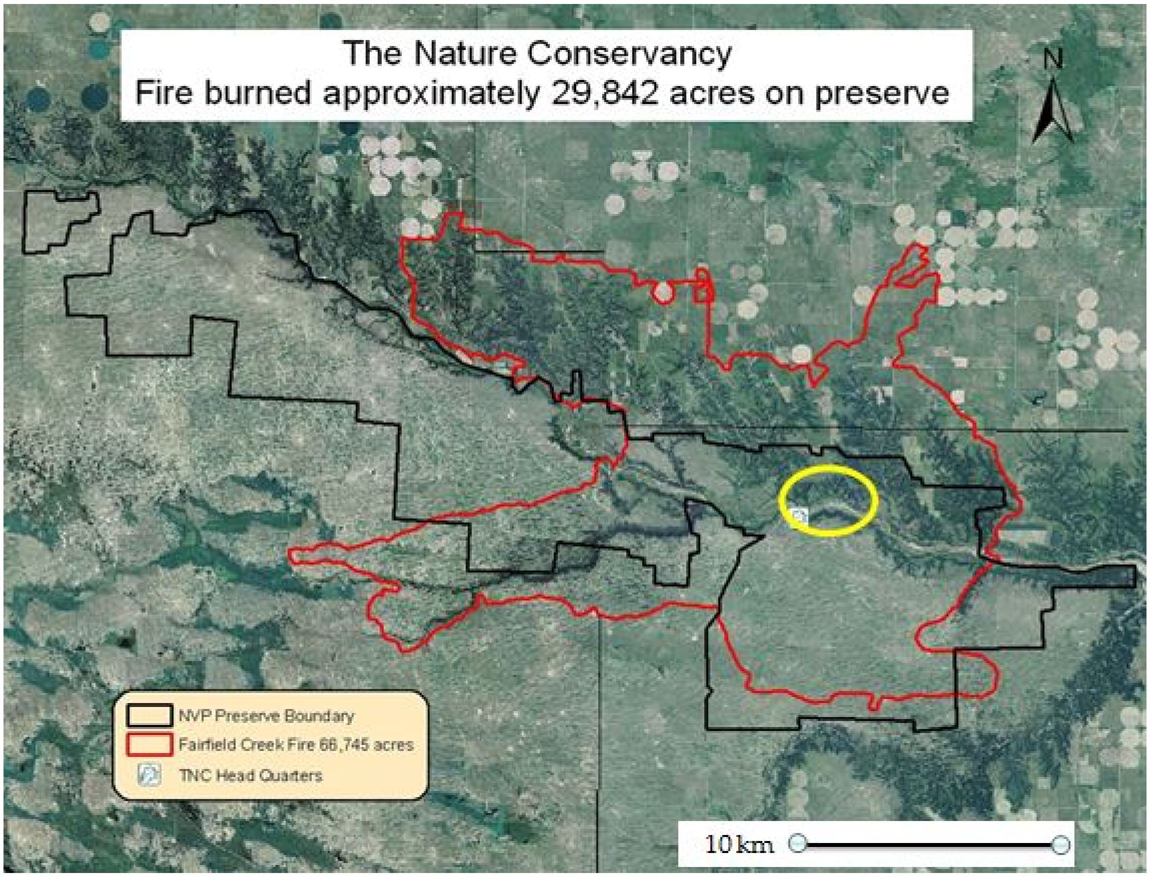

Figure 2: The Nature Conservancy's Niobrara Valley Preserve (NVP). The boundary of the preserve is noted in black, while the acres consumed in the Region 24 Complex Fire is noted in red. The yellow circle notes the area of interest for the study.

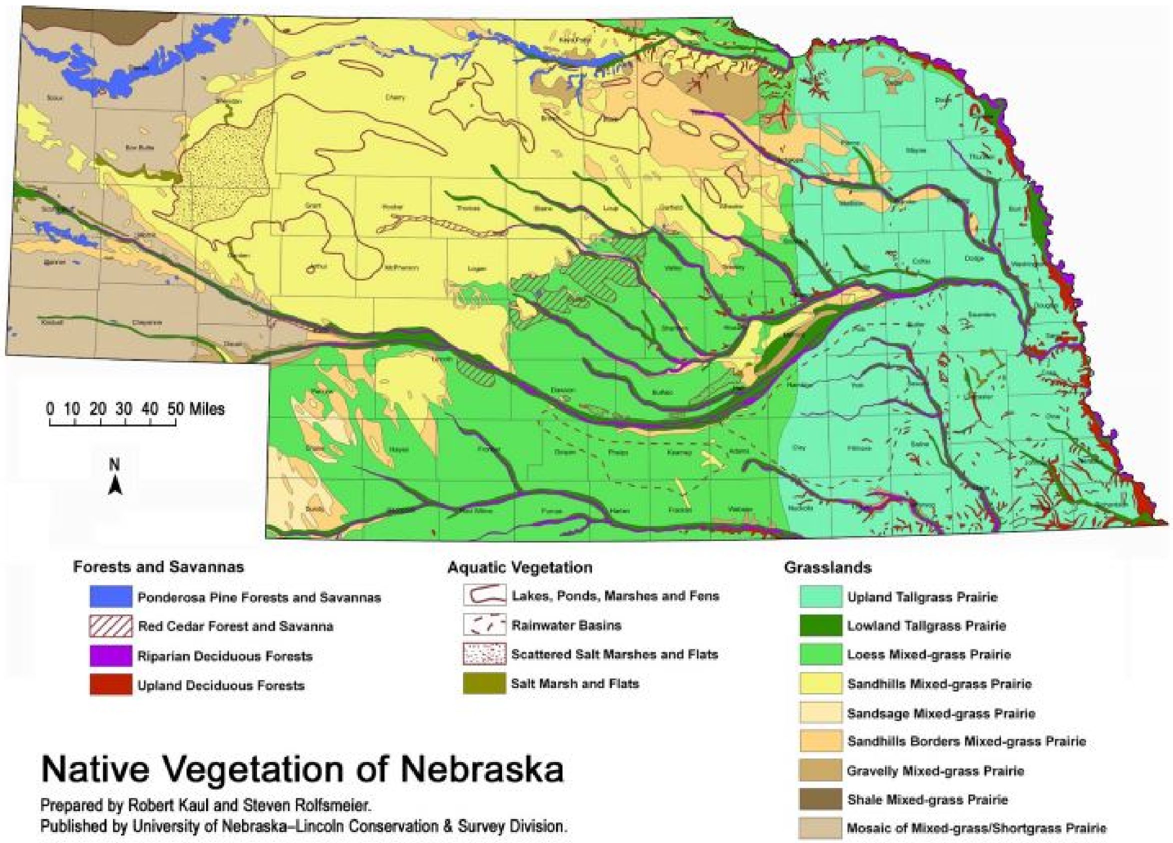

Figure 3: Native Vegetation of Nebraska from NEBRASKAland Magazine's *Walk in the Woods*. This figure highlights the biological crossroads in north central Nebraska.

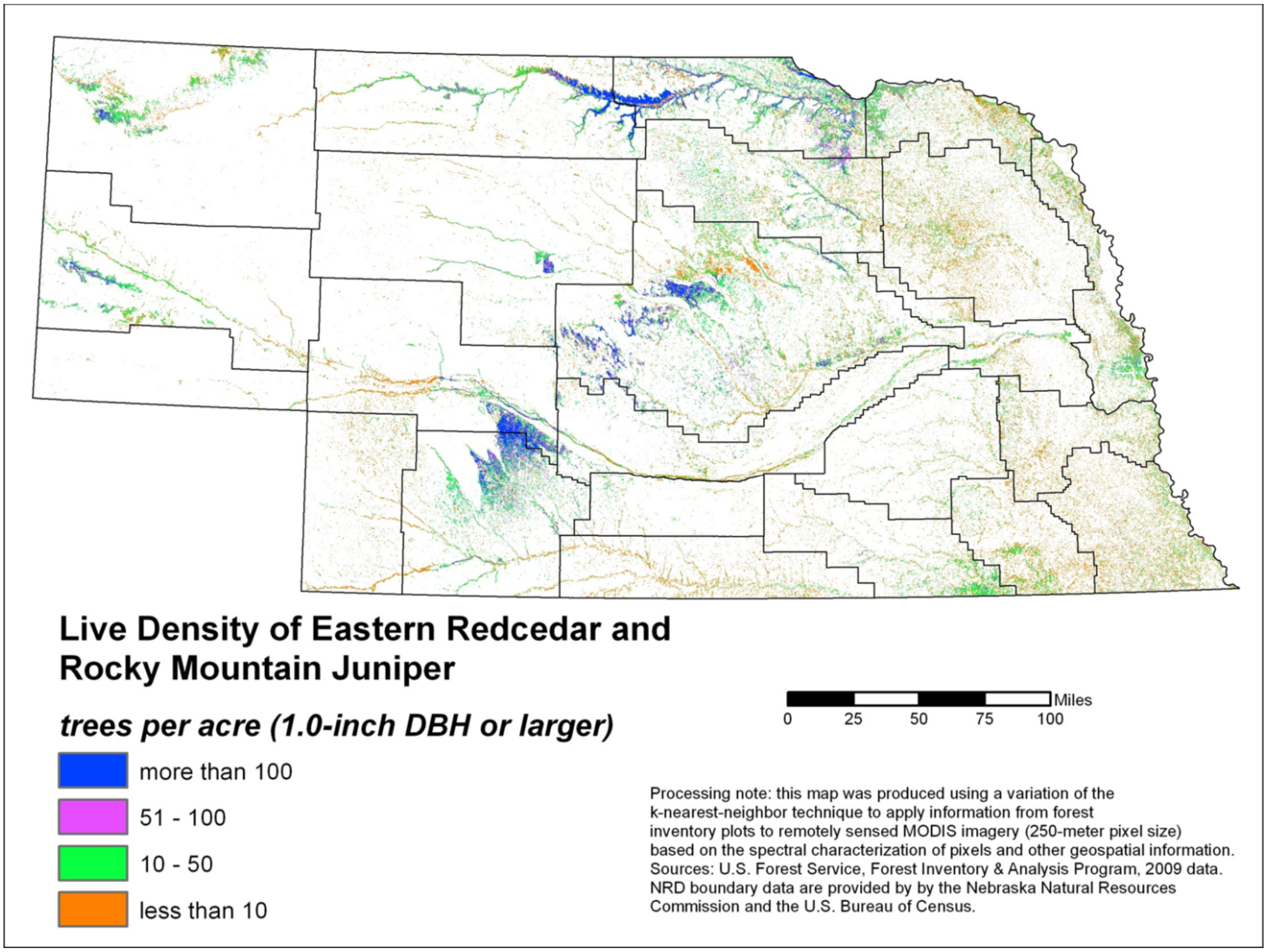

Figure 4: Live Density of Eastern Redcedar and Rocky Mountain Juniper in Nebraska from the Nebraska Forest Service.

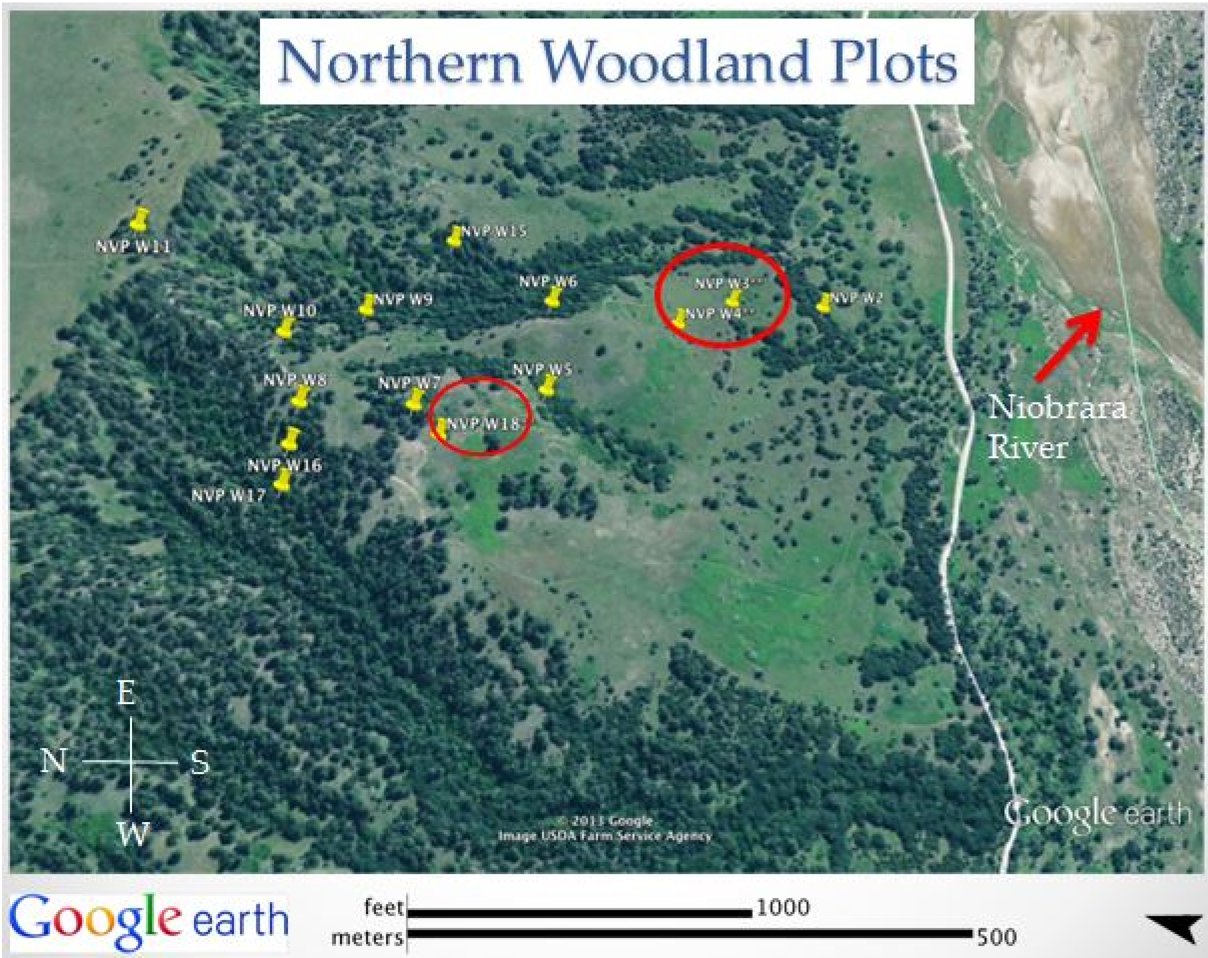

Figure 5: The 15 northern woodland plots established on the north side of the Niobrara River with the majority (12 plots) in ponderosa pine woodland and a three in grasslands. These grassland plots are noted by the red circles (plots 3,4, & 18). The other three plots not shown were established south of the river in deciduous forest (plots 12-14).

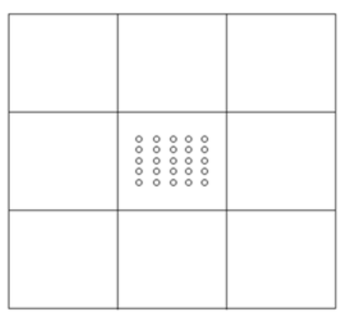

Figure 6: Plot setup with 25 erosion pins in the center subplot.

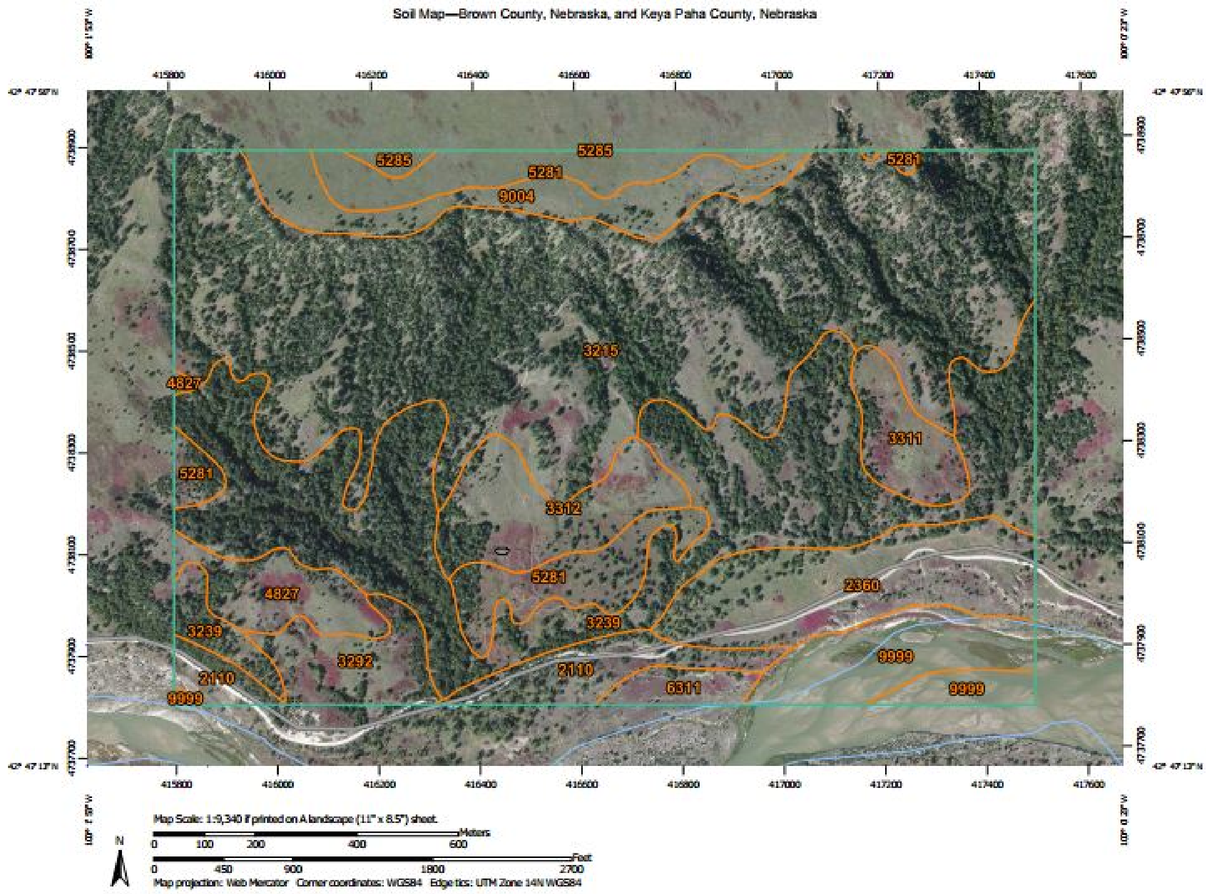

Figure 7: USDA NRCS Web Soil Survey Map of the Northern Plots.

Figure 8: Digital images showcased erosion occurring. The image on the left showcases erosion taking out the river road that runs along the Niobrara River between the Norden Bridge and Meadville. The top right image displays a washout fan into the Niobrara River. The bottom right image displays the erosion off the slopes after the first big rain of the season.

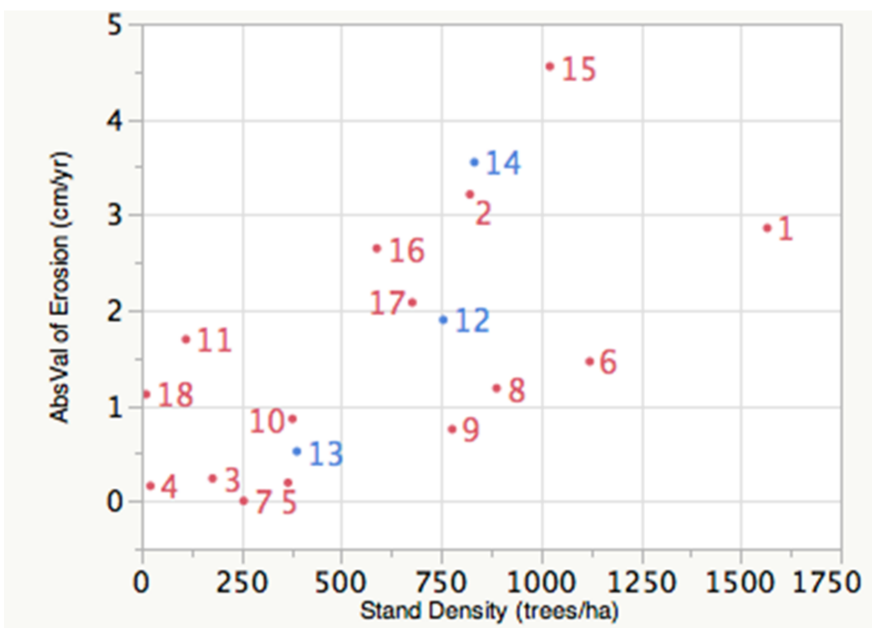

Figure 9: Erosion Pin Data vs. Stand Density. Soil Movement data (May 2013- Sept. 2013) where absolute value is the total of erosion and deposition at each pin. Blue denotes south plots in deciduous forest.

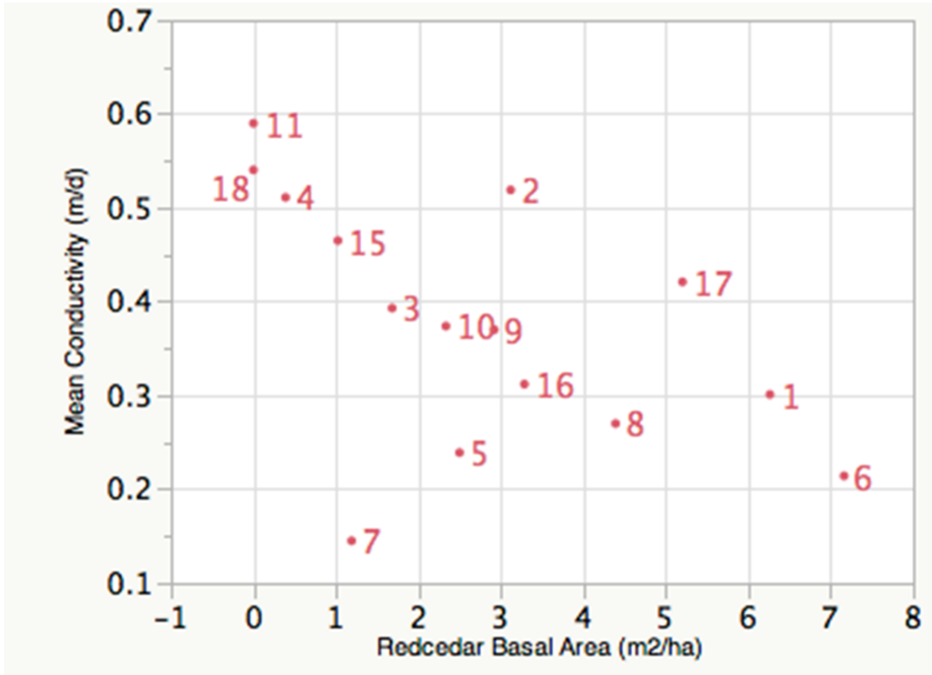

Figure 10: Soil Infiltration Rate vs. Basal Area of Eastern Redcedar. Soil infiltration rate helps to determine mean hydraulic conductivity of the soil.

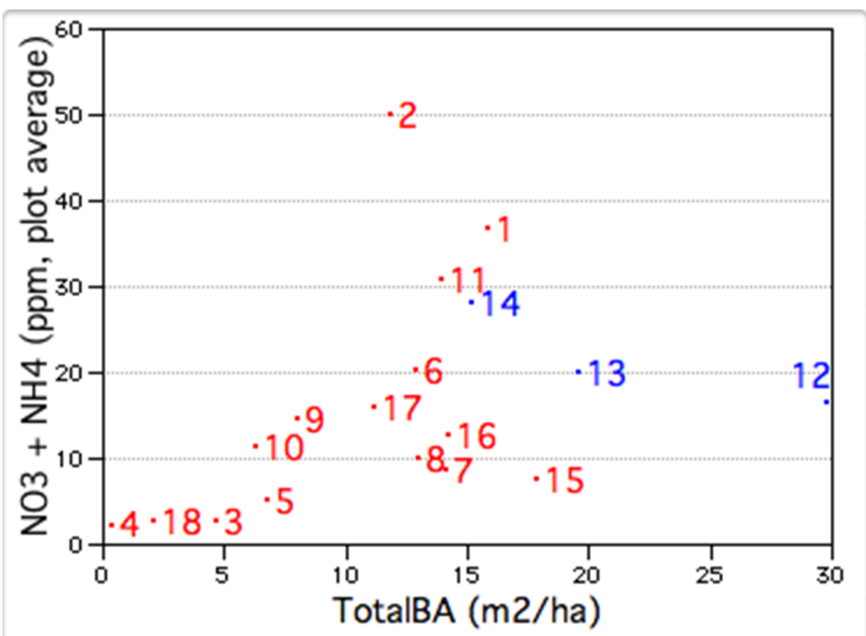

Figure 11: Soil Nitrogen Increased with Fire Intensity. Available soil nitrogen is NO3 and NH4. Blue denotes deciduous forest plots on the south side, whereas red denotes ponderosa pine woodland plots on the north side. Total basal area (BA) is a measure of wood volume in the plot.

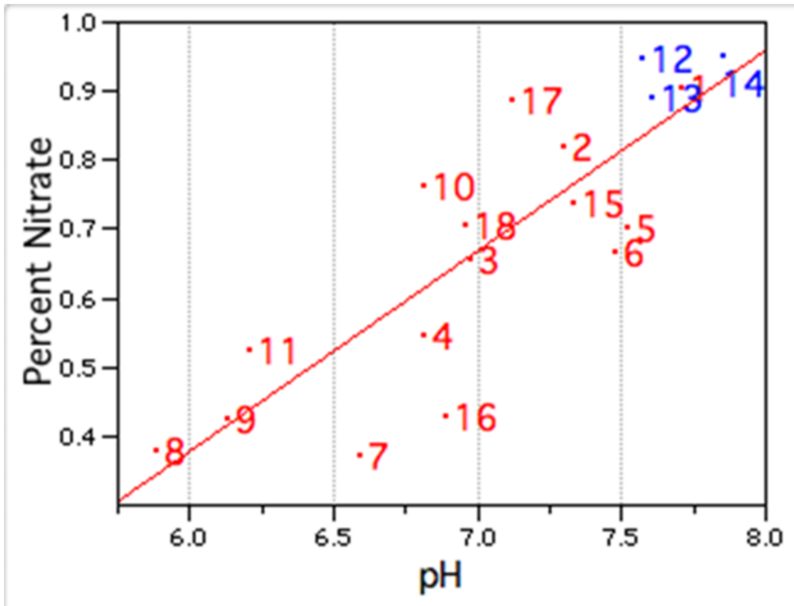

Figure 12: Nitrification is dependent on Forest Type and pH. High pH in soils is found more in deciduous forest soils. Percent Nitrate is the ratio of NO3/(N03 + NH4) as an index of nitrification

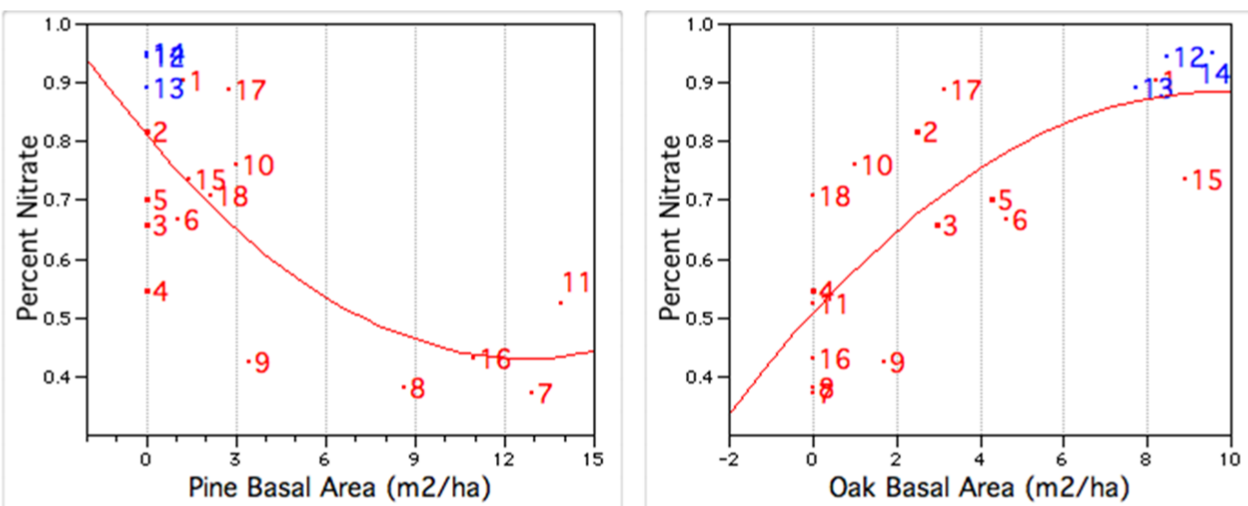

Figure 13 & 14: Nitrification dependent on forest type and pH. Figure 13 (left) demonstrates volume of pine in the plots compared to the percent nitrate (NO_3/ ($N0_3$ + NH_4)). Figure 14 (right) demonstrates the volume of oak in the plots compared to percent nitrate (NO_3/ ($N0_3$ + NH_4)).

Table 1: Wildfire Components and Definitions

Table 1—Components of a fire regime.

Component	Definition
Fire frequency	Number of fires occurring within a specified area during a specified time period, for example, number of fires in the Pike – San Isabel National Forest per year
Fire size or fire extent	The size (hectares) of an individual fire, or the statistical distribution of individual fire sizes, or the total area burned by all fires within a specified time period, for example, total hectares within the Pike – San Isabel National Forest that burned in 2002
Fire interval (or fire recurrence interval)	The number of years between successive fires, either within a specified landscape or at any single point within the landscape
Fire season	The time of year at which fires occur, for example, spring and fall fires, when most plants are semi-dormant and relatively less vulnerable to fire injury, or summer fires when most plants are metabolically active and relatively more vulnerable to fire injury
Fire intensity	Amount of heat energy released during a fire … rarely measured directly, but sometimes inferred indirectly from *fire severity*
Fire severity	Fire effects on organisms and the physical environment (see table 2)

USDA Forest Service Gen. Tech. Rep. RMRS-GTR-114. 2003

Table 2: USDA NRCS Web Soil Survey Soil Chart.

Brown County, Nebraska (NE017)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
9999	Water	4.5	1.0%
Subtotals for Soil Survey Area		**4.5**	**1.0%**
Totals for Area of Interest		**459.5**	**100.0%**

Keya Paha County, Nebraska (NE103)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
2110	Inavale loamy fine sand, occasionally flooded	15.4	3.4%
2360	Munjor fine sandy loam, rarely flooded	30.7	6.7%
3215	Longpine-Ronson-Duda complex, 15 to 70 percent slopes	183.8	40.0%
3239	Mariaville-Keota silt loams, 11 to 60 percent slopes	98.4	21.4%
3292	Paka-Mariaville loams, 11 to 30 percent slopes	12.4	2.7%
3311	Ronson-Anselmo fine sandy loams, 6 to 11 percent slopes	10.3	2.2%
3312	Ronson-Anselmo fine sandy loams, 6 to 30 percent slopes	19.1	4.2%
4827	Valentine loamy fine sand, gently rolling	11.7	2.6%
5281	Vetal fine sandy loam, 0 to 3 percent slopes	29.9	6.5%
5285	Vetal loam, 0 to 1 percent slopes	1.4	0.3%
6311	Barney fine sandy loam, frequently flooded	4.7	1.0%
9004	Anselmo fine sandy loam, 3 to 6 percent slopes	19.7	4.3%
9999	Water	17.4	3.8%
Subtotals for Soil Survey Area		**455.0**	**99.0%**
Totals for Area of Interest		**459.5**	**100.0%**

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