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The Effects of Prescribed Burning on Soil Water Infiltration Rates and Other Select Soil Physical and Chemical Properties in East Texas

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By

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Natural Resource Management

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ABSTRACT

This study focused on whether prescribed burning affects soil physical and chemical properties, especially water infiltration, in Western Gulf Coast forests. Soil water infiltration rates were measured 1) pre-burn (before the fire), 2) post-burn (one month after the fire), and 3) at vegetation green-up (three months after the fire). Soil samples were also collected to determine the effects of prescribed burning on soil pH, bulk density, particle density, pore space, soil strength, O-horizon weight and depth (organic matter), water stable aggregates, and soil fertility. This project was conducted on two different burn intervals. The National Forests and Grasslands of Texas (NFGT) of the United States Forest Service burns, perform prescribed burns every two to three years, predominantly during the dormant season. The Winston 8 Land and Cattle Ltd. Tree Farm, south of Nacogdoches, Texas, is often burned biannually during the dormant season, but occasionally during the growing season. The study was aimed at developing an understanding of any correlation between the soil physical and chemical properties among the burn intervals and between different time frames and the effects prescribed burning has on them. Very little research has been done to determine the effects of prescribed fire on soil water infiltration rates, and none have been done in the forests of the Western Gulf Coast or in Texas. All soils in the study were sand and loamy sand surface soil texture classes, because surface soil textures were so similar, it was assumed

texture would not greatly affect the results in this study. SAS was used to determine the effects of prescribed burning between three different time spans (pre-burn to post-burn, post-burn to green-up and pre-burn to green-up), and between two different burn intervals, National Forest and Grasslands of Texas mean three-year interval and Winston 8 Land and Cattle Ltd. Tree Farm annual interval (National Forest and Winston 8). There was a significant increase in soil water infiltration rates between pre-burn to post-burn and pre-burn to green-up time frames, and between the two different burn intervals. The soil strength initially decreased slightly, but increased over time. Soil stable aggregates increased significantly over time, leading to an increase in soil structure after burning. This study found there could be short-term responses on soil physical and chemical properties from repeated burning treatments. Soil physical properties which significantly changed due to this prescribed burn include soil bulk density, pore space, water stable soil aggregates, and soil strength. Soil properties which significantly changed due to this prescribed burn include nitrogen in the forms of ammonium and nitrate, the carbon to nitrogen ratio, and electrical conductivity. Based on these results, these burn intervals do not change the availability of nutrients within the soil.

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INTRODUCTION

Soil water infiltration may be one of the most important physical properties of soils, and describes the ability of soils to absorb and move water into and through the soil profile. Infiltration rates influence the potential for soil erosion and reflects surface soil macroporosity, which in turn affects soil aeration, bioavailability of nutrients for plants, and soil aggregate strength. While there are studies of fires affecting forest soils in other regions, relatively few took place in the Southeastern United States, let alone East Texas, and none of the latter studies observed the effects of prescribed fire on soil water infiltration rates. In addition, most studies have focused on post-fire soil properties, but none have included pre-fire sampling, making direct evidence of burn effects on soil properties, especially infiltration rates, scarce (Agee 1993, Cass et al. 1984, Erickson and White 2008, Verma and Jayakumar 2012). The role prescribed fire plays on soil water infiltration rates is unclear. Some research suggests infiltration rates decrease after fire (Agee 1993, Cass et al. 1984, Erickson and White 2008, Mallik et al. 1984, and Rowe 1941), while other research contradicts this, indicating infiltration rates may increase after fire (Wahlenberg et al. 1939). Other studies indicated no difference in soil water infiltration rates after a fire (Burgy and Scott 1952). Different ecosystems may have fire intensities and severities which differ and change the soil water infiltration rates (Certini 2005).

Agee (1993) reported results performed in the Pacific Northwestern Forests of the United States and concluded soil water infiltration rates to decrease after a fire. Burgy and Scott (1952) reported upon chaparral soils within the Southwestern United States, where they found soil water infiltration rates did not change after a fire but remained constant. Cass et al. (1984) and Gardner (1986) both reported on various studies in Southern Africa; they both reported soil water infiltration rates to decrease after a fire. Erickson and White (2008) summarized research from the Northern Rockies and the Pacific Northwest United States and stated soil water infiltration rates decreased after a fire. Verma and Jayakumar (2012) also reported on a collection of research about forest soils; they found the soil water infiltration rates to increase soon after a fire and then decrease over time. Mallik et al. (1984), in Northeastern Scotland found soil water infiltration rates to decrease directly after a fire. Rowe (1941) worked in a woodland chaparral in the Sierra Nevada foothills and reported the soil water infiltration rate decreased after a fire. In contrast Wahlenberg et al. (1939) reported soil water infiltration rates to increase after a fire in Mississippi.

Prescribed burning is heavily utilized in the Western Gulf Coast and East Texas. Because of the lack of regional efforts to quantify the impact of prescribed burning on soil water infiltration rates, and the conflicting nature of previous research on this topic, a better understanding of how fire influences soil water infiltration, and also potential changes is soil physical and chemical properties is needed. Because regionally more prescribed burns are performed in higher frequency and without adequate data and research there is no accurate data predicting what affects prescribed burning has on soils in this region.

GOAL AND OBJECTIVES

The goal of this project was to determine if prescribed burning has an effect on soil water infiltration rates in common forest soils in East Texas. This study also focused on the effects of prescribed fire on select soil physical and chemical properties. The specific objectives of the study were to:

- Test if soil water infiltration rates are influenced by prescribed fire in selected East Texas forest soils.
- Assess the impacts of prescribed fire on select soil physical and chemical properties on the same soils.

LITERATURE REVIEW

History of Prescribed Fire

A fire regime in a particular ecosystem may be naturally occurring or it may be maintained/managed by humans. Ecosystems which evolved with fire are often more resilient when prescribed burning is used; and different regions exhibit different burn intervals and intensities (Kruger 1984). Plants which evolved with fire tend to return quicker after a burn than plants which did not evolve with fire. Before anthropogenic processes, lightning served as the common medium for starting fires, which occurred frequently enough to guide the evolution of plants. Natural fire regimes have often been replaced with anthropogenic fire regimes, which include exclusion or suppression of fire beyond the natural fire return interval (Wanthongchai et al. 2008). Native Americans and early settlers of America used prescribed burning, and it has been hypothesized that Native Americans used fire for a number of reasons, such as herding American bison (*Bison bison*) and other animals as a hunting technique. Native Americans also used fires because new plant growth provided food; they also used fire to increase the diversity of plants and modify the landscape (Kayll 1974, Komarek 1974, Ryan et al. 2013).

Early Euro-American settlers used fire for agricultural purposes and clearing areas for expanding communities, and they learned quickly how useful fire was in southern forests. Fire was used to clear the thick understory and allow for grazing and hunting, and was also used to clear land for farming. As more settlers started arriving, fewer and fewer fires were being utilized by Native Americans; the landscape was shifting from having many to fewer fires (Ryan et al. 2013). Governmental suppression of fire began with the United States Forest Service (USFS), when fears of fires would become wildfires, therefore prohibited even small fires in National Forests. Since then, research has shown prescribed fire, low in intensity, and with constant intervals, may have a positive impact on many ecosystems (Kayll 1974, Komarek 1974, Ryan et al. 2013, Van Lear 1984).

Uses of Prescribed Fire on the Landscape

The uses of prescribed fire are typically based on the landowner's desire and goals, such as reduction of excess vegetation, especially woody vegetation, to gain access to an area, reducing fuel loads, reducing the intensity and severity of fires, and maintaining plant composition (Kayll 1974, Verma and Jayakumar 2012). The exclusion of invasive species and improving forage quality and nutritional values of existing plant species can be achieved through a different season of burn. Fire may be used to control parasites and insects by disrupting their life cycle (Kayll 1974). While fire can be used to remove excess vegetation, it can also be used to increase herbaceous ground cover in areas primarily covered in woody vegetation, which may reduce the amount of erosion and runoff (Certini 2005, Edwards 1984, Erickson and White 2008).

Prescribed burning has also been found to stimulate growth in individual plants by removing old growth and allowing new growth generation. Similar to the Native Americans, managers may use fire to assist the movement of animals and to distribute animals across a landscape. Wildlife habitat can be significantly improved by fire, allowing previously un-grazable/un-browsable areas to become more preferred. Fire can also help increase plant diversity (Certini 2005, Edwards 1984, Erickson and White 2008, Kayll 1974, Verma and Jayakumar 2012). Decreasing the fire return interval often produces a reduction in plant diversity (Cohen 2006, Edwards 1984). Fire may, directly and indirectly, affect the plants, animals, soil, microorganisms, and even human activities (Agee 1993, Kayll 1974). Fire has been used as a restoration tool on the landscape by reducing the encroachment of invasive species on the landscape (Bowman and Boggs 2006, Cohen 2006, Renschin et al. 2002). Prescribed burning can be used in preparing a seedbed for farming, forestry, reseeding to native rangelands, and increasing forage production in heavily managed pastures. The use of fire can be detrimental when used incorrectly, too frequently, when the fire is too intense, or in the wrong season; this can cause a setback of management objectives (Erickson and White 2008, Van Lear 1984, Verma and Jayakumar 2012). Using prescribed fire can help reduce understory litter in forested ecosystems. Excessive amounts of litter have the ability to potentially reduce the amount of water able to infiltrate into the soil; the litter acts as an interceptor of rainfall (Granger 1984).

Fire Affecting Plant Communities

Fire affects plant communities by scorching overstory plants, top-killing understory plants, and therefore reducing their density. Growth rates may be altered as well as the structure of plants, and vegetation is affected by the season of burn. Warm-season burns typically burn hotter, and with more intensity, than cool-season burns; warm-season burns tend to burn more completely and leave a less noticeable mosaic pattern (Komarek 1974, Kruger 1984). The mosaic pattern is caused by differences in fire severities, since the fire may burn hotter and more prolonged in one area, but cooler and shorter in another area. Local plant communities are subject to higher rates of change and are affected by fire differently than at a regional scale; this is also because of the mosaic effect fire has on the landscape. Fire not only affects vegetation and soils, but also has the ability to affect groundwater recharge by restricting infiltration rates and increasing overland flow of water, increasing soil erosion (Certini 2005, Komarek 1974, Kruger 1984).

Nutrient cycles are affected by prescribed burning by releasing nutrients from plants and organic matter into the soil and allowing them to be utilized by plants. Some nutrients are lost due to volatilization, while others are leached into the soil, but are not initially bioavailable to plants (Renschin et al. 2002, Wanthongchai et al. 2008). Fire can impact the forest floor by reducing the O-horizon during high-intensity burns, and low-intensity burns can partially remove the organic horizons, dead litter, and the understory of southern forests (Van Lear 1984).

Plants which have evolved with fire have formed adaptations to help them survive and thrive in their fire regime. Thick bark, self-pruning, up-turned branches, waxy leaves, and quick re-growth after fire are a few adaptations plants have evolved to survive fire. Plant competition after a fire is a key driver to which fire adapted plants come back first and grow faster than others after a fire, and more fire tolerant plants have a significant likelihood of returning before other non-fire tolerant plants (Van Lear 1984).

Fire suppression can result in more fire-sensitive plant species, and the ecosystem structure can drastically change over time; this may cause a loss or change of function and services in the ecosystem. This also alters the fuels and fuel load, which in turn may cause a more severe fire. Restoration of fire can restore historical plant communities and further change the ecosystem structure before the onset of fire suppression (Ryan et al. 2013). Thinning the O-horizon depth allows plants to grow where before the littler layer may have been too thick to support grasses or forbs. Reducing the litter layer periodically may help control woody plant material (Agee 1993, Certini 2005, Erickson and White 2008, Viro 1974).

Fuel loading is the amount of different types of fuels distributed throughout a fire's path. Fuels have the ability to influence burn severity and intensities. Fuel loading also has the ability to change soil physical and chemical properties, such as bulk density and the cation exchange capacity (Oswald et al. 1998).

Fire Affecting Soil Water Infiltration Rates

Vegetation type, litter cover, and microbial activity all influence the soil surface structure, which affects the amount of water which may infiltrate into the soil. Infiltration rates are typically higher in forest soils and forested ecosystems than non-forested ecosystems (Neary and Ffolliott 2005, Robichaud 2000). Fire has the ability to change the surface structure of the soil; in general, as a fire reduces the soil surface vegetation and litter, the structure of the soil changes and often the result is a reduction in the amount of water infiltration. Infiltration rates are reported to decline with fire; however, it is not well documented if this is just an initial decrease nor how long the decrease of infiltration lasts. High intensity or repeated fire exposure can cause a significant decrease in soil water infiltration (Agee 1993, Erickson and White 2008). Lower infiltration rates after fire can cause an increase in soil erosion and runoff. Some studies show a significant decrease after a fire (Agee 1993, Cass et al. 1234, Erickson and White 2008, Mallik et al. 1984, and Rowe 1941), while other studies have shown an increase in water infiltration rates (Wahlenberg et al. 1939), an initial increase followed by a decrease following a fire (Verma and Jayakumar 2012), or soil water infiltration rates remained constant (Burgy and Scott 1952). Lowered infiltration rates can be attributed to a number of variables such as an increase in bulk density, reduced porosity, and ash or char clogging soil macropores (Neary and Ffolliott 2005). Infiltration rates have been shown to vary between burn intensity within the same forest type or the same ecosystem with a prescribed fire (Robichaud 1999). These differences may be caused by factors such as the climate, forest type, burn regime and season of burn. There have been very few studies which included the pre-fire infiltration rates, so it is a challenge to state if infiltration rates decrease after a fire, as soil water infiltration is highly variable after a fire (Neary and Ffolliott 2005). Most studies are performed after a wildfire, which often are not comparable to prescribed burns, as the wildfires typically burn hotter and with more intensity than prescribed burns (Cass et al. 1984). There is potential for soil water infiltration rates to drop dramatically after a fire, when hydrophobic substrates from vegetation heat up and migrate into the soil profile before cooling again and creating a thin water-repellant layer. These layers are variable and can be very thick, thin, small and patchy, or extensive, depending on the temperature of the fire and the amount of hydrophobic materials entering the soil surface. The nature of the fire is the main factor in determining the intensity and distribution of the hydrophobic material. This may be influenced by fuel loads and vegetation type (Agee 1993, Certini 2005, DeBano et al. 2005, Erickson and White 2008).

Fire Affecting Soil Physical and Chemical Properties

The intensity and duration of a fire often determines which physical and chemical properties are affected. Moisture content of fuel sources and fuel loading are major factors when determining the intensity and severity of a fire, and these variables may also affect the physical and chemical properties of the soil (Wells 1979). When a fire burns at a high temperature, it can trigger the breakdown of clay minerals and a loss of soil organic matter, which may lead to erosion and may lower the stability of soil aggregates. Soil aggregates allow stability of the soil and decreases the chance of erosion, enhancing plant root penetration (Agee 1993, Cass et al. 1984, Granger 1984, Verma and Jayakumar 2012), and soil aggregate stability is the measure of how well a soil resists outside forces of change and is very important because it keeps the soil in place and reduces the amount of erosion and it affects how plant roots grow (USDA 1996).

Macropores can be attached or detached from the soil surface. Macropores which open to the soil surface allow for rapid infiltration into the soil surface then into the subsurface. Subsurface macropores which are not open to the soil surface do not increase the soil water infiltration rates as much as the macropores opening to the soil surface (USDA 2008a). After a burn, ash and charred organic matter may obstruct macropores causing a decrease in soil water infiltration rates. This may happen from intense burns with high fuel loads (Burgy and Scott 1952, Mallik et al. 1984). Soil moisture retention has been found to be higher after a burn than found on similar unburned plots. This retention is highest in the upper two cm of soil, and decreases with depth. Burned plots were also observed to have greater available water capacity than those unburned (Mallik et al. 1984). A fire can either completely consume the organic matter or leave it charred. This residual material may have the ability to slow infiltration rates by obstructing soil surface macropores. Charred organic matter may have the ability to migrate down into the subsurface soil and stay there for an extended period of time, slowly releasing organic carbon into the soil profile (Burgy and Scott 1952, Mallik et al. 1984).

There is no consistency on the effects of fire on soil strength. Soil strength differences can be caused by different fire regimes, climate, vegetation type, and soil types. There is no single reason why soil strength changes with fire as it may not change with fire, or it might change with the season due to changes in vegetation type (Cass et al. 1984, Certini 2005).

Fire has the ability to negatively affect soil bulk density if the fire is severe enough. Fire is not often hot enough to change the physical properties of the soil, although this may not be the case in wildfires due to the lack of on-site pre-fire measurements. While most prescribed fires may not be hot enough to change soil structure, extending the fire interval could lead to higher porosity and more penetrable soil. Prescribed burning could lead to the formation of biological soil crusts and lower porosity (Cass et al. 1984). Soil exposed to repeated prescribed burns or extreme wildfires can cause an increase in soil bulk density, while under the same conditions soil porosity tends to decrease (Agee 1993, Cass et al. 1984, Certini 2005, Verma and Jayakumar 2012).

Soil nutrient levels are also potentially affected by fire. As the fire consumes the litter layer, some of the nutrients are released back into the soil. Soils which are severely burned tend to have lower nitrogen levels and higher calcium levels than unburned soils due to volatilization. Also, in a typical prescribed burn, potassium, magnesium and phosphorous do not significantly change after a burn (Erickson and White 2008, Renschin et al. 2002, Verma and Jayakumar 2012). A severe fire could cause mass amounts of nutrient volatilization; or the nutrients going into the soil may not become bioavailable for plants, and remain unused until they dissolve in the soil water and can be taken up by plants (Granger 1984, Viro 1974). Fire can cause nutrients to become more mobile, either entering into the soil and remaining within the range of plant roots or leaching down into the soil profile and into the ground water (Cass et al. 1984, Granger 1984, Neary et al. 2003, Verma and Jayakumar 2012, Viro 1974). Usually a low intensity single burn does not change the nutrient availability in soils. Soil pH often increases significantly after a fire in forest soils, possibly caused by an influx of nutrients released from the litter layer by the fire, especially mineralization of nitrogen and nitrogen fixation. Following higher temperature burns it is typical to see an increase of pH (Cass et al. 1984, Granger 1984, Jurgensen et al. 1981, Verma and Jayakumar 2012) in neutral or slightly acidic soils. Burning of the litter layer is in most cases an alkaline reaction, which raises the pH of the soil as the nutrients become mobile and enter the soil profile. Ash may be left behind from the litter layer after a burn, this often creates an increase in soil pH as well. Ash is composed of nutrients from the burned litter layer and they are released back into the soil profile. It has been noted the slight increase in pH does not last very long after a fire. This can be attributed to leaching of nutrients below the plant roots zone, or in some cases runoff from lowered infiltration or over saturation of the soil profile (Viro 1974). Creating a low intensity fire regime can, however, lead to an overall increase in soil pH levels (Agee 1993). The season of burn also has an effect of the soil nutrients, as soil surface temperatures control which nutrients become volatile, which become bioavailable to plants, and which will be leached down into the soil profile. Fuel moisture also determines how hot a fire will burn, which affects the nutrients as well (Certini 2005, Erickson and White 2008).

METHODOLOGY

Sampling occurred pre-burn, post-burn (one month after the burn), and at green-up (three months after the burn) during the 2020-2021 burn seasons on the USFS Davy Crockett National Forest, USFS Angelina National Forest, and Simon Winston's Winston 8 Land and Cattle Ltd. Tree Farm. Two plots were located on the Davy Crockett National Forest, six plots were located on the Angelina National Forest, and 30 plots on the Winston 8 Land and Cattle Ltd. Tree Farm.

Site Descriptions

The areas utilized at the Winston 8 Tree Farm is comprised predominantly of longleaf pine (*Pinus palustris*) and scattered shortleaf pine (*Pinus echinata*) trees in the overstory with no notable mid-story. The understory is a mixture of wild blackberry (*Rubus spp.*), American beautyberry (*Callicarpa americana*), and a mixture of grasses (*Poaceae spp.*). The Davy Crockett National Forest is a mix of loblolly pine (*Pinus taeda*) and shortleaf pine (*Pinus echinata*) trees in the overstory. The mid-story species are comprised of hickory species (*Carya spp.*), while the understory is mostly comprised of American beautyberry (*Callicarpa americana*), wax myrtle (*Myrica spp.*), sassafras (*Sassafras albidum*), sweetgum (*Liquidambar styraciflua*), elm species (*Ulmus spp.*), and greenbriar

(*Smilax spp.*). The Angelina National Forest differs from the Davy Crockett in the overstory, which is comprised of longleaf pine (*Pinus palustris*) and loblolly pine (*Pinus taeda*) trees.

Plot Establishment

Global Positioning System (GPS) coordinates for plot center were given by the United States Forest Service for four utilized pre-existing plots. Plots were established on the Winston 8 using ArcGIS mapping system, to establish a plot center. GPS coordinates were also taken for sub-plot 1, which was located at a randomly selected location and direction, not to exceed 15 m from plot center, within the originally established plot, determined by a random number generator. Another sample was taken at a random distance and direction based on the sub-plot 1. Sub-plot 2 was a maximum of 50 m from sub-pot 1 (Figure 1). The GPS used was a Garmin Montana 680, and waypoint averaging was used to increase the accuracy of each plot location. All locations (property the sample was located on, sub-plot number, and the latitude and longitude of each sub-plot) were recorded (Table 1).

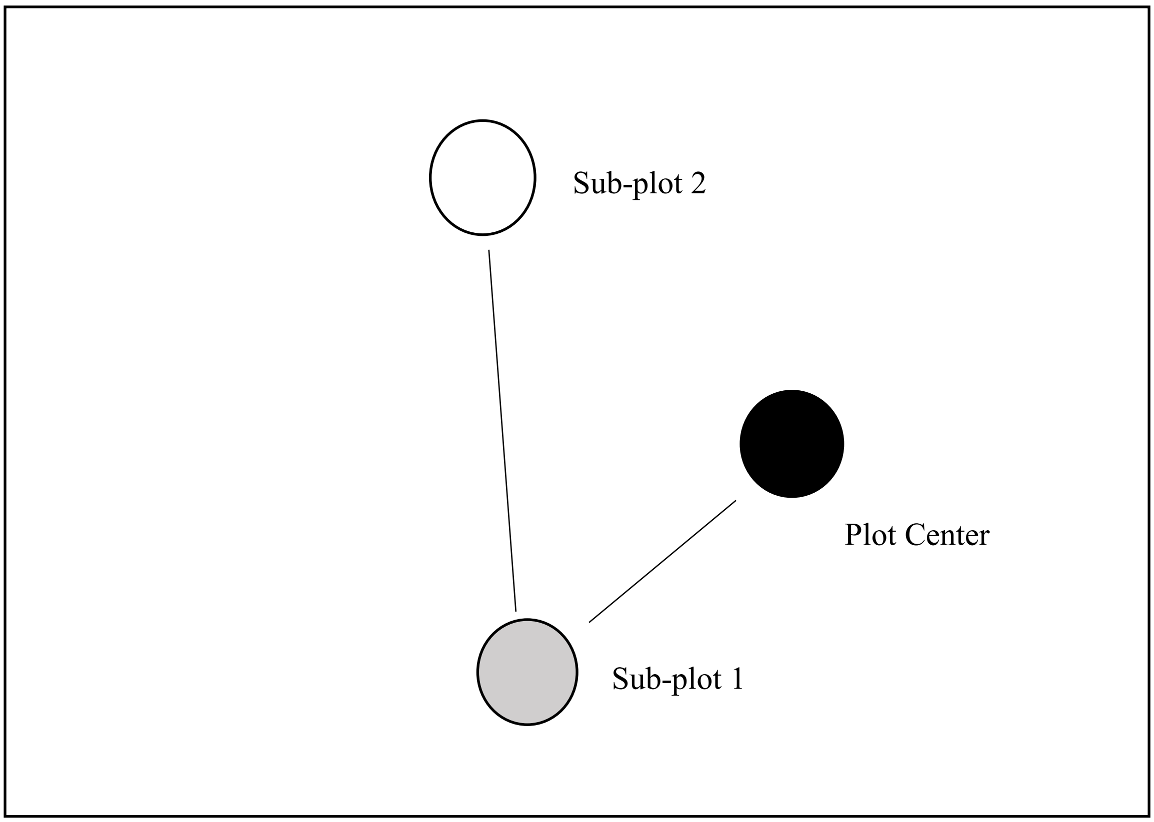


Figure 1. Example of plot layout with plot center and two measurement sub-plots

Field Sampling Methods

At each sub-plot, soil water infiltration rates, soil map unit confirmation, the O-horizon depth and weight, soil strength, mineral soil sampling at a depth of 0 to 15 cm; soil texture, bulk density, particle density, soil organic carbon content, soil fertility (nutrients), soil pH, and water stable aggregates were measured pre-burn, and re-measurements of everything except soil texture occurred at post-burn and green-up. Soil series confirmation was also conducted at pre-burn (Table 1). Samples were not collected directly on top of one another, and space was allowed to ensure samples at post-burn and green-up were not on previously disturbed points.

Table 1. Location of each sampling plot along with the name given to each sampling plot and the GPS coordinates associated with each sampling plot. Winston 8 = Winston 8 Land and Cattle Tree Farm; Angelina NF = Angelina National Forest; Davy Crockett NF = Davy Crockett National Forest.

Site Location	Sub-Plot	Latitude	Longitude
Winston 8	W01	31.510600	-94.719893
Winston 8	W01-1	31.510487	-94.720059
Winston 8	W02	31.508886	-94.719574
Winston 8	W02-1	31.508764	-94.719721
Winston 8	W03	31.506644	-94.719835
Winston 8	W03-1	31.506842	-94.719789
Winston 8	W04	31.501833	-94.720773
Winston 8	W04-1	31.501936	-94.720595
Winston 8	W05.1	31.499962	-94.720910
Winston 8	W05.1-1	31.500002	-94.721071
Winston 8	W5	31.507570	-94.719086
Winston 8	W5-1	31.507749	-94.719333
Continued			

Site Location	Sub-Plot	Latitude	Longitude
Winston 8	W7	31.510930	-94.717413
Winston 8	W7-1	31.513396	-94.717528
Winston 8	W8	31.508660	-94.717010
Winston 8	W8-1	31.508419	-94.717083
Winston 8	W11	31.509117	-94.710175
Winston 8	W11-1	31.509008	-94.7102450
Winston 8	W12	31.508924	-94.709120
Winston 8	W12-1	31.508819	-94.708880
Winston 8	W13	31.510535	-94.710096
Winston 8	W13-1	31.510437	-94.709962
Winston 8	W14	31.511139	-94.709232
Winston 8	W14-1	31.510971	-94.709108
Winston 8	W15	31.510659	-94.707995
Winston 8	W15-1	31.510727	-94.708101
Continued			

Site Location	Sub-Plot	Latitude	Longitude
Winston 8	W16	31.508251	-94.710421
Winston 8	W16-1	31.508113	-94.710509
Winston 8	W17	31.506903	-94.710493
Winston 8	W17-1	31.506788	-94.710293
Angelina NF	66.01	31.143155	-94.337276
Angelina NF	66.01-2	31.142935	-94.337451
Angelina NF	66.02	31.143159	-94.338407
Angelina NF	66.02-2	31.143163	-94.338073
Angelina NF	67.02	31.146366	-94.350587
Angelina NF	67.02-2	31.146049	-94.350452
Davy Crockett NF	19	31.557650	-95.164706
Davy Crockett NF	19-2	31.557674	-95.165070

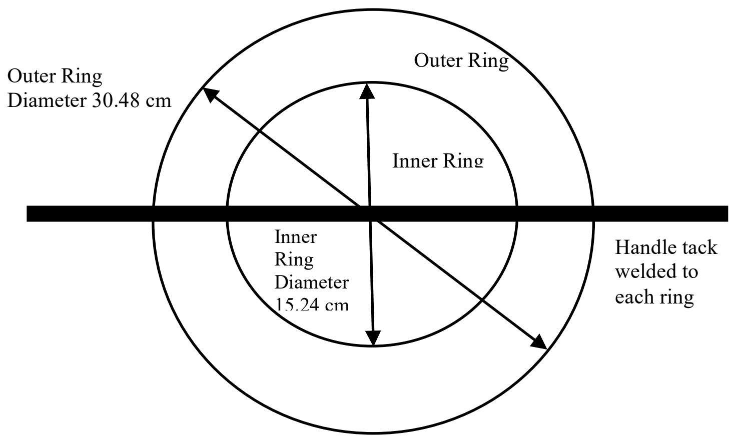
Soil Series Confirmation

The Web Soil Survey was created by NRCS (Natural Resources Conservation Service) within the United States Department of Agriculture (USDA); an app was later created by UC Davis in conjunction with NRCS. This app was used to tentatively identify the map unit at each sample location and a soil auger was then used to a maximum depth of 1.5 m to confirm the soil series (https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm). If soil mapping units recorded in Web Soil Survey did not match what was found in the field, the corrected soil mapping unit was recorded in its place (Table 2).

Soil Water Infiltration

A double-ring cylindrical infiltrometer was used to determine the amount of infiltration occurring in the soil profile at the soil surface. The infiltrometer was placed 5 cm into the soil surface. Water was then filled to a line of 5 cm below the top lip of both the outside and inside ring. Measurements were made from the top lip of the inside ring in cm (Bouwer, 1986) at set time increments which depended on the soil type and how quickly the water was infiltrating. The double-ring infiltrometer was designed to reduce the interference from lateral flow into the soil surface (Figure 2). Measurements were taken from the inside ring accounting for only downward infiltration.

A. Top View of Double-Ring Infiltrometer



B. Side View of Double-Ring Infiltrometer

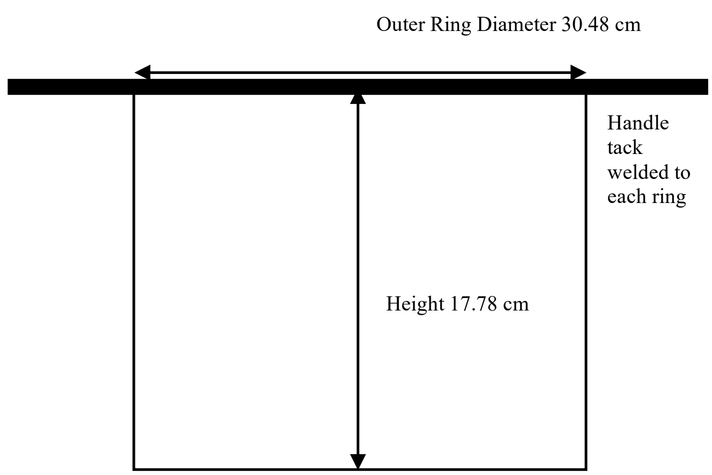


Figure 2. Schematics of a Double Ring Infiltrometer

A. The top view of a Double Ring Infiltrometer and its dimensions
B. The side view of a Double Ring Infiltrometer and its dimensions

Soil Bulk Density

The Excavation Method was used, where a small hole, located within 0.5 m of the infiltrometer, was dug to the depth of 15 cm and all the soil was collected from the hole. The hole was then lined with plastic food wrap, ensuring there was no room or gaps along the walls of the hole and the plastic was flush with hole bottom. A known measurement of water was then poured into the hole using a Pyrex graduated cylinder with a volume of 250 mL. Water was filled flush to the top of the hole to determine the volume of the soil excavated. Soil moisture content was also determined using the soil collected from this hole. Pre-burn, post-burn, and green-up soil bulk density were collected in the same location as the organic matter collection at each plot, because soil bulk density does not include the organic matter layer (Blake and Hartge, 1986). This sample was taken back to the Forestry Soils Lab at Stephen F. Austin State University to be weighed and dried at 105° C until the weight in grams remained constant.

Mineral Soil Samples

Two bags of mineral soil samples, not to exceed 15 cm in depth, were taken from each sub-plot. One bag was sent to the Stephen F. Austin State University Soil, Plant, and Water Analysis Laboratory to determine total organic carbon, total nitrogen, extractable phosphorous, exchangeable potassium, calcium, magnesium, extractable sulfur, and extractable sodium. The other bag was used to determine soil pH, soil texture, and percentage of water stable aggregates in the Forest Soils Laboratory at Stephen F. Austin

State University, pre-burn, post-burn, and green-up; soil texture was only determined for the pre-burn sample. Mineral soil samples were taken at each sub-plot and was taken adjacent to the soil bulk density hole before water was applied to not contaminate the mineral soil samples.

O-Horizon Depth and Weight

A 22 cm by 22 cm square was placed on the surface of the ground, not to exceed 0.5 m from the infiltrometer, and all of the organic matter (litter and O-horizon) was collected and taken to the lab to be weighed and dried to determine the moisture content. The depth of the O-horizon was also recorded in the field to estimate the amount of pre-burn, post-burn and green-up of O-horizon density.

Soil Strength

A cone penetrometer utilizing a 19.05 mm diameter cone was used to determine the strength of the soil to a depth of 15.2 cm, recorded in kg cm^{-2} at pre-burn, post-burn, and green-up at each sub-plot location (Bradford, 1986).

Lab Sampling Methods

Soil Texture

Soil texture was determined using the Bouyoucos Hydrometer Method (Gee and Bauder, 1986). The sample was taken from a mineral soil sample bag and included any of the O-Horizon in the sample. Samples were not sieved prior to being dried or measured. Soils were dried at 105°C to a constant weight and then 100 g of the sample was placed into a Bouyoucos graduated cylinder with a known volume of water. Measurements were taken with a soil hydrometer at the 40-second interval to determine the amount of sand in the suspension. A second measurement was taken after two hours to determine the amount of clay still in suspension. Readings were corrected for both suspension temperature and a blank, following Gee and Bauder (1986). Soil texture classes were determined based on the NRCS (Natural Resources Conservation Service) Soil Texture Triangle, based on the percentage of sand, silt, and clay. Temperature was measured in Fahrenheit for this process, as the Bouyoucos Hydrometer is calibrated in Fahrenheit.

Temperature correction was calculated based on:

$$\text{Corrected Temperature} = (\text{Temperature} - 68) \times 0.2$$

The corrected blank reading was calculated by adding the corrected temperature to the blank reading:

Blank Corrected Reading = Blank Hydrometer Reading + Blank Corrected Temperature

Calculating the percentage of sand:

Corrected Reading at 40 seconds = Reading at 40 seconds + Corrected 40 second Temperature – Blank Corrected Reading

% Sand = 100 – Corrected Reading at 40 seconds

Calculating the percentage of Clay:

Corrected Reading at 2 hours = Reading at 2 hours + Corrected 2-hour Temperature – Blank Corrected Reading

% Clay = (Corrected Reading at 2 hours x 100) / 100 g

Calculating the percentage of Silt:

% Silt = 100 – (% Sand + % Clay)

Soil Texture was then determined using the percentages of sand, silt, and clay with the USDA/NRCS (United States Department of Agriculture / Natural Resources

Conservation Service) Soil Texture Calculator

(https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/?cid=nrcs142p2_054167).

Soil Bulk Density

The excavated soil was weighed wet and then after a period of drying, until the dry weight was constant, and weighed again when dry. Particle volume, particle density, and pore space were all calculated from the bulk density sample. To determine the soil bulk density (Db):

$$Db = \text{Oven Dried Soil Weight} / \text{Excavated Soil Water Volume}$$

Soil Water Content

The soil water content was measured from the soil bulk density sample, based on the soil wet weight and soil dry weight to determine moisture content. Water content was calculated as MWC_s (Mass Water Content of Soil) and VWC_s (Volumetric Water Content of soil) (Gardner, 1986):

$$MWC_s = (\text{Wet Soil Weight} - \text{Dry Soil Weight}) / \text{Dry Soil Weight}$$

$$VWC_s = MWC \times Db$$

Particle Density

Particle density (Dp) was calculated using the dried bulk density sample. The dried soil was added to a graduated cylinder with 1000 mL of water already in place, then the measurement was taken of how much water was displaced by the soil.

Dp = Oven Dried Soil Weight / (Soil Displaced Water Volume / Starting Water Volume)

Pore space (% PS) was also calculated by using particle density and the following equation (Danielson and Sutherland, 1986):

$$\% PS = 100 - (Db / Dp \times 100)$$

Soil pH

Using one of the mineral soil samples from each sub-plot, 20 g of field moist soil was put into an Erlenmeyer flask and 40 mL of water was added. The flask was then put on a shaker for a minimum of 15 minutes. A pH probe was calibrated using pH standards and the soil pH was then recorded.

Water Stable Soil Aggregates

The percentage of water stable aggregates were determined using the same field moist mineral soil samples used for soil pH. Two hundred g of wet soil was weighed and put though a nest of sieves (2 mm, 1 mm, 0.5 mm, and 0.25 mm sieve sizes). The sieves were suspended in an 18.9 L container filled with water and the soil placed in the top sieve.

After 5 minutes the sieves were taken out and then dunked two more times and the water was allowed to completely drain. Aggregates on each sieve were then back washed into a jar and the contents then poured through a funnel with a coffee filter in it, catching all of the soil from each sieve. The coffee filters and soil were then placed in a 60°C drying oven before moving to a 105°C oven to finish drying to a constant weight. The initial sample dry weight was calculated using a 5 g subsample of soil which was previously dried at 105°C. Soil aggregates for each sieve was used for calculating percentages of water stable soil aggregates and total percentage of water stable aggregates (Kemper and Rosenau, 1986).

Total Corrected Dry Weight = 200 g x water content correction value

Water Content Correction Value = 1 – ((5 g – dry weight) / 5 g)

Total % Soil Aggregates = (total aggregate weight / total corrected dry weight) x 100

% of each Aggregate = (aggregate weight per sieve / total corrected dry weight) x 100

Water Content of the O-Horizon

The O-Horizon was measured wet and then dried at 60°C until the weight remained constant. Water content was then calculated based on the wet and dry weight to give the water content in the O-Horizon. Water content was calculated by MWC_o (Mass Water Content of O-Horizon) using the following equation (Gardner, 1986):

MWC_o = (O-Horizon Wet Weight – O-Horizon Dry Weight) / O-Horizon Dry Weight

Soil Chemical Properties

The second bag of soil mineral sample was sent to the Stephen F. Austin State University Soil, Plant and Water Analysis Laboratory to be evaluated for total organic carbon content and total nitrogen, also expressed as the C:N ratio. Phosphorus, potassium, calcium, magnesium, and sulfur were extracted by Mehlich-3 extractable nutrients and recorded in mg kg^{-1}. Electrical conductivity was also reported in µS cm^{-1}.

Statistics

A two-factor design and interaction of time and site was implemented using a t-test analysis. Data was analyzed at the pre-burn, post-burn and at green-up stages and compared with a p-value of 0.1. The t-test compared the three different times (pre-burn to post-burn, post-burn to green-up, and pre-burn to green-up). The t-test allows for generalizations between interactions. A One-way ANOVA was run on each of the variables to determine a more specific interaction in differences in the burn intervals. Each variable was tested at each time (pre-burn, post-burn, and green-up) and also the two different burn intervals.

RESULTS

Soil Classification

USDA Natural Resources Conservation Service (NRCS) county soil survey maps were accessed with the Web Soil Survey Application and their published soil map units. Soil mapping units were either confirmed as correct or corrected to what was actually found. All soil samples were classified as either sand or loamy sand in texture in the 0 to 15 cm depth (Table 2), and it was assumed these soils would likely respond similarly (Chaudhari et al. 2013). Soil textures were very close to one another on the soil texture triangle. These textures may be sandier than expected due to leaving the O-Horizon intact during sampling and not sieving the samples before taking measurements in the Bouyoucos hydrometer. NRCS recorded average infiltration rates for each soil map unit these can be compared to this studies infiltration rates and the average infiltration rates for each sampling location and each sampling time frame (Tables 2, 3).

Table 2. Confirmed or corrected soil map unit and upper 15 cm soil texture associated with each plot. Winston 8 = Winston 8 Land and Cattle Tree Farm; Angelina NF = Angelina National Forest; Davy Crockett NF = Davy Crockett National Forest. NRCS classified each soil map unit into different soil water infiltration rates measured in cm min^{-1}

Location	**Sub-Plot**	**Map Unit**	**Soil Texture**	**NRCS Reported Infiltration Rates**
Davy Crockett NF	19.01	Darco	Sand	0.55
Davy Crockett NF	19.01-2	Darco	Sand	0.55
Angelina NF	66.01	Alazan	Loamy Sand	0.17
Angelina NF	66.01-2	Alazan	Sand	0.17
Angelina NF	66.02	Alazan	Loamy Sand	0.17
Angelina NF	66.02-2	Alazan	Sand	0.17
Angelina NF	67.02	Moswell	Loamy Sand	0.05
Angelina NF	67.02-2	Moswell	Sand	0.05
Winston 8	W01	Kirvin	Sand	0.17
Winston 8	W01-1	Kirvin	Sand	0.17
Winston 8	W02	Bowie	Sand	0.17
Winston 8	W02-1	Bowie	Sand	0.17
Winston 8	W03	Bowie	Sand	0.17
Winston 8	W03-1	Bowie	Loamy Sand	0.17
Winston 8	W04	Kirvin	Sand	0.17
Winston 8	W04-1	Kirvin	Sand	0.17
Winston 8	W05.1	Bernaldo	Sand	0.17
Winston 8	W05.1-1	Bernaldo	Sand	0.17
Winston 8	W5	Bowie	Loamy Sand	0.17
Winston 8	W5-1	Bowie	Loamy Sand	0.17
Winston 8	W7	Culthbert	Sand	0.17
Winston 8	W7-1	Culthbert	Sand	0.17
Winston 8	W8	Bernaldo	Sand	0.17
Winston 8	W8-1	Bernaldo	Loamy Sand	0.17
Winston 8	W11	Darco	Loamy Sand	0.55
Winston 8	W11-1	Bowie	Loamy Sand	0.17
Winston 8	W12	Tenaha	Sand	0.55
Winston 8	W12-1	Tenaha	Sand	0.55
Winston 8	W13	Tenaha	Sand	0.55
Winston 8	W13-1	Tenaha	Sand	0.55
Winston 8	W14	Tenaha	Sand	0.55
Winston 8	W14-1	Darco	Sand	0.55
Winston 8	W15	Tenaha	Sand	0.55
Winston 8	W15-1	Tenaha	Sand	0.55
Winston 8	W16	Darco	Sand	0.55
Winston 8	W16-1	Darco	Loamy Sand	0.55
Winston 8	W17	Tenaha	Sand	0.55
Winston 8	W17-1	Tenaha	Sand	0.55

Table 3. Soil water infiltration rates measured in cm min^{-1} at the three time frames and their averages

Location	Sub-Plot	Pre-Burn	Post-Burn	Green-up	Average Infiltration Rate
Davy Crockett NF	19.01	3.17	3.33	4.00	**3.50**
Davy Crockett NF	19.01-2	3.33	4.50	5.67	**4.50**
Angelina NF	66.01	0.43	0.60	0.75	**0.59**
Angelina NF	66.01-2	1.00	0.80	0.69	**0.83**
Angelina NF	66.02	1.60	3.50	3.50	**2.87**
Angelina NF	66.02-2	1.50	1.83	0.75	**1.36**
Angelina NF	67.02	3.00	1.40	1.63	**2.01**
Angelina NF	67.02-2	1.70	7.00	2.50	**3.73**
Winston 8	W01	0.93	2.17	1.63	**1.57**
Winston 8	W01-1	0.79	1.30	1.63	**1.24**
Winston 8	W02	3.00	0.55	1.50	**1.68**
Winston 8	W02-1	1.38	1.10	1.20	**1.23**
Winston 8	W03	0.65	0.60	1.38	**0.88**
Winston 8	W03-1	1.20	0.60	1.50	**1.10**
Winston 8	W04	1.60	0.60	0.86	**1.02**
Winston 8	W04-1	1.10	1.10	1.25	**1.15**
Winston 8	W05.1	3.00	0.65	1.75	**1.80**
Winston 8	W05.1-1	1.30	0.65	1.50	**1.15**
Winston 8	W5	0.34	1.00	1.50	**0.95**
Winston 8	W5-1	0.75	1.30	1.83	**1.29**
Winston 8	W7	3.00	5.00	2.20	**3.40**
Winston 8	W7-1	1.40	0.39	1.83	**1.21**
Winston 8	W8	0.55	0.69	1.83	**1.02**
Winston 8	W8-1	1.50	2.75	2.17	**2.14**
Winston 8	W11	2.00	1.67	2.75	**2.14**
Winston 8	W11-1	2.80	3.00	1.83	**2.54**
Winston 8	W12	2.33	6.00	8.00	**5.44**
Winston 8	W12-1	1.38	2.75	13.00	**5.71**
Winston 8	W13	2.33	2.75	1.75	**2.28**
Winston 8	W13-1	1.63	6.50	2.50	**3.54**
Winston 8	W14	5.25	4.50	7.50	**5.75**
Winston 8	W14-1	2.67	8.00	6.00	**5.56**
Winston 8	W15	2.60	2.75	2.75	**2.70**
Winston 8	W15-1	1.50	2.75	7.50	**3.92**
Winston 8	W16	2.00	3.00	3.75	**2.92**
Winston 8	W16-1	3.25	7.00	2.75	**4.33**
Winston 8	W17	2.17	3.00	3.50	**2.89**
Winston 8	W17-1	2.17	3.00	2.50	**2.56**
Average Infiltration Rate		**1.90**	**2.63**	**2.92**	

Soil Physical Properties

Soil water infiltration significantly increased from pre-burn to post-burn and pre-burn to green-up time frames, and a significant difference at green-up between the two burn intervals (Tables 4, 5, A8). All three time frames showed increases in infiltration rates. Sub-plot W12-1 at the green-up time frame was considerably higher than any other infiltration rate, and this may have been caused by soil macropores opening to the soil surface and the amount of small to fine sized roots from plants acting as conduits for quicker soil water infiltration (Table 3).

Soil bulk density significantly decreased from the post-burn to green-up and the pre-burn to green-up time frames, and only increased from the pre-burn to post-burn time frame (Table A11). Particle density had no significant difference in any of the time frames or between the two burn intervals (Table A17). Pore space significantly increased at the post-burn to green-up time frame, and increased through all three time frames (Table A19). Particle volume significantly decreased from the post-burn to green-up and pre-burn to green-up time frames, as well as at the green-up between the two burn intervals (Table A18). The particle volume increased from pre-burn to post-burn time frames (Tables 4, 5, A8).

The total percentage of water stable soil aggregates showed a significant increase between the pre-burn to post-burn and a significant decrease from post-burn to green-up time frames and at green-up between the two burn intervals (Table A12). Soil aggregates retained on the 2 mm sieve significantly decreased at the pre-burn to green-up time frame and at the post-burn between the two burn intervals, while the soil aggregates retained on the 1 mm sieve percentage had a significant decrease at the post-burn to green-up time frame and the post-burn between the two burn intervals (Tables A13, A14). Soil aggregates retained on the 0.5 mm sieve only had a significant increase from pre-burn to post-burn and at pre-burn to green-up interval (Tables A15). Soil aggregates retained on the 0.25 mm sieve had a significant increase at the pre-burn to post-burn and pre-burn to green-up time frames, as well as at the green-up between the two burn intervals (Tables 4, 5, A8, A16).

Soil strength showed a significant decrease at the pre-burn to post-burn time frame (Tables 4, 5, A8), but significantly increased at the post-burn to green-up time frame. All three time frames showed a significant difference between the two different burn intervals. At the soil surface (0 cm), there was only a significant difference at the green-up between the two burn intervals, and there was an only a decrease at the pre-burn to green-up time frame. At 2.5 cm there was a significant decrease at the pre-burn to post-burn and the pre-burn to green-up time frames. There was a significant decrease at the pre-burn to post-burn and at the green-up between the two burn intervals in the 5.1 cm depth. At 7.6 cm there was a significant difference at the pre-burn and the green-up time frame between the two burn intervals. The 10.2 cm depth soil strength showed significant decrease at the pre-burn to post-burn and a significant increase from the post-burn to green-up time frames. Soil strength also had a significant difference at all three of the burn intervals between the two burn intervals. At 12.7 cm there was a significant decrease at the pre-burn to post-burn time frame with an increase only at the post-burn to green-up interval. There was also a significant difference at the pre-burn, post-burn, and green-up between the two burn intervals. Soil strength at 15.2 cm was significantly different in all three frames between the two burn intervals (Tables 4, 5).

Water content was calculated for both the O-Horizon and the mineral soil. Mass water content (MWC_s) and volumetric water content (VWCs) both showed a significant increase from pre-burn to post-burn followed by a significant decrease from post-burn to green-up time frames, they both also showed a significant difference between the two burn intervals during the pre-burn, and green-up time frames (Tables 4, 5, A8, A23, A24). The MWC_o (metric water content of the O-Horizon) showed a significant decrease from post-burn to green-up and pre-burn to green-up time frames and was significantly different between the two burn intervals at the pre-burn time frame (Tables 4, 5, A8, A25).

The O-Horizon density showed a significant decrease from pre-burn to post-burn and from pre-burn to green-up time frames. O-Horizon depths had a significant decrease from pre-burn to post-burn and pre-burn to green-up time frames, but showed a significant increase from post-burn to green-up. There was also a significant difference between the two different burn intervals at pre-burn and post-burn time frames (Tables 4, 5, A8, A20, A21).

Table 4. Comparisons of soil physical properties with their mean and change in mean between the three time frames

Variable	Units	Pre-Burn Mean	Post-Burn Mean	Green-Up Mean	Change in Mean Pre-Burn to Post-Burn	Change in Mean Post-Burn to Green-Up	Change in Mean Pre-Burn to Green-Up
Infiltration	cm min^{-1}	1.90	2.63	2.92	*0.73	0.47	*1.02
Soil Bulk Density	Mg m^{-3}	1.31	1.31	1.20	0.01	*-0.10	*-0.11
Particle Density	Mg m^{-3}	2.19	2.14	2.14	0.03	-0.00	-0.05
Pore Space	%	0.40	0.40	0.43	0.05	*0.04	0.03
Particle Volume	ml^{3}	243.95	291.82	218.68	21.67	*-73.16	*-25.26
MWC_s	g	0.11	0.19	0.13	*0.08	*-0.05	0.02
VWC_s	g^{3}	0.15	0.24	0.16	*0.09	*-0.08	0.01
MWC_o	g	0.34	0.26	0.15	-0.08	*-0.11	*-0.18
O-Horizon	g m^{-2}	6.67	4.40	4.53	*-2.26	0.13	*-2.13
O-Horizon Depth	cm	2.43	0.84	1.41	*-1.60	*0.58	*-1.02
Soil Aggregates	g	0.83	0.85	0.81	*0.06	*-0.03	-0.02
2 mm	g	0.62	0.51	0.52	-0.08	0.01	*-0.10
1 mm	g	0.04	0.07	0.05	-0.01	*-0.02	0.01
0.5 mm	g	0.06	0.10	0.08	*0.07	-0.02	0.02
0.25 mm	g	0.11	0.17	0.17	*0.07	-0.00	*0.06
Soil Strength	kg cm^{-2}	1144.98	882.68	1037.03	*-240.60	*438.70	175.50
0.0 cm depth	kg cm^{-2}	153.46	138.49	92.08	-14.97	-46.41	-61.38
Continued							

Variable	Units	Pre-Burn Mean	Post-Burn Mean	Green-Up Mean	Change in Mean Pre-Burn to Post-Burn	Change in Mean Post-Burn to Green-Up	Change in Mean Pre-Burn to Green-Up
2.5 cm depth	kg cm^{-2}	455.88	285.21	214.10	*-170.70	-71.12	*-241.80
5.1 cm depth	kg cm^{-2}	1018.81	543.63	810.18	*475.00	-248.20	226.80
7.6 cm depth	kg cm^{-2}	1250.13	1062.24	1296.91	187.90	-243.70	-46.79
10.2 cm depth	kg cm^{-2}	1617.33	1095.17	1546.59	*606.40	*-451.40	154.90
12.7 cm depth	kg cm^{-2}	2005.26	1434.69	1817.92	*570.60	-383.20	187.30
15.2 cm depth	kg cm^{-2}	1729.28	1815.79	1662.51	-341.30	65.41	339.30

*Indicates a significant difference at P-Value 0.01

Table 5. One-way ANOVA of soil physical properties comparing the differences between the two different burn intervals at three different time frames. NF = National Forest burn interval; W8 = Winston 8 burn interval.

Variable	Units	Pre-Burn NF Mean	Pre-Burn W8 Mean	Post-burn NF Mean	Post-burn W8 Mean	Green-up NF Mean	Green-up W8 Mean	Pre-Burn P-Value	Post-Burn P-Value	Green-Up P-Value
Infiltration	cm min^{-1}	1.97	1.88	2.87	2.57	2.44	3.05	0.93	0.72	*0.10
Soil Bulk Density	Mg m^{-3}	1.34	1.31	1.22	1.33	1.29	1.18	0.68	0.27	0.30
Particle Density	Mg m^{-3}	2.22	2.18	2.07	2.15	2.14	2.14	0.65	0.42	0.99
Pore Space	%	0.40	0.40	0.41	0.38	0.39	0.44	0.93	0.52	0.32
Particle Volume	Volume	260.00	239.67	285.00	293.67	175.00	230.33	0.30	0.69	*0.07
MWC_s	g	0.22	0.08	0.23	0.18	0.26	0.10	*0.07	0.29	*0.01
VWC_s	g^3	0.29	0.11	0.29	0.22	0.33	0.11	*0.07	0.15	*0.01
MWC_o	g	0.81	0.21	0.33	0.24	0.16	0.15	*0.01	0.27	0.97
O-Horizon	g m^{-2}	7.31	6.49	5.30	4.17	6.13	4.11	0.48	0.27	0.13
O-Horizon Depth	cm	3.75	2.08	0.42	0.95	1.44	1.41	*0.01	*0.06	0.92
Soil Aggregates	g	0.83	0.83	0.84	0.85	0.77	0.83	0.96	0.96	*0.02
2 mm	g	0.62	0.61	0.62	0.48	0.57	0.50	0.87	*0.01	0.29
1 mm	g	0.04	0.04	0.02	0.08	0.04	0.05	0.74	*0.01	0.26
0.5 mm	g	0.07	0.06	0.10	0.10	0.09	0.07	0.62	0.87	0.71
0.25 mm	g	0.09	0.11	0.09	0.19	0.07	0.20	0.89	0.76	*0.02
Soil Strength	kg cm^{-2}	440.78	1255.81	519.01	976.01	453.61	1201.21	*0.01	*0.01	*0.01
0.0 cm depth	kg cm^{-2}	103.12	166.88	145.79	136.54	0.01	116.63	0.52	0.90	*0.10
Continued										

Variable	Units	Pre-Burn NF Mean	Pre-Burn W8 Mean	Post-burn NF Mean	Post-burn W8 Mean	Green-up NF Mean	Green-up W8 Mean	Pre-Burn P-Value	Post-Burn P-Value	Green-Up P-Value
2.5 cm depth	kg cm^{-2}	216.90	519.61	188.45	311.01	60.45	255.07	0.15	0.28	0.12
5.1 cm depth	kg cm^{-2}	455.14	1169.12	419.58	576.71	277.35	952.27	0.11	0.34	*0.03
7.6 cm depth	kg cm^{-2}	508.47	1447.90	504.92	1210.85	448.02	1523.28	*0.02	0.38	*0.02
10.2 cm depth	kg cm^{-2}	618.70	1883.63	597.37	1227.92	547.59	1812.99	*0.01	*0.02	*0.01
12.7 cm depth	kg cm^{-2}	720.96	2347.74	846.27	1591.60	736.04	2106.42	*0.01	*0.02	*0.01
15.2 cm depth	kg cm^{-2}	483.58	1978.42	1177.67	1943.42	1105.84	1896.90	*0.03	*0.09	*0.06

*Indicates a significant difference at P-Value 0.01

Soil Chemical Properties

Phosphorus had a significant decrease in the post-burn to green-up and pre-burn to green-up time frames; there was also a significant difference with all three time frames between the two different burn intervals (Table A27). There was a significant increase for potassium and magnesium at the pre-burn to post-burn and significantly decreased from the post-burn to green-up time frames (Table A28). Calcium only had a significant difference at green-up between the two burn intervals and increased from pre-burn to post-burn time frame (Table A29). Magnesium had a significant increase from pre-burn to post-burn time interval, but a significant decrease from post-burn to green-up. Magnesium also had a significant difference between the two burn intervals at the green-up time frame (Table A30). There was a significant decrease with sulfur at the post-burn to green-up and the pre-burn to green-up (Table A31. Sodium only had a significant decrease at the pre-burn to green-up time frame and at the pre-burn and green-up time frames between the two different burn intervals (Tables 6, 7, A9, A32).

The pH analyzed in water had a significant decrease at the post-burn to green-up and the pre-burn to green-up time frames. pH was analyzed in a buffer solution which used the Moore-Sikora buffer method. The pH in water and pH in buffer were used to estimate the cation exchange capacity (CEC), which significantly increased from pre-burn to green-up time frames, and was significantly different between the two burn intervals during the post-burn and green-up time frames (Tables 6, 7, A9, A10, A38).

Electrical conductivity was significantly decreased in the post-burn to green-up and the pre-burn to green-up time frames with an increase from the pre-burn to post-burn interval. There was also a significant difference at post-burn and green-up between the two burn intervals (Tables 6, 7, A9, A33).

The carbon to nitrogen ratio significantly decreased in the post-burn to green-up time frame. A significant difference was also observed at all three time frames between the two burn intervals (Table A34). Soil organic matter percentage showed a significant difference at the pre-burn and the post-burn between the two burn intervals, but the carbon percentage and nitrogen percentage did not have significant statistical differences in any of the three time frames. The total carbon percentage did have a significant difference at the pre-burn and post-burn between the two burn intervals, while the total nitrogen percentage only had a significant difference at the post-burn between the two burn intervals (Tables 6, 7, A9, A35, A36, A367.

Nitrogen was measured as Ammonium and Nitrate using different wavelengths. Ammonium was measured using a 670 and 800 nm light wave scale. Nitrate was measured using a 540 and 600 nm wavelength scale. Nitrogen measured as Ammonium showed a significant increase from pre-burn to post-burn followed by a significant decrease from post-burn to green-up time frames. Nitrogen measured as Nitrate significantly decreased from post-burn to green-up time frame (Tables 6, 7, A9, A25, A24).

Table 6. Comparisons of soil chemical properties with their mean and change in mean between three time frames

Variable	Units	Pre-Burn Mean	Post-Burn Mean	Green-Up Mean	Change in Mean Pre-Burn to Post-Burn	Change in Mean Post-Burn to Green-Up	Change in Mean Pre-Burn to Green-Up
Phosphorus	mg kg^{-1}	8.52	8.79	6.51	0.44	*-2.45	*-2.01
Potassium	mg kg^{-1}	45.16	54.34	41.58	*9.18	*-12.76	-3.56
Calcium	mg kg^{-1}	425.14	433.36	397.77	8.22	-32.98	-40.91
Magnesium	mg kg^{-1}	67.10	73.98	62.62	*6.88	*-11.36	-4.48
Sulfur	mg kg^{-1}	4.77	4.72	3.90	-0.05	*-0.81	*-0.86
Sodium	mg kg^{-1}	59.43	58.93	57.03	-0.50	-1.89	*-2.39
pH Water		5.03	5.01	5.48	-0.01	*-0.01	*-0.01
Estimated CEC	cmoles kg^{-1}	5.42	6.09	6.26	0.75	0.06	*0.99
Electrical Conductivity	µS cm^{-1}	73.94	76.05	41.51	2.11	*-34.51	*-32.43
Carbon:Nitrogen Ratio		20.79	21.44	19.72	0.66	*-1.72	-1.07
Organic Matter	%	3.36	3.49	3.05	-0.01	-0.01	-0.01
Total Carbon	%	1.68	1.75	1.53	0.01	-0.01	-0.01
Total Nitrogen	%	0.08	0.08	0.08	-0.01	-0.01	-0.01
Nitrogen as Ammonium	mg kg^{-1}	5.03	8.30	5.08	*3.27	*-3.22	0.05
Nitrogen as Nitrate	mg kg^{-1}	8.24	10.16	2.11	3.91	*-7.61	-4.07

*Indicates a significant difference at P-Value 0.01

Table 7. One-way ANOVA of soil chemical properties comparing the differences between two burn intervals at three different time frames. NF = National Forest burn interval; W8 = Winston 8 burn interval.

Variable	Units	Pre-Burn NF Mean	Pre-Burn W8 Mean	Post-Burn NF Mean	Post-Burn W8 Mean	Green-Up NF Mean	Green-Up W8 Mean	Pre-Burn P-Value	Post-Burn P-Value	Green-Up P-Value
Phosphorus	mg kg^{-1}	5.46	9.34	4.56	10.14	4.15	7.14	*0.01	*0.01	*0.01
Potassium	mg kg^{-1}	39.92	46.56	58.61	53.20	34.35	43.51	0.34	0.50	0.16
Calcium	mg kg^{-1}	406.29	430.16	388.10	445.43	246.83	438.03	0.73	0.37	*0.03
Magnesium	mg kg^{-1}	57.02	69.71	63.08	76.89	44.37	67.49	0.15	0.13	*0.02
Sulfur	mg kg^{-1}	4.48	4.84	4.55	4.77	3.49	4.02	0.47	0.66	0.21
Sodium	mg kg^{-1}	53.97	60.88	60.71	58.45	61.14	55.94	*0.01	0.39	*0.01
pH Water		4.50	5.17	4.77	5.08	5.08	5.58	0.98	0.73	0.86
Estimated CEC	cmoles kg^{-1}	5.98	5.28	7.77	5.61	7.41	5.91	0.38	*0.01	*0.04
Electrical Conductivity	µS cm^{-1}	71.51	74.59	44.24	84.53	34.08	43.49	0.84	*0.02	*0.10
Carbon: Nitrogen Ratio		23.13	20.16	24.10	20.73	22.06	19.10	*0.01	*0.02	*0.04
Organic Matter	%	0.04	0.03	0.05	0.03	0.04	0.03	*0.10	*0.01	0.24
Total Carbon	%	2.01	1.59	2.36	1.58	1.80	1.46	*0.10	*0.01	0.24
Total Nitrogen	%	0.09	0.08	0.10	0.08	0.08	0.08	0.47	*0.08	0.72
Nitrogen as Ammonium	mg kg^{-1}	5.87	4.81	10.40	7.74	5.14	5.07	0.32	0.43	0.96
Nitrogen as Nitrate	mg kg^{-1}	2.86	9.35	15.96	8.72	2.17	2.10	0.32	0.14	0.96

*Indicates a significant difference at P-Value 0.01

DISCUSSION

Soil Water Infiltration

Soil water infiltration rates have no definite trend after a burn, as some studies showed a decrease (Mallik et al. 1984, Rowe 1941), others an increase (Wahlenberg et al. 1939), and some no change (Burgy and Scott 1952). Very few, if any, studies have done pre-burn testing over the same location as the post-burn testing. Most studies involving soil water infiltration rates have been performed after a wildfire and the pre-fire samples are taken at a site with comparable soils and conditions which had not burned. In this study, there was a significant difference from the pre-burn to post-burn and pre-burn to green-up time frames but not during other time frames. Each time frame showed an increase in soil water infiltration rates following the burn (Table 4). Soil water infiltration rates also showed a significant difference between the two burn intervals at the green-up time frame (Table 5). This corresponded with Wahlenberg et al. (1939), who described an increase in soil water infiltration rates, but contradicted with Agee (1993), Cass et al. (1984), Erickson and White (2008), Mallik et al. (1984) and Rowe (1941) who found soil water infiltration rates decreased after a disturbance or an intense fire. The data also contradicts Verma and Jayakumar (2012), who found infiltration rates to increase at first and then slowly decrease over time. Burgy and Scott (1952) found there was no difference in infiltration rates after a fire, which also contradicts what was found in this study.

Infiltration rates in this study likely increased due to the sites being on long-term prescribed burn intervals. Although not many studies have been performed on comparable forest types, ecosystems or burn intervals, there are studies which align with these results. Wahlenberg et al. (1939) conducted research in Mississippi and concluded soil water infiltration rates to increase after a fire, in an ecological region similar to East Texas. Soil water infiltration rates in this study contradicted the results which Agee (1993) reported in the Pacific Northwestern United States, Cass et al. (1984) in Southern Africa, Erickson and White (2008) who reported results from others which occurred in the Northern Rockies and the Pacific Northwest, Mallik et al. (1984) in Northeastern Scotland, and Rowe (1941), whose study was in woodland chaparral in the Sierra Nevada, all who reported soil water infiltration rates to decrease after a fire. Soil moisture content was measured and compared to the results of soil water infiltration. There is no trend in soil moisture content (MWC_s, VWC_s) or the O-Horizon moisture content (MWC_o), although the MWC_s and VWC_s initially significantly increased and the infiltration rate also significantly increased during this time frame. The MWC_s, VWC_s, and MWC_o significantly decreased post-burn to green-up, and the infiltration rate increased, but not significantly, during this same time frame. The MWC_o significantly increased from pre-burn to green-up which may have influenced the increase during the same time frame for soil water infiltration rate. The MWC_s, VWC_s, and MWC_o may be co-variants for soil water infiltration rates, which may cause soil moisture to influence the soil water infiltration rates (Robichaud et al. 2016).

Soil Physical Properties

The total percentage of water stable soil aggregates showed a significant decrease from post-burn to green-up and from pre-burn to green-up time frames; there was an initial significant increase from pre-burn to post-burn time frames, reflecting a decrease in total aggregate percentage over time, driven by the fire treatment. There was also a significant difference between the two different burn intervals at the green-up time frame. These results showed there was a decrease in the soils ability to decrease erosion and show lower resistance to change, such as burning. Cass et al. (1984) and Certini (2005) both described high intensity burns decreasing the stability of soil aggregates, although Certini (2005) also found soil stability to increase when fires are of lower intensity. This data is consistent with what Certini (2005) described with low intensity fires. Granger (1984) described a decrease of organic matter covering the soil surface after a burn may be the cause for lowering soil aggregate stability. By utilizing low intensity prescribed burns, the total soil aggregate percentage increased initially following the burn.

Soil bulk density refers to the mineral soil and its voids and relates to soil compaction (USDA 2008b). The soil bulk density increased initially from the pre-burn to post-burn time frame, but showed a significant decrease from post-burn to green-up and pre-burn to green-up time frames, inconsistent with Agee (1993), Cass et al. (1984), and Certini (2005); there was no significant difference between the two burn intervals. Soil compaction was not considered an issue from these burning treatments because the soil bulk density values were below the threshold value of high soil compaction (USDA 1996, USDA 2008c). As soil compaction increases the soil water infiltration rate should decrease. Verma and Jayakumar (2012) reported bulk density to significantly increase directly after a fire due to soil particles collapsing and filling in void spaces with organic matter. Soil bulk density slightly increased initially and did not show a significant decrease until the post-burn to green-up time interval. This showed soil bulk density was affected by fire. Particle density slightly increased between the pre-burn to post-burn time frame, but showed no significant difference in any time frame or between the two burn intervals; there was a decrease between the post-burn to green-up and the pre-burn to green-up time frames. While particle density does not totally depend on the pore space (USDA 2008b), pore space is related to the soil bulk density; as the bulk density increased the pore space decreased. A decrease in pore space can potentially cause lower infiltration and percolation rates in soils; as the pore spaces close, either from compaction of the soil or water between soil particles, less water can be moved through the soil (USDA 2008b). Auten (1933) also noted decreases in porosity of soils with disturbances such as fire.

Soil strength decreased from pre-burn to post-burn, but increased from the post-burn to green-up time frames. Soil strength was significantly different between the two burn intervals during all three time frames. The strength of the soil relates to compaction and may be affected by the soil moisture content. Cass et al. (1984) described differences in soil strength caused by many different variables such as organic matter, intensity of the fire, and repetitive burning, the latter may be the driver in this study.

O-Horizon significantly decreased immediately after the prescribed burn, which is what was expected to happen, the O-Horizon is made up of decomposed litter and whole litter on top of the mineral soil surface. The O-Horizon decreased significantly during the pre-burn to post-burn and pre-burn to green-up time frames, which was expected as well and follows the normal trends associated with O-Horizon reduction after a fire (Komarek 1974, Kruger 1984). The O-Horizon depths showed significant differences between all three time frames an initial significant decrease which is expected directly after a prescribed burn (Certini 2005, Komarek 1974, Kruger 1984).

Soil Chemical Properties

Phosphorus decreased from pre-burn to post-burn, but significantly decreased from the post-burn to green-up and the pre-burn to green-up time frame, with a significant difference between the two different burn intervals at all three intervals. This is inconsistent with findings of Renschin et al. (2002) and Verma and Jayakumar (2012), who both described finding no difference in phosphorus after a burn. Phosphorus levels started and stayed very low throughout this study, so in this case fire had no effect on the levels of phosphorus, even though there were significant differences between the measured levels these were not enough to change phosphorus to a higher and more available level of concentration in the soil (Espinoza 2012). Potassium significantly increased from the pre-burn to post-burn time frame, but significantly decreased from post-burn to green-up time frame. This agrees with Renschin et al. (2002) who found a significant increase of potassium after a fire, but contradicts Verma and Jayakumar (2012), who found there is typically no significant change in potassium after a burn. Even though there were significant differences between time frames and burn intervals, this was not enough to change the level of potassium in the soil (Espinoza 2012). Calcium was only significantly different between the two burn intervals at the green-up time frame, inconsistent with the findings of Verma and Jayakumar (2012) and Renschin et al. (2002) who both found the calcium to increase after a fire. Calcium was at the optimum level during the pre-burn and post-burn time frames and was slightly below optimum at the green-up time frame, so there may have been a slight influence from a prescribed fire over time (Espinoza 2012). There was a significant increase of magnesium from the pre-burn to post-burn time frame, but a significant decrease from the post-burn to green-up time frame. There was also a significant difference between the two burn intervals at the green-up time frame. This was inconsistent with Renschin et al. (2002), who reported a significant decrease after a burn. Since magnesium levels were high throughout this study, there was no influence of prescribed fire on the levels of magnesium (Espinoza 2012). Sulfur had a significant decrease from the post-burn to green-up and the pre-burn to green-up time frames. Sulfur is known to easily volatize during a fire, and often there is a decrease in sulfur directly after a fire (Smith 1970), so the results of this study agree with what Smith (1970) found. This data also contradicts Renschin et al. (2002), who did not find any differences in sulfur after the burn. Sulfur levels throughout this study were low, indicating there was not enough to change the category level of sulfur (Espinoza 2012), and indicated there was no influence of prescribed burning on sulfur. The amount of sodium significantly decreased from the pre-burn to green-up time frame and was significantly different between the two burn intervals at the pre-burn and green-up time frames, agreeing with Smith (1970). Sodium levels were low throughout the study, this was no indication of prescribed fire influencing the levels of sodium measured in the soil (Horneck 2011).

Soil pH has significantly increased directly after a fire, especially after a hotter burn (Agee 1993, Certini 2005, Granger 1984, Verma and Jayakumar 2012). The pH in this study was analyzed in water, and also in a buffer solution based on the Moore-Sikora buffer method. The pH in water showed a decrease throughout all three time frames and significantly decreased over time, contradicting Agee (1993), Certini (2005), Granger (1984), and Verma and Jayakumar (2012). The pH did not increase but may increase beyond the time which this study covered. pH measured in the buffer solution was used to estimate the cation exchange capacity of the soil. The CEC increased over time. CEC has been reported to decrease after a fire, but not at a significant level (Ekinci 2006).

Higher electrical conductivity indicates higher concentrations of ions in the soil solution. If inorganic ions increase in concentration after a fire, the electrical conductivity will increase. The electrical conductivity significantly decreased from the post-burn to green-up and the pre-burn to green-up time frames. There was also a significant difference between the two different burn intervals at the post-burn and green-up time frames. This indicates a decrease in ions in solution, so nutrients in ionic form would be less readily available for plant uptake. This data contradicts Ekinci (2006) who found electrical conductivity increased after a fire.

The carbon to nitrogen ratio indicates the amount of carbon related to nitrogen in organic matter in the soil, and had a significant decrease from post-burn to green-up. It was also significantly different between the two different burn intervals at all three intervals. This agrees with what Kolka et al. (2014) found, as they reported a decrease from the unburned plots to the burned plots. The soil organic matter percentage was only significantly different between the two burn intervals at the pre-burn and post-burn time frames, with no significant difference in the soil organic matter percentage over time. The percentage of total carbon and the percentage of total nitrogen also showed no significant difference over time. The percentage of total nitrogen was significant between the two burn intervals at the post-burn time frame. Total carbon percentage was significant between the two burn intervals at the pre-burn and post-burn time frames. Even though there was not a significant change over time, the slight changes were enough to significantly change the carbon nitrogen ratio.

Nitrate measured as both ammonium and nitrate have been found to increase directly after a prescribed burn (Kavanagh et al. 2010). Ammonium was measured with a wave lengths of 670 nm and 800 nm. The lower wave length value included values measured between 0 nm and 5 nm while the higher wave length value includes values measured between 0 nm and 50 nm. Nitrate was measured with a wave length at 540 nm and 600 nm. The lower value wave length included values measured between 0 nm and 5 nm, while the higher wave length included values measured between 0 nm and 25 nm. Kavanagh et al. (2010) reported both ammonium and nitrate increased significantly after a prescribed burn and did not decrease for some time afterwards. This study partially contradicts Kavanagh et al. (2010), finding both ammonium and nitrate to increase with nitrogen as ammonium increasing significantly initially followed by both significantly decreasing. This may be caused by the soil moisture content and by leaching of nitrogen further into the soil profile. Another possibility is soil texture being sandy, which holds less water and leaches more easily (USDA 2014).

CONCLUSIONS

While prescribed burns may help in the reduction of the O-Horizon, this study found an increase in soil water infiltration rate over time, with a significant increase occurring between the pre-bun to post-burn and pre-burn to green-up time frames. There was also a significant difference between the two burn intervals at the green-up time frame for soil water infiltration rates. Prescribed burning did positively impact the infiltration of water on these East Texas soils, which may result in a decrease in runoff. The strength of the soil initially became weaker, or less compacted, but increased towards the end of the study. Soil aggregates can be related to soil strength, as both describe how well the soil may resist the changes of outside forces such as fire. Soil aggregates increased significantly over all time frames, showing prescribed burning increased the soil structure. The O-Horizon density did not follow trends normally associated with the O-Horizon after a fire, typically there is a significant decrease followed by a slow build up, this study found the opposite. Fuel loads were not measured during this study, but may have had an effect on soil physical and chemical properties such as soil water infiltration rates and nutrient availability.

Prescribed burns have been used to decrease the likelihood of a wildfire and increase some nutrients. This study found prescribed burning over a short-time frame to increase soil water infiltration rates by 53.68 percent from pre-burn to green-up time frames. If the study was extended for a number of years, and these same trends were found, this would indicate prescribed burning on these intervals is slowly increasing the soils ability to infiltrate water into the surface. Otherwise, the results found may be a short-term response to repeated burning treatments on the resilient soils found in East Texas. Although historically unburned sites were not measured as a control variable, these results may differ from sites which are not burned frequently or have lower burn intervals.

Soil water infiltration rates were compared to those recorded by NRCS, these infiltration rates are similar within both data sets. The total carbon percentage within the soil organic matter showed slight changes over time, mostly decreasing. This indicates prescribed burning does not have a negative impact of releasing carbon into the atmosphere, the carbon is still retained within the soil.

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APPENDIX

Table A8. P-Values between the time frames for soil physical properties

Variable	**Units**	**Pre-Burn to Post-Burn**	**Post-Burn to Green-Up**	**Pre-Burn to Green-Up**
Infiltration	cm min^{-1}	*0.02	0.47	*0.01
Soil Bulk Density	Mg m^{-3}	0.93	*0.06	*0.03
Particle Density	Mg m^{-3}	0.82	0.93	0.35
Pore Space	%	0.25	*0.10	0.24
Particle Volume	ml^3	0.29	*0.01	*0.09
MWC_s	g	*0.02	*0.06	0.47
VWC_s	g^3	*0.03	*0.01	0.75
MWC_o	g	0.20	*0.07	*0.05
O-Horizon	g m^{-2}	*0.01	0.81	*0.01
O-Horizon Depth	cm	*0.01	*0.01	*0.01
Soil Aggregates	g	*0.09	*0.06	0.35
2 mm	g	0.11	0.77	*0.01
1 mm	g	0.50	*0.03	0.25
0.5 mm	g	*0.08	0.29	0.34
0.25 mm	g	*0.05	0.94	*0.02
Soil Strength	kg cm^{-2}	*0.01	*0.01	0.12
0.0 cm depth	kg cm^{-2}	0.78	0.29	0.24
2.5 cm depth	kg cm^{-2}	*0.05	0.32	*0.01
Continued				

Variable	Units	Pre-Burn to Post-Burn	Post-Burn to Green-Up	Pre-Burn to Green-Up
5.1 cm depth	kg cm^{-2}	*0.01	0.15	0.37
7.6 cm depth	kg cm^{-2}	0.55	0.56	0.85
10.2 cm depth	kg cm^{-2}	*0.01	*0.07	0.61
12.7 cm depth	kg cm^{-2}	*0.01	0.13	0.52
15.2 cm depth	kg cm^{-2}	0.16	0.78	0.50

*Indicates a significant difference at P-Value of 0.1

Table A9. P-Values between the time frames for soil chemical properties

Variable	Units	Pre-Burn to Post-Burn	Post-Burn to Green-Up	Pre-Burn to Green-Up
Phosphorus	mg kg^{-1}	0.61	*0.01	*0.01
Potassium	mg kg^{-1}	*0.01	*0.01	0.29
Calcium	mg kg^{-1}	0.78	0.47	0.40
Magnesium	mg kg^{-1}	*0.10	*0.03	0.34
Sulfur	mg kg^{-1}	0.85	*0.01	*0.01
Sodium	mg kg^{-1}	0.72	0.14	*0.10
pH Water		0.37	*0.01	*0.01
Estimated CEC	cmoles kg^{-1}	0.18	0.86	*0.07
Electrical Conductivity	µS cm^{-1}	0.82	*0.01	*0.01
Carbon:Nitrogen Ratio		0.31	*0.02	0.14
Organic Matter	%	0.68	0.16	0.32
Total Carbon	%	0.68	0.16	0.32
Total Nitrogen	%	0.83	0.45	0.60
Nitrogen as Ammonium	mg kg^{-1}	*0.02	*0.03	0.94
Nitrogen as Nitrate	mg kg^{-1}	0.23	*0.02	0.14

*Indicates a significant difference at P-Value 0.1

Table A10. Soil pH during each time frame

Sub-Plot	Pre-Burn	Post-Burn	Green-Up
66.01	4.09	4.79	5.46
66.01-2	4.46	4.56	5.01
66.02	4.63	4.91	5.25
66.02-2	4.34	4.66	5.11
67.02-1	4.65	5.06	5.27
67.02-2	4.52	5.04	5.05
19.01	4.86	4.45	4.65
19.01-2	4.44	4.65	4.85
W01	4.10	4.51	5.50
W01-1	3.96	4.40	5.23
W02	4.86	5.18	5.36
W02-1	4.29	4.88	5.46
W03	4.43	5.02	5.55
W03-1	5.02	4.85	5.49
W04	3.39	4.95	5.84
W04-1	4.66	5.63	5.94
W05.1	4.22	5.16	5.75
W05.1-1	5.11	5.55	6.05
W5	4.23	4.44	5.52
W5-1	5.27	5.40	5.61
W7	4.73	4.07	5.57
W7-1	4.02	4.37	5.59
W8	4.63	4.08	5.12
W8-1	4.34	5.25	5.58
W11	6.20	6.65	6.33
W11-1	6.00	5.58	5.61
W12	6.09	5.14	6.38
W12-1	6.00	4.93	5.98
W13	6.14	5.17	6.15
W13-1	6.25	4.97	5.82
W14	5.6	5.59	4.89
W14-1	5.91	5.67	4.85
W15	5.95	5.33	5.37
W15-1	6.09	5.53	5.46
W16	5.91	4.78	5.81
W16-1	5.86	4.72	5.72
W17	5.93	5.17	5.14
W17-1	6.04	5.39	4.80

Table A11. Soil bulk density for each time frame measured in Mg m^{-3}

Plot Point	Pre-Burn	Post-Burn	Green-Up
66.01	1.19	0.87	0.99
66.01-2	1.19	1.64	1.59
66.02	1.07	1.32	1.73
66.02-2	1.98	1.32	1.41
67.02-1	1.55	1.48	1.33
67.02-2	0.95	1.21	0.93
19.01	1.41	0.86	1.00
19.01-2	1.37	1.05	1.30
W01	1.36	1.59	1.06
W01-1	1.59	1.80	1.05
W02	1.25	1.27	0.88
W02-1	1.42	1.40	1.11
W03	1.42	0.91	1.19
W03-1	1.31	1.47	1.11
W04	1.08	1.01	1.15
W04-1	1.15	1.41	1.06
W05.1	1.48	1.31	1.05
W05.1-1	1.47	1.04	1.03
W5	1.56	1.67	1.27
W5-1	1.36	1.15	1.53
W7	1.25	0.95	1.22
W7-1	1.54	1.75	1.66
W8	1.25	1.45	0.90
W8-1	1.19	0.89	1.15
W11	1.36	1.34	1.14
W11-1	1.20	1.50	1.30
W12	1.13	1.43	0.82
W12-1	1.34	1.58	0.95
W13	1.36	1.35	1.08
W13-1	1.25	1.16	0.90
W14	1.15	1.18	1.05
W14-1	1.05	1.07	1.89
W15	1.17	1.34	1.47
W15-1	1.21	1.48	1.10
W16	1.27	1.40	1.25
W16-1	1.38	1.15	1.21
W17	1.33	1.42	1.48
W17-1	1.33	1.41	1.33

Table A12.Total percentage of water stable soil aggregates for each time frame measured in g

Sub-Plot	Pre-Burn	Post-Burn	Green-Up
66.01	66.38	83.28	73.79
66.01-2	77.36	60.37	80.90
66.02	89.57	78.69	67.21
66.02-2	72.89	86.34	64.97
67.02-1	98.57	82.99	76.87
67.02-2	78.83	75.11	72.43
19.01	92.15	90.27	87.86
19.01-2	90.23	117.83	88.24
W01	69.60	82.12	85.93
W01-1	74.46	76.42	80.41
W02	85.57	81.99	81.99
W02-1	82.29	95.61	91.18
W03	71.90	77.92	79.24
W03-1	61.33	84.92	77.44
W04	83.09	87.73	90.79
W04-1	81.38	108.60	83.72
W05.1	82.04	89.33	89.99
W05.1-1	74.34	88.89	86.05
W5	67.40	68.00	83.23
W5-1	78.11	95.34	94.75
W7	74.28	84.33	79.67
W7-1	77.09	89.20	79.01
W8	74.61	87.88	78.09
W8-1	73.32	89.18	81.59
W11	89.01	82.23	84.73
W11-1	89.41	78.37	73.04
W12	92.27	83.42	85.13
W12-1	93.98	85.23	88.08
W13	96.82	77.54	81.29
W13-1	94.01	98.65	85.13
W14	96.86	94.53	79.43
W14-1	90.26	89.99	86.30
W15	90.15	83.77	75.05
W15-1	89.02	82.13	89.98
W16	92.77	71.73	80.84
W16-1	89.53	78.29	69.52
W17	88.89	70.30	76.03
W17-1	87.54	75.00	82.68

Table A13. 2 mm water stable soil aggregates percentage for each time frame measured in g

Sub-Plot	Pre-Burn	Post-Burn	Green-Up
66.01	52.82	80.82	64.46
66.01-2	71.76	53.78	73.69
66.02	74.10	76.26	63.59
66.02-2	62.11	84.30	61.48
67.02-1	90.39	72.09	74.63
67.02-2	69.32	67.73	58.16
19.01	51.46	24.23	31.21
19.01-2	27.03	39.10	29.49
W01	46.59	60.43	54.73
W01-1	59.72	54.03	49.53
W02	57.21	40.06	31.61
W02-1	71.34	59.62	39.27
W03	49.56	65.90	64.27
W03-1	40.59	57.75	56.67
W04	66.22	50.36	74.91
W04-1	56.33	50.70	43.93
W05.1	52.52	51.07	63.48
W05.1-1	56.13	31.64	36.77
W5	49.26	48.94	56.22
W5-1	64.02	34.52	31.28
W7	59.49	39.62	31.72
W7-1	67.90	47.23	58.03
W8	63.26	62.86	57.68
W8-1	61.75	43.39	49.30
W11	70.61	41.05	44.65
W11-1	54.34	42.93	32.96
W12	42.92	50.45	59.68
W12-1	60.47	45.82	59.62
W13	81.09	40.80	69.22
W13-1	83.42	53.72	67.07
W14	81.21	66.28	20.89
W14-1	56.22	47.51	39.91
W15	74.15	48.57	38.51
W15-1	74.12	57.97	62.00
W16	80.67	18.56	69.64
W16-1	36.86	29.17	55.86
W17	68.72	46.96	16.46
W17-1	57.13	45.85	71.99

Table A14. 1 mm water stable soil aggregates percentage for each time frame measured in g

Sub-Plot	**Pre-Burn**	**Post-Burn**	**Green-Up**
66.01	3.49	1.14	2.86
66.01-2	1.67	3.41	1.82
66.02	6.82	0.92	1.77
66.02-2	3.46	1.28	1.72
67.02-1	3.27	2.15	1.20
67.02-2	4.80	3.51	11.00
19.01	2.36	3.52	4.47
19.01-2	7.37	3.22	5.40
W01	2.73	3.48	5.95
W01-1	2.88	3.23	4.36
W02	11.43	14.01	9.09
W02-1	3.94	16.41	15.36
W03	7.49	5.12	5.64
W03-1	5.25	9.58	5.83
W04	5.54	13.31	4.13
W04-1	8.35	16.87	12.28
W05.1	5.10	6.31	3.70
W05.1-1	1.99	20.04	5.93
W5	5.84	5.12	4.62
W5-1	5.10	4.26	7.02
W7	4.32	9.69	15.98
W7-1	3.80	7.16	4.19
W8	4.34	5.48	5.65
W8-1	4.13	17.98	4.80
W11	3.64	9.56	6.81
W11-1	3.12	0.39	5.55
W12	3.42	6.36	4.04
W12-1	7.43	14.82	4.22
W13	3.95	6.75	2.53
W13-1	2.96	15.04	5.43
W14	1.67	1.74	1.09
W14-1	6.61	2.26	3.09
W15	2.63	2.27	3.63
W15-1	2.83	2.63	3.31
W16	0.10	11.14	1.86
W16-1	5.56	3.26	1.03
W17	3.51	4.05	2.80
W17-1	3.66	5.54	2.23

Table A15. 0.5 mm water stable soil aggregates percentage for each time frame measured in g

Sub-Plot	Pre-Burn	Post-Burn	Green-Up
66.01	1.90	0.57	2.58
66.01-2	1.62	1.18	0.55
66.02	4.45	0.49	0.83
66.02-2	2.17	0.05	0.72
67.02-1	2.05	2.42	0.68
67.02-2	3.21	1.96	1.81
19.01	10.10	14.55	31.86
19.01-2	32.44	62.04	29.20
W01	2.07	1.90	3.72
W01-1	0.91	2.08	3.34
W02	7.44	8.96	9.82
W02-1	2.94	13.44	31.18
W03	2.95	3.53	3.59
W03-1	1.86	5.80	3.45
W04	3.56	8.81	2.54
W04-1	7.22	9.87	7.70
W05.1	3.58	9.72	3.80
W05.1-1	1.83	28.28	2.99
W5	4.34	3.12	4.33
W5-1	4.78	42.22	2.93
W7	3.20	25.40	17.84
W7-1	2.16	1.21	2.16
W8	2.81	1.48	2.35
W8-1	3.17	4.18	2.70
W11	5.33	19.05	20.62
W11-1	5.58	23.26	25.71
W12	37.89	11.29	6.25
W12-1	5.74	1.80	12.30
W13	3.15	21.86	2.55
W13-1	3.36	1.69	3.70
W14	2.44	8.66	4.52
W14-1	13.85	0.88	1.31
W15	2.38	1.56	2.83
W15-1	2.32	1.32	1.16
W16	4.38	7.57	2.45
W16-1	21.57	1.58	0.46
W17	4.87	11.33	33.38
W17-1	1.94	4.27	3.29

Table A16. 0.25mm water stable soil aggregates percentage for each time frame measured in g

Sub-Plot	Pre-Burn	Post-Burn	Green-Up
66.01	8.17	0.75	3.90
66.01-2	2.32	2.00	4.84
66.02	4.20	1.02	1.01
66.02-2	5.14	0.70	1.05
67.02-1	2.85	6.33	0.36
67.02-2	1.49	1.91	1.45
19.01	28.22	47.98	20.32
19.01-2	23.40	13.47	24.15
W01	18.20	16.32	21.54
W01-1	10.95	17.08	23.18
W02	9.49	18.96	31.47
W02-1	4.07	6.14	5.37
W03	11.90	3.37	5.74
W03-1	13.62	11.78	11.50
W04	7.76	15.26	9.21
W04-1	9.49	31.16	19.81
W05.1	20.84	22.23	19.02
W05.1-1	14.39	8.94	40.36
W5	7.96	10.82	18.05
W5-1	4.20	14.33	53.52
W7	7.27	9.61	14.13
W7-1	3.23	33.61	14.63
W8	4.20	18.06	12.42
W8-1	4.26	23.63	24.79
W11	9.44	12.57	12.66
W11-1	26.37	11.80	8.82
W12	8.03	15.33	15.17
W12-1	20.34	22.78	11.94
W13	8.63	8.13	6.99
W13-1	4.26	28.21	8.93
W14	11.55	17.85	52.93
W14-1	13.58	39.35	42.00
W15	10.99	31.38	30.07
W15-1	9.76	20.20	23.51
W16	7.62	34.46	6.89
W16-1	25.54	44.29	12.17
W17	11.79	7.95	23.38
W17-1	24.82	19.33	5.16

Table A17. Particle density for each time frame measured in Mg m^{-3}

Sub-Plot	Pre-Burn	Post-Burn	Green-Up
66.01	2.20	1.97	2.47
66.01-2	2.15	2.09	1.99
66.02	2.06	2.07	2.06
66.02-2	2.16	1.96	1.82
67.02-1	2.20	2.04	2.22
67.02-2	1.96	1.95	1.93
19.01	2.52	2.20	2.51
19.01-2	2.48	2.31	2.13
W01	2.32	2.34	2.05
W01-1	2.41	2.16	2.40
W02	2.12	2.24	1.95
W02-1	2.26	2.37	1.80
W03	2.39	1.42	2.24
W03-1	2.24	2.17	2.16
W04	2.17	1.97	2.41
W04-1	1.97	2.34	2.23
W05.1	2.17	2.11	2.21
W05.1-1	2.11	2.25	2.19
W5	2.30	2.26	2.10
W5-1	2.13	2.20	2.47
W7	2.13	2.11	2.20
W7-1	2.37	2.31	2.43
W8	2.21	2.19	1.95
W8-1	2.06	2.10	1.88
W11	2.27	2.19	1.84
W11-1	2.28	2.01	2.17
W12	2.18	2.08	0.87
W12-1	2.29	2.58	2.30
W13	1.76	2.25	2.25
W13-1	2.10	1.58	2.05
W14	2.04	1.48	2.38
W14-1	2.05	2.42	2.31
W15	2.41	2.40	2.22
W15-1	1.90	2.17	1.82
W16	2.26	2.22	2.50
W16-1	2.20	1.91	1.96
W17	2.55	2.28	2.52
W17-1	1.85	2.49	2.38

Table A18. Particle Volume for each time frame measured in ml^3

Sub-Plot	Pre-Burn	Post-Burn	Green-Up
66.01	270.00	220.00	80.00
66.01-2	240.00	340.00	200.00
66.02	260.00	320.00	210.00
66.02-2	340.00	250.00	170.00
67.02-1	290.00	300.00	150.00
67.02-2	210.00	270.00	120.00
19.01	260.00	240.00	200.00
19.01-2	210.00	340.00	270.00
W01	200.00	340.00	340.00
W01-1	330.00	350.00	260.00
W02	260.00	240.00	180.00
W02-1	240.00	260.00	210.00
W03	250.00	320.00	260.00
W03-1	210.00	340.00	280.00
W04	220.00	240.00	240.00
W04-1	320.00	300.00	320.00
W05.1	260.00	310.00	300.00
W05.1-1	320.00	300.00	220.00
W5	240.00	370.00	270.00
W5-1	320.00	340.00	280.00
W7	230.00	180.00	210.00
W7-1	200.00	280.00	220.00
W8	260.00	380.00	200.00
W8-1	260.00	190.00	290.00
W11	300.00	280.00	260.00
W11-1	260.00	300.00	300.00
W12	260.00	280.00	200.00
W12-1	200.00	280.00	70.00
W13	300.00	300.00	120.00
W13-1	220.00	360.00	110.00
W14	220.00	400.00	220.00
W14-1	190.00	210.00	360.00
W15	200.00	280.00	300.00
W15-1	160.00	340.00	200.00
W16	140.00	280.00	60.00
W16-1	230.00	300.00	80.00
W17	160.00	240.00	270.00
W17-1	230.00	220.00	280.00

Table A19. Pore space for each time frame measured in %

Sub-Plot	Pre-Burn	Post-Burn	Green-Up
66.01	46.00	56.00	60.00
66.01-2	44.70	21.66	20.00
66.02	48.00	36.00	16.00
66.02-2	8.11	32.43	22.73
67.02-1	29.61	27.18	40.00
67.02-2	51.61	37.79	52.00
19.01	43.97	60.66	60.00
19.01-2	44.74	54.67	39.19
W01	41.18	32.00	48.01
W01-1	34.00	16.67	56.52
W02	41.18	43.13	55.00
W02-1	37.17	40.91	38.24
W03	40.48	36.00	46.72
W03-1	41.67	32.00	48.72
W04	50.00	48.94	52.00
W04-1	41.82	40.00	52.24
W05.1	31.58	38.00	52.53
W05.1-1	30.43	53.70	52.79
W5	32.20	26.00	39.60
W5-1	36.00	47.69	38.05
W7	41.33	54.77	44.74
W7-1	35.06	24.32	31.68
W8	43.48	33.80	53.92
W8-1	42.22	57.78	38.82
W11	40.00	38.86	38.39
W11-1	47.47	25.37	40.00
W12	48.00	31.03	4.76
W12-1	41.52	38.86	58.82
W13	22.68	40.00	52.00
W13-1	40.54	26.53	56.00
W14	43.59	20.00	56.00
W14-1	48.92	55.51	18.18
W15	51.46	44.00	33.92
W15-1	36.00	32.00	39.39
W16	44.00	36.94	50.00
W16-1	37.16	40.00	38.46
W17	48.05	37.82	41.30
W17-1	28.13	43.59	44.00

Table A20. O-Horizon for each time frame measured in g m^{-2}

Plot Point	Pre-Burn	Post-Burn	Green-Up
66.01	5.50	10.05	2.73
66.01-2	6.92	3.87	9.56
66.02	10.37	3.19	3.71
66.02-2	7.78	2.07	2.51
67.02-1	5.68	9.76	18.98
67.02-2	3.83	6.14	2.48
19.01	9.90	2.87	4.28
19.01-2	8.52	4.41	4.77
W01	6.10	3.30	2.38
W01-1	10.27	1.10	0.48
W02	5.06	2.32	2.48
W02-1	2.23	2.48	1.46
W03	6.20	0.54	1.76
W03-1	5.06	0.22	4.31
W04	9.40	5.99	4.32
W04-1	11.58	4.65	7.74
W05.1	5.88	1.36	3.42
W05.1-1	6.99	3.88	5.04
W5	10.65	2.36	2.31
W5-1	4.08	3.70	2.39
W7	5.52	2.52	1.51
W7-1	8.21	0.22	1.10
W8	5.08	2.90	2.96
W8-1	11.29	3.74	8.89
W11	7.36	5.85	5.89
W11-1	7.57	4.18	3.20
W12	3.39	4.42	5.78
W12-1	5.22	3.08	6.13
W13	6.39	7.03	3.67
W13-1	3.93	7.59	3.43
W14	7.26	8.31	3.82
W14-1	15.69	6.19	4.13
W15	5.19	8.43	8.27
W15-1	5.08	8.16	2.31
W16	2.50	6.08	3.54
W16-1	4.12	5.61	5.86
W17	3.14	5.55	4.45
W17-1	4.33	3.22	10.19

Table 21. O-Horizon depths for each time frame measured in cm

Sub-Plot	Pre-Burn	Post-Burn	Green-Up
66.01	6.00	0.25	1.00
66.01-2	3.00	0.25	2.50
66.02	4.00	0.25	0.50
66.02-2	3.00	0.10	0.50
67.02-1	3.50	0.25	2.50
67.02-2	3.00	0.25	1.00
19.01	3.50	1.00	2.00
19.01-2	4.00	1.00	1.50
W01	2.50	2.00	1.50
W01-1	3.00	0.50	0.50
W02	2.00	1.50	1.00
W02-1	1.00	2.50	0.50
W03	2.00	0.10	1.50
W03-1	2.50	0.10	1.00
W04	3.00	1.00	1.50
W04-1	3.50	1.50	2.50
W05.1	3.00	0.25	1.50
W05.1-1	2.50	0.25	2.00
W5	3.00	1.50	1.50
W5-1	1.00	1.00	1.50
W7	2.00	0.50	1.00
W7-1	3.00	0.25	0.50
W8	1.00	1.00	1.00
W8-1	3.00	1.00	2.00
W11	1.25	0.50	3.00
W11-1	1.50	0.50	1.00
W12	0.25	0.25	2.00
W12-1	1.25	0.50	2.00
W13	0.75	1.00	0.50
W13-1	0.50	3.00	2.50
W14	3.50	1.50	1.00
W14-1	7.00	1.50	1.50
W15	2.00	1.00	1.00
W15-1	3.50	1.75	0.25
W16	0.75	1.00	1.00
W16-1	1.25	0.50	0.50
W17	0.25	0.25	2.50
W17-1	0.75	0.25	2.50

Table A22. O-Horizon mass water content measured in g

Sub-Plot	Pre-Burn	Post-Burn	Green-Up
66.01	0.35	0.63	0.20
66.01-2	0.81	0.39	0.80
66.02	0.63	0.15	0.32
66.02-2	0.24	0.06	0.16
67.02-1	1.41	0.53	-0.85
67.02-2	1.84	0.28	0.14
19.01	0.70	0.38	0.32
19.01-2	0.50	0.20	0.17
W01	0.26	0.32	0.08
W01-1	0.23	0.35	0.23
W02	0.26	0.35	0.15
W02-1	0.35	0.43	0.18
W03	0.20	0.55	0.18
W03-1	1.18	0.53	-0.70
W04	0.18	0.15	0.16
W04-1	0.16	0.39	0.18
W05.1	0.25	0.25	0.16
W05.1-1	0.20	0.33	0.10
W5	0.21	0.31	0.25
W5-1	0.15	0.32	0.25
W7	0.37	0.37	0.28
W7-1	0.33	0.70	0.27
W8	0.21	0.36	0.23
W8-1	0.16	0.45	0.26
W11	0.13	0.07	0.11
W11-1	0.13	0.06	0.07
W12	0.09	0.13	0.29
W12-1	0.10	0.07	0.21
W13	0.14	0.27	0.26
W13-1	0.11	0.08	0.24
W14	0.17	0.07	0.10
W14-1	0.12	0.09	0.03
W15	0.17	0.20	0.14
W15-1	0.14	0.10	0.07
W16	0.07	0.12	0.22
W16-1	0.06	-0.26	0.24
W17	0.06	0.05	0.11
W17-1	0.05	0.03	0.26

Table A23. Soil mass water content measured in g

Sub-Plot	Pre-Burn	Post-Burn	Green-Up
66.01	0.29	0.28	0.34
66.01-2	0.24	0.30	0.30
66.02	0.28	0.26	0.24
66.02-2	0.28	0.24	0.31
67.02-1	0.24	0.27	0.33
67.02-2	0.38	0.26	0.35
19.01	0.03	0.14	0.09
19.01-2	0.03	0.11	0.11
W01	0.15	0.14	0.05
W01-1	0.13	0.17	0.02
W02	0.18	0.19	0.05
W02-1	0.15	0.17	0.07
W03	0.19	0.90	0.03
W03-1	0.17	0.21	0.03
W04	0.15	0.26	0.03
W04-1	0.16	0.21	0.04
W05.1	0.14	0.20	0.00
W05.1-1	0.20	0.21	0.04
W5	0.17	0.11	0.05
W5-1	0.18	0.22	0.03
W7	0.17	0.18	0.12
W7-1	0.16	0.16	0.03
W8	0.15	0.14	0.06
W8-1	0.20	0.22	0.07
W11	0.06	0.13	0.11
W11-1	0.04	0.12	0.10
W12	0.07	0.12	0.24
W12-1	0.05	0.09	0.21
W13	0.06	0.15	0.30
W13-1	0.07	0.10	0.27
W14	0.04	0.08	0.08
W14-1	0.06	0.09	0.09
W15	0.06	0.13	0.11
W15-1	-0.95	0.13	0.08
W16	0.04	0.12	0.18
W16-1	0.03	0.09	0.20
W17	0.05	0.11	0.10
W17-1	0.04	0.13	0.18

Table A24. Soil volumetric water content measured in g^3

Sub-Plot	Pre-Burn	Post-Burn	Green-Up
66.01	0.34	0.25	0.33
66.01-2	0.29	0.50	0.49
66.02	0.30	0.34	0.42
66.02-2	0.55	0.32	0.44
67.02-1	0.37	0.40	0.44
67.02-2	0.36	0.31	0.33
19.01	0.04	0.12	0.09
19.01-2	0.04	0.11	0.14
W01	0.21	0.22	0.05
W01-1	0.21	0.30	0.03
W02	0.23	0.24	0.04
W02-1	0.21	0.23	0.08
W03	0.27	0.82	0.03
W03-1	0.22	0.30	0.04
W04	0.17	0.26	0.03
W04-1	0.18	0.30	0.04
W05.1	0.21	0.27	0.00
W05.1-1	0.30	0.21	0.05
W5	0.26	0.18	0.07
W5-1	0.25	0.25	0.04
W7	0.21	0.17	0.15
W7-1	0.24	0.27	0.05
W8	0.19	0.21	0.05
W8-1	0.24	0.20	0.08
W11	0.08	0.17	0.13
W11-1	0.04	0.17	0.13
W12	0.08	0.17	0.20
W12-1	0.06	0.14	0.20
W13	0.08	0.20	0.32
W13-1	0.08	0.12	0.25
W14	0.05	0.10	0.08
W14-1	0.06	0.10	0.17
W15	0.08	0.18	0.16
W15-1	-1.15	0.19	0.08
W16	0.05	0.17	0.23
W16-1	0.05	0.11	0.24
W17	0.06	0.16	0.14
W17-1	0.06	0.18	0.23

Table A25. Nitrogen measured as ammonium in mg kg^{-1}

Sub-Plot	Pre-Burn	Post-Burn	Green-Up
67.02-2	8.52	2.69	5.11
67.02-1	7.25	3.25	4.96
66.02-2	4.50	3.26	3.06
66.02	7.22	13.88	3.35
66.01-2	4.01	4.28	2.31
66.01	4.23	35.71	17.69
19.01-2	8.11	3.64	2.27
19.01	3.11	16.50	2.38
W8-1	4.70	21.63	3.28
W8	7.32	2.33	5.31
W7-1	2.82	5.24	6.22
W7	15.06	31.06	2.28
W17-1	2.27	12.77	3.49
W17	2.92	10.30	1.76
W16-1	3.37	5.24	2.85
W16	4.79	2.99	5.17
W15-1	3.77	3.40	4.76
W15	2.93	2.78	6.92
W14-1	4.28	2.80	6.45
W14	5.16	10.96	5.40
W13-1	2.68	19.13	3.71
W13	3.14	3.72	3.10
W12-1	5.58	23.99	2.98
W12	3.17	8.02	2.36
W11-1	2.20	10.21	2.30
W11	2.21	10.93	3.02
W05.1-1	2.55	3.03	3.27
W05.1	6.00	6.47	1.81
W05-1	9.30	2.76	2.43
W05	2.32	5.50	5.22
W04-1	6.59	3.45	8.89
W04	4.45	3.87	6.78
W03-1	7.09	2.23	5.77
W03	2.51	1.76	5.87
W02-1	8.60	2.62	6.94
W02	5.33	2.82	6.40
W01-1	6.00	5.41	18.04
W01	5.06	4.84	9.18

Table A26. Nitrogen measured as nitrate in mg kg^{-1}

Sub-Plot	Pre-Burn	Post-Burn	Green-Up
67.02-2	0.15	8.74	3.98
67.02-1	--	4.26	0.71
66.02-2	0.25	--	0.26
66.02	5.15	18.34	--
66.01-2	--	--	--
66.01	0.59	55.84	3.72
19.01-2	3.83	7.97	--
19.01	7.20	0.62	--
W8-1	0.82	14.31	5.57
W8	3.74	3.48	0.64
W7-1	0.75	3.48	0.81
W7	71.05	16.71	--
W17-1	--	13.72	1.01
W17	0.27	9.63	5.62
W16-1	0.06	6.50	7.71
W16	0.60	3.87	0.80
W15-1	0.06	4.84	0.56
W15	5.38	5.64	2.40
W14-1	0.70	3.94	--
W14	1.06	13.87	--
W13-1	1.04	1.61	1.44
W13	0.95	12.92	0.25
W12-1	5.96	17.87	--
W12	0.95	0.50	--
W11-1	0.02	22.49	--
W11	1.02	2.11	--
W05.1-1	17.81	4.66	--
W05.1	5.36	13.17	--
W05-1	4.72	3.41	0.56
W05	13.03	21.58	3.02
W04-1	7.41	--	0.28
W04	15.69	--	--
W03-1	47.10	--	0.17
W03	14.06	--	0.05
W02-1	20.60	--	--
W02	5.83	--	--
W01-1	20.05	2.94	3.93
W01	5.05	5.91	2.98

Table A27. Phosphorus for each time frame measured in mg kg^{-1}

Sub-Plot	Pre-Burn	Post-Burn	Green-Up
67.02-2	4.45	4.99	3.70
67.02-1	3.29	2.63	2.84
66.02-2	1.70	4.64	2.43
66.02	6.78	3.23	2.28
66.01-2	2.42	3.98	4.25
66.01	3.93	4.28	2.60
19.01-2	12.98	6.40	10.56
19.01	8.11	6.35	4.49
W8-1	7.31	10.78	8.30
W8	9.26	4.77	9.44
W7-1	3.97	2.77	4.20
W7	13.40	5.31	14.73
W17-1	12.00	9.82	5.81
W17	14.45	19.73	10.79
W16-1	12.99	6.06	6.07
W16	13.03	5.56	7.41
W15-1	5.21	12.78	2.02
W15	5.42	10.47	2.93
W14-1	17.78	15.74	6.03
W14	6.80	7.17	7.15
W13-1	17.06	7.35	6.64
W13	15.66	12.83	4.31
W12-1	6.84	9.87	6.89
W12	11.39	5.81	7.07
W11-1	7.02	14.66	6.46
W11	8.57	17.12	8.86
W05.1-1	8.69	16.57	6.90
W05.1	7.04	7.02	7.63
W05-1	10.02	5.27	8.37
W05	4.84	6.20	4.84
W04-1	7.04	15.42	10.36
W04	6.67	13.01	10.04
W03-1	9.93	11.06	6.28
W03	5.95	11.84	7.70
W02-1	10.04	6.96	9.22
W02	9.01	11.93	6.73
W01-1	7.32	4.56	4.71
W01	5.49	15.76	6.40

Table A28. Potassium for each time frame measured in mg kg^{-1}

Sub-Plot	Pre-Burn	Post-Burn	Green-Up
67.02-2	43.26	73.95	73.59
67.02-1	39.94	57.64	39.15
66.02-2	42.02	71.58	22.85
66.02	51.66	66.96	35.55
66.01-2	19.21	59.67	25.94
66.01	27.67	66.25	20.48
19.01-2	56.69	34.92	29.95
19.01	38.93	37.92	27.28
W8-1	32.40	53.25	35.61
W8	30.58	27.89	24.90
W7-1	34.28	25.23	35.43
W7	47.07	33.12	52.07
W17-1	52.95	42.18	62.29
W17	45.48	52.73	49.87
W16-1	60.64	68.29	32.87
W16	56.10	60.98	28.83
W15-1	34.36	59.61	38.81
W15	39.23	57.05	50.23
W14-1	99.26	61.77	58.64
W14	34.57	31.35	59.78
W13-1	78.32	112.58	34.45
W13	97.62	98.63	59.88
W12-1	37.98	72.58	58.67
W12	51.31	68.88	54.32
W11-1	43.07	40.11	59.41
W11	38.02	72.24	66.66
W05.1-1	52.52	48.31	26.95
W05.1	35.79	38.19	37.90
W05-1	46.69	29.86	23.64
W05	29.09	35.03	27.98
W04-1	44.28	90.33	89.55
W04	38.17	61.38	42.97
W03-1	61.61	42.85	24.79
W03	29.13	35.13	32.02
W02-1	33.83	46.92	37.54
W02	46.72	54.10	33.54
W01-1	35.35	36.08	32.81
W01	30.32	39.42	33.01

Table A29. Calcium for each time frame measured in mg kg^{-1}

Sub-Plot	Pre-Burn	Post-Burn	Green-Up
67.02-2	358.13	428.65	462.73
67.02-1	389.27	293.30	351.52
66.02-2	277.38	398.14	220.41
66.02	596.43	350.02	191.35
66.01-2	174.14	281.88	118.90
66.01	234.30	576.73	110.51
19.01-2	424.25	321.13	311.59
19.01	796.41	454.92	207.66
W8-1	432.54	606.45	399.64
W8	419.96	291.91	445.07
W7-1	241.62	158.91	242.51
W7	484.07	104.68	740.67
W17-1	240.72	456.70	309.04
W17	312.35	472.63	305.56
W16-1	513.63	323.13	192.48
W16	482.22	294.17	313.84
W15-1	290.60	324.40	97.49
W15	315.55	384.60	132.73
W14-1	686.96	422.12	350.70
W14	264.89	199.03	534.17
W13-1	461.64	497.12	872.74
W13	525.25	606.17	270.45
W12-1	339.07	328.64	1209.04
W12	501.90	466.47	413.38
W11-1	275.66	351.00	307.63
W11	421.20	459.97	359.93
W05.1-1	731.82	705.61	436.67
W05.1	301.86	328.17	320.04
W05-1	830.36	612.94	491.93
W05	360.78	389.53	345.52
W04-1	539.34	670.72	640.94
W04	240.32	390.57	659.34
W03-1	596.80	505.81	446.01
W03	484.17	574.26	491.26
W02-1	454.02	400.10	650.91
W02	667.90	875.34	543.08
W01-1	264.08	503.17	224.94
W01	223.55	658.58	393.06

Table A30. Magnesium for each time frame measured in mg kg^{-1}

Sub-Plot	Pre-Burn	Post-Burn	Green-Up
67.02-2	57.38	75.27	90.41
67.02-1	60.42	55.03	55.21
66.02-2	38.50	64.89	32.04
66.02	91.03	71.88	37.28
66.01-2	35.07	54.68	33.71
66.01	33.52	85.17	23.78
19.01-2	55.53	43.22	45.20
19.01	84.73	54.51	37.33
W8-1	91.95	119.09	69.06
W8	82.49	85.11	73.86
W7-1	35.87	29.55	42.81
W7	79.30	31.29	130.86
W17-1	51.17	75.74	74.45
W17	62.85	86.58	54.07
W16-1	83.58	64.20	40.37
W16	88.96	62.47	63.19
W15-1	46.92	66.54	22.64
W15	69.67	70.31	32.26
W14-1	102.75	59.82	51.29
W14	41.02	31.24	71.83
W13-1	86.80	92.42	89.02
W13	73.86	125.16	62.23
W12-1	59.67	72.57	121.23
W12	77.49	99.75	69.02
W11-1	43.95	69.24	69.86
W11	60.91	98.30	70.79
W05.1-1	97.62	86.85	58.65
W05.1	53.22	56.29	53.59
W05-1	103.04	70.54	68.78
W05	55.50	75.20	54.89
W04-1	75.43	111.99	106.94
W04	54.03	78.65	86.14
W03-1	90.36	64.50	68.56
W03	59.56	76.74	76.68
W02-1	71.98	82.55	67.75
W02	114.44	118.66	77.36
W01-1	39.69	60.71	49.56
W01	39.55	84.69	47.04

Table A31. Sulfur for each time frame measured in mg kg^{-1}

Sub-Plot	Pre-Burn	Post-Burn	Green-Up
67.02-2	4.92	3.42	2.79
67.02-1	3.72	3.93	2.87
66.02-2	4.63	5.18	2.84
66.02	5.26	3.80	3.46
66.01-2	4.58	5.90	4.34
66.01	4.15	4.44	3.24
19.01-2	4.61	5.22	4.26
19.01	3.94	4.46	4.09
W8-1	5.11	4.58	3.92
W8	4.72	5.44	4.73
W7-1	4.83	3.78	3.95
W7	5.69	6.76	5.75
W17-1	4.96	6.50	3.53
W17	4.39	5.59	3.95
W16-1	5.33	5.47	2.74
W16	4.96	5.80	3.57
W15-1	3.65	4.70	2.60
W15	2.92	3.14	2.89
W14-1	5.58	2.56	2.87
W14	2.31	1.40	2.36
W13-1	2.95	3.75	3.33
W13	9.79	4.00	4.36
W12-1	4.15	3.90	4.61
W12	5.31	3.39	8.30
W11-1	3.70	3.04	3.71
W11	3.71	5.92	3.51
W05.1-1	4.40	6.04	4.00
W05.1	5.37	3.79	3.67
W05-1	6.96	4.20	4.41
W05	4.11	4.34	3.80
W04-1	5.01	6.35	4.18
W04	4.56	5.27	4.81
W03-1	5.57	5.63	3.49
W03	4.30	5.18	4.46
W02-1	5.47	5.58	4.41
W02	6.39	6.52	5.00
W01-1	4.12	3.88	3.22
W01	4.97	6.44	4.34

Table A32. Sodium for each time frame measured in mg kg^{-1}

Sub-Plot	Pre-Burn	Post-Burn	Green-Up
67.02-2	54.70	59.06	62.05
67.02-1	52.92	51.61	63.53
66.02-2	53.41	58.06	55.59
66.02	54.30	67.42	56.77
66.01-2	54.16	69.59	74.69
66.01	54.57	62.98	55.02
19.01-2	55.45	59.64	65.07
19.01	52.24	57.28	56.40
W8-1	64.88	56.85	53.32
W8	67.74	61.72	54.96
W7-1	56.78	56.44	63.49
W7	59.33	59.56	56.83
W17-1	55.65	56.21	50.52
W17	56.70	52.32	58.29
W16-1	52.23	60.16	58.88
W16	60.47	70.36	57.71
W15-1	52.08	58.87	52.83
W15	57.15	47.19	56.72
W14-1	57.99	56.70	54.83
W14	48.35	44.54	50.71
W13-1	59.43	61.83	54.85
W13	72.22	61.70	53.12
W12-1	57.01	55.00	63.17
W12	51.69	63.13	52.41
W11-1	56.72	53.09	48.35
W11	53.49	54.98	62.63
W05.1-1	51.95	64.50	53.46
W05.1	61.97	58.63	59.93
W05-1	68.01	43.83	57.49
W05	63.89	51.17	51.96
W04-1	63.91	63.73	59.72
W04	68.06	62.71	60.09
W03-1	69.29	67.03	57.63
W03	71.96	51.80	59.91
W02-1	64.87	59.12	52.07
W02	69.37	68.48	57.97
W01-1	66.05	63.95	50.49
W01	67.21	68.00	53.83

Table A33. Electrical conductivity for each time frame measured in $\mu S\ cm^{-1}$

Sub-Plot	Pre-Burn	Post-Burn	Green-Up
67.02-2	89.70	41.90	54.30
67.02-1	77.40	43.20	33.30
66.02-2	53.70	50.60	23.00
66.02	114.10	28.90	25.70
66.01-2	49.50	44.80	42.30
66.01	57.70	49.00	31.20
19.01-2	65.90	42.90	31.70
19.01	64.10	52.60	31.10
W8-1	46.70	65.50	46.20
W8	58.10	32.90	41.90
W7-1	24.40	19.38	24.10
W7	236.00	38.60	85.60
W17-1	42.80	82.20	49.50
W17	50.70	133.70	47.00
W16-1	65.40	44.60	25.20
W16	69.40	56.00	29.90
W15-1	59.90	158.10	20.40
W15	69.40	115.50	26.00
W14-1	81.70	98.30	54.00
W14	58.00	64.00	64.10
W13-1	57.40	52.40	39.20
W13	66.00	63.00	27.20
W12-1	51.50	48.40	70.80
W12	57.80	51.50	53.90
W11-1	43.40	121.60	39.30
W11	48.00	103.70	39.70
W05.1-1	79.30	221.00	32.60
W05.1	60.30	53.90	38.50
W05-1	75.30	75.60	49.40
W05	79.50	88.10	35.30
W04-1	73.50	135.30	67.40
W04	71.50	68.50	44.50
W03-1	181.00	136.80	40.90
W03	87.90	74.00	46.90
W02-1	121.20	46.20	48.10
W02	66.70	120.30	44.40
W01-1	102.00	42.40	36.80
W01	52.90	124.50	35.90

Table A34. Carbon nitrogen ratio for each time frame

Sub-Plot	Pre-Burn	Post-Burn	Green-Up
67.02-2	21.89	19.51	22.10
67.02-1	23.17	20.63	23.89
66.02-2	21.44	21.44	20.59
66.02	23.12	20.92	22.19
66.01-2	24.69	25.98	20.42
66.01	25.74	28.42	18.62
19.01-2	21.25	32.03	25.69
19.01	23.76	23.91	23.01
W8-1	23.27	22.26	23.27
W8	21.89	19.79	27.37
W7-1	27.32	22.12	20.08
W7	22.18	24.00	17.56
W17-1	23.39	23.69	16.34
W17	18.34	21.20	19.85
W16-1	21.36	18.02	16.70
W16	21.75	19.08	19.57
W15-1	23.53	18.82	15.03
W15	18.59	21.79	14.39
W14-1	19.51	18.43	12.20
W14	20.19	18.75	15.48
W13-1	22.23	17.18	17.93
W13	18.77	17.32	13.64
W12-1	19.35	20.04	14.88
W12	17.82	17.34	13.52
W11-1	19.41	21.10	24.25
W11	15.90	20.88	23.85
W05.1-1	21.47	16.38	18.77
W05.1	20.89	29.28	21.38
W05-1	19.87	21.20	18.08
W05	18.54	18.87	23.28
W04-1	17.65	18.41	19.30
W04	16.85	19.33	19.36
W03-1	18.89	20.69	26.04
W03	21.21	26.11	20.02
W02-1	16.10	19.98	19.99
W02	18.52	19.66	18.77
W01-1	16.59	28.47	20.95
W01	23.55	21.82	21.12

Table A35. Soil organic matter for each time frame measured in %

Sub-Plot	Pre-Burn	Post-Burn	Green-Up
67.02-2	5.06	4.88	7.67
67.02-1	4.81	3.22	4.37
66.02-2	2.48	4.96	2.57
66.02	5.94	3.65	2.34
66.01-2	2.51	6.92	3.69
66.01	3.25	8.73	2.15
19.01-2	3.81	2.79	3.93
19.01	4.27	2.63	2.02
W8-1	4.56	3.47	2.53
W8	3.40	2.42	5.20
W7-1	2.64	1.02	1.40
W7	3.86	2.56	5.79
W17-1	4.18	4.19	2.33
W17	2.90	5.28	4.15
W16-1	4.85	2.43	2.16
W16	6.03	2.33	2.74
W15-1	2.85	2.67	0.85
W15	2.11	2.56	1.12
W14-1	5.58	2.94	1.34
W14	2.41	2.06	2.29
W13-1	2.78	3.17	4.63
W13	4.31	4.03	1.54
W12-1	2.78	2.61	4.22
W12	3.25	3.17	2.27
W11-1	1.70	3.34	4.60
W11	1.67	4.21	5.09
W05.1-1	2.88	3.24	1.96
W05.1	2.16	1.77	2.11
W05-1	5.36	2.89	3.16
W05	1.77	2.23	1.78
W04-1	3.03	3.60	3.22
W04	1.42	3.03	2.78
W03-1	3.42	2.75	2.70
W03	2.28	4.27	3.20
W02-1	2.58	2.44	4.05
W02	4.10	5.50	3.25
W01-1	1.88	3.21	1.97
W01	2.80	5.55	2.88

Table A36. Soil organic matter carbon percentage for each time frame

Sub-Plot	Pre-Burn	Post-Burn	Green-Up
67.02-2	2.53	2.44	3.84
67.02-1	2.40	1.61	2.19
66.02-2	1.24	2.48	1.28
66.02	2.97	1.82	1.17
66.01-2	1.25	3.46	1.84
66.01	1.62	4.36	1.07
19.01-2	1.91	1.40	1.97
19.01	2.13	1.32	1.01
W8-1	2.28	1.74	1.27
W8	1.70	1.21	2.60
W7-1	1.32	0.51	0.70
W7	1.93	1.28	2.89
W17-1	2.09	2.10	1.16
W17	1.45	2.64	2.08
W16-1	2.43	1.22	1.08
W16	3.02	1.16	1.37
W15-1	1.42	1.33	0.43
W15	1.06	1.28	0.56
W14-1	2.79	1.47	0.67
W14	1.20	1.03	1.15
W13-1	1.39	1.59	2.31
W13	2.15	2.02	0.77
W12-1	1.39	1.30	2.11
W12	1.62	1.58	1.13
W11-1	0.85	1.67	2.30
W11	0.84	2.11	2.54
W05.1-1	1.44	1.62	0.98
W05.1	1.08	0.88	1.05
W05-1	2.68	1.45	1.58
W05	0.88	1.11	0.89
W04-1	1.52	1.80	1.61
W04	0.71	1.51	1.39
W03-1	1.71	1.38	1.35
W03	1.14	2.13	1.60
W02-1	1.29	1.22	2.03
W02	2.05	2.75	1.62
W01-1	0.94	1.60	0.99
W01	1.40	2.78	1.44

Table A37. Soil organic matter nitrogen percentage for each time frame

Sub-Plot	Pre-Burn	Post-Burn	Green-Up
67.02-2	0.12	0.12	0.17
67.02-1	0.10	0.08	0.09
66.02-2	0.06	0.12	0.06
66.02	0.13	0.09	0.05
66.01-2	0.05	0.13	0.09
66.01	0.06	0.15	0.06
19.01-2	0.09	0.04	0.08
19.01	0.09	0.06	0.04
W8-1	0.10	0.08	0.05
W8	0.08	0.06	0.10
W7-1	0.05	0.02	0.03
W7	0.09	0.05	0.16
W17-1	0.09	0.09	0.07
W17	0.08	0.12	0.10
W16-1	0.11	0.07	0.06
W16	0.14	0.06	0.07
W15-1	0.06	0.07	0.03
W15	0.06	0.06	0.04
W14-1	0.14	0.08	0.05
W14	0.06	0.05	0.07
W13-1	0.06	0.09	0.13
W13	0.11	0.12	0.06
W12-1	0.07	0.07	0.14
W12	0.09	0.09	0.08
W11-1	0.04	0.08	0.09
W11	0.05	0.10	0.11
W05.1-1	0.07	0.10	0.05
W05.1	0.05	0.03	0.05
W05-1	0.13	0.07	0.09
W05	0.05	0.06	0.04
W04-1	0.09	0.10	0.08
W04	0.04	0.08	0.07
W03-1	0.09	0.07	0.05
W03	0.05	0.08	0.08
W02-1	0.08	0.06	0.10
W02	0.11	0.14	0.09
W01-1	0.06	0.06	0.05
W01	0.06	0.13	0.07

Table A38. Estimated cation exchange capacity for each time frame measured in cmoles kg^{-1}

Sub-Plot	Pre-Burn	Post-Burn	Green-Up
67.02-2	6.18	10.32	10.24
67.02-1	7.34	7.22	7.80
66.02-2	5.59	8.33	9.97
66.02	7.44	8.35	7.13
66.01-2	5.91	9.46	7.78
66.01	5.14	10.26	7.52
19.01-2	4.87	4.38	5.28
19.01	5.37	3.83	3.56
W8-1	5.18	--	3.48
W8	4.43	4.26	6.75
W7-1	3.88	2.08	4.03
W7	3.71	4.07	--
W17-1	6.99	7.67	8.60
W17	6.43	7.78	7.93
W16-1	8.14	7.34	7.44
W16	9.02	7.44	9.23
W15-1	5.33	5.56	5.35
W15	5.38	5.11	6.19
W14-1	10.16	6.31	6.23
W14	5.41	4.08	7.28
W13-1	7.86	8.11	--
W13	8.32	9.65	7.84
W12-1	6.71	8.95	--
W12	7.43	9.14	8.65
W11-1	5.22	5.93	8.87
W11	5.38	7.79	9.74
W05.1-1	2.80	2.61	3.51
W05.1	3.17	2.41	3.35
W05-1	6.10	4.08	4.39
W05	1.88	2.38	3.08
W04-1	3.15	--	--
W04	2.23	3.91	4.62
W03-1	3.57	3.30	3.94
W03	3.56	5.75	4.46
W02-1	3.50	4.56	6.37
W02	6.53	6.06	4.67
W01-1	2.68	4.66	2.65
W01	4.11	6.08	4.87

VITAE

Cassady Pennington Dunson was born 1998 in Fort Worth, Texas. She grew up as the only child and daughter of Cliff and Ronda Pennington in Joshua, Texas. She attended Joshua ISD until she graduated from Joshua High School in 2016. After graduating high school, Cassady attended Angelo State University (ASU). At ASU, she was heavily involved in the agriculture department as she perused her undergraduate degree. She was inducted into three different collegiate honor societies while at ASU, Phi Kappa Phi, Alpha Chi, and Delta Tau Alpha. Cassady graduated from Angelo State University in 2019 with her Bachelor of Science in Natural Resource Management. After graduating, Cassady started attending Stephen F. Austin State University (SFASU) to work towards her goal of obtaining a Master of Science degree. Since being at SFASU, Cassady has worked diligently through adverse conditions and the world shutting down. She got married during this time to her amazing husband, who has supported her every day in achieving her goals. Cassady has spent countless hours working on collecting data, analyzing data and preparing for her thesis defense to graduate in August of 2021 with a Master of Science in Environmental Science.

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This thesis was typed by Cassady Pennington Dunson