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Impacts of the Chimney Tops 2 Wildfire on Soil and Stream Water Chemistry in the Great Smoky Mountains National Park

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To the Graduate Council:

I am submitting herewith a thesis written by Salley Reamer entitled "Impacts of the Chimney Tops 2 Wildfire on Soil and Stream Water Chemistry in the Great Smoky Mountains National Park." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Environmental Engineering.

John S. Schwartz, Major Professor

We have read this thesis and recommend its acceptance:

Michael E. Essington, Qiang He

Accepted for the Council:
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Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

Impacts of the Chimney Tops 2 Wildfire on Soil and Stream Water Chemistry in the Great Smoky Mountains National Park

A Thesis Presented for the

Master of Science

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Salley Anne Reamer

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Abstract

The 2016 Chimney Tops 2 wildfire in the Great Smoky Mountains National Park (GRSM) has given a unique opportunity to investigate the effects of wildfire in the eastern US, in a humid climate that rarely experiences wildfire. With ongoing water quality monitoring efforts in the GRSM and a 2010 soil study, pre-fire data were available for evaluation of the potential effects to water and soil chemistry. The acid-base status of soils and streams which govern transport, fate and effects of acidic pollutants were considered in this study. Soils from A/O and B horizons were compared based upon burn severity level, with categories of high burn, low/medium burn, unburned and reference. Collections began immediately after the fire and continued into 2019. A post-fire characterization was conducted for stream water and soil on chemical parameters that were also measured pre-fire. In burned soils, pH, percent base saturation, exchangeable base cations and nitrate were significantly lower than non-burned soils. Exchangeable acidity and Al were significantly greater in burned areas than non-burned areas. An increase in exchangeable Al coupled with a decrease in exchangeable base cations resulted in increased exchangeable acidity and decreased percent base saturation in burned soils. These soil impacts could affect the regrowth of sensitive plant species due to loss of available nutrient cations and increased Al. The water samples showed consistent decreases in pH, conductivity and acid neutralizing capacity (ANC) post-fire, at all sites, burned and reference. The most significant change in stream water was a decrease in ammonium in burned watersheds, however the decline in pH and ANC remains unexplained based on this study's measured parameters. This study contributes valuable information noting the lack of post-fire export of sulfate and nitrate in streams, and generally aligns with the few studies published on responses of forest fires on soil and stream chemistry in humid, acidic environments. The relationships identified on the response of soil and stream chemical properties to burn severity will inform understanding of patterns and timing of revegetation and recovery of the ecosystem from wildfire as well as the role of wildfire in exacerbating effects of acid deposition.

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List of Abbreviations

ANC:	Acid Neutralizing Capacity
BAER:	Burned Area Emergency Response
BARC:	Burned Area Reflectance Classification
%BS:	Percent Base Saturation
CT2:	Chimney Tops 2 Fire
DC:	Dudley Creek Watershed
EBC:	Exchangeable Base Cations
ECEC:	Effective Cation Exchange Capacity
GIS:	Geographic Information System
GRSM:	Great Smoky Mountains National Park
IC:	Ion Chromatography
ICP:	Inductively Coupled Plasma Spectroscopy
LC:	LeConte Creek Watershed
MC:	Moisture Content
NPS:	National Park Service
OM:	Organic Matter Content
TA:	Total Acidity
TS:	Total Sulfur
WPLP:	West Prong Little Pigeon Watershed

I. INTRODUCTION

Wildfires are more prevalent in the western US compared to the East, and as a result impacts of fire on soil and stream water chemistry have been studied to a greater extent in those regions (Earl & Blinn, 2003; Waksom et al., 2014; Murphy et al., 2006; Bormann et al., 2008). However, it would be expected that soil and water impacts from wildfires would differ between the southeastern and western parts of the US due to dissimilarities in climate and biogeographic factors. The southeastern US has a humid sub-tropical climate with evenly disturbed rainfall throughout the year and forested land cover consisting mostly of dense hardwoods (Ingram et al., 2013; USDA Forest Service FIA, 2013). In contrast, the western US is mostly semi-arid and a Mediterranean continental climate with hot and dry summers, and forested land cover consisting mostly of conifers.

In the western US, studies examining the impacts of wildfire on soil and stream water chemistry have shown elevated concentrations of inorganic N immediately following wildfires (Earl & Blinn, 2003; Murphy et al., 2006). Wildfires have caused increased sediment erosion from burned land with a lack of ground cover, which threatens waterways and wildlife when sediment, ash and excess nutrients readily enter waters under increased runoff (Barkley, 2013; BAER, 2017; Ice et al., 2004). Significant loss of C (up to 50%), N and organic matter and increased pH have been common responses of soils from western fires (Baird 1999; Murphy et al., 2006; Bormann et al., 2008). Studies in the western US tend to focus on C and N, with little attention to other nutrients, such as S and cations, which are important in montain soils in the eastern United States such as the Great Smoky Mountains National Park (GRSM) (Gonzalez, 2018; Cai et al., 2010).

Contrary to the West, the eastern US experiences less prevalence and shorter periods of drought, land is more densely populated and fire suppression has long occurred to protect developed lands (Melvin et al., 2012; Fesenmyer & Christensen, 2010; Brose et al., 2001). A few studies have focused on prescribed burns in this region, but none on wildfires. High intensity prescribed fire has been shown to increase the occurrence of oak in the understory of Appalachian forests, increase herbaceous layer diversity, while reducing flammable fuels without negatively impacting pine or oak populations (Elliott et al., 2009; Vose et al., 2016). Knoepp et al. (2012) studied prescribed fire in the southern Appalachian Mountain region and found that the understory and overstory both experienced large vegetation losses. Soil Ca was not impacted by fire, however effective cation exchange capacity declined significantly in surface and subsurface soils, and exchangeable Al increased over time at some sites (Knoepp et al., 2012). One study showed an increase in NH_4 immediately following fire, with a return to normal levels within 10 months (Knoepp et al., 2009). Understanding regional differences in biogeochemical responses is critical to interpreting the effects of an emerging disturbance, wildfire, on the long-term recovery of ecosystems from acid deposition, which is more prevalent in the eastern US.

Decades of acid deposition in the eastern US has resulted in the acidification of soils and streams where the base-poor surficial geology dominates the landscape (Sullivan et al., 2007; Ryan et al., 1989; Driscoll et al., 2001; Baker et al., 1991). Streams in the GRSM, underlain by sandstone geology, have been impacted by acid deposition, where baseflow pH values range approximately from 5.0 to 6.7, but decreases as low as 4.0 during storm events (Robinson et al., 2008; Neff et. al., 2013). During stormflow, significant declines in stream pH are primarily associated with increases in sulfate (Cook et al., 2004). However Deyton et al. (2009) found that other causes, such as nitrate, soil depletion of available base cations and organic acids, can also contribute to episodic acidification. They also found that dominant causes of stormflow acidification were watershed specific and varied seasonally.

High elevation watersheds in the GRSM have been classified as Stage 2 Nitrogen saturation, indicating that atmospheric N deposition exceeds vegetative assimilation resulting in elevated nitrate export of in streams (Van Miegroet, 2002; NPS, 2019a). Prior to marked decreases in S and N deposition in 2008, Cai et al. (2010) estimated that approximately 60% of atmospheric sulfate deposition was retained in soils at a high-elevation watershed. Although there has been substantial decrease in atmospheric S deposition since 2008, stream sulfate concentrations have remained relatively constant (Schwartz et al., 2014, 2019). Watershed sulfate retention is thought to be due to soil adsorption. Indeed it is anticipated with a decrease in sulfate deposition, there would be a resulting increase in stream sulfate (Cai et al., 2010, 2012; Rice et al., 2014). However, this pattern has not occurred (Schwartz et al., 2019). Recent evidence from Gonzalez (2018) suggests that S is largely bound in soil organic matter which might explain its continued retention. With decreases in sulfate and nitrate deposition, base cations on soil exchange sites and in streams appear to be playing a large role in controlling the acid-base status of watersheds in the GRSM. Watershed system models applied to predict long-term trends in stream chemistry demonstrate the complexity of biogeochemical reactions and controls, and that stream recovery may take decades in the GRSM (Zhou et al., 2015; Fakhraei et al., 2017). Model understanding can be tested with extreme disturbance, such as a wildfire, and subsequent monitoring.

With the significant decline in sulfate and nitrate deposition observed in the GRSM, and the probable large sink for these chemical constituents stored in soil organic matter, full and partial burning of surface (A/O) soil could alter and release these constituents. In addition, nutrient cations assimilated by vegetation or retained by soil organic matter could also be released by burning, particularly K (Raison, 1979; Bayley et al., 1992).

The Chimney Tops 2 (CT2) Wildfire impacting the GRSM provided a rare opportunity to study these biogeochemical transformations. New knowledge could be gained on the impacts of wildfire in forested lands in eastern US and how this disturbance could alter the recovery of soil and stream water from remnant impacts from acid deposition. The CT2 wildfire started five days before intense, dry winds occurred on the morning of 28 November 2016 which expanded the fire into the city of Gatlinburg. The CT2 wildfire burned an area of 72.7 km^2, about 44.5 km^2 being within GRSM. The long-term GRSM Water Quality Monitoring Program provided historic stream chemistry data, and a study by Grell (2010) provided some limited soil chemistry data in the CT2 Fire burn footprint.

The study objectives were to: 1) investigate the biogeochemical impacts of wildfire by examining changes in soil chemistry between burned and unburned lands, and concentrations and export of acid anions, ammonium, base cations, and dissolved metals from streams in the burn footprint; and 2) describe any changes in biogeochemical processes within the historic context of a forested, base-poor landscape affected by decades of acid deposition. Recognizing the climate and biogeographic characteristics of the southeastern US, this study addressed the following hypotheses of wildfire effects: 1) C, S, and N will be lost from soil, and with the loss of organic matter, exchangeable base cations will be reduced; 2) ion concentrations in streams, including sulfate, nitrate, ammonium and base cations, will be elevated due to releases from soil, however this perturbation will be short-lived as materials released from soil following wildfire are flushed from the watersheds and as regrowing vegetation quickly assimilates available nutrients; 3) stored S in soils from decades of acid deposition, is expected to be released from soil increasing stream losses, although stream pH is expected to remain unchanged due to a compensatory increase in base cation export; and 4) chemistry will only be affected in smaller streams in the burn footprint, and these effects will be diminished when diluted by waters from unburned watersheds.

II. METHODS

A. Study Site Description

The CT2 fire occurred within the GRSM (Figure 1). The GRSM consists of 2,114.2 km^2 located between North Carolina and Tennessee. Its elevation ranges from 266.7 m to 2,024.8 m at Clingman's Dome (NPS, 2017). The climate is varied due to the large elevation range. At lower elevations, in the general vicinity where the fire occurred, the climate is moderate year round, with about 55 inches of average annual precipitation including some snow events in winter (NPS, 2019b). Typical monthly average temperatures range from 4.2 °C in January to 23.1 °C in July at low elevations, and -2.8 °C in January to 15 °C in July at high elevation (NPS, 2019b). The lower elevations lie within a humid mesothermal climate and support deciduous forest vegetation. During the fall of 2016 extreme drought conditions persisted in the southeast US, and an unusual weather front with dry, high winds on the morning of November 23, 2016 facilitated the CT2 fire. Approximately 44.5 km^2 within the GRSM, roughly 2.1% of the total park area was burned during the CT2 fire. The fire occurred in the north-central area of the park, and only spread within the portion of the park in Tennessee, from the Chimney Tops geological feature southward into Gatlinburg, Tennessee. The study area included the burn portions within and just outside the GRSM with the collection of soil and stream water samples.

The spatial location of different soil complexes in the burn area were obtained from the GRSM Soil Survey Geographic database (Appendix A). Through the use of ArcGIS, the dominant soil complexes throughout the sampling sites selected were (in order of most common to least): Cataska-Sylco, Soco-Stecoah, Spivey-Santeetlah-Nowhere, Ditney-Unicoi, Luftee-Anakeesta, Rosman-Reddies-Urban, Dellwood-Smokemont, Junalaska-Brasstown, Breakneck-Pullback, Junalaska-Cataska, Rock outcrop-Luftee and Rock outcrop-Unicoi. A complete list of soil types present and the associated taxonomic classifications can be found in Appendix A2.

Soil samples at each collection site were separated by horizon between A/O and B at sites when both horizons were present. The horizons were separated by characteristics visually by color; the depth increments per horizon varied with soil type at each site. Sites were selected in part to overlap with Grell (2010) sampling sites, for use of historic soil data (Appendix B).

Water sampling sites were selected in coordination with routine sampling collections by the GRSM. These sample locations were part of the GRSM water quality monitoring program in which historic, pre-fire water quality data were available. This on-going monitoring program dates back to 1993 with various sampling locations and frequencies with the priority objective to quantify trends in stream acidification due to acid pollutant deposition (Cai et al., 2011a; Schwartz et al., 2014).

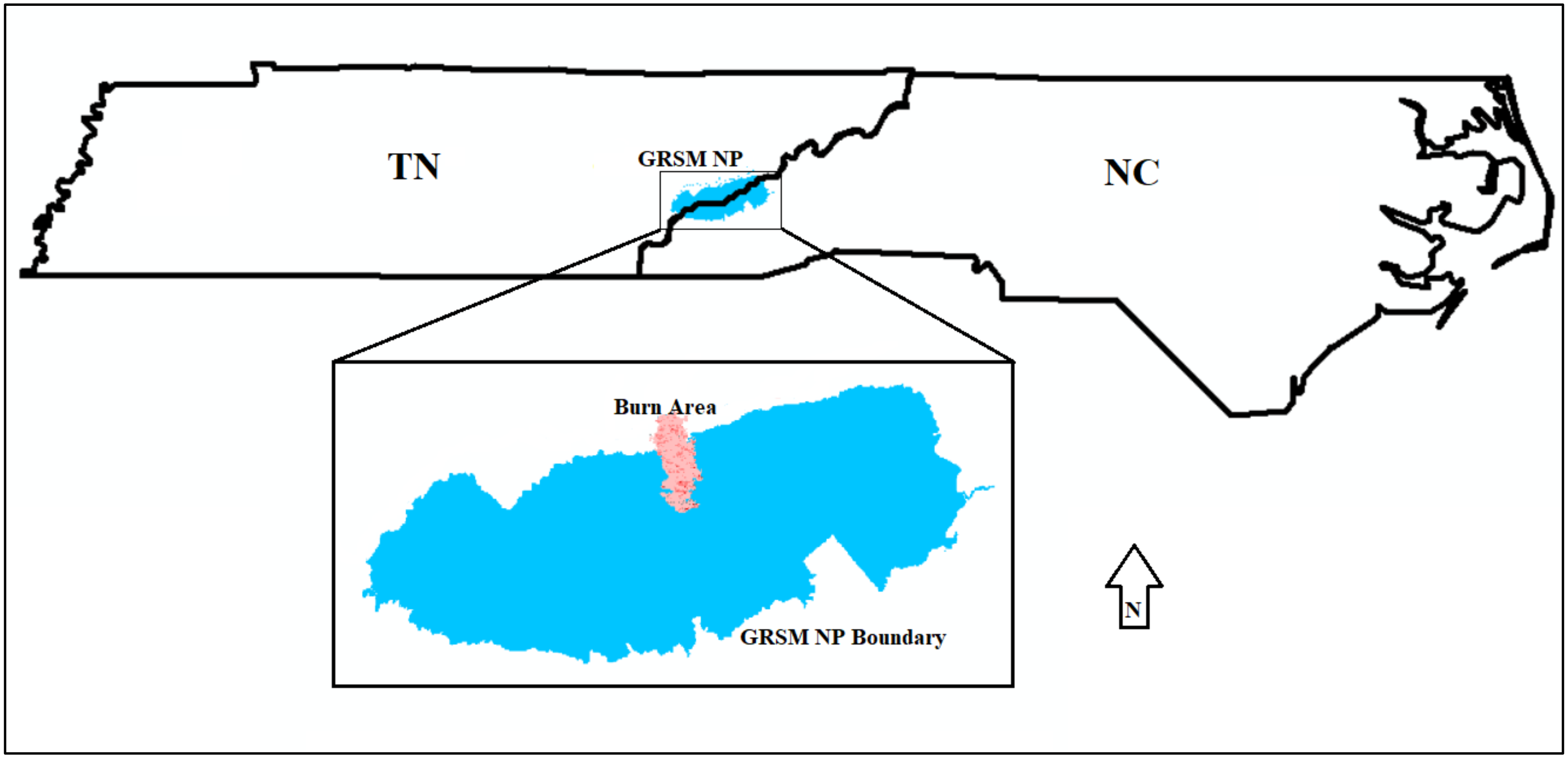

Figure 1. Location of the Chimney Tops 2 wildfire burn area within the Great Smoky Mountains National Park (GRSM) and GRSM location within Tennessee and North Carolina state boundaries.

B. Soil and Water Sample Collection

A total of 30 soil sample sites were selected in or immediately adjacent to the GRSM and in and around the fire footprint (Figure 2). More detailed maps of the specific burn areas are included in Appendix C. Sites were classified by four categories of burn severity including: high burn, low/medium burn, unburned, and reference areas. The unburned areas were within the fire area but did not burn, whereas the reference sites were outside the burn area as a control. The burn level in each area was determined using the NPS Geographic Information System (GIS) layer 'Burn Severity Resulting from Chimney Tops 2 Fire' (GRSM_GIS, 2016). The NPS used Burned Area Reflectance Classification (BARC) images and field surveys by the Burned Area Emergency Response (BAER) Team to create this map examining factors including char depth, organic matter loss, altered color and structure and reduced infiltration (Appendix D). The sites were randomly selected within each burn level using GIS ArcMap. Each site selected in GIS represented a 90 by 90 m plot, within 300 m of a road or trail for access. Sites were inspected before collections began to ensure safe access was available. Soil site locations are listed in Table 1, with level of burn severity, location, watershed and collection dates indicated. Science research permits through the NPS were accepted for the soil collections from April 2018 through August 2019. NPS permit numbers were: GRSM-2019-SCI-2076 and GRSM-2019-SCI-2024.

Initially, 20 sites were selected for the study with 10 in the natural category and 10 in the exurban category. Of the 10 sites selected in each category, 3 were in high burn areas, 3 were low/medium burn severity, 3 were unburned and 1 was a reference site (Figure 2). The first round of collections took place between April and October of 2018, with a total of four collections at each of the original 20 soil sampling sites. Two of the unburned sites were located adjacent to US Highway 411 (site RS411 and site PL441). A key site condition to note is that during winter snow conditions, historically the GRSM used a dolomite chat for road traction enhancement. A second set of samples were collected in May and June of 2019, one more collection was completed at the initial 20 sites in summer 2019, in addition to 2 collections at the 10 new sites. These sites were added in order to incorporate additional sites at the high burn level and unburned level, and to include 6 sites with historical soil data studied in 2010 that were near or within the burn footprint. Grell (2010) previously characterized soil chemistry in the GRSM. One site studied in the Road Prong (RP3) watershed was in the burn footprint. Five other sites included two in the Road Prong watershed (RP1, RP2) just outside the burn footprint, and three in Walker Camp Prong (WCP1, WCP2, and WCP3) within 3-6 km from the burn footprint (Figure 3). Though limited, soil chemistry data from the sites sampled by Grell (2010) were used for a separate pre- and post-fire analysis.

The same sampling technique was used for all six collections. From the center of each plot, a bean bag was thrown in a random direction and the landing location was designated the center of the collection area. Sites were collected for the A/O and B horizons. Some sites within the burn area did not have an A/O soil horizon as soil rich in organic matter content was burned off during the fire, most commonly in sites classified as high burn. During each collection effort, 10 random soil samples were taken per site per horizon and then pooled. Samples were collected using a clean 2.5-cm diameter stainless steel corer, which was rinsed with DI water after each use. Collected soil samples were immediately transported back to the University of Tennessee in coolers and then stored at 2-6 °C in a laboratory walk-in cold room prior to chemical analyses.

The water sampling sites were selected within or near the CT2 fire footprint in the GRSM. A total of seven sites were selected, all with historic water quality data (Figure 3; Table 2). Field grab samples were collected by the GRSM staff immediately following the fire, one week post-fire, and then on a bimonthly basis, ending November 2019. A total of 14 collections were completed. Samples were collected following standard US Geological Survey sampling protocols (USDA, 2009). Water samples were transported to the University of Tennessee in coolers, and then stored at 2-6 °C in a laboratory walk-in cold room prior to chemical analyses. Historic water quality data were obtained from the NPSTORET database. The historic data consisted of observations from study sites dating back to 1993. The water was analyzed for electrical conductivity (EC), pH, acid neutralizing capacity (ANC), chloride, nitrate, sulfate, NH_4, Na, K, Mg, Ca, and Al.

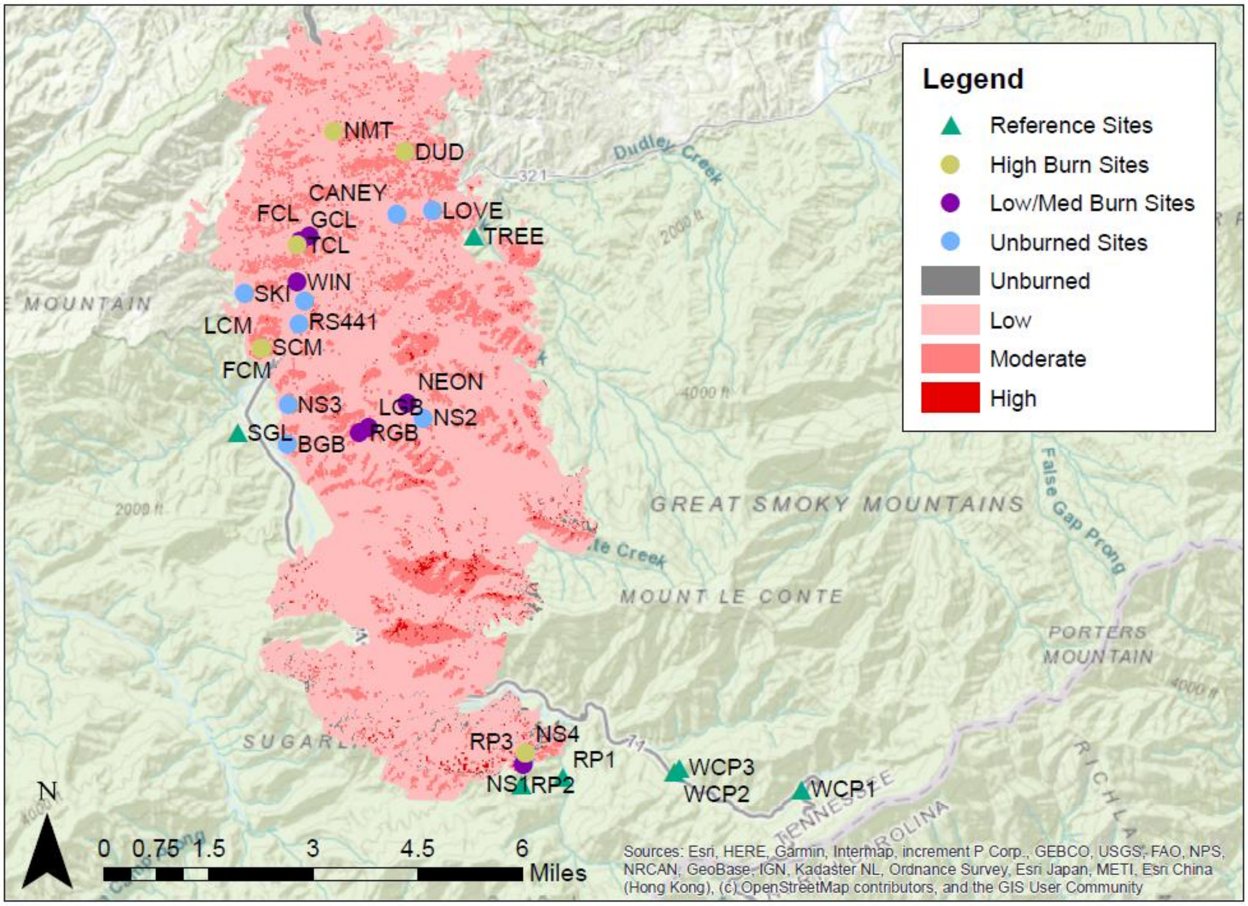

Figure 2. *Locations of all 30 soil sampling sites in Great Smoky Mountains National Park and the city of Gatlinburg, Tennessee. Study sites were classified into four burn severity categories; 1) unburned, 2) low/med burn, 3) high burn, and 4) reference.*

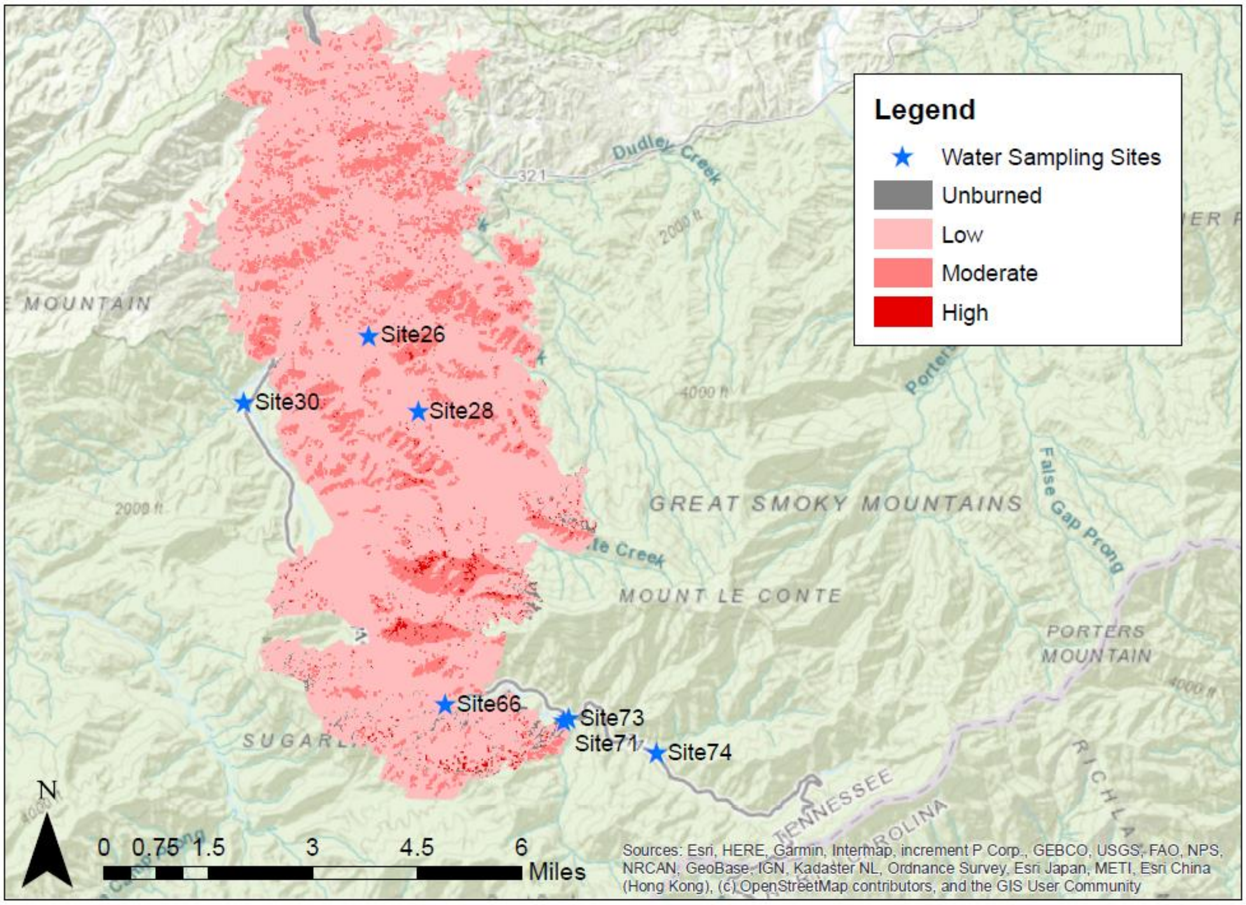

Figure 3. *Locations of seven water quality sampling sites in Great Smoky Mountains National Park, Tennessee.*

Table 1*. Site ID names, latitude and longitude of soil sampling locations, burn severity, watershed and collection dates. Sites sampled in 2018 and 2019 included.*

Site ID	North Latitude (deg)	West Longitude (deg)	Burn Level	Watershed*	Dates Collected (month/year)
DUD	35.73017	-83.50323	High Burn	DC	5/18, 6/18, 7/18, 10/18, 4/19
FCM	35.69720	-83.53287	High Burn	WPLP	5/18, 6/18, 7/18, 10/18, 4/19
LCM	35.69720	-83.53287	High Burn	WPLP	5/18, 6/18, 7/18, 10/18, 4/19
NMT	35.73374	-83.51797	High Burn	WPLP	5/18, 6/18, 7/18, 10/18, 4/19
NS4	35.6290	-83.4782	High Burn	WPLP	5/19, 6/19
SCM	35.69720	-83.53287	High Burn	WPLP	5/18, 6/18, 7/18, 10/18, 4/19
TCL	35.71447	-83.52560	High Burn	WPLP	4/18, 6/18, 7/18, 10/18, 4/19
FCL	35.71596	-83.52303	Low/Med Burn	WPLP	4/18, 6/18, 7/18, 10/18, 4/19
GCL	35.71513	-83.52498	Low/Med Burn	WPLP	4/18, 6/18, 7/18, 10/18, 4/19
LGB	35.68377	-83.51074	Low/Med Burn	LC	4/18, 6/18, 7/18, 10/18, 4/19
NEON	35.68788	-83.50272	Low/Med Burn	LC	4/18, 6/18, 7/18, 10/18, 4/19
RGB	35.68292	-83.51270	Low/Med Burn	WPLP	4/18, 6/18, 7/18, 10/18, 4/19
RP3	35.6271	-83.4787	Low/Med Burn	WPLP	5/19, 6/19
WIN	35.70831	-83.52558	Low/Med Burn	WPLP	4/18, 6/18, 7/18, 10/18, 4/19
BGB	35.68099	-83.52755	Unburned	WPLP	5/18, 6/18, 7/18, 10/18, 5/19
CANEY	35.71959	-83.50490	Unburned	DC	5/18, 6/18, 7/18, 10/18, 4/19
LOVE	35.72033	-83.49750	Unburned	DC	4/18, 6/18, 7/18, 10/18, 4/19
NS1	35.6277	-83.4785	Unburned	WPLP	5/19, 6/19
NS2	35.6854	-83.4995	Unburned	LC	5/19, 6/19
NS3	35.6877	-83.5275	Unburned	WPLP	5/19, 6/19
PL441	35.70517	-83.52405	Unburned	WPLP	5/18, 6/18, 7/18, 10/18, 4/19
RS441	35.70132	-83.52521	Unburned	WPLP	5/18, 6/18, 7/18, 10/18, 5/19
SKI	35.70634	-83.53653	Unburned	WPLP	5/18, 6/18, 7/18, 10/18, 4/19
RP1	35.6249	-83.4706	Reference	WPLP	5/19, 6/19
RP2	35.6237	-83.4792	Reference	WPLP	5/19, 6/19
SGL	35.682934	-83.53795	Reference	WPLP	5/18, 6/18, 7/18, 10/18, 5/19
TREE	35.71607	-83.48904	Reference	RF	4/18, 6/18, 7/18, 10/18, 4/19
WCP1	35.6229	-83.4212	Reference	WPLP	5/19, 6/19
WCP2	35.6259	-83.4475	Reference	WPLP	5/19, 6/19
WCP3	35.6265	-83.4465	Reference	WPLP	5/19, 6/19

*WPLP = West Prong of the Little Pigeon, DC = Dudley Creek, LC = LeConte Creek, RF = Roaring Fork

Table 2. *Water quality sampling locations: site ID names, latitude and longitude, burn severity level, elevation, watershed, drainage area, area burned and collection dates.*

Site ID #	**Site Name**	**North Latitude (degrees)**	**West Longitude (degrees)**	**Elevation (m)**	**Drainage Area (ha)**	**Area Burned (ha)**	**Area Burned (%)**	**Watershed***	**Dates Collected (month/year)**	**Soil Sites Within Watershed**
26	LeConte Creek at boundary	35.6994	-83.5105	481.6	218.4	217.9	99.8%	LC	1/17, 1/18, 7/18, 11/18	LGB
28	LeConte Creek at Uplands	35.6866	-83.5005	593.8	575.9	272.9	47.4%	LC	12/16, 1/17, 3/17, 1/18, 7/18, 11/18	NS2
30	West Prong Little Pigeon at Headquarters	35.6882	-83.5367	442.3	1798.3	1091.0	60.7%	WPLP	12/16, 1/17, 3/17, 1/18, 7/18, 11/18	BGB
66	West Prong Little Pigeon at Chimneys Picnic Area	35.6372	-83.4948	816.6	3439.8	574.0	16.7%	WPLP	1/17, 3/17, 1/18, 7/18, 11/18	NS1, NS4, RP1, RP2, RP3, WCP1, WCP2, WCP3
71	Road Prong above barrier cascade	35.6344	-83.4703	1038.2	828.3	21.6	2.6%	WPLP	1/17, 3/17, 1/18, 7/18, 11/18	NS1, RP1, RP2, RP3
73	Walker Camp Prong above Road Prong	35.6348	-83.4693	1037.8	2052.7	0.0	0.0%	WPLP	1/17, 3/17, 1/18, 7/18, 11/18	WCP1, WCP2, WCP3
74	Walker Camp Prong above Alum Cave Creek	35.6291	-83.4510	1177.1	742.8	0.0	0.0%	WPLP	1/17, 3/17, 1/18, 7/18, 11/18	WCP1, WCP2, WCP3

*WPLP = West Prong of the Little Pigeon, DC = Dudley Creek, LC = LeConte Creek, RF = Roaring Fork

C. Laboratory Analysis of Soil and Water

Soil Laboratory Analysis Methods: Physical and Chemical Properties

The collected soil samples were prepped for physical and chemical analyses by first removing gravel and debris by passing the samples through a 2-mm sieve, discarding the gravel and debris. The soil collections were well mixed and the soil replicates were taken from the well mixed composite soil. Soil at this stage, sieved of debris but not dried, is referred to as field moist soil. Soil samples were prepared for laboratory analyses by being left to dry in a laboratory fume hood for 72 hours up to one week, depending on the moisture level of the collected soils. The resulting soils are referred to as 'air dry' samples. The air dry samples were stored at room temperature. Two replicates per parameter were run for each soil sample for quality control and assurance.

The physical and chemical analyses conducted on the soil samples for this study included: soil pH (deionized water and $CaCl_2$), moisture content (MC), organic matter content, exchangeable base cations (EBC), which include Ca, Mg, K, Na, exchangeable nitrate, sulfate and ammonium, exchangeable Al, total acidity (TA), effective cation exchange capacity (ECEC), percent base saturation (%BS), total sulfur (TS), percent C and percent N. Methods are summarized in Table 3, and described in more detail in Appendix E. Solute/leachate concentrations were measured with a Thermo-Scientific Ion Chromatogram System 1100 (IC) and a Thermo-Scientific iCAP-DUO 7400 inductively coupled argon plasma (ICP-OES). TS analysis was completed for a subset of soil samples, which consisted of all samples collected in 2017 along with 6 samples from 2018 collections and 11 from 2019 (N = 46). The total percent N and percent C were measured at the Colorado Plateau Stable Isotope Laboratory in a continuous-flow mode using a Thermo-Finnigan Delta^{plus} Advantage gas isotope-ratio mass spectrometer interfaced with a Costech Analytical ECS4010 elemental analyzer.

Table 3. *Summary of procedures used for soil chemical analyses, procedures, and method references.*

Analysis	**Procedure**	**Method References**
Water pH	Calibrated combination pH electrode	Thomas (1996)
$CaCl_2$ pH	Calibrated combination pH electrode	Thomas (1996)
Oven-dry moisture content (MC)	105°C oven until constant mass	Hart et al. (1994)
Organic matter content (OM)	Loss on ignition	Nelson and Sommers (1996)
Effective cation exchange capacity (ECEC = Na + K + Mg + Ca + NH_4 + TA)	NH_4Cl exchange for Na, K, Mg, Ca, and Al; KCl exchange for NH_4	Sumner and Miller (1996)
Exchangeable anions (EA = NO_3 + SO_4)	KCl exchange	Cronan and Schofield (1990); Stams and Marnette (1990)
Total Acidity (TA)	Titration to phenolphthalein endpoint	Sumner and Miller (1996)
% Base saturation (%BS)	Sum of base cation charge (Na + K + Mg + Ca + NH_4) divided by ECEC	Brady and Weil (2008)
Total sulfur (TS)	Thermal oxidation	Eivazi et al. (1988); Rossete et al. (2008)
Total carbon (TC), total nitrogen (TN), C:N ratio	Thermal oxidation	Werner and Brand (2001)

Stream Laboratory Analysis Methods: Chemical Properties

Water samples were analyzed for pH, ANC, conductivity, chloride, nitrate, sulfate, ammonium, and base cations (Ca, Mg, K, Na). Within 48 hours of sample collection, samples were allowed to equilibrate to room temperature and analyzed for pH, ANC, and conductivity using a ManTech Inc. PC-Titrate(R) System autotitrator. Other analyses were performed with a Thermo-Scientific Ion Chromatogram System 1100 (IC) and a Thermo-Scientific iCAP-DUO 7400 inductively coupled argon plasma (ICP-OES), within standard holding times (Standard Methods, 1999). A summary of parameters, analytical instruments, and referenced standard methods are summarized in Table 4. The pre-fire data were divided into years before and after 2008, when the acid deposition significantly decreased in the park due to changes in national regulations and the addition of scrubbers to nearby Tennessee Valley Authority (TVA) coal units, including those at the Bull Run and Kingston Power plants (Schwartz et al., 2014). Here, the data before the decrease in acid deposition (2008) were omitted in pre-fire averages. Additionally, sites 26 and 28 are not included as no pre-fire data were available.

Table 4. *Summary of water chemical analyses, procedures, and method references.*

Analysis	Procedure	Method References
pH (temperature-compensated)	Calibrated combination pH electrode	EPA Method 150.1
Conductivity (25°C)	Electrometric	EP Method 120.1
Acid Neutralizing Capacity (ANC)	Automated Titration	Automated Gran Titration for low ionic strength waters, as in Hillman et al., 1986
Anions (NO_3, Cl, SO_4)	Ion Chromatography	Standard Methods 4110
Monovalent Cations (NH_4)	Ion Chromatography	Modification of Standard Methods 4110
Earth and Trace Metals (Na, K, Mg, Ca, Mn, Al, Fe, Cu, Zn, & Si)	Inductively Coupled Plasma Spectrophotometer	Standard Methods 3120B EPA Method 6010B EPA Method 3005A

D. Statistical Analysis and Qualitative Trend Assessments

Soil Chemistry

Descriptive statistics were summarized for the physical/chemical parameters for the A/O and B soil horizons consisting of means and standard deviations. An ANOVA was performed to compare the physical/chemical properties between the A/O and B soil horizons per site burn level (site condition classification). A comparison of soil chemistry parameters among site burn levels and per each horizon separately, using an ANOVA, Tukey-Kramer Honestly Significant Difference (HSD) means separation method. An unequal variance t-test was used to statistically compare means for selected parameter and burn condition sites of interest. Significant differences were based on a p-value less than 0.05. A t-test was performed to compare high burn sulfate values with low/medium, unburned and reference site values, all in the B soil horizon.

In order to examine co-related chemical parameters, a Pearson correlation method was chosen for the multivariate, pairwise analysis and relation coefficients were reported, with an indication of significant correlations in bold ($p<0.05$) (Appendix F).

Pre- and post-fire analysis was completed on historic soil chemistry data (Grell 2010) which included one site (RP3) located in the fire footprint and re-sampled seven years later. Chemical parameters analyzed by the same laboratory methodology were tabulated for six sites in or adjacent to the fire footprint. The sites were in Road Prong watershed (RP1, 2, and 3) and Walker Camp Prong watershed (WCP1, 2, and 3). A two-way contingency analysis was used to compare pre- and post-fire chemical differences. Only site RP3 (low/medium burn) represented the pre- and post-fire comparison, whereas the other sites served as a control (reference sites).

Stream Water Chemistry

Descriptive statistics were summarized for the stream water chemistry parameters for pre- and post-fire data consisting of means and standard deviations. The pre-fire data included the period from January 2008 to May 2014. Post-fire data included water samples taken immediately following the CT2 fire until November 2019.

Individually, per sample location, stream water chemistry parameters were compared for differences between pre- and post-fire periods using a repeated measures ANOVA.

A qualitative assessment of stream water chemistry patterns post-fire were visualized on scatter plots to observe whether there were rapid shifts in chemistry immediately following the fire in November 2016.

III. RESULTS

A. Post-Burn Soil Chemistry Characterization

Chemical properties measured and calculated on soil samples are displayed in Table 5 (A/O horizon) and Table 6 (B horizon). Individual parameters are displayed in box plots to compare the A/O and B horizon and 4 burn severity levels: reference, unburned, low/medium and high burn (Figures 4 – 14). Note, two unburned sites, PL441 and RS441, were omitted from statistical analyses due to their proximity to US441, a major roadway that received dolomite chat during the winter months to improve traction for vehicles. Road applications resulted in elevated base cations making it difficult to discern whether changes in soil chemistry were due to fire or the chat applied in winter. The two sites are displayed in Table 5 & 6 as unburned (road), whereas the remaining unburned samples unaffected by the road chat are labeled as unburned (no road).

Salt pH, the pH measured in 0.01M $CaCl_2$, as it is less affected by soil electrolytes and a more consistent measure, had a mean value of 5.06 to 5.64 in non-burned (reference and unburned sites, respectively) A/O horizon samples and a mean of 4.38 in A/O horizon low/medium burn samples (Figure 4) (Minasny et al., 2011). In the B horizon, mean salt pH were 5.14 and 5.35 at reference and unburned sites, respectively, and 4.20 and 4.27 at low/medium sites and high burn sites. TA in the A/O horizon reference and unburned sites had means of 0.4 $cmol_c$/kg and 0.8 $cmol_c$/kg respectively, compared with a mean of 2.4 $cmol_c$/kg in the low/medium burn sites (Figure 5). In the B horizon, TA averaged 0.69 $cmol_c$/kg at reference sites and 1.21 $cmol_c$/kg at unburned sites, while in burned areas the averages were 3.82 $cmol_c$/kg and 4.52 $cmol_c$/kg, in low/medium and high burn sites respectively. Organic matter in the A/O low/medium sites averaged 18.6%, while reference and unburned sites averaged 19.2% and 20.1%, respectively (Figure 6). In the B horizon, high burn areas had the lowest average organic matter content (7.5%), while low/medium sites averaged 8.3%, unburned sites 9.0% and reference sites 9.8%. The total EBC was lower in the B horizon than the A/O horizon, with means of 2.77 $cmol_c$/kg in B horizon reference sites and 6.16 $cmol_c$/kg in A/O horizon reference sites, similarly, 4.77 $cmol_c$/kg and 12.4 $cmol_c$/kg in unburned B and A/O horizons respectively, and 0.96 $cmol_c$/kg in B low/medium sites and 4.81 $cmol_c$/kg in A/O low/medium sites (Figure 7). High burn sites saw a larger range of EBC values (0.78-9.08 $cmol_c$/kg) than did low/medium sites in the B horizon (0.30- 2.47 $cmol_c$/kg), with high sites having a higher range for EBC (0.78-9.08 $cmol_c$/kg).

The ECEC in the A/O horizon (7.40-13.97 $\mathrm{cmol_c/kg}$) averaged greater values than the B horizon (4.35-7.60 $\mathrm{cmol_c/kg}$) (Figure 8). The %BS was lower in burned areas in both horizons, and higher in the A/O horizon than the B horizon (Figure 9). The %BS ranged from 68.0% to 88.1% in the A/O horizon, and 32.4% to 78.7% in the B horizon in all burn levels. Sulfate averaged 0.34 and 0.11 $\mathrm{cmol_c/kg}$ for reference sites (A/O and B horizon respectively), unburned sites averaged 0.28 $\mathrm{cmol_c/kg}$ in A/O and 0.33 $\mathrm{cmol_c/kg}$ in B and in low/medium sites A/O average sulfate was 0.32 $\mathrm{cmol_c/kg}$ and B horizon average was 0.16 $\mathrm{cmol_c/kg}$ (Figure 10). Nitrate in the A/O horizon ranged 0.64 to 1.25 $\mathrm{cmol_c/kg}$ and in the B horizon averaged 0.39 $\mathrm{cmol_c/kg}$ at high burn sites, 0.21 $\mathrm{cmol_c/kg}$ at low/medium sites, 0.81 $\mathrm{cmol_c/kg}$ at reference and 0.75 $\mathrm{cmol_c/kg}$ at unburned sites (Figure 11). In the A/O horizon, ammonium averaged 0.84 $\mathrm{cmol_c/kg}$ at reference sites, 0.74 $\mathrm{cmol_c/kg}$ at unburned sites, and 0.64 $\mathrm{cmol_c/kg}$ at low/medium sites (Figure 12). In the B horizon, reference sites averaged 0.89 $\mathrm{cmol_c/kg}$, unburned averaged 0.69 $\mathrm{cmol_c/kg}$, low/medium averaged 0.54 $\mathrm{cmol_c/kg}$ and high burn sites averaged 0.61 $\mathrm{cmol_c/kg}$. The percent C ranged from 6.6% to 9.1% in the A/O horizon, and 3.7% to 4.9% in the B horizon (Figure 13). Reference sites in the A/O horizon had the lowest C content of A/O sites, at 6.6% compared to 9.1% and 9.0% in unburned and low/medium sites respectively. In the B horizon, burned areas showed the lowest C content, with low/medium sites averaging 3.7% and high burn sites 3.9%, while reference and unburned sites averaged 4.9% and 4.6%, respectively. Percent N (%N) had a small range in both soil horizons (Figure 14). The B horizon sites averaged between 0.15% and 0.29%, and the A/O horizon sites ranged 0.44% to 0.54%. In the B horizon, which showed consistently lower N content than the A/O horizon, the burned sites (low/medium and high burn) both averaged 0.29% N, while the non-burned sites (reference and unburned) both averaged 0.15%. The ratio of C/N is reported in analyses. In the A/O horizon, C/N ratio was between 14.3 and 21.6, with the lowest ratio at reference sites and highest at low/medium burn sites. The B horizon showed a similar pattern, with higher values. Reference sites in the B horizon had a C/N ratio of 17.1, while high burn sites averaged 26.9, the highest reported ratio average in either horizon. Individual cations (Na, K, Mg, Ca and Al) were measured. Na showed no pattern between burn levels or horizons, with a range of 0.03 to 0.09 $\mathrm{cmol_c/kg}$. K averages ranged 0.37 to 0.65 $\mathrm{cmol_c/kg}$ in the A/O horizon and 0.14 to 0.36 $\mathrm{cmol_c/kg}$ in the B horizon. Mg tended to be higher in the B horizon, with values ranging 0.76 to 1.78 $\mathrm{cmol_c/kg}$, than in the A/O horizon (0.18-0.58 $\mathrm{cmol_c/kg}$). Ca was consistently greater than Na, K and Mg, with A/O means ranging 0.46 to 3.76 $\mathrm{cmol_c/kg}$, and B horizon means from 3.47 to

9.84 cmol$_c$/kg. Al tended to be higher in the B horizon, with a range of 0.88 to 2.93 cmol$_c$/kg, while in the A/O horizon the means ranged from 0.11 to 1.02 cmol$_c$/kg (Figure 15). Al was greatest in burned areas, with highest values in high burn B horizon sites.

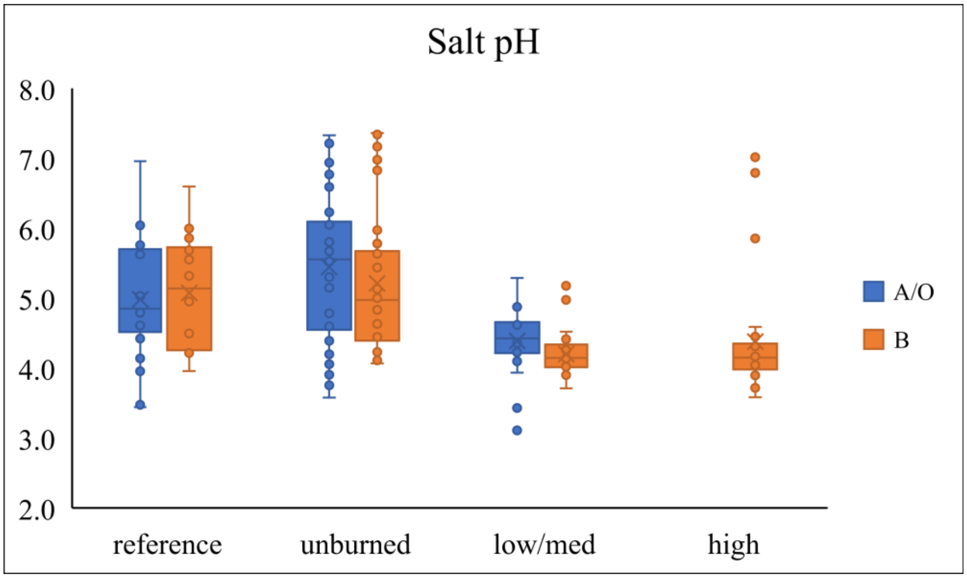

Figure 4. *Box plot displaying the soil salt pH per burn severity level for A/O and B horizons. The 25th to 75th quartile are encompassed within the box, the median is represented by the horizontal line in the box, and points outside the error bars are outliers.*

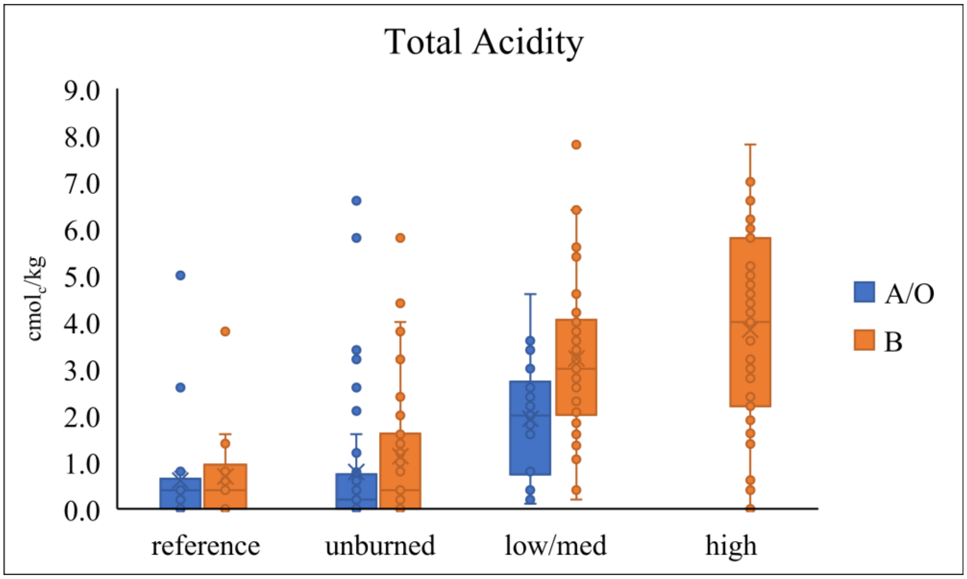

Figure 5. *Box plot displaying the soil total acidity per burn severity level for A/O and B horizons. The 25th to 75th quartile are encompassed within the box, the median is represented by the horizontal line in the box, and points outside the error bars are outliers.*

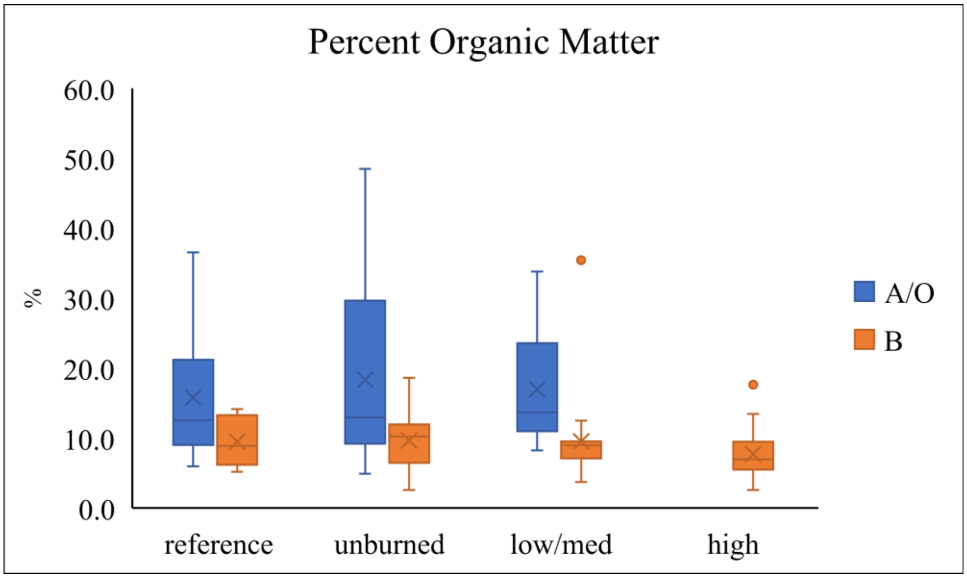

Figure 6. *Box plot displaying the percent soil organic matter per burn severity level for A/O and B horizons. The 25th to 75th quartile are encompassed within the box, the median is represented by the horizontal line in the box, and points outside the error bars are outliers.*

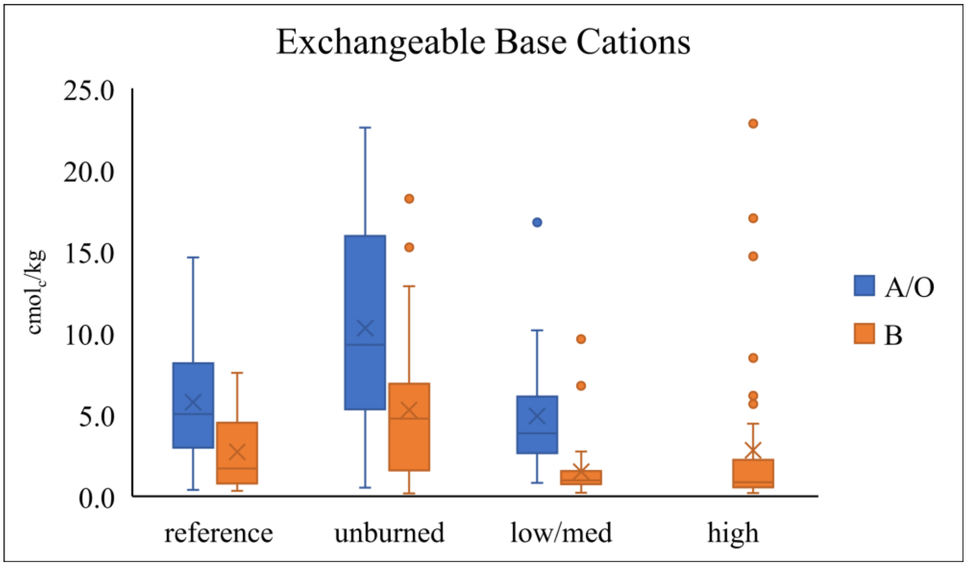

Figure 7. *Box plot displaying the soil exchangeable base cations per burn severity level for A/O and B horizons. The 25th to 75th quartile are encompassed within the box, the median is represented by the horizontal line in the box, and points outside the error bars are outliers. One outlier point (44.9 cmol$_c$/kg) not shown in the unburned category A/O horizon.*

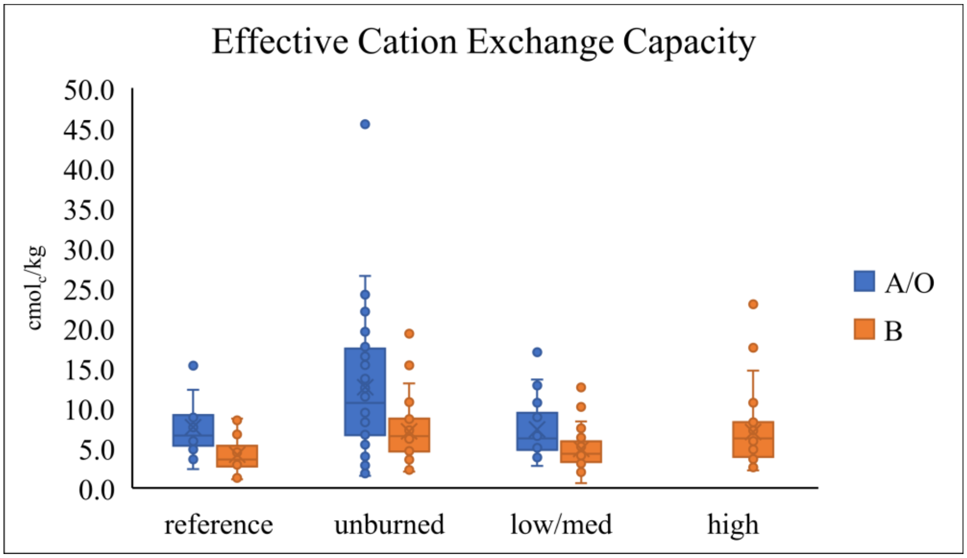

Figure 8. *Box plot displaying the soil effective cation exchange capacity per burn severity level for A/O and B horizons. The 25th to 75th quartile are encompassed within the box, the median is represented by the horizontal line in the box, and points outside the error bars are outliers.*

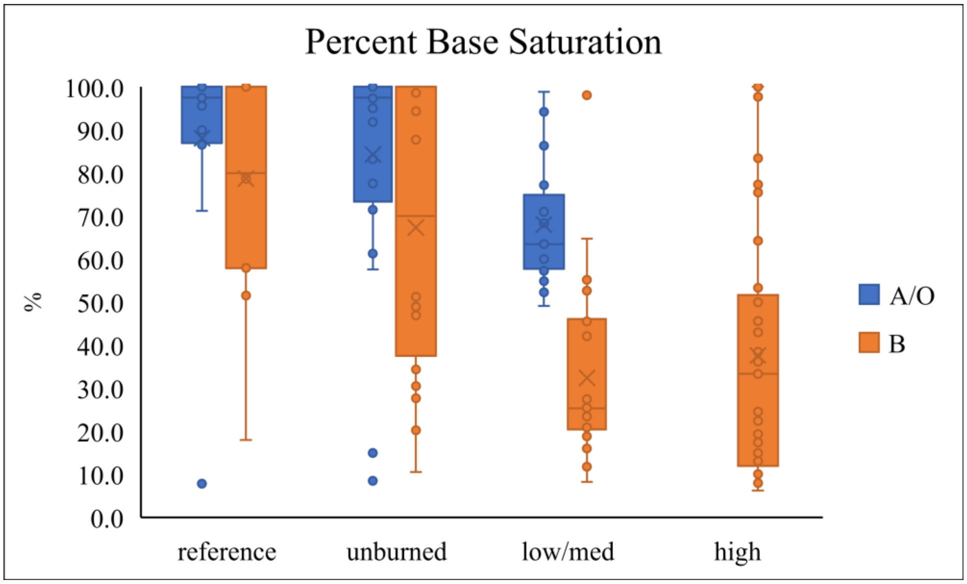

Figure 9. *Box plot displaying the soil percent base saturation per burn severity level for A/O and B horizons. The 25th to 75th quartile are encompassed within the box, the median is represented by the horizontal line in the box, and points outside the error bars are outliers.*

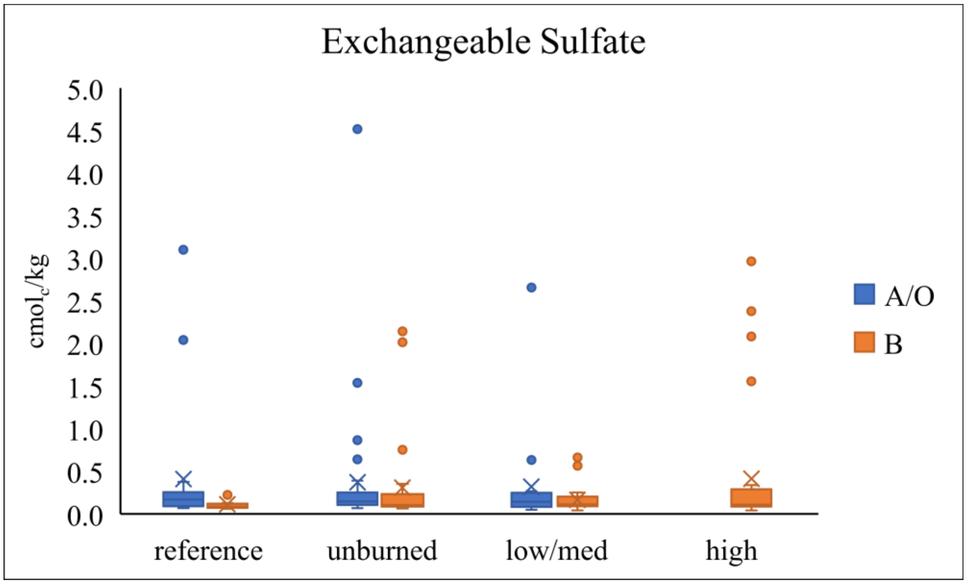

Figure 10. *Box plot displaying the soil exchangeable sulfate per burn severity level for A/O and B horizons. The 25th to 75th quartile are encompassed within the box, the median is represented by the horizontal line in the box, and points outside the error bars are outliers.*

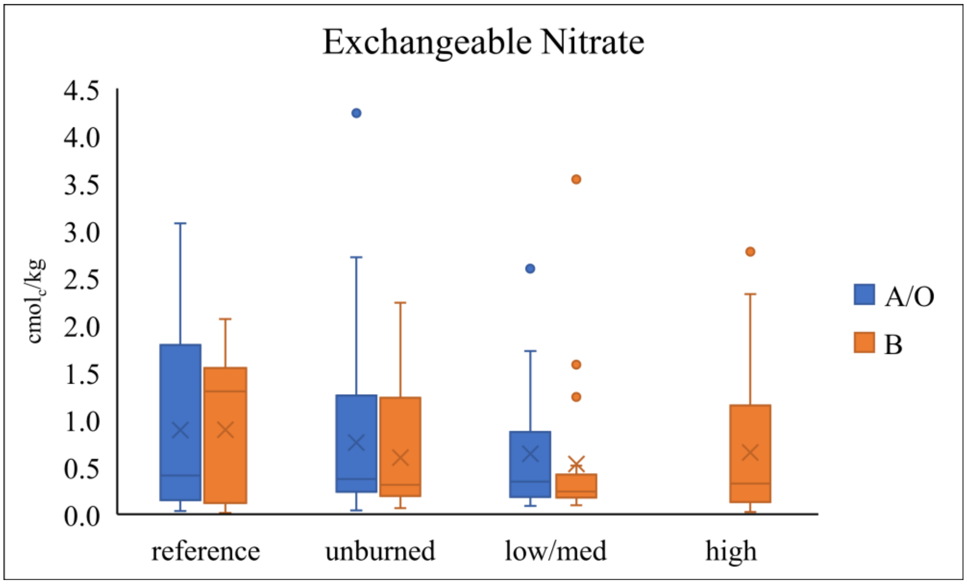

Figure 11. *Box plot displaying the soil exchangeable nitrate per burn severity level for A/O and B horizons. The 25th to 75th quartile are encompassed within the box, the median is represented by the horizontal line in the box, and points outside the error bars are outliers.*

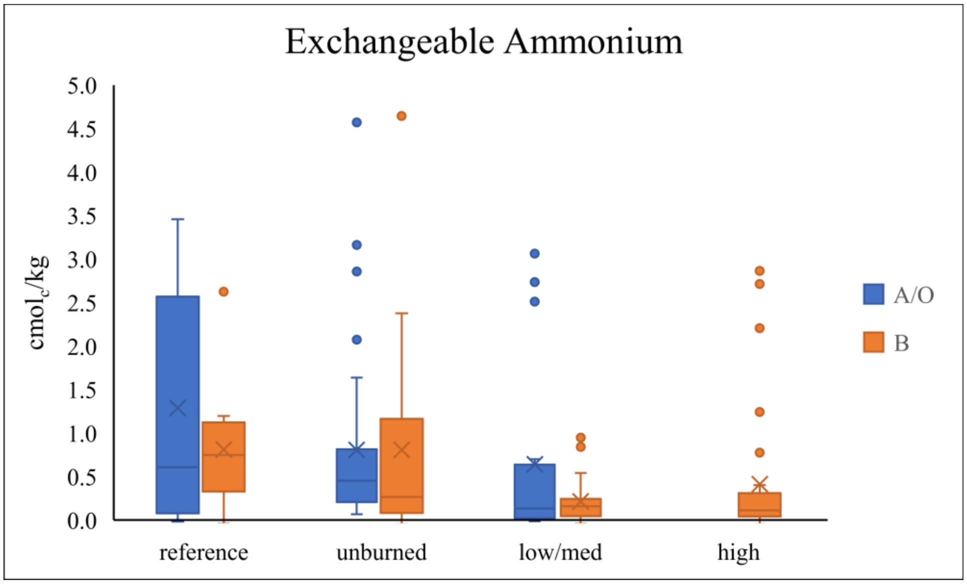

Figure 12*. Box plot displaying the soil exchangeable ammonium per burn severity level for A/O and B horizons. The 25th to 75th quartile are encompassed within the box, the median is represented by the horizontal line in the box, and points outside the error bars are outliers.*

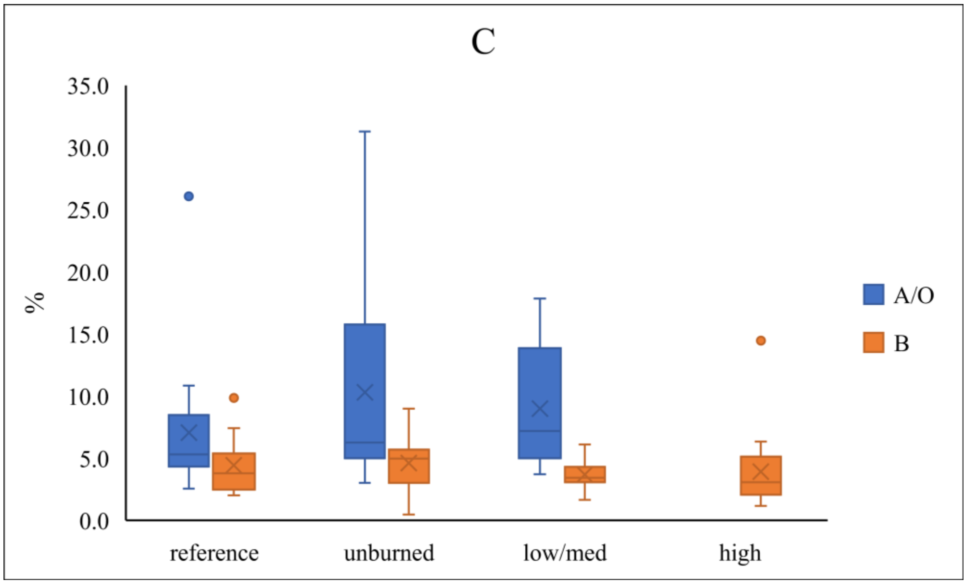

Figure 13. *Box plot displaying the soil percent C per burn severity level for A/O and B horizons. The 25th to 75th quartile are encompassed within the box, the median is represented by the horizontal line in the box, and points outside the error bars are outliers.*

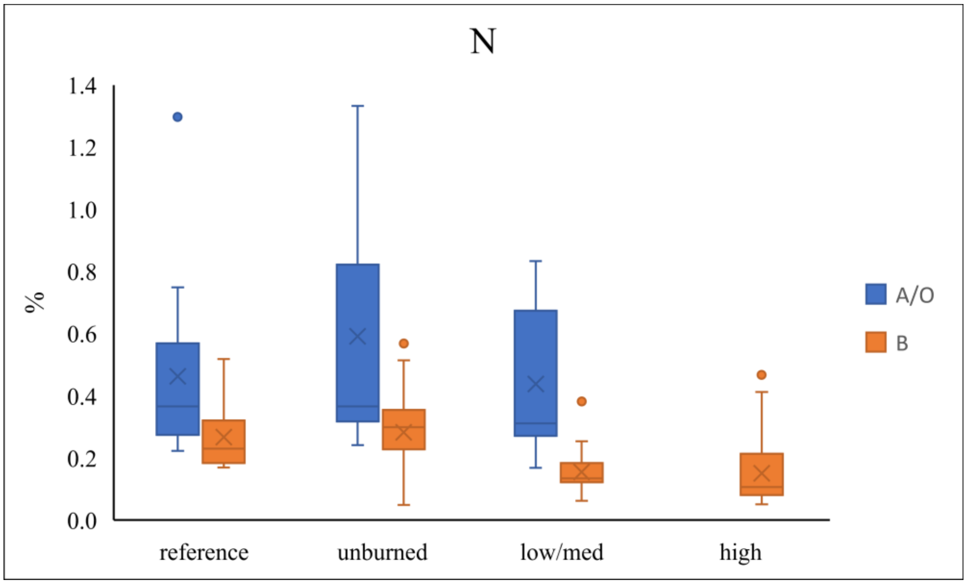

Figure 14. *Box plot displaying the soil percent N per burn severity level for A/O and B horizons. The 25th to 75th quartile are encompassed within the box, the median is represented by the horizontal line in the box, and points outside the error bars are outliers.*

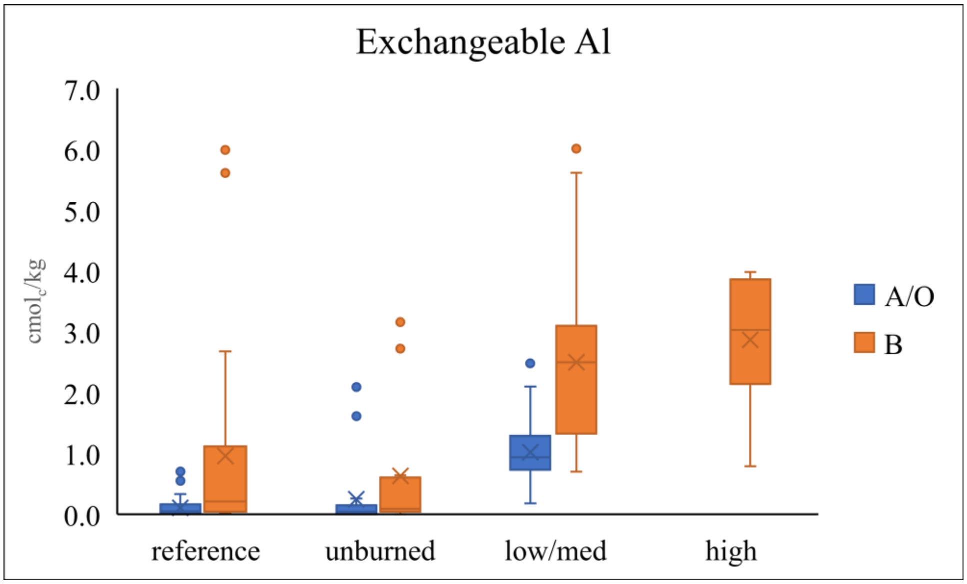

Figure 15. *Box plot displaying soil exchangeable Al per burn severity level for A/O and B horizons. The 25th to 75th quartile are encompassed within the box, the median is represented by the horizontal line in the box, and points outside the error bars are outliers.*

Table 5. *Soil chemistry parameters for the A/O horizon summarized as collection means and standard deviations. Per site burn level category, a range of means are summarized.*

A. Low/medium burn sites; N = 4.

Site ID	**Site Burn Level**	**MC (%)**	**DI pH**	**Salt pH**	**TA (cmol$_c$/kg)**	**EBC (cmol$_c$/kg)**	**ECEC (cmol$_c$/kg)**	**BS (%)**	**OM (%)**	**SO$_4$ (cmol$_c$/kg)**
FCL	Low/med	25.7 ± 12.8	5.63 ± 0.38	4.74 ± 0.37	1.56 ± 1.31	6.80 ± 5.82	8.39 ± 5.14	74.6 ± 20.1	12.8 ± 5.05	0.10 ± 0.06
NEON	Low/med	28.3 ± 4.58	5.39 ± 0.24	4.54 ± 0.21	2.42 ± 1.38	2.47 ± 1.79	5.60 ± 2.12	62.7 ± 15.7	11.4 ± 1.56	0.54 ± 1.04
RP3	Low/med	42.9 ± 6.65	5.35 ± 0.56	4.63 ± 0.38	1.30 ± 0.71	1.26 ± 0.62	4.22 ± 2.54	64.9 ± 10.8	18.9 ± 7.04	0.14 ± 0.07
WIN	Low/med	29.9 ± 20.1	5.15 ± 0.33	4.20 ± 3.02	4.29 ± 3.02	5.06 ± 3.42	10.2 ± 3.24	68.0 ± 7.13	26.1 ± 6.34	0.28 ± 0.18
Mean		**31.7**	**5.38**	**4.38**	**2.40**	**4.81**	**7.85**	**68.0**	**18.6**	**0.32**
Means Range		**25.7 – 42.9**	**5.15 – 5.63**	**4.20 – 4.74**	**1.30 – 4.29**	**1.26 – 6.80**	**4.22 – 10.2**	**62.7 – 74.6**	**11.4 – 26.1**	**0.10 – 0.54**

Site ID	**Site Burn Level**	**C (%)**	**N (%)**	**C/N**	**Na (cmol$_c$/kg)**	**K (cmol$_c$/kg)**	**Mg (cmol$_c$/kg)**	**Ca (cmol$_c$/kg)**	**Al (cmol$_c$/kg)**	**NH$_4$ (cmol$_c$/kg)**	**NO$_3$ (cmol$_c$/kg)**
FCL	Low/med	7.67 ± 2.83	0.31 ± 0.13	24.8 ± 2.58	0.09 ± 0.04	0.72 ± 0.42	0.83 ± 0.72	4.71 ± 4.48	0.85 ± 0.43	0.03 ± 0.06	0.49 ± 0.42
NEON	Low/med	5.22 ± 0.43	0.28 ± 0.04	18.8 ± 2.04	0.08 ± 0.05	0.34 ± 0.11	0.47 ± 0.21	2.06 ± 1.12	0.87 ± 0.23	0.71 ± 1.66	0.80 ± 1.53
RP3	Low/med	7.25 ± 3.43	0.46 ± 0.19	15.4 ± 1.02	0.01 ± 0.00	0.12 ± 0.02	0.15 ± 0.09	0.97 ± 0.40	1.07 ± 0.41	1.66 ± 2.16	0.91 ± 0.96
WIN	Low/med	16.5 ± 1.09	0.74 ± 0.07	23.2 ± 2.16	0.09 ± 0.05	0.60 ± 0.18	1.23 ± 0.46	4.63 ± 1.90	1.32 ± 0.61	0.79 ± 0.92	0.52 ± 0.50
Mean		**8.98**	**0.44**	**21.6**	**0.08**	**0.50**	**0.76**	**3.47**	**1.02**	**0.64**	**0.64**
Means Range		**5.22 – 16.5**	**0.28 - 0.74**	**15.4 – 24.8**	**0.01 – 0.09**	**0.12 – 0.72**	**0.15 – 1.23**	**0.97 – 4.71**	**0.85 – 1.32**	**0.03 – 1.66**	**0.49 – 0.91**

*MC = moisture content, TA = total acidity, EBC = exchangeable base cations, ECEC = effective cation exchange capacity, BS = base saturation, OM = organic matter content.

Table 5 Continued.

B. Unburned (no road) sites; N = 7.

Site ID	**Site Burn Level**	**MC (%)**	**DI pH**	**Salt pH**	**TA (cmol$_c$/kg)**	**EBC (cmol$_c$/kg)**	**ECEC (cmol$_c$/kg)**	**BS (%)**	**OM (%)**	**SO_4 (cmol$_c$/kg)**
BGB	Unburned	49.3 ± 14.6	6.19 ± 0.52	5.56 ± 0.17	2.31 ± 4.19	19.3 ± 17.2	22.2 ± 14.8	98.1 ± 2.40	32.2 ± 2.91	0.15 ± 0.12
CANEY	Unburned	38.2 ± 14.6	4.95 ± 0.47	3.95 ± 0.28	3.86 ± 2.44	8.15 ± 5.20	13.15 ± 3.77	65.0 ± 30.0	39.0 ± 5.87	0.07 ± 0.00
LOVE	Unburned	27.4 ± 4.67	6.89 ± 0.46	6.30 ± 0.46	2.28 ± 5.20	12.2 ± 8.26	14.7 ± 5.77	99.0 ± 1.12	9.56 ± 2.68	0.09 ± 0.01
NS1	Unburned	36.1 ± 0.55	5.61 ± 0.05	4.79 ± 0.01	0.60 ± 0.28	0.82 ± 0.00	1.75 ± 0.35	66.6 ± 7.60	13.0 ± 1.08	0.12 ± 0.01
NS2	Unburned	35.8 ± 0.93	6.13 ± 0.36	5.36 ± 0.24	0.00 ± 0.00	2.87 ± 0.34	3.72 ± 0.72	100 ± 0.00	11.7 ± 1.97	0.86 ± 1.79
NS3	Unburned	34.8 ± 8.94	6.44 ± 0.02	5.95 ± 0.15	0.00 ± 0.00	6.28 ± 0.11	8.43 ± 2.18	100 ± 0.00	17.6 ± 4.57	0.25 ± 0.24
SKI	Unburned	28.4 ± 7.87	7.02 ± 1.07	6.61 ± 1.23	4.22 ± 8.59	9.10 ± 7.82	13.7 ± 6.81	82.5 ± 37.8	7.83 ± 2.06	0.36 ± 0.32
Mean		**35.7**	**6.18**	**5.64**	**0.80**	**12.4**	**13.97**	**84.3**	**20.1**	**0.28**
Means Range		**27.4 – 49.3**	**4.95 – 7.02**	**3.95 – 6.61**	**0.00 – 4.22**	**0.82 – 19.3**	**1.75 – 22.2**	**66.6 – 100**	**7.83 – 39.0**	**0.07 – 0.86**

Site ID	**Site Burn Level**	**C (%)**	**N (%)**	**C/N**	**Na (cmol$_c$/kg)**	**K (cmol$_c$/kg)**	**Mg (cmol$_c$/kg)**	**Ca (cmol$_c$/kg)**	**Al (cmol$_c$/kg)**	**NH_4 (cmol$_c$/kg)**	**NO_3 (cmol$_c$/kg)**
BGB	Unburned	17.1 ± 3.70	0.90 ± 0.18	19.0 ± 0.39	0.12 ± 0.14	1.06 ± 0.54	4.33 ± 2.70	18.6 ± 11.2	0.02 ± 0.01	0.63 ± 0.58	0.71 ± 0.62
CANEY	Unburned	19.5 ± 9.38	0.90 ± 0.38	22.7 ± 1.02	0.09 ± 0.04	0.93 ± 0.37	2.24 ± 0.77	6.38 ± 2.88	0.93 ± 0.66	1.15 ± 1.07	0.83 ± 0.93
LOVE	Unburned	4.54 ± 1.07	0.32 ± 0.05	14.1 ± 2.01	0.06 ± 0.04	0.93 ± 0.25	1.75 ± 0.63	11.9 ± 5.32	0.01 ± 0.02	0.16 ± 0.13	0.56 ± 0.41
NS1	Unburned	6.27 ± 0.64	0.33 ± 0.04	18.8 ± 0.57	0.19 ± 0.32	0.14 ± 0.06	0.08 ± 0.07	0.43 ± 0.18	1.05 ± 0.94	0.33 ± 0.19	0.68 ± 0.74
NS2	Unburned	5.58 ± 1.29	0.39 ± 0.08	14.2 ± 0.23	0.04 ± 0.06	0.27 ± 0.04	0.36 ± 0.13	2.20 ± 0.42	0.08 ± 0.05	0.85 ± 0.64	1.84 ± 2.06
NS3	Unburned	10.3 ± 0.20	0.78 ± 0.01	13.2 ± 0.31	0.05 ± 0.07	0.26 ± 0.03	0.57 ± 0.24	5.40 ± 0.56	0.04 ± 0.01	2.15 ± 2.18	0.63 ± 0.08
SKI	Unburned	5.20 ± 0.81	0.30 ± 0.06	17.3 ± 1.57	0.07 ± 0.04	0.30 ± 0.13	1.04 ± 0.35	12.8 ± 3.94	0.01 ± 0.01	0.42 ± 0.36	0.90 ± 1.10
Mean		**9.13**	**0.54**	**16.7**	**0.09**	**0.65**	**1.78**	**9.84**	**0.29**	**0.77**	**0.76**
Means Range		**4.54 – 19.5**	**0.30 – 0.90**	**13.2 – 22.7**	**0.04 – 0.19**	**0.14 – 1.06**	**0.08 – 4.33**	**0.43 – 18.6**	**0.01 – 1.05**	**0.16 – 2.15**	**0.63 – 1.84**

*MC = moisture content, TA = total acidity, EBC = exchangeable base cations, ECEC = effective cation exchange capacity, BS = base saturation, OM = organic matter content.

Table 5 Continued.

C. Unburned (road) sites; N=2.

Site ID	**Site Burn Level**	**MC (%)**	**DI pH**	**Salt pH**	**TA ($cmol_c$/kg)**	**EBC ($cmol_c$/kg)**	**ECEC ($cmol_c$/kg)**	**BS (%)**	**OM (%)**	**SO_4 ($cmol_c$/kg)**
PL441	Unburned	22.8 ± 7.07	5.78 ± 0.78	4.90 ± 0.72	1.63 ± 2.59	4.66 ± 3.78	7.34 ± 3.65	68.7 ± 45.3	8.96 ± 2.41	0.45 ± 0.54
RS441	Unburned	38.2 ± 8.84	6.09 ± 0.65	5.42 ± 0.27	2.51 ± 4.95	11.5 ± 8.39	14.4 ± 5.66	98.1 ± 2.37	20.9 ± 2.36	0.17 ± 0.05
Mean		**30.5**	**5.94**	**5.16**	**2.07**	**8.10**	**10.9**	**80.5**	**14.9**	**0.31**
Means Range		**22.8 – 38.2**	**5.78 – 6.09**	**4.90 – 5.42**	**1.63 – 2.51**	**4.66 – 11.5**	**7.34 – 14.4**	**68.7 – 98.1**	**8.96 – 20.9**	**0.17 – 0.45**

Site ID	**Site Burn Level**	**C (%)**	**N (%)**	**C/N**	**Na ($cmol_c$/kg)**	**K ($cmol_c$/kg)**	**Mg ($cmol_c$/kg)**	**Ca ($cmol_c$/kg)**	**Al ($cmol_c$/kg)**	**NH_4 ($cmol_c$/kg)**	**NO_3 ($cmol_c$/kg)**
PL441	Unburned	3.81 ± 0.86	0.24 ± 0.04	15.8± 1.69	0.07 ± 0.04	0.31 ± 0.12	1.06 ± 0.33	5.20 ± 1.67	0.03 ± 0.03	1.05 ± 2.46	1.37 ± 2.62
RS441	Unburned	10.4 ± 1.68	0.70 ± 0.09	14.8 ± 0.86	0.10 ± 0.05	0.62 ± 0.22	2.67 ± 1.01	11.0 ± 4.51	0.02 ± 0.01	0.40 ± 0.25	0.43 ± 0.21
Mean		**7.11**	**0.47**	**15.3**	**0.09**	**0.47**	**1.87**	**8.11**	**0.03**	**0.73**	**0.90**
Means Range		**3.81 – 10.4**	**0.24 – 0.70**	**14.8 – 15.8**	**0.07 – 0.10**	**0.31 – 0.62**	**1.06 – 2.67**	**5.20 – 11.0**	**0.02 – 0.03**	**0.40 – 1.05**	**0.43 – 1.37**

*MC = moisture content, TA = total acidity, EBC = exchangeable base cations, ECEC = effective cation exchange capacity, BS = base saturation, OM = organic matter content.

Table 5 Continued.

D. Reference sites; N = 7.

Site ID	Site Burn Level	MC (%)	DI pH	Salt pH	TA (cmol$_c$/kg)	EBC (cmol$_c$/kg)	ECEC (cmol$_c$/kg)	BS (%)	OM (%)	SO$_4$ (cmol$_c$/kg)
RP1	Ref	45.8 ± 2.16	5.37 ± 0.62	4.60 ± 0.65	0.40 ± 0.57	3.60 ± 1.77	5.25 ± 1.63	93.1 ± 8.82	18.7 ± 0.69	0.10 ± 0.03
RP2	Ref	38.9 ± 0.17	6.02 ± 0.54	5.33 ± 0.62	0.20 ± 0.28	2.21 ± 0.19	3.40 ± 0.98	95.0 ± 7.11	11.7 ± 0.62	0.08 ± 0.02
SGL	Ref	31.0 ± 8.44	5.77 ± 0.68	5.31 ± 0.98	3.98 ± 6.89	5.39 ± 4.85	10.0 ± 5.03	77.9 ± 39.5	11.6 ± 5.12	0.50 ± 0.77
TREE	Ref	27.3 ± 7.24	6.59 ± 0.65	5.67 ± 0.82	1.42 ± 2.86	7.05 ± 5.13	9.09 ± 4.12	97.8 ± 2.06	8.80 ± 2.45	0.67 ± 1.20
WCP1	Ref	46.4 ± 7.09	5.95 ± 0.15	4.64 ± 0.30	0.20 ± 0.28	4.55 ± 1.72	5.56 ± 2.19	97.8 ± 3.09	27.4 ± 8.76	0.18 ± 0.12
WCP2	Ref	61.3 ± 15.1	4.76 ± 1.03	4.13 ± 0.98	1.30 ± 1.84	4.49 ± 0.22	6.99 ± 2.13	85.6 ± 20.4	51.7 ± 39.3	0.20 ± 0.01
WCP3	Ref	52.1 ± 10.3	4.99 ± 0.50	4.07 ± 0.84	0.40 ± 0.57	4.82 ± 0.32	6.17 ± 1.39	93.5 ± 9.22	29.3 ± 10.3	0.17 ± 0.03
Mean		**43.3**	**5.64**	**5.06**	**0.40**	**6.16**	**7.40**	**88.1**	**19.2**	**0.34**
Means Range		**27.3 – 61.3**	**4.76 – 6.59**	**4.07 – 5.67**	**0.20 – 3.98**	**2.21 – 7.05**	**3.40 – 10.0**	**77.9 – 97.8**	**8.80 – 51.7**	**0.08 – 0.67**

Site ID	Site Burn Level	C (%)	N (%)	C/N	Na (cmol$_c$/kg)	K (cmol$_c$/kg)	Mg (cmol$_c$/kg)	Ca (cmol$_c$/kg)	Al (cmol$_c$/kg)	NH$_4$ (cmol$_c$/kg)	NO$_3$ (cmol$_c$/kg)
RP1	Ref	8.15 ± 0.33	0.61 ± 0.06	13.3 ± 0.80	0.07 ± 0.11	0.15 ± 0.03	0.36 ± 0.07	3.02 ± 1.40	0.15 ± 0.10	1.25 ± 1.11	2.00 ± 1.50
RP2	Ref	4.97 ± 0.85	0.30 ± 0.06	16.7 ± 0.43	0.03 ± 0.02	0.18 ± 0.01	0.24 ± 0.12	1.76 ± 0.26	0.09 ± 0.03	0.99 ± 0.98	0.76 ± 1.14
SGL	Ref	4.59 ± 1.03	0.37 ± 0.07	12.5 ± 0.60	0.06 ± 0.04	0.75 ± 0.23	1.28 ± 0.35	6.23 ± 2.44	0.09 ± 0.09	0.65 ± 0.85	1.34 ± 1.55
TREE	Ref	3.66 ± 1.15	0.28 ± 0.06	12.9 ± 1.26	0.08 ± 0.05	0.42 ± 0.17	1.51 ± 0.51	6.45 ± 3.62	0.01 ± 0.01	0.61 ± 0.93	0.96 ± 1.41
WCP1	Ref	10.8 ± 0.03	0.51 ± 0.07	21.3 ± 2.99	0.05 ± 0.06	0.10 ± 0.01	0.69 ± 0.51	3.71 ± 0.96	0.04 ± 0.00	0.81 ± 0.90	1.63 ± 2.07
WCP2	Ref	18.2 ± 11.2	1.02 ± 0.39	16.9 ± 4.49	0.02 ± 0.01	0.16 ± 0.01	0.46 ± 0.21	3.84 ± 0.37	0.20 ± 0.14	1.20 ± 0.57	1.14 ± 0.82
WCP3	Ref	8.47	0.67	12.7	0.11 ± 0.20	0.17 ± 0.04	0.53 ± 0.08	4.01 ± 0.27	0.33 ± 0.35	0.95 ± 1.07	1.12 ± 1.56
Mean		**6.59**	**0.44**	**14.3**	**0.06**	**0.37**	**0.93**	**4.80**	**0.11**	**0.84**	**1.25**
Means Range		**3.66 – 18.2**	**0.28 – 1.02**	**12.5 – 21.3**	**0.02 – 0.11**	**0.10 – 0.75**	**0.24 – 1.51**	**1.76 – 6.45**	**0.01 – 0.33**	**0.61 – 1.25**	**0.76 – 2.00**

*MC = moisture content, TA = total acidity, EBC = exchangeable base cations, ECEC = effective cation exchange capacity, BS = base saturation, OM = organic matter content.

***Table 6.** Soil chemistry parameters for the B horizon summarized per collection means and standard deviations. Per site burn level category, a range of means are summarized.*

A. High burn sites; N = 7.

Site ID	**Site Burn Level**	**MC (%)**	**DI pH**	**Salt pH**	**TA (cmol$_c$/kg)**	**EBC (cmol$_c$/kg)**	**ECEC (cmol$_c$/kg)**	**BS (%)**	**OM (%)**	**SO_4 (cmol$_c$/kg)**
DUD	High	16.8 ± 4.45	4.83 ± 0.33	4.05 ± 0.17	4.40 ± 1.96	0.81 ± 0.36	6.10 ± 1.84	24.2 ± 17.1	4.89 ± 0.59	0.50 ± 0.78
FCM	High	16.6 ± 2.53	5.43 ± 1.28	4.59 ± 1.20	4.02 ± 2.86	1.86 ± 2.35	6.75 ± 1.96	40.5 ± 40.4	5.55 ± 1.86	0.58 ± 1.17
LCM	High	18.8 ± 6.52	5.41 ± 1.15	4.56 ± 1.24	3.32 ± 2.83	4.01 ± 6.42	7.74 ± 5.40	44.8 ± 36.8	7.62 ± 3.22	0.13 ± 0.06
NMT	High	24.7 ± 9.62	5.99 ± 1.04	5.10 ± 1.00	1.99 ± 1.54	9.08 ± 8.39	11.5 ± 7.04	67.9 ± 31.6	9.86 ± 1.69	0.47 ± 0.58
NS4	High	6.89 ± 3.83	4.84 ± 0.40	3.82 ± 0.33	2.90 ± 0.99	0.82 ± 0.30	4.84 ± 1.46	38.8 ± 0.14	14.8 ± 4.07	0.20 ± 0.14
SCM	High	17.7 ± 2.17	5.06 ± 0.16	4.14 ± 0.12	4.31 ± 3.26	0.78 ± 0.57	5.31 ± 2.24	12.1 ± 3.07	7.73 ± 3.46	0.14 ± 0.11
TCL	High	19.9 ± 6.87	4.99 ± 0.17	4.10 ± 0.16	5.15 ± 1.79	1.93 ± 1.45	7.78 ± 2.70	31.3 ± 15.1	7.64 ± 1.38	0.52 ± 0.91
Mean		**17.3**	**5.22**	**4.27**	**4.52**	**2.48**	**7.60**	**37.6**	**7.53**	**0.40**
Means Range		**6.89 – 24.7**	**4.83 – 5.99**	**3.82 – 5.10**	**1.99 – 5.15**	**0.78 – 9.08**	**4.84 – 11.5**	**12.1 – 67.9**	**4.89 – 14.8**	**0.13 – 0.58**

Site ID	**Site Burn Level**	**C (%)**	**N (%)**	**C/N**	**Na (cmol$_c$/kg)**	**K (cmol$_c$/kg)**	**Mg (cmol$_c$/kg)**	**Ca (cmol$_c$/kg)**	**Al (cmol$_c$/kg)**	**NH_4 (cmol$_c$/kg)**	**NO_3 (cmol$_c$/kg)**
DUD	High	2.03 ± 0.90	0.11 ± 0.03	18.3 ± 3.59	0.07 ± 0.04	0.25 ± 0.11	0.10 ± 0.04	0.27 ± 0.22	3.98 ± 1.33	0.89 ± 0.81	0.32 ± 0.76
FCM	High	2.50 ± 0.64	0.07 ± 0.01	34.7 ± 6.27	0.06 ± 0.04	0.25 ± 0.11	0.06 ± 0.03	0.09 ± 0.04	3.86 ± 0.94	0.87 ± 1.60	0.62 ± 1.72
LCM	High	2.68 ± 1.04	0.08 ± 0.03	31.3 ± 2.87	0.09 ± 0.10	0.53 ± 0.57	0.12 ± 0.06	0.27 ± 0.17	3.03 ± 1.14	0.41 ± 0.50	0.08 ± 0.11
NMT	High	5.42 ± 0.58	0.24 ± 0.03	22.7 ± 4.58	0.11 ± 0.13	0.50 ± 0.15	1.01 ± 0.40	9.15 ± 7.16	0.79 ± 0.68	0.37 ± 0.17	0.24 ± 0.32
NS4	High	12.4 ± 2.86	0.44 ± 0.04	28.1 ± 4.02	0.02 ± 0.02	0.07 ± 0.02	0.19 ± 0.17	0.54 ± 0.11	2.14 ± 1.57	1.12 ± 0.69	1.01 ± 1.18
SCM	High	3.03 ± 1.76	0.09 ± 0.03	33.0 ± 6.47	0.04 ± 0.03	0.20 ± 0.08	0.09 ± 0.05	0.11 ± 0.07	2.52 ± 1.44	0.22 ± 0.16	0.10 ± 0.17
TCL	High	3.09 ± 0.69	0.12 ± 0.03	25.2 ± 2.88	0.06 ± 0.03	0.35 ± 0.22	0.38 ± 0.29	1.33 ± 1.09	3.73 ± 2.07	0.70 ± 1.24	0.68 ± 1.48
Mean		**3.92**	**0.15**	**26.88**	**0.07**	**0.33**	**0.29**	**1.79**	**2.93**	**0.61**	**0.39**
Means Range		**2.03 – 12.4**	**0.07 – 0.44**	**18.25 – 34.68**	**0.02 – 0.11**	**0.07 – 0.53**	**0.06 – 1.01**	**0.09 – 9.15**	**0.79 – 3.98**	**0.22 – 1.12**	**0.08 – 1.01**

*MC = moisture content, TA = total acidity, EBC = exchangeable base cations, ECEC = effective cation exchange capacity, BS = base saturation, OM = organic matter content.

Table 6 Continued.

B. Low/medium burn sites; N = 6.

Site ID	**Site Burn Level**	**MC (%)**	**DI pH**	**Salt pH**	**TA (cmol$_c$/kg)**	**EBC (cmol$_c$/kg)**	**ECEC (cmol$_c$/kg)**	**BS (%)**	**OM (%)**	**SO$_4$ (cmol$_c$/kg)**
FCL	Low/med	20.8 ± 9.33	5.36 ± 0.37	4.45 ± 0.38	2.42 ± 1.31	2.47 ± 3.54	5.35 ± 2.63	39.3 ± 30.4	7.84 ± 2.81	0.14 ± 0.12
GCL	Low/med	24.9 ± 9.57	4.93 ± 0.18	4.01 ± 0.18	5.43 ± 2.33	2.29 ± 2.26	8.79 ± 3.72	32.9 ± 22.2	13.2 ± 12.5	0.24 ± 0.22
LGB	Low/med	30.5 ± 5.94	5.02 ± 0.26	4.16 ± 0.13	3.04 ± 1.08	1.32 ± 0.79	4.86 ± 1.28	32.4 ± 17.5	8.50 ± 2.37	0.22 ± 0.19
RGB	Low/med	27.5 ± 4.85	5.10 ± 0.14	4.29 ± 0.05	3.00 ± 0.99	0.87 ± 0.24	4.10 ± 0.97	26.0 ± 10.4	8.86 ± 1.24	0.16 ± 0.11
RP3	Low/med	34.0 ± 2.99	5.06 ± 0.22	4.66 ± 0.44	1.00 ± 0.85	0.30 ± 0.12	2.35 ± 1.20	46.4 ± 1.28	9.47 ± 1.05	0.19 ± 0.01
WIN	Low/med	19.2 ± 9.70	4.91 ± 0.09	4.04 ± 0.12	3.45 ± 1.00	0.99 ± 0.31	4.64 ± 1.16	26.7 ± 9.38	9.11 ± 1.24	0.16 ± 0.06
Mean		**26.2**	**5.06**	**4.20**	**3.82**	**0.96**	**5.32**	**32.4**	**8.34**	**0.16**
Means Range		**19.2 – 34.0**	**4.91 – 5.36**	**4.01 – 4.66**	**1.00 – 5.43**	**0.30 – 2.47**	**2.35 – 8.79**	**26.7 – 46.4**	**7.84 – 13.2**	**0.14 – 0.24**

Site ID	**Site Burn Level**	**C (%)**	**N (%)**	**C/N**	**Na (cmol$_c$/kg)**	**K (cmol$_c$/kg)**	**Mg (cmol$_c$/kg)**	**Ca (cmol$_c$/kg)**	**Al (cmol$_c$/kg)**	**NH$_4$ (cmol$_c$/kg)**	**NO$_3$ (cmol$_c$/kg)**
FCL	Low/med	2.79 ± 0.73	0.11 ± 0.03	26.1 ± 1.57	0.07 ± 0.04	0.22 ± 0.07	0.14 ± 0.06	0.39 ± 0.26	2.23 ± 0.66	0.45 ± 0.57	0.10 ± 0.08
GCL	Low/med	3.07 ± 0.74	0.13 ± 0.01	23.5 ± 3.57	0.06 ± 0.03	0.38 ± 0.15	0.18 ± 0.12	0.55 ± 0.28	4.38 ± 1.22	1.07 ± 2.14	0.22 ± 0.32
LGB	Low/med	3.77 ± 1.15	0.15 ± 0.04	25.1 ± 3.45	0.08 ± 0.05	0.34 ± 0.17	0.27 ± 0.14	0.62 ± 0.50	2.49 ± 0.79	0.51 ± 0.43	0.18 ± 0.28
RGB	Low/med	4.16 ± 0.64	0.13 ± 0.01	31.5 ± 1.93	0.06 ± 0.04	0.28 ± 0.09	0.16 ± 0.05	0.32 ± 0.09	2.04 ± 0.86	0.23 ± 0.08	0.11 ± 0.21
RP3	Low/med	4.75 ± 1.91	0.31 ± 0.10	15.1 ± 1.31	0.01 ± 0.01	0.08 ± 0.02	0.03 ± 0.03	0.17 ± 0.09	0.80 ± 0.12	1.05 ± 0.71	0.55 ± 0.53
WIN	Low/med	4.36 ± 0.86	0.20 ± 0.03	21.7 ± 1.13	0.06 ± 0.03	0.19 ± 0.07	0.19 ± 0.07	0.53 ± 0.22	1.56 ± 0.77	0.21 ± 0.06	0.27 ± 0.31
Mean		**3.69**	**0.15**	**24.8**	**0.06**	**0.27**	**0.18**	**0.46**	**2.41**	**0.54**	**0.21**
Means Range		**2.79 – 4.75**	**0.11 – 0.31**	**15.1 – 31.5**	**0.01 – 0.08**	**0.08 – 0.38**	**0.03 – 0.27**	**0.17 – 0.62**	**0.80 – 4.38**	**0.21 – 1.07**	**0.10 – 0.55**

*MC = moisture content, TA = total acidity, EBC = exchangeable base cations, ECEC = effective cation exchange capacity, BS = base saturation, OM = organic matter content.

Table 6 Continued.

C. Unburned (no road) sites; N = 7.

Site ID	**Site Burn Level**	**MC (%)**	**DI pH**	**Salt pH**	**TA (cmol_c/kg)**	**EBC (cmol_c/kg)**	**ECEC (cmol_c/kg)**	**BS (%)**	**OM (%)**	**SO_4 (cmol_c/kg)**
BGB	Unburned	28.5 ± 5.63	5.77 ± 0.14	4.98 ± 0.18	1.21 ± 1.96	5.31 ± 2.95	7.38 ± 2.01	94.4 ± 5.08	10.3 ± 1.91	0.44 ± 0.84
CANEY	Unburned	25.6 ± 5.62	5.12 ± 0.16	4.17 ± 0.04	3.54 ± 1.47	1.47 ± 0.26	5.79 ± 1.93	37.1 ± 12.5	11.8 ± 1.15	0.45 ± 0.77
LOVE	Unburned	16.8 ± 6.28	6.32	5.71 ± 0.10	3.41 ± 4.83	5.13 ± 7.25	8.77 ± 2.43	100	6.60	0.13 ± 0.04
NS1	Unburned	41.0 ± 5.41	5.07 ± 0.48	4.64 ± 0.28	1.70 ± 0.42	0.40 ± 0.31	2.89 ± 0.70	42.8 ± 11.9	16.2 ± 3.43	0.26 ± 0.14
NS2	Unburned	28.6 ± 2.72	5.96 ± 0.77	5.12 ± 0.58	0.60 ± 0.85	1.71 ± 1.25	3.17 ± 0.78	76.1 ± 33.7	7.72 ± 2.35	0.08 ± 0.01
NS3	Unburned	25.2 ± 5.39	6.37 ± 0.34	5.61 ± 0.52	0.00 ± 0.00	3.26 ± 1.24	4.16 ± 1.34	100 ± 0.00	7.45 ± 2.38	0.09 ± 0.01
SKI	Unburned	18.5 ± 4.72	7.43 ± 1.40	6.71 ± 1.25	3.74 ± 7.28	6.53 ± 5.55	10.6 ± 5.20	81.8 ± 39.9	4.21 ± 2.03	0.26 ± 0.25
Mean		**26.3**	**6.01**	**5.35**	**1.21**	**4.77**	**6.66**	**67.3**	**8.96**	**0.33**
Means Range		**16.8 – 41.0**	**5.07 – 7.43**	**4.17 – 6.71**	**0.00 – 3.74**	**0.40 – 6.53**	**2.89 – 10.6**	**37.1 – 100**	**4.21 – 16.2**	**0.08 – 0.45**

Site ID	**Site Burn Level**	**C (%)**	**N (%)**	**C/N**	**Na (cmol_c/kg)**	**K (cmol_c/kg)**	**Mg (cmol_c/kg)**	**Ca (cmol_c/kg)**	**Al (cmol_c/kg)**	**NH_4 (cmol_c/kg)**	**NO_3 (cmol_c/kg)**
BGB	Unburned	4.90 ± 0.41	0.33 ± 0.03	14.8. ± 0.53	0.09 ± 0.03	0.63 ± 0.15	1.14 ± 0.33	4.51 ± 1.07	0.14 ± 0.19	0.86 ± 1.04	0.69 ± 1.10
CANEY	Unburned	5.95 ± 1.56	0.29 ± 0.07	20.7 ± 1.00	0.08 ± 0.04	0.38 ± 0.11	0.38 ± 0.08	0.62 ± 0.17	2.90 ± 1.27	0.78 ± 1.15	0.68 ± 1.33
LOVE	Unburned	2.67	0.23	11.7	0.05 ± 0.01	0.84 ± 0.02	1.40 ± 0.03	7.97 ± 0.23	0.00 ± 0.00	0.22 ± 0.10	0.06 ± 0.13
NS1	Unburned	8.27 ± 1.04	0.45 ± 0.09	18.6 ± 1.48	0.01 ± 0.00	0.08 ± 0.02	0.03 ± 0.01	0.28 ± 0.22	1.77 ± 1.36	0.79 ± 0.69	1.02 ± 1.63
NS2	Unburned	4.38 ± 2.01	0.30 ± 0.11	14.3 ± 2.07	0.03 ± 0.03	0.19 ± 0.08	0.19 ± 0.03	1.30 ± 0.88	0.23 ± 0.18	0.86 ± 0.67	0.76 ± 0.44
NS3	Unburned	4.77 ± 1.99	0.44 ± 0.18	10.8 ± 0.10	0.02 ± 0.01	0.21 ± 0.05	0.28 ± 0.01	2.75 ± 0.97	0.05 ± 0.01	0.90 ± 0.52	1.73 ± 0.78
SKI	Unburned	1.78 ± 1.54	0.10 ± 0.08	17.4 ± 4.70	0.08 ± 0.04	0.23 ± 0.11	0.57 ± 0.13	8.09 ± 3.03	0.01 ± 0.02	0.30 ± 0.19	0.50 ± 0.66
Mean		**4.58**	**0.29**	**16.0**	**0.06**	**0.36**	**0.58**	**3.76**	**0.88**	**0.69**	**0.75**
Means Range		**1.78 – 8.27**	**0.10 – 0.45**	**10.8 – 20.7**	**0.01 – 0.09**	**0.08 – 0.84**	**0.03 – 1.40**	**0.28 – 8.09**	**0.00 – 2.90**	**0.22 – 0.90**	**0.06 – 1.73**

*MC = moisture content, TA = total acidity, EBC = exchangeable base cations, ECEC = effective cation exchange capacity, BS = base saturation, OM = organic matter content.

Table 6 Continued.

D. Unburned (road) sites; N =1.

Site ID	**Site Burn Level**	**MC (%)**	**DI pH**	**Salt pH**	**TA (cmol$_c$/kg)**	**EBC (cmol$_c$/kg)**	**ECEC (cmol$_c$/kg)**	**BS (%)**	**OM (%)**	**SO_4 (cmol$_c$/kg)**
RS441	Unburned	26.9 ± 2.90	5.71 ± 0.34	4.83 ± 0.38	1.82 ± 2.27	4.25 ± 2.42	6.31 ± 1.12	84.5 ± 12.1	12.0 ± 1.84	0.18 ± 0.08

Site ID	**Site Burn Level**	**C (%)**	**N (%)**	**C/N**	**Na (cmol$_c$/kg)**	**K (cmol$_c$/kg)**	**Mg (cmol$_c$/kg)**	**Ca (cmol$_c$/kg)**	**Al (cmol$_c$/kg)**	**NH_4 (cmol$_c$/kg)**	**NO_3 (cmol$_c$/kg)**
RS441	Unburned	4.40 ± 0.76	0.35 ± 0.04	12.6 ± 0.69	0.09 ± 0.05	0.32 ± 0.09	1.05 ± 0.35	3.64 ± 0.96	0.39 ± 0.37	0.24 ± 0.11	1.16 ± 2.01

*MC = moisture content, TA = total acidity, EBC = exchangeable base cations, ECEC = effective cation exchange capacity, BS = base saturation, OM = organic matter content.

Table 6 Continued.

E. Reference sites; N = 7.

Site ID	Site Burn Level	MC (%)	DI pH	Salt pH	TA (cmol$_c$/kg)	EBC (cmol$_c$/kg)	ECEC (cmol$_c$/kg)	BS (%)	OM (%)	SO$_4$ (cmol$_c$/kg)
RP1	Ref	35.9 ± 5.81	5.73 ± 0.52	4.94 ± 0.54	0.30 ± 0.42	2.65 ± 1.90	4.01 ± 1.89	90.0 ± 14.2	10.8 ± 3.74	0.09 ± 0.01
RP2	Ref	35.3 ± 4.72	6.02 ± 0.59	5.48 ± 0.74	0.20 ± 0.28	1.07 ± 0.32	1.99 ± 0.81	90.0 ± 14.2	8.54 ± 1.00	0.07 ± 0.01
SGL	Ref	28.3 ± 11.9	6.57	6.33 ± 0.92	7.63 ± 10.79	3.03 ± 4.27	11.0 ± 6.52	100	13.5	0.11 ± 0.03
TREE	Ref	21.8 ± 5.81	6.27 ± 0.22	5.06 ± 0.70	0.82 ± 1.10	2.38 ± 3.23	3.94 ± 3.17	97.0 ± 4.22	6.18 ± 0.25	0.11 ± 0.04
WCP1	Ref	27.0 ± 9.97	6.78 ± 0.11	6.23 ± 0.52	0.00 ± 0.00	5.77 ± 2.52	7.25 ± 2.76	100 ± 0.00	8.66 ± 4.00	0.19 ± 0.13
WCP2	Ref	38.9 ± 7.33	4.82 ± 0.07	4.09 ± 0.18	2.60 ± 1.70	0.48 ± 0.22	3.96 ± 2.08	34.8 ± 23.7	11.5 ± 3.71	0.17 ± 0.08
WCP3	Ref	33.4 ± 8.73	5.13 ± 0.24	4.37 ± 0.18	1.20 ± 0.57	1.75 ± 1.05	3.74 ± 0.97	68.3 ± 14.7	9.18 ± 5.65	0.07 ± 0.01
Mean		**31.5**	**5.90**	**5.14**	**0.69**	**2.77**	**4.35**	**78.7**	**9.77**	**0.11**
Means Range		**21.8 – 38.9**	**4.82 – 6.78**	**4.09 – 6.33**	**0.00 – 7.63**	**0.48 – 5.77**	**1.99 – 11.0**	**34.8 – 100**	**6.18 – 13.5**	**0.07 – 0.19**

Site ID	Site Burn Level	C (%)	N (%)	C/N	Na (cmol$_c$/kg)	K (cmol$_c$/kg)	Mg (cmol$_c$/kg)	Ca (cmol$_c$/kg)	Al (cmol$_c$/kg)	NH$_4$ (cmol$_c$/kg)	NO$_3$ (cmol$_c$/kg)
RP1	Ref	3.93 ± 2.06	0.31 ± 0.17	12.7 ± 0.27	0.03 ± 0.03	0.11 ± 0.03	0.27 ± 0.08	2.24 ± 1.45	0.16 ± 0.09	1.06 ± 1.18	0.94 ± 0.20
RP2	Ref	3.55 ± 0.52	0.20 ± 0.04	17.4 ± 0.58	0.02 ± 0.01	0.12 ± 0.02	0.09 ± 0.02	0.85 ± 0.26	0.14 ± 0.09	0.72 ± 0.81	0.35 ± 0.60
SGL	Ref	-	-	-	0.01 ± 0.00	0.41 ± 0.03	0.90 ± 0.08	4.73 ± 0.36	0.03 ± 0.00	0.28 ± 0.07	2.62 ± 0.24
TREE	Ref	2.19 ± 0.23	0.18 ± 0.01	12.4 ± 0.59	0.03 ± 0.03	0.20 ± 0.13	0.67 ± 0.70	2.33 ± 2.47	0.89 ± 1.01	0.73 ± 0.66	0.46 ± 0.31
WCP1	Ref	6.26 ± 1.65	0.29 ± 0.04	21.4 ± 2.53	0.06 ± 0.07	0.08 ± 0.02	0.45 ± 0.17	5.18 ± 2.05	0.03 ± 0.01	1.48 ± 1.12	0.69 ± 0.31
WCP2	Ref	6.82 ± 4.28	0.36 ± 0.23	19.2 ± 0.28	0.04 ± 0.04	0.09 ± 0.01	0.04 ± 0.00	0.31 ± 0.14	3.23 ± 2.97	0.88 ± 0.82	0.68 ± 0.64
WCP3	Ref	3.18	0.26	12.5	0.03 ± 0.01	0.11 ± 0.03	0.14 ± 0.04	1.47 ± 0.80	1.75 ± 1.07	0.79 ± 0.84	0.83 ± 0.51
Mean		**4.92**	**0.29**	**17.1**	**0.03**	**0.14**	**0.33**	**2.27**	**0.96**	**0.89**	**0.81**
Means Range		**2.19 – 6.82**	**0.18 – 0.36**	**12.4 – 21.4**	**0.01 – 0.06**	**0.08 – 0.41**	**0.04 – 0.90**	**0.31 - 5.18**	**0.03 – 3.23**	**0.28 – 1.48**	**0.35 – 2.62**

*MC = moisture content, TA = total acidity, EBC = exchangeable base cations, ECEC = effective cation exchange capacity, BS = base saturation, OM = organic matter content.

B. Comparison of Soil Chemistry between Horizons

Mean values of each chemical parameter were compared between soil A/O and B horizons for low/med burn, unburned, and reference sites (Table 7 a-c). The high burn sites were not compared because the A/O horizon rich in organic matter was completely burned and no longer existed post-fire. Salt pH values were similar for the A/O and B horizons averaging for the reference sites 5.06 and 5.14, the unburned sites 5.64 and 5.35, and the low/med burn sites 4.38 and 4.20 ($p = 0.69$, 0.18, and 0.64), respectively. Similarly, TA were similar for the A/O and B horizons averaging for the reference sites 0.40 and 0.69 $cmol_c$/kg, the unburned sites 0.80 and 1.21 $cmol_c$/kg, ($p = 0.15$, 0.19), respectively. The only significant difference was at low/medium sites, where the A/O horizon sites had a TA (2.40 $cmol_c$/kg) significantly lower than the B horizon (3.82 $cmol_c$/kg) ($p<0.01$). Nitrate was not significantly different between the two soil horizons for reference and unburned levels ($p = 0.08$, 0.98 respectively). In low/medium burn areas, the nitrate was significantly lower in the B horizon (0.21 $cmol_c$/kg) than the A/O (0.64 $cmol_c$/kg) ($p = 0.02$). The %OM was significantly greater in A/O horizon with a range among reference, unburned, and low/med/burn sites of 18.6-20.1% compared to the B horizon with a range of 7.53-9.77% ($p <0.01$, <0.01, and < 0.01, respectively). As evidenced by the higher %OM content in the A/O horizon compared with the B horizon, EBC, ECEC, and %BS were also significantly greater in the A/O horizon. For example, ECEC A/O and B horizon averages for the reference sites were 7.40 and 4.35 $cmol_c$/kg, the unburned sites 13.97 and 6.66 $cmol_c$/kg, and the low/med burn sites 7.85 and 5.32 $cmol_c$/kg, respectively (all $p < 0.01$). In these acidic soils demonstrating the influence of Al, ECEC values were greater than EBC for all burn conditions and both soil horizons. The individual base cations measured were all, aside from Na, significantly lower in the B horizon than A/O at all burn levels ($p<0.01$). Na was significantly lower in the B horizon, only at reference sites ($p = 0.04$). Conversely, Al was consistently greater in the B horizon than the A/O at all burn levels ($p<0.01$). Measures of %C and %N were greater in the A/O horizon compared to the B horizon among all site burn levels, though not significantly for the references sites, where %C ranged from 6.59-9.13 for the A/O horizon compared to 3.69-4.92% for the B horizon, and %N ranged from 0.54-0.44 for the A/O horizon compared to 0.15-0.29% for the B horizon. Overall, the chemical properties were greater in the A/O horizon for all parameters, aside from the salt pH at the reference sites. TS was greater in the A/O horizon compared with the B horizon illustrating higher amounts of S in the A/O horizon.

Table 7. *Comparison of soil chemistry between the A/O and B soil horizons. ANOVA significant differences appear in bold ($p<0.05$).*

A. Reference sites; N=22.

Horizon	Salt pH	TA (cmol$_c$/kg)	EBC (cmol$_c$/kg)	ECEC (cmol$_c$/kg)	BS (%)	OM (%)	C (%)	N (%)	C/N
A/O	5.06	0.40	**6.16**	**7.40**	**88.1**	**19.2**	6.59	0.44	**14.4**
B	5.14	0.69	**2.77**	**4.35**	**78.7**	**9.77**	4.92	0.29	**17.1**
Prob > F	0.71	0.15	**p<0.01**	**p<0.01**	**p<0.01**	**p<0.01**	0.37	0.11	**0.046**

Horizon	Na (cmol$_c$/kg)	K (cmol$_c$/kg)	Mg (cmol$_c$/kg)	Ca (cmol$_c$/kg)	Al (cmol$_c$/kg)	NO_3 (cmol$_c$/kg)	NH_4 (cmol$_c$/kg)	SO_4 (cmol$_c$/kg)	TS (mg-S/kg)
A/O	**0.06**	**0.37**	**0.93**	**4.80**	**0.11**	1.25	0.84	0.34	577
B	**0.03**	**0.14**	**0.33**	**2.27**	**0.96**	0.81	0.89	0.11	304
Prob > F	**0.04**	**p<0.01**	**p<0.01**	**p<0.01**	**p<0.01**	0.08	0.80	0.08	0.11

*TA = total acidity, EBC = exchangeable base cations, ECEC = effective cation exchange capacity, BS = base saturation, OM = organic matter content, TS = total sulfur.

B. Unburned (no road) sites; N=36.

Horizon	Salt pH	TA (cmol$_c$/kg)	EBC (cmol$_c$/kg)	ECEC (cmol$_c$/kg)	BS (%)	OM (%)	C (%)	N (%)	C/N
A/O	5.64	0.80	**12.4**	**13.97**	**84.3**	**20.1**	**9.13**	**0.54**	16.7
B	5.35	1.21	**4.77**	**6.66**	**67.3**	**8.96**	**4.58**	**0.29**	16.0
Prob > F	0.23	0.19	**p<0.01**	**p<0.01**	**p<0.01**	**p<0.01**	**p<0.01**	**p<0.01**	0.49

Horizon	Na (cmol$_c$/kg)	K (cmol$_c$/kg)	Mg (cmol$_c$/kg)	Ca (cmol$_c$/kg)	Al (cmol$_c$/kg)	NO_3 (cmol$_c$/kg)	NH_4 (cmol$_c$/kg)	SO_4 (cmol$_c$/kg)	TS (mg-S/kg)
A/O	0.09	**0.65**	**1.78**	**9.84**	**0.29**	0.76	0.77	0.28	400
B	0.06	**0.36**	**0.58**	**3.76**	**0.88**	0.75	0.69	0.33	259
Prob > F	0.16	**p<0.01**	**p<0.01**	**p<0.01**	**p<0.01**	0.98	0.66	0.68	0.12

*TA = total acidity, EBC = exchangeable base cations, ECEC = effective cation exchange capacity, BS = base saturation, OM = organic matter content, TS = total sulfur.

Table 7 Continued.

C. Low/medium burn sites; N=14.

Horizon	Salt pH	TA (cmol$_c$/kg)	EBC (cmol$_c$/kg)	ECEC (cmol$_c$/kg)	BS (%)	OM (%)	C (%)	N (%)	C/N
A/O	**4.38**	**2.40**	**4.81**	**7.85**	**68.0**	**18.6**	**8.98**	**0.44**	**21.6**
B	**4.20**	**3.82**	**0.96**	**5.32**	**32.4**	**8.34**	**3.69**	**0.15**	**24.8**
Prob > F	**p<0.01**	**p<0.01**	**p<0.01**	**p<0.01**	**p<0.01**	**p<0.01**	**p<0.01**	**p<0.01**	**0.03**

Horizon	Na (cmol$_c$/kg)	K (cmol$_c$/kg)	Mg (cmol$_c$/kg)	Ca (cmol$_c$/kg)	Al (cmol$_c$/kg)	NO_3 (cmol$_c$/kg)	NH_4 (cmol$_c$/kg)	SO_4 (cmol$_c$/kg)	TS (mg-S/kg)
A/O	0.08	**0.50**	**0.76**	**3.47**	**1.02**	**0.64**	0.64	0.32	339
B	0.06	**0.27**	**0.16**	**0.46**	**2.41**	**0.21**	0.54	0.16	207
Prob > F	0.16	**p<0.01**	**p<0.01**	**p<0.01**	**p<0.01**	**0.02**	0.71	0.20	0.16

*TA = total acidity, EBC = exchangeable base cations, ECEC = effective cation exchange capacity, BS = base saturation, OM = organic matter content, TS = total sulfur.

C. Comparison of Soil Chemistry among Site Burn Severity Levels

Soil chemical parameters were compared independently for the A/O and B horizons among site burn severity levels including: high burn, low/med burn, unburned, and reference sites (Table 8). Salt pH values were significantly lower in burned areas for both the A/O and B horizons ($p < 0.01$). A/O horizon salt pH for the reference and unburned sites were 5.06 and 5.64 respectively compared to the low/medium burn site average pH of 4.38. B horizon salt pH for the reference and unburned sites were 5.14 and 5.35 compared to the low/medium and high burn sites of 4.20 and 4.27 respectively. TA were significantly greater ($p<0.001$) in burned sites in the A/O horizon, with an average of 2.40 $cmol_c/kg$ in low/medium sites compared to reference and unburned sites of 0.40 $cmol_c/kg$ and 0.80 $cmol_c/kg$, respectively. Similarly, TA were significantly greater ($p<0.001$) in the B horizon in low/medium and high burned sites, with means of 3.82 and 4.52 $cmol_c/kg$, respectively, compared to the references and unburned site means of 0.69 and 1.21 $cmol_c/kg$, respectively. The %OM values were similar at all burn severity levels, with reference sites averaging 19.2% and 9.77% in the A/O and B horizon, the unburned sites 20.1 and 8.96, low/medium sites 18.6 and 8.34, and high burn sites averaging 7.53 in the B horizon, with no significant differences. The average EBC was highest in unburned sites in both soil horizons (12.4 and 4.77 $cmol_c/kg$, in the A/O and B horizon respectively). Both horizons EBC was significantly greater in the unburned sites as compared to low/medium and reference sites ($p = 0.017$). Similarly, the ECEC was greatest at the unburned sites in the A/O horizon, with an average of 13.97 $cmol_c/kg$, significantly greater than both reference (7.40 $cmol_c/kg$) and low/medium (7.85 $cmol_c/kg$) sites ($p<0.001$). In the B horizon, unburned sites averaged 5.97 $cmol_c/kg$, while reference sites averaged 3.46 $cmol_c/kg$ and low/medium and high burn sites 4.78 $cmol_c/kg$ and 6.99 $cmol_c/kg$ respectively. The high burn areas had the greatest value, significantly greater ($p<0.001$) than reference and low/medium sites, which were statistically similar ($p = 0.25$). As the ECEC is the sum of TA and EBC, it was not surprising to see a similar pattern between EBC and ECEC. EBC and ECEC were significantly correlated for each site burn condition and soil horizon (t-test, $p < 0.001$).

%BS was significantly lower in burned areas in both horizons; 68.0% in burned A/O horizon, compared to 88.1 and 84.3% in reference and unburned sites in the A/O horizon. %BS averaged 32.4 and 37.6% in low/medium and high burn sites compared to 78.7 and 67.3% in reference and unburned sites in the B horizon ($p<0.01$). In these acidic soils demonstrating the influence of Al, ECEC values were greater than EBC for all burn conditions and both soil horizons. Al was significantly higher in burned areas ($p<0.01$) for both soil horizons. A/O horizon Al averaged 1.02 $cmol_c/kg$ in low/medium sites, and just 0.84 and 0.77 $cmol_c/kg$ in reference and unburned areas. B horizon patterns were similar, with 2.41 and 2.93 $cmol_c/kg$ Al in low/medium and high burn sites, and 0.96 and 0.88 $cmol_c/kg$ in reference and unburned areas. Sulfate and ammonium means per burn severity level showed no pattern. High burn site sulfate was significantly different than reference site sulfate ($p = 0.023$), with high sites averaging 0.40 $cmol_c/kg$ and reference B horizon sites averaging 0.11 $cmol_c/kg$. Low/medium and high sites were not statistically different ($p = 0.062$), and neither were high sites compared to unburned sites ($p = 0.698$). Measures of %C and %N were similar at all burn levels in the A/O horizon, where %C ranged from 6.59 to 9.13 and %N ranged from 0.44 to 0.54. In the B horizon, %C and %N was greater in unburned areas, though only significantly for %N. %C averaged 4.92 to 4.58 in reference and unburned sites, respectively, and 3.69 to 3.92 in low/medium and high burn sites, respectively. %N was significantly lower in burned areas, 0.154 and 0.151 in low/medium and high burn sites, and 0.288 and 0.292 in reference and unburned sites ($p<0.01$). The TS was lower for burned areas in both horizons with averages in the low/medium burn sites 339 mg-S/kg in A/O and 207 mg-S/kg in the B horizon, with lowest averages in high burn areas (171 mg-S/kg**)**. However, no statistically significant differences were found between the burn levels in either the A/O and B horizon ($p = 0.63$; $= 0.61$, respectively). Additionally, TS was lower in the unburned sites (400 mg-S/kg in A/O and 259 mg-S/kg in B horizon) than in the reference sites (577 mg-S/kg in A/O and 304 mg-S/kg in B). In the high burn areas that lacked an A/O horizon, the S in organic material that burned likely was exported.

The ratios of ECEC/%OM and ECEC/%C were calculated per burn severity level and soil horizon. ECEC/%OM in the A/O and B horizon was significantly greater in unburned sites (0.885 in A/O; 1.09 in B), compared to reference (0.545 in A/O and 0.392 in B) and low/medium burn sites (0.401 in A; 0.604 in B) ($p<0.01$). In high burn sites, the ECEC/%OM ratio averaged 1.01, statistically similar to that of unburned sites ($p = 0.96$). ECEC/%C was similarly greatest at unburned sites, 1.71 in the A/O horizon and 2.48 in the B horizon. In the A/O horizon, reference sites were significantly lower than unburned sites with ECEC/%C of 1.33, and low/medium sites weren’t significantly from either reference or unburned sites at 0.877. In the B horizon, no statistically significant differences were noted for ECEC/%C, however the unburned was again the greatest ratio (2.48).

Table 8. *ANOVA means separation analysis per burn severity level in A/O and B soil horizons. ANOVA significant differences (p<0.05) appear in bold.*

Horizon	Burn Level	Salt pH	TA (cmol$_c$/kg)	EBC (cmol$_c$/kg)	(cmol$_c$/kg)	BS (%)	OM (%)	Sulfate (cmol$_c$/kg)	C (%)	N (%)	C/N
A/O	Reference	**5.06 A**	**0.40 A**	**6.16 A**	**7.40 A**	**88.1 A**	19.2	0.34	6.59	0.44	**14.4 A**
	Unburned	**5.64 B**	**0.80 A**	**12.4 B**	**13.97 B**	**84.3 A**	20.1	0.28	9.13	0.539	**16.7 B**
	Low/Med	**4.38 C**	**2.40 B**	**4.81 A**	**7.85 A**	**68.0 B**	18.6	0.32	8.98	0.438	**21.6 C**

Horizon	Burn Level	Salt pH	TA (cmol$_c$/kg)	EBC (cmol$_c$/kg)	ECEC (cmol$_c$/kg)	BS (%)	OM (%)	Sulfate (cmol$_c$/kg)	C (%)	N (%)	C/N
B	Reference	**5.14 A**	**0.69 A**	**2.77 A**	**4.35 A**	**78.7 A**	9.77	0.11	4.92	**0.288 A**	**17.1 A**
	Unburned	**5.35 A**	**1.21 A**	**4.77 B**	**6.66 BC**	**67.3 A**	8.96	0.33	4.58	**0.292 A**	**16.0 A**
	Low/Med	**4.20 B**	**3.82 B**	**0.96 C**	**5.32 AB**	**32.4 B**	8.34	0.16	3.69	**0.154 B**	**24.8 B**
	High	**4.27 B**	**4.52 B**	**2.48 A**	**7.60 C**	**37.6 B**	7.53	0.40	3.92	**0.151 B**	**26.9 B**

*TA = total acidity, EBC = exchangeable base cations, ECEC = effective cation exchange capacity, BS = base saturation, OM = organic matter content, TS = total sulfur.

Horizon	Burn Level	Na (cmol$_c$/kg)	K (cmol$_c$/kg)	Mg (cmol$_c$/kg)	Ca (cmol$_c$/kg)	Al (cmol$_c$/kg)	NH_4 (cmol$_c$/kg)	NO_3 (cmol$_c$/kg)	TS (mg-S/kg)	ECEC/ %OM	ECEC/ %C
A/O	Reference	0.064	**0.366 A**	**0.928 A**	**4.803 A**	**0.106 A**	0.840	1.247	577	**0.545 A**	**1.33 AB**
	Unburned	0.087	**0.652 B**	**1.78 B**	**9.842 B**	**0.287 A**	0.768	0.757	400	**0.885 B**	**1.71 A**
	Low/Med	0.078	**0.501 AB**	**0.762 A**	**3.465 A**	**1.02 B**	0.636	0.644	339	**0.401 A**	**0.877 B**

Horizon	Burn Level	Na (cmol$_c$/kg)	K (cmol$_c$/kg)	Mg (cmol$_c$/kg)	Ca (cmol$_c$/kg)	Al (cmol$_c$/kg)	NH_4 (cmol$_c$/kg)	NO_3 (cmol$_c$/kg)	TS (mg-S/kg)	ECEC/ %OM	ECEC/ %C
B	Reference	**0.032 A**	**0.141 A**	**0.325 A**	**2.27 A**	**0.955 A**	0.894	**0.810 A**	304	**0.392 A**	0.878
	Unburned	**0.063 AB**	**0.363 B**	**0.584 B**	**3.76 A**	**0.881 A**	0.688	**0.752 A**	259	**1.09 B**	2.48
	Low/Med	**0.063 AB**	**0.265 AB**	**0.175 A**	**0.461 B**	**2.41 B**	0.544	**0.209 B**	207	**0.604 A**	1.57
	High	**0.071 B**	**0.330 B**	**0.288 A**	**1.79 AB**	**2.93 B**	0.613	**0.391 AB**	171	**1.01 B**	2.43

*TA = total acidity, EBC = exchangeable base cations, ECEC = effective cation exchange capacity, BS = base saturation, OM = organic matter content, TS = total sulfur.

D. Qualitative Assessment of Post-fire Trends in Soil Chemistry

Exchangeable Base Cations

A temporal analysis was done comparing burn levels (REF = reference, UNB = unburned, LMB = low/medium burn, HB = high burn) over time post-fire for EBC (Figure 16). EBC tended to decrease at all levels, in both horizons. High burn EBC was highly variable.

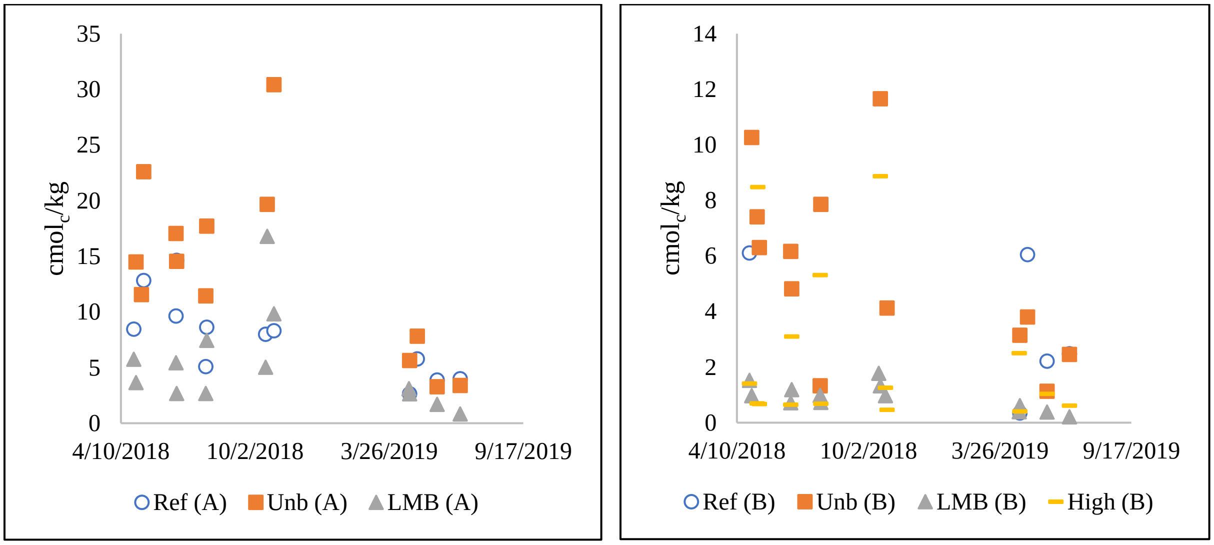

Figure 16. *Post-fire trends for exchangeable base cations at reference, unburned and low/medium burn sites in the A/O (left)and B (right) soil horizons (REF = reference, UNB = unburned, LMB = low/medium burn, HB = high burn).*

Percent Base Saturation

A temporal analysis was done comparing burn levels (REF = reference, UNB = unburned, LMB = low/medium burn, HB = high burn) over time post-fire for %BS (Figure 17). Similar to EBC, the %BS decreased as time went on and the high burn sites were highly varied.

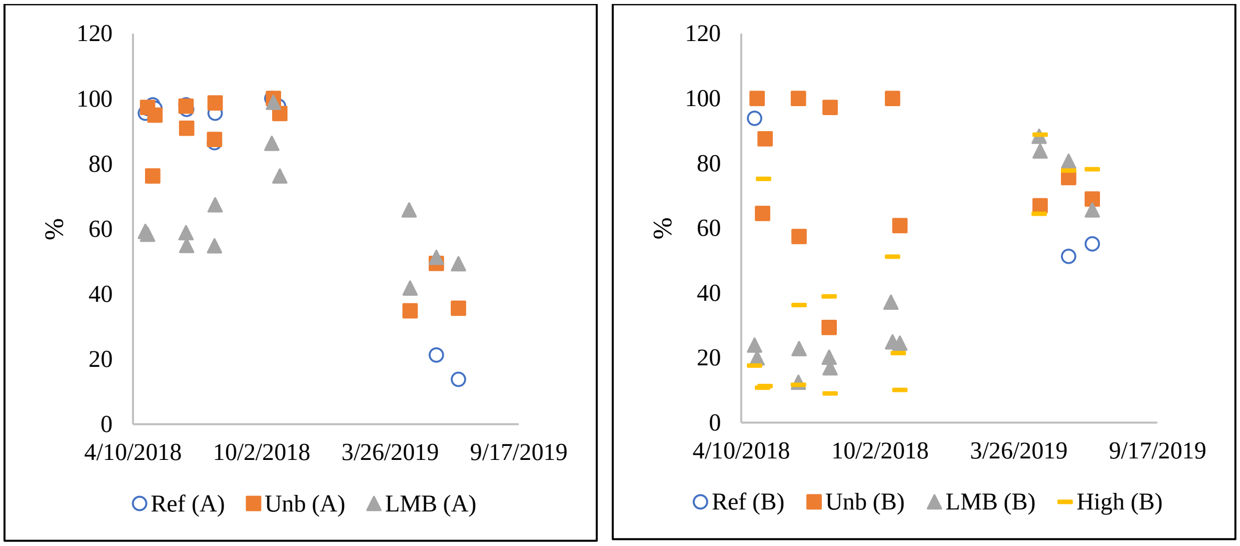

Figure 17. *Post-fire trends for percent base saturation at reference, unburned and low/medium burn sites in the A/O (left)and B (right) soil horizons (REF = reference, UNB = unburned, LMB = low/medium burn, HB = high burn).*

Total Acidity

A temporal analysis was done comparing burn levels (REF = reference, UNB = unburned, LMB = low/medium burn, HB = high burn) over time post-fire for TA (Figure 18). TA decreased over time post-fire. Burned sites had the greatest TA values.

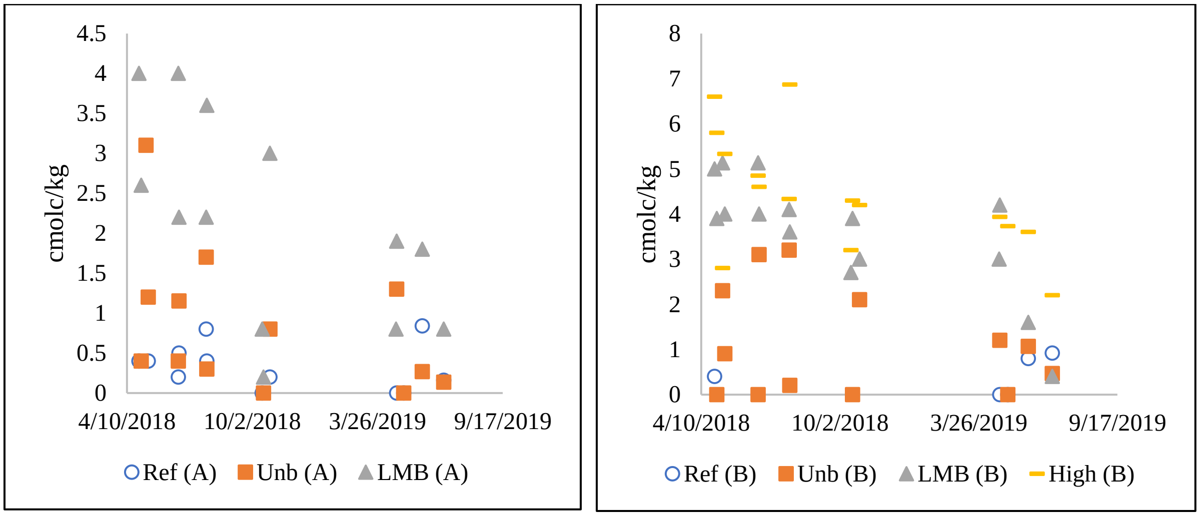

Figure 18. *Post-fire trends for total acidity at reference, unburned and low/medium burn sites in the A/O (left)and B (right) soil horizons (REF = reference, UNB = unburned, LMB = low/medium burn, HB = high burn).*

Total Sulfur

A temporal representation of TS data was done on sites with more than two collection dates. Figure 19 displays the data for the B horizon of site BGB (unburned), B horizon of site SCM (high burn) and A/O horizon of site NEON (low/medium burn). The TS measured tended to decrease as time passed post-fire at the sites analyzed, in both the A/O and B soil horizons at unburned and low/medium sites, while the high burn site increased post-fire after an initial decrease. The unburned site had a smaller range of values over the four analyzed dates than did the burned sites. The site in the A/O horizon tended to have the highest values.

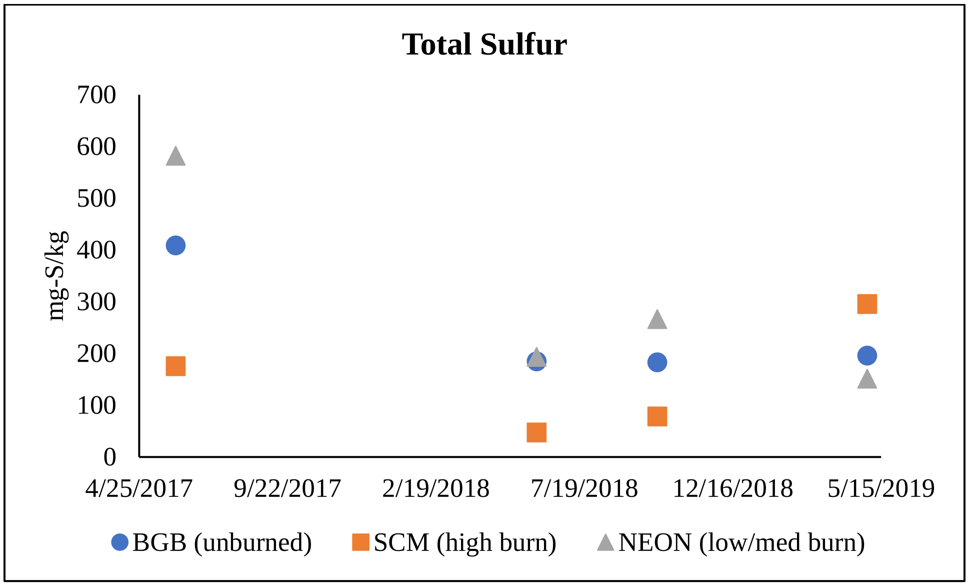

Figure 19. *Total sulfur at site BGB (unburned) in the B horizon, SCM (high burn) in the B horizon and NEON (low/medium burn) in the A/O horizon over time post-fire, 4 dates plotted.*

Soil Carbon and Nitrogen

A temporal analysis was done comparing burn levels (REF = reference, UNB = unburned, LMB = low/medium burn, HB = high burn) over time post-fire for %C, %N and C/N. The percent C over time per burn severity level in the A/O and B horizons is displayed on Figure 20. The percent N in the A/O horizon and B horizon is shown in Figure 21, and the ratio of C:N in the A/O and B horizons is indicated in Figure 22. The A/O horizon showed a larger range of values and more change over the two year period than the B horizon for both %C and %N. No soil samples from directly following the fire (2017) were available for %C and %N analysis. The %C and %N showed similar trends over the two year period, which is indicated by the steady nature of the ratio of C:N. The C:N was highest for high burn sites (26.9), indicating that the burned areas had more C compared to N than did unburned areas. However, high burn sites (all B horizon) tended to have the lowest %C and %N content of all tested sites.

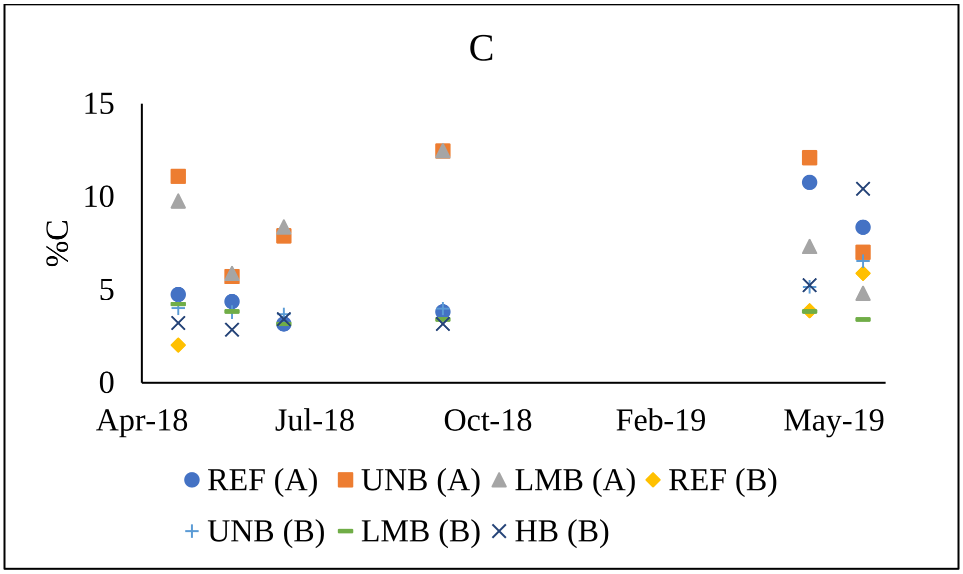

Figure 20. *Post-fire trends for percent C at reference, unburned and low/medium burn sites in the A/O and B soil horizons (REF = reference, UNB = unburned, LMB = low/medium burn, HB = high burn).*

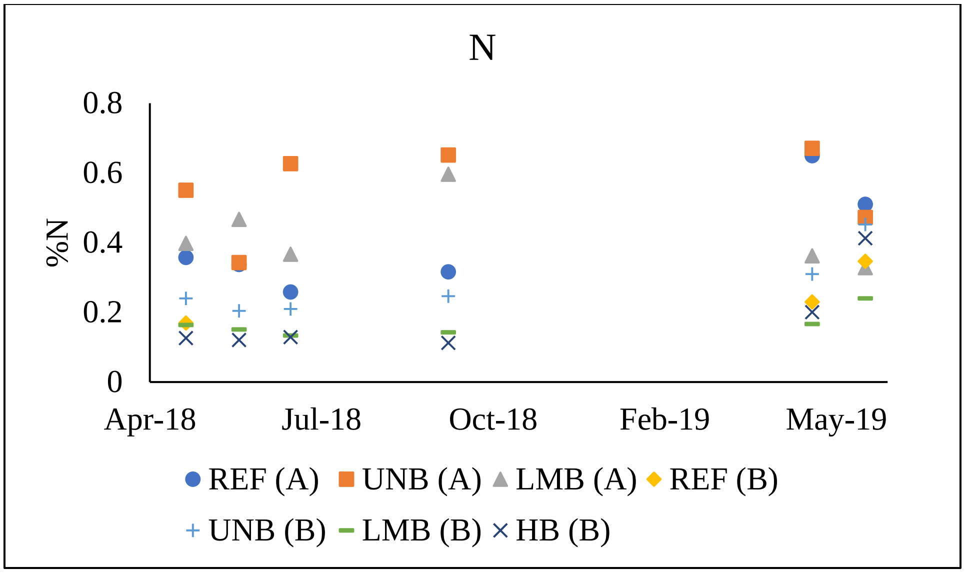

Figure 21. *Post-fire trends for percent N at reference, unburned and low/medium burn sites in the A/O and B soil horizons (REF = reference, UNB = unburned, LMB = low/medium burn, HB = high burn).*

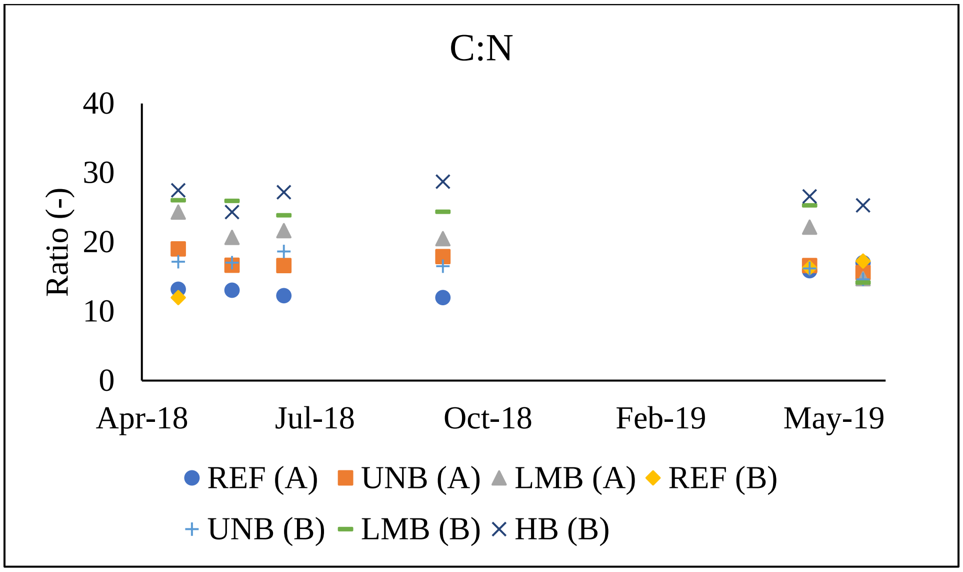

Figure 22. *Post-fire trends for C to N ratio at reference, unburned and low/medium burn sites in the A/O and B soil horizons (REF = reference, UNB = unburned, LMB = low/medium burn, HB = high burn).*

E. Historical Soil Data Comparison

A two-way contingency analysis was used to compare pre- and post-fire chemical differences. Of the sites with historic soil data available, 6 total, the only site that burned was RP3 (Road Prong site 3). RP3 was in an area classified as low/medium burn severity. The remaining historic sites were all outside the burn footprint, and therefore reference sites. The data were compared pre- and post-fire for both the A/O and B soil horizons (Table 9 & 10). No differences were significant ($p<0.05$) between pre- and post-fire data, as indicated by the p-values displayed in Table 9 and 10. Salt pH in the A/O horizon increased after the fire at all sites, whereas in the B horizon the salt pH decreased post-fire at all sites besides WCP1. TA consistently decreased post-fire, in both horizons and at all sites, as did nitrate content, aside from site RP1 in the A/O horizon. Ammonium was elevated at all six sites, including burned and unburned, for both soil horizons, post-fire. The %BS increased most drastically at the burned RP3 site in both soil horizons.

Table 9. *Comparison of soil chemistry between pre- and post-fire periods for Road Prong and Walker Camp Prong watersheds in A/O horizon. Parameters reported as means. Pre-fire data collected in 2009 from Grell (2010).*

Road Prong (RP) watershed:

Soil Chemical Parameters	**Unburned RP1 Site (p=0.253)**		**Unburned RP2 Site (p=0.175)**		**Burned RP3 Site (p=0.252)**	
	Pre-fire	Post-fire	Pre-fire	Post-fire	Pre-fire	Post-fire
Salt pH	3.83	4.60	4.32	5.33	3.64	4.63
TA (cmol$_c$/kg)	4.53	0.40	3.65	0.20	3.04	1.30
EBC (cmol$_c$/kg)	2.10	3.60	4.73	2.21	12.5	1.26
ECEC (cmol$_c$/kg)	6.63	4.00	2.17	2.41	2.98	2.56
%BS	31.7	93.8	6.9	95.0	15.4	64.9
%OM	11.9	18.7	31.5	11.7	19.3	18.9
NO_3 (cmol$_c$/kg)	0.21	1.25	13.7	0.99	48.7	0.91
SO_4 (cmol$_c$/kg)	0.03	0.10	0.25	0.08	0.42	0.13
NH_4 (cmol$_c$/kg)	0.03	2.00	0.03	0.76	0.08	1.66

*TA = total acidity, EBC = exchangeable base cations, ECEC = effective cation exchange capacity, BS = base saturation, OM = organic matter content.

Walker Camp Prong (WCP) watershed:

Soil Chemical Parameters	**Unburned WCP1 Site (p=0.143)**		**Unburned WCP2 Site (p=0.242)**		**Unburned WCP3 Site (p=0.184)**	
	Pre-fire	Post-fire	Pre-fire	Post-fire	Pre-fire	Post-fire
Salt pH	5.2	4.64	4.48	4.13	4.97	4.07
TA (cmol$_c$/kg)	4.67	0.20	3.9	1.30	4.42	0.40
EBC (cmol$_c$/kg)	0.57	4.54	3.97	4.49	1.15	4.82
ECEC (cmol$_c$/kg)	8.34	4.74	2.05	5.79	5.26	5.22
%BS	8.91	97.8	6.22	85.6	6.41	93.5
%OM	93.7	27.4	33.0	51.7	82.1	29.3
NO_3 (cmol$_c$/kg)	20.4	0.81	9.98	1.20	11.4	0.95
SO_4 (cmol$_c$/kg)	0.27	0.18	0.23	0.19	0.29	0.17
NH_4 (cmol$_c$/kg)	0.09	1.63	0.04	1.14	0.03	1.12

*TA = total acidity, EBC = exchangeable base cations, ECEC = effective cation exchange capacity, BS = base saturation, OM = organic matter content.

Table 10. *Comparison of soil chemistry between pre- and post-fire periods for Road Prong and Walker Camp Prong watersheds in B horizon. Parameters reported as means. Pre-fire data collected in 2009 from Grell (2010).*

Road Prong (RP) watershed:

Soil Chemical Parameters	**Unburned RP1 Site (p=0.242)**		**Unburned RP2 Site (p=0.143)**		**Burned RP3 Site (p=0.086)**	
	Pre-fire	Post-fire	Pre-fire	Post-fire	Pre-fire	Post-fire
Salt pH	4.67	4.94	4.6	5.48	4.45	4.66
TA ($cmol_c$/kg)	4.18	0.30	4.01	0.20	4.19	1.00
EBC ($cmol_c$/kg)	2.54	2.65	3.08	1.07	2.45	0.30
ECEC ($cmol_c$/kg)	0.47	2.95	0.45	1.27	0.21	1.30
%BS	3.02	90.0	3.53	90.0	2.66	46.4
%OM	15.7	10.8	12.7	8.53	7.89	9.47
NO_3 ($cmol_c$/kg)	6.42	1.06	6.51	0.72	13.3	1.05
SO_4 ($cmol_c$/kg)	0.06	0.09	0.07	0.07	0.05	0.19
NH_4 ($cmol_c$/kg)	0.02	0.94	0.03	0.35	0.08	0.55

*TA = total acidity, EBC = exchangeable base cations, ECEC = effective cation exchange capacity, BS = base saturation, OM = organic matter content.

Walker Camp Prong (WCP) watershed:

Soil Chemical Parameters	**Unburned WCP1 Site (p=0.099)**		**Unburned WCP2 Site (p=0.358)**		**Unburned WCP3 Site (p=0.148)**	
	Pre-fire	Post-fire	Pre-fire	Post-fire	Pre-fire	Post-fire
Salt pH	5.25	6.23	4.67	4.09	5.54	4.37
TA ($cmol_c$/kg)	4.59	0.00	4.2	2.60	4.85	1.20
EBC ($cmol_c$/kg)	1.12	5.77	2.72	0.48	1.18	1.74
ECEC ($cmol_c$/kg)	1.92	5.77	0.6	3.08	3.92	2.94
%BS	3.23	100	3.14	34.8	5.09	68.3
%OM	59.4	8.66	19.3	11.5	76.9	9.18
NO_3 ($cmol_c$/kg)	9.51	1.48	5.82	0.88	7.01	0.79
SO_4 ($cmol_c$/kg)	0.09	0.19	0.10	0.17	0.13	0.07
NH_4 ($cmol_c$/kg)	0.11	0.69	0.05	0.68	0.04	0.83

*TA = total acidity, EBC = exchangeable base cations, ECEC = effective cation exchange capacity, BS = base saturation, OM = organic matter content.

F. Stream Water Chemistry: Pre- and Post-fire Parameter Characterization

Means and standard deviations of chemical properties measured were calculated for the water sampling sites (Table 11). Note, sites 73 and 74 were reference sites; neither site had any forest area burned within its watershed. These two sites were sampled by the same method and have historic data available. The pH was not highly variable among the sites and time frames, with a range of 6.10 to 6.77. The conductivity among the sites had a range of 11.7-18.0 µS/cm post-fire, and 16.1-29.8 µS/cm from 2008-2014. The average ANC at all stream sites was between 30.3 to 107 µmol$_c$/L from 2008 to 2014 and considerably lower, 17.7 to 54.1 µmol$_c$/L, post-fire. Chloride had a range of 13.6 to 24.6 µmol/L, at all sites and time frames. Nitrate tended to be lower post-fire, with averages per site between 14.5 and 29.1 µmol/L. Between 2008 and 2014 average nitrate fell between 31.3 and 35.5 µmol/L. Sulfate per site did not show a large range of average values between timeframes. Site 30, which had 60.7% watershed burned, averaged 29.6-32.6 µmol/L, site 66 averaged between 32.7 and 34.4 µmol/L, site 71 fell between 22.3 and 24.3 µmol/L, site 73 averaged 32.2 to 38.6 µmol/L and site 74 averaged 38.7 to 43.7 µmol/L. Ammonium from 2008 – 2014 ranged 1.09 to 2.01 µmol/L and post-fire ammonium ranged 0.01–1.27 µmol/L, with the higher values post-fire being at reference sites (1.03–1.27 µmol/L) compared to burned sites (0.01-0.36 µmol/L). Of the individual cations tested, Na, K, Mg and Al were not highly variable between time frames per site. Ca was the most varied cation, contributing the most to changes in the sum of cations, which among post-fire data at all sites, ranged 42.4 to 88.5 µmol/L. From 2008 to 2014, values were between 45.4 and 95.5 µmol/L.

Table 11. *Stream water chemistry for sites in or near the Chimney Tops 2 fire. A summary of means and standard deviations for pre-fire (1993 – 2007 and 2008 – fire) and post-fire periods. Units shown in title block.*

Site ID	**Time Frame**	**pH**	**Conductivity (µS/cm)**	**ANC (µmol$_c$/L)**	**Chloride (µmol/L)**	**Nitrate (µmol/L)**	**Sulfate (µmol/L)**	**Na (µmol/L)**
26	Post-Fire	6.28 ± 0.31	13.0 ± 4.92	42.6 ± 19.1	21.3 ± 14.9	14.5 ± 5.01	19.7 ± 2.58	83.5 ± 58.0
28	Post-Fire	6.32 ± 0.28	13.9 ± 5.65	54.1 ± 37.3	15.3 ± 4.90	15.9 ± 9.11	20.6 ± 2.49	37.2 ± 7.94
30	1993 – 2007	6.42 ± 0.29	20.9 ± 2.30	61.7 ± 23.5	18.4 ± 7.40	28.7 ± 11.2	32.6 ± 6.35	34.8 ± 8.78
30	2008 – Fire	6.60 ± 0.25	20.6 ± 2.35	55.6 ± 30.0	18.5 ± 4.80	31.9 ± 8.82	31.3 ± 6.75	30.8 ± 14.6
30	Post-Fire	6.35 ± 0.25	17.0 ± 4.73	45.9 ± 17.0	19.0 ± 10.7	25.7 ± 6.28	29.6 ± 2.51	34.9 ± 6.02
66	1993 – 2007	6.25 ± 0.28	19.9 ± 2.45	38.4 ± 23.4	16.0 ± 5.04	34.9 ± 9.59	34.4 ± 5.21	25.5 ± 5.02
66	2008 – Fire	6.47 ± 0.36	20.4 ± 5.77	39.6 ± 26.2	16.8 ± 2.82	35.5 ± 10.6	32.7 ± 8.45	24.9 ± 14.7
66	Post-Fire	6.24 ± 0.25	14.8 ± 5.09	28.8 ± 9.50	18.7 ± 10.7	29.1 ± 5.95	32.8 ± 1.39	27.4 ± 2.24
71	1993 – 2007	6.13 ± 0.26	15.9 ± 1.91	29.3 ± 20.4	15.2 ± 7.16	35.0 ± 8.94	23.2 ± 7.46	28.1 ± 6.24
71	2008 – Fire	6.32 ± 0.37	16.1 ± 3.37	30.3 ± 23.1	13.6 ± 4.62	34.5 ± 10.6	24.3 ± 6.30	23.9 ± 9.52
71	Post-Fire	6.10 ± 0.25	11.7 ± 5.48	17.7 ± 7.92	13.6 ± 5.86	24.8 ± 5.49	22.3 ± 6.52	26.8 ± 2.63
73	1993 – 2007	6.23 ± 0.30	21.0 ± 2.55	34.1 ± 19.3	17.5 ± 5.97	36.6 ± 9.06	38.6 ± 6.60	24.4 ± 4.85
73	2008 – Fire	6.52 ± 0.27	20.9 ± 4.00	42.2 ± 29.1	17.5 ± 4.88	34.2 ± 12.4	35.5 ± 8.35	24.1 ± 11.3
73	Post-Fire	6.20 ± 0.28	14.2 ± 4.19	25.0 ± 12.6	20.3 ± 13.6	26.8 ± 4.78	32.2 ± 5.95	26.0 ± 3.06
74	1993 – 2007	6.37 ± 0.34	24.9 ± 3.61	58.1 ± 33.5	18.5 ± 7.72	36.8 ± 8.73	43.7 ± 7.15	25.8 ± 5.02
74	2008 – Fire	6.77 ± 0.47	29.8 ± 14.6	107 ± 193	21.4 ± 6.66	31.3 ± 11.2	42.7 ± 10.7	27.4 ± 13.4
74	Post-Fire	6.37 ± 0.27	18.0 ± 6.25	46.8 ± 19.7	24.6 ± 16.5	28.7 ± 5.34	38.7 ± 3.93	30.5 ± 2.60

Table 11 Continued.

Site ID	Time Frame	K (μmol/L)	Mg (μmol/L)	Ca (μmol/L)	Al (μmol/L)	Sum of Cations (μmol$_c$/L)	Sum of Anions (μmol$_c$/L)	Ammonium (μmol/L)
26	Post-Fire	13.4 ± 3.17	27.2 ± 20.8	67.4 ± 49.8	0.007 ± 0.007	162 ± 5.43	74.6 ± 17.1	0.24 ± 0.54
28	Post-Fire	12.1 ± 2.54	14.1 ± 3.61	32.3 ± 8.65	0.007 ± 0.007	143 ± 32.5	80.9 ± 11.9	0.02 ± 0.04
30	1993 – 2007	9.66 ± 2.79	22.4 ± 5.1	48.6 ± 12.43	0.010 ± 0.007	182 ± 42.9	109 ± 29.9	0.15 ± 0.50
30	2008 – Fire	8.60 ± 5.32	18.9 ± 9.15	42.5 ± 21.3	0.020 ± 0.027	159 ± 77.9	99.6 ± 42.5	2.01 ± 2.03
30	Post-Fire	9.49 ± 1.32	21.3 ± 1.64	44.7 ± 2.75	0.007 ± 0.003	177 ± 9.25	108 ± 14.4	0.06 ± 0.12
66	1993 – 2007	7.08 ± 2.59	22.8 ± 5.41	49.2 ± 11.6	0.017 ± 0.010	176 ± 35.2	118 ± 22.3	0.24 ± 0.85
66	2008 – Fire	6.02 ± 4.38	18.0 ± 9.60	38.2 ± 20.4	0.017 ± 0.010	141 ± 73.1	107.3 ± 40.7	1.29 ± 1.84
66	Post-Fire	7.23 ± 1.01	20.5 ± 1.35	42.9 ± 2.72	0.013 ± 0.007	162 ± 8.69	116 ± 15.5	0.01 ± 0.01
71	1993 – 2007	9.35 ± 2.78	14.8 ± 3.59	37.8 ± 8.62	0.020 ± 0.013	141 ± 27.9	95.2 ± 24.7	0.38 ± 1.17
71	2008 – Fire	7.97 ± 4.39	14.0 ± 6.75	31.2 ± 14.7	0.025 ± 0.020	113 ± 55.7	90.7 ± 32.8	1.09 ± 1.12
71	Post-Fire	8.74 ± 2.15	13.1 ± 5.62	31.5 ± 8.45	0.020 ± 0.007	126 ± 27.6	84.8 ± 22.8	0.36 ± 0.48
73	1993 – 2007	6.29 ± 3.95	25.4 ± 6.19	50.6 ± 11.2	0.020 ± 0.017	183 ± 30.7	131 ± 19.2	0.38 ± 1.87
73	2008 – Fire	6.05 ± 4.60	22.2 ± 18.6	56.6 ± 82.5	0.023 ± 0.033	151 ± 71.1	124 ± 25.3	1.32 ± 1.99
73	Post-Fire	-	19.7 ± 3.82	41.5 ± 6.36	0.017 ± 0.003	281 ± 310	118 ± 40.3	1.03 ± 1.94
74	1993 – 2007	5.62 ± 2.65	27.9 ± 8.40	64.2 ± 17.9	0.023 ± 0.017	216 ± 49.8	142 ± 17.9	0.72 ± 1.73
74	2008 – Fire	5.41 ± 4.00	26.2 ± 18.2	76.2 ± 79.1	0.037 ± 0.083	191 ± 110	127 ± 49.4	1.23 ± 1.37
74	Post-Fire	5.59 ± 1.13	23.5 ± 2.18	57.9 ± 5.54	0.013 ± 0.007	201 ± 16.6	136 ± 21.1	1.27 ± 2.87

G. Impacts of the CT2 Fire on Stream Water Chemistry

Mean values of each chemical parameter were compared using a repeated measures ANOVA between time frames pre- and post-fire for all water sites (Tables 12 a-e). Average water pH was significantly greater during 2008-fire period (6.47-6.77) compared to post-fire (6.20-6.37) ($p < 0.004$) at all sites, aside from site 71, which had 2.6% watershed burn and pH 6.32 pre-fire, 6.10 post-fire ($p = 0.201$). The conductivity of stream samples was significantly lower post-fire (11.7-18.0 µS/cm) than pre-fire (16.1-29.8 µS/cm) ($p < 0.032$) at all sites. The reference sites (73 & 74, 0% watershed burned) had the lowest p-values for conductivity pre- to post-fire, therefore the most significant change between time frames, with a similar trend evident for ANC which had significantly higher averages before the fire at all sites ($p < 0.039$). Chloride concentrations were not significantly different pre- to post-fire ($0.540 < p < 0.909$) at any sites, burned or reference. Sulfate at site 30, with 60.7% burned watershed, went from 31.3 µmol/L to 29.6 µmol/L pre- to post-fire ($p = 0.024$), while at site 66 and 71, also burned (16.7% and 2.6% watershed burn, respectively), the changes were not significant (32.7 to 32.8 µmol/L ($p = 0.865$) and 24.3 to 22.3 µmol/L ($p = 0.211$), respectively). Nitrate concentrations were not consistent between reference or burned sites, but in all cases the average was lower post-fire than pre-fire. Ammonium concentrations were lower post-fire at all three burned sites, significantly at site 30 (60.7% burned watershed) and 66 (16.7% burned watershed) ($p = 0.009$, 0.006), and lower post-fire at site 71 (2.6% burned watershed), $p = 0.058$. At both reference sites, ammonium was not significantly lower post-fire ($p = 0.126$, 0.834). Sum of base cations were greater pre-fire (124 & 191 μmol_c/L), compared to post-fire (118 & 136 μmol_c/L) at reference sites ($p = 0.018$, 0.004), whereas no significant change in base cations were evident at burned sites ($p = 0.134$, 0.249 & 0.116).

Table 12a. *Repeated measures ANOVA analysis of water pre- and post-fire for the West Prong of the Pigeon River at Headquarters (Site 30), with pre-fire data from 2008 – 2014, Significant differences (p<0.05) appear in bold. Site 30 watershed was 60.7% burned with a drainage area of 18.0 km*^{2}.

Time	pH	Conductivity (μS/cm)	ANC (μmol$_c$/L)	Chloride (μmol/L)	Sulfate (μmol/L)	Nitrate (μmol/L)	Ammonium (μmol/L)	Base Cations (μmol$_c$/L)
2008-Fire	**6.60**	**20.6**	**55.6**	18.5	**31.3**	**31.9**	**2.01**	159
Post-Fire	**6.35**	**17.0**	**45.9**	19.0	**29.6**	**25.7**	**0.06**	177
p-value	**0.004**	**0.028**	**0.027**	0.668	**0.024**	**0.030**	**0.009**	0.134
N	14	9	14	9	14	14	9	9

Table 12b. *Repeated measures ANOVA analysis of water pre- and post-fire for the West Prong of the Pigeon River at Chimneys Picnic Area (Site 66), with pre-fire data from 2008 – 2014, Significant differences (p<0.05) appear in bold. Site 66 watershed was 16.7% burned with a drainage area of 34.4 km*^{2}.

Time	pH	Conductivity (μS/cm)	ANC (μmol$_c$/L)	Chloride (μmol/L)	Sulfate (μmol/L)	Nitrate (μmol/L)	Ammonium (μmol/L)	Base Cations (μmol$_c$/L)
2008-Fire	**6.47**	**20.4**	**39.6**	16.8	32.7	35.5	**1.29**	141
Post-Fire	**6.24**	**14.8**	**28.8**	18.7	32.8	29.1	**0.01**	116
p-value	**0.002**	**0.003**	**0.020**	0.632	0.865	0.278	**0.006**	0.249
N	11	12	11	12	11	11	12	12

Table 12c. *Repeated measures ANOVA analysis of water pre- and post-fire for the Road Prong above Barrier Cascade (Site 71), with pre-fire data from 2008 – 2014, Significant differences (p<0.05) appear in bold. Site 71 watershed was 2.6% burned with a drainage area of 8.28 km*^{2}.

Time	pH	Conductivity (μS/cm)	ANC (μmol$_c$/L)	Chloride (μmol/L)	Sulfate (μmol/L)	Nitrate (μmol/L)	Ammonium (μmol/L)	Base Cations (μmol$_c$/L)
2008-Fire	6.32	**16.1**	**30.3**	13.6	24.3	**34.5**	1.09	90.7
Post-Fire	6.10	**11.7**	**17.7**	13.6	22.3	**24.8**	0.36	84.8
p-value	0.201	**0.032**	**0.039**	0.909	0.211	**0.007**	0.058	0.116
N	11	12	11	12	11	11	12	12

Table 12d. *Repeated measures ANOVA analysis of water pre- and post-fire for the Walker Camp Prong above Road Prong (Site 73), with pre-fire data from 2008 – 2014, Significant differences (p<0.05) appear in bold. Site 73 watershed was 0% burned with a drainage area of 20.5 km^2.*

Time	**pH**	**Conductivity (μS/cm)**	**ANC (μmol$_c$/L)**	**Chloride (μmol/L)**	**Sulfate (μmol/L)**	**Nitrate (μmol/L)**	**Ammonium (μmol/L)**	**Base Cations (μmol$_c$/L)**
2008-Fire	**6.52**	**20.9**	**42.2**	17.5	**35.5**	**34.2**	1.32	**124**
Post-Fire	**6.20**	**14.2**	**25.0**	20.3	**32.2**	**26.8**	1.03	**116**
p-value	**0.001**	**0.001**	**0.002**	0.589	**0.014**	**0.025**	0.126	**0.018**
N	11	12	11	12	11	11	12	12

Table 12e. *Repeated measures ANOVA analysis of water pre- and post-fire for the Walker Camp Prong above Alum Cave Creek (Site 74), with pre-fire data from 2008 – 2014, Significant differences (p<0.05) appear in bold. Site 74 watershed was 0% burned with a drainage area of 7.43 km^2.*

Time	**pH**	**Conductivity (μS/cm)**	**ANC (μmol$_c$/L)**	**Chloride (μmol/L)**	**Sulfate (μmol/L)**	**Nitrate (μmol/L)**	**Ammonium (μmol/L)**	**Base Cations (μmol$_c$/L)**
2008-Fire	**6.77**	**29.8**	**107**	21.4	**42.7**	31.3	1.23	**191**
Post-Fire	**6.37**	**18.0**	**46.8**	24.6	**38.7**	28.7	1.27	**136**
p-value	**0.000**	**0.002**	**0.003**	0.540	**0.001**	0.412	0.834	**0.004**
N	11	12	11	12	11	11	12	12

H. Qualitative Assessment of Post-fire Trends in Stream Water Chemistry

Post-fire data were plotted over time per parameter, beginning just after the fire ended in December 2016 through November 2019 (Figure 23-30). The stream pH had a very similar trend for all sites tested. A decrease in pH was evident at all sites in March 2019, with values increasing into the end of the same year. Initially post-fire, pH was lower. ANC remained fairly consistent at all sites in 2018, with a spike seen at the end of 2019 at all sites. Nitrate and sulfate both tended to decrease with time post-fire. The conductivity trend was similar at all 7 sites, with peak conductivity just after the fire, followed by a decrease into early 2018 after which it increased in summer of 2018 and then decreased to similar levels in the late fall of 2018. Chloride was highest in the reference sites, throughout the post-fire analysis. A peak in chloride was evident in February 2018 at all sites, after which the concentrations decreased and were consistent into the end of 2018. Ammonium was fairly consistent over time. Base cations were fairly consistent in time after the fire at all sites.

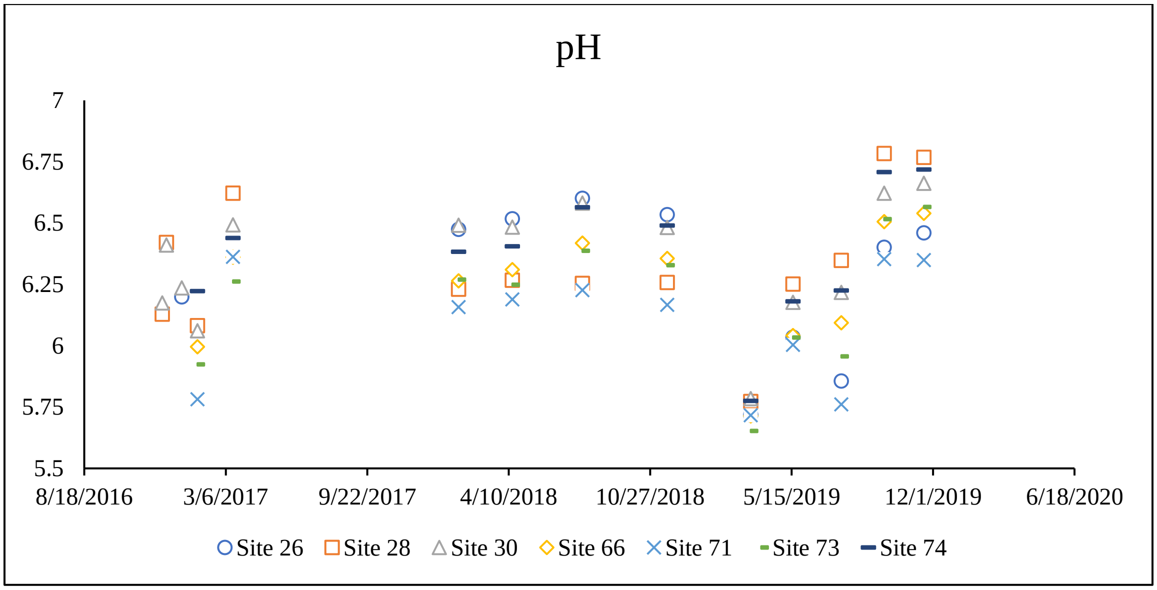

Figure 23. *pH at water sampling sites over time following the fire, December 2016 to Novermber 2019. Sites with burned watershed: Site 26, 28, 30, 66 and 71. Reference sites include: Site 73 and 74.*

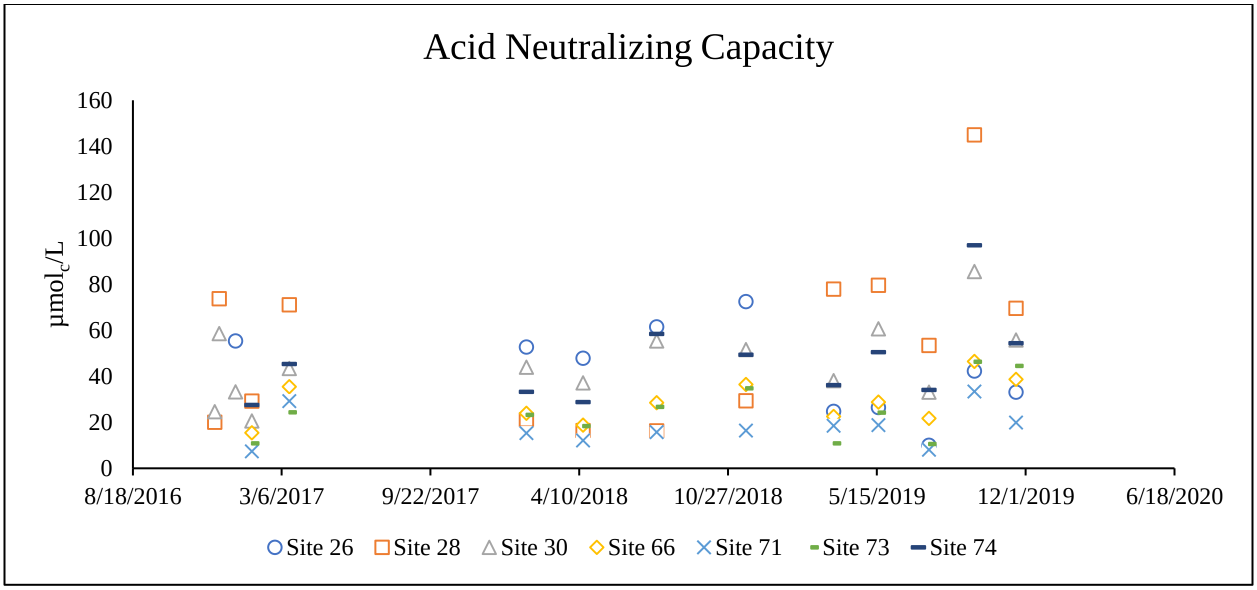

Figure 24. *ANC (µmol$_c$/L) at water sampling sites over time following the fire, December 2016 to November 2019. Sites with burned watershed: Site 26, 28, 30, 66 and 71. Reference sites include: Site 73 and 74.*

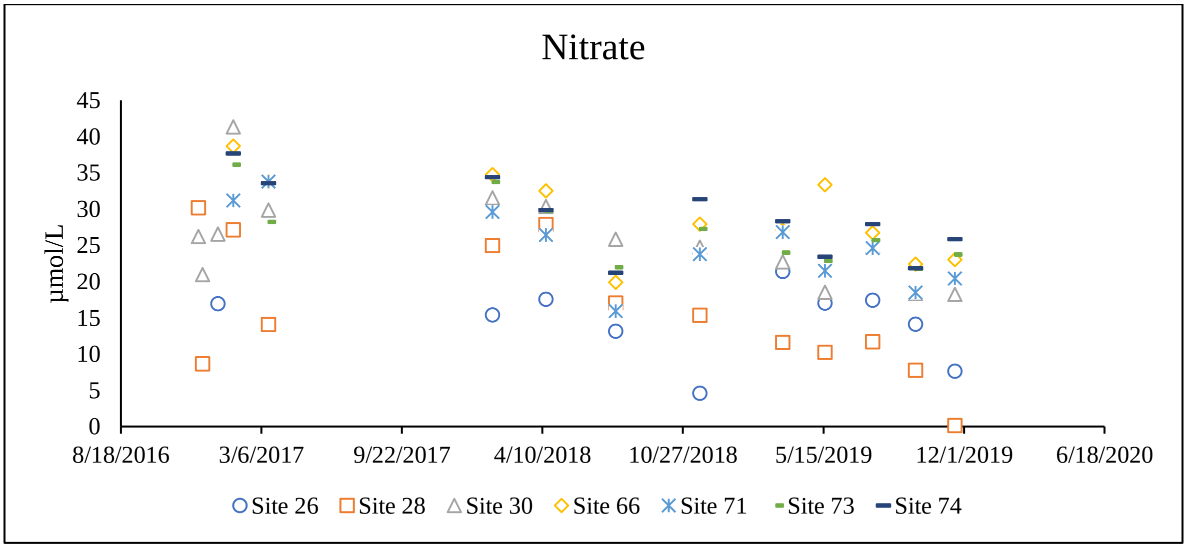

Figure 25. *Nitrate (µmol/L) for water sampling sites over time following the fire, December 2016 to November 2019. Sites with burned watershed: Site 26, 28, 30, 66 and 71. Reference sites include: Site 73 and 74.*

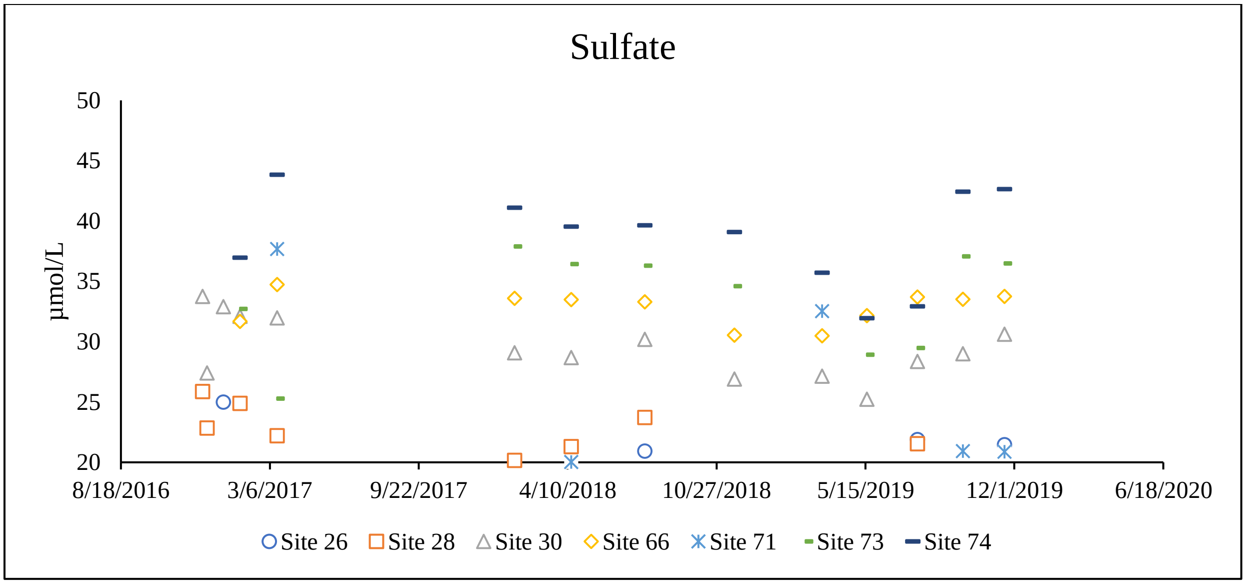

Figure 26. *Sulfate (µmol/L) for water sampling sites over time following the fire, December 2016 to November 2019. Sites with burned watershed: Site 26, 28, 30, 66 and 71. Reference sites include: Site 73 and 74.*

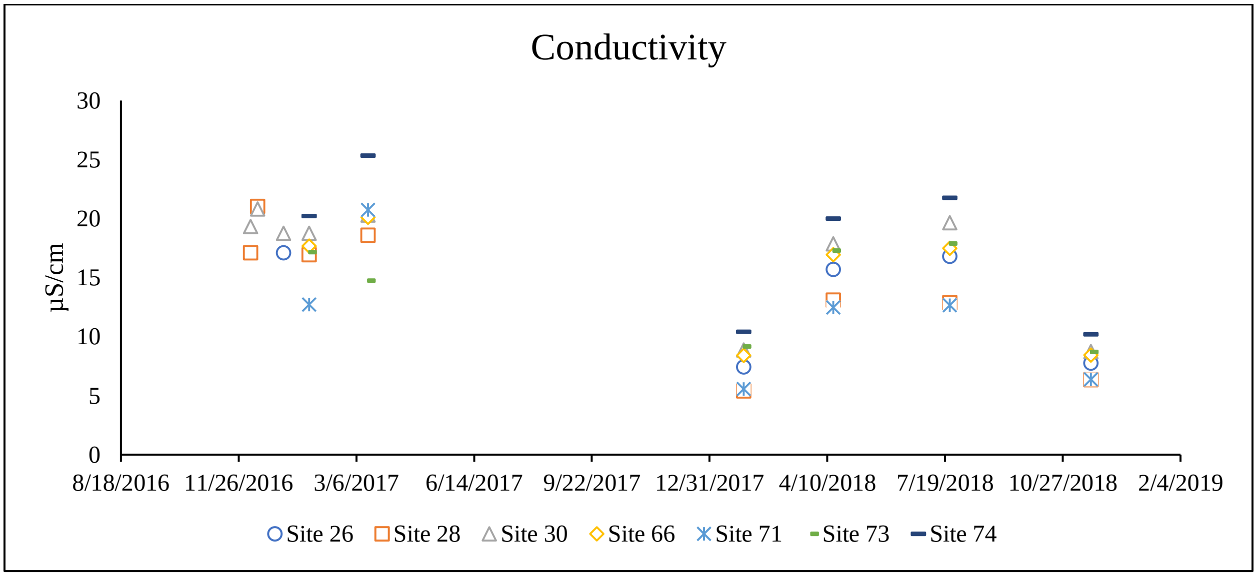

Figure 27. *Conductivity (µS/cm) at water sampling sites over time following the fire, December 2016 to November 2019. Sites with burned watershed: Site 26, 28, 30, 66 and 71. Reference sites include: Site 73 and 74.*

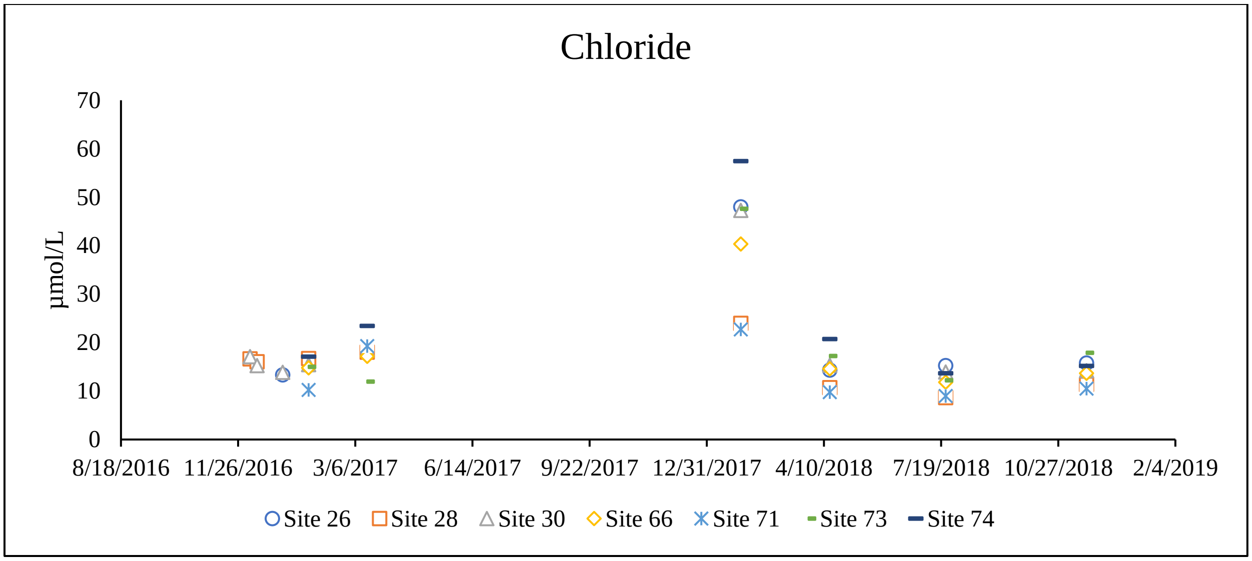

Figure 28. *Chloride (µmol/L) for water sampling sites over time following the fire, December 2016 to November 2019. Sites with burned watershed: Site 26, 28, 30, 66 and 71. Reference sites include: Site 73 and 74.*

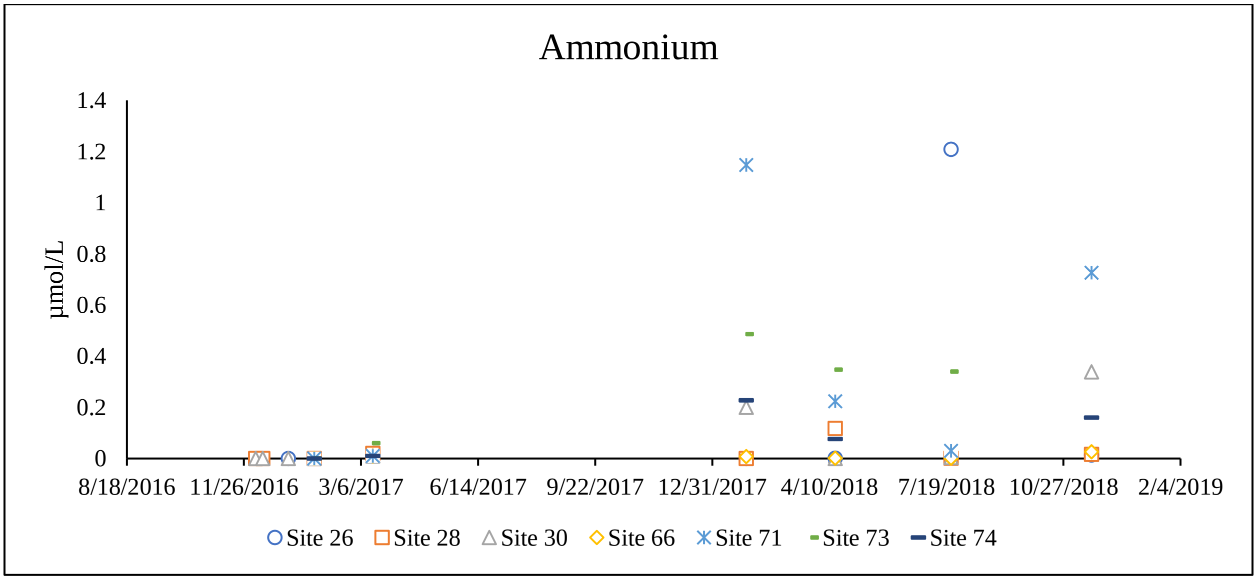

Figure 29. *Ammonium (µmol/L) for water sampling sites over time following the fire, December 2016 to November 2019. One outlier point for site 73 (4.97 µmol/L) omitted. Sites with burned watershed: Site 26, 28, 30, 66 and 71. Reference sites include: Site 73 and 74.*

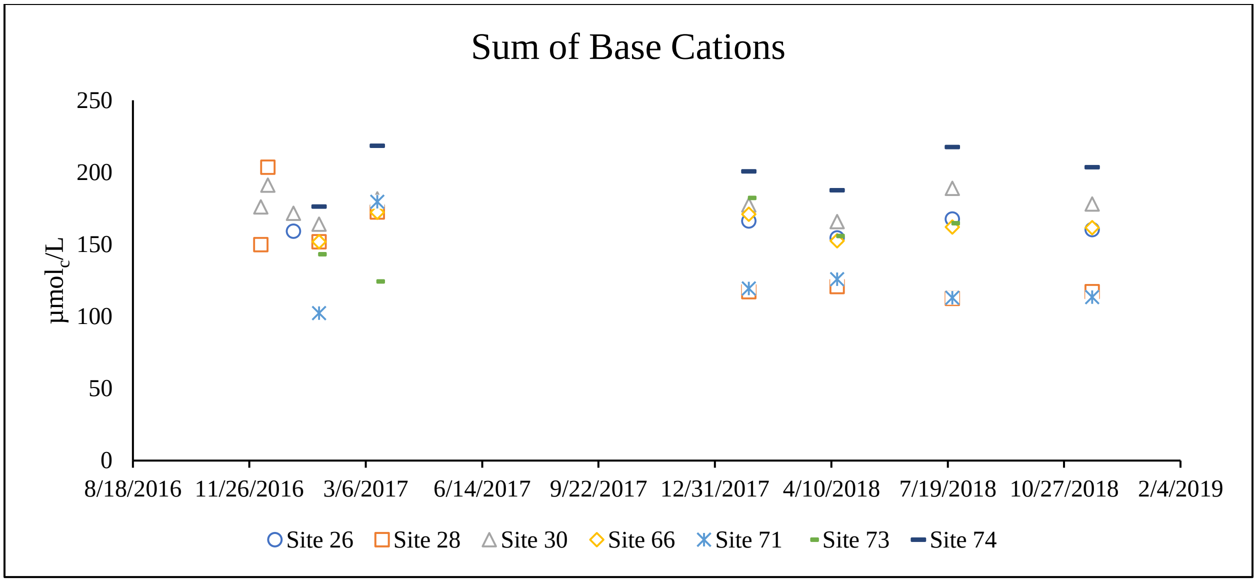

Figure 30. *Sum of base cations (µmol$_c$/L) for water sampling sites over time following the fire, December 2016 to November 2019. Sites with burned watershed: Site 26, 28, 30, 66 and 71. Reference sites include: Site 73 and 74.*

IV. DISCUSSION

It was anticipated that fire would have the greatest impact on the upper soil horizons with more organic matter content than the mineral soil layers below, and more with direct exposure to fire with high intensity. There was a significant difference in most soil chemical properties from the A/O horizon to the B horizon, with most parameters being significantly lower in the B horizon than the A/O horizon regardless of burn severity level. The A/O horizon typically contains higher organic matter content due to partially decomposed and humidified organic matter (Brady & Weil, 2008), and a lower percent organic matter was measured in the B horizon as compared to the A/O horizon. Organic matter tends to have high ECEC, as it can absorb more exchangeable cations than pure mineral soils with significantly higher EBC and ECEC in the A/O horizon than the B soil horizon. It should be noted that in high organic matter soils ECEC is a smaller fraction of the cation exchange capacity (CEC), most likely due to the presence of organic cations. Due to the measurement of ECEC as opposed to CEC, the reference and unburned sites not exposed to fire could have greater CEC due to their greater organic matter, thus, in the reference systems, the proportion of ECEC that is CEC could be greater than that in the burned systems, assuming that burning can degrade adsorbed organic cations. Although, due to the organic matter between burned areas and non-burned areas not being significantly different, this difference is not expected to be significant. Similar patterns of significantly greater values of EBC, ECEC, and EA in the A/O horizon than B horizon were evident in the park in 2010 (Grell, 2010).

The soil salt pH was significantly lower in burned sites, as compared to unburned sites, while the TA was significantly greater at burned sites, showing a pattern of more acidic soil conditions in burned areas. Fires in base-poor environments have shown to decrease pH in runoff, and therefore streams receiving runoff, by releasing base cations from burned soils and vegetation (Raison, 1979; Bayley et al., 1992). Consistent with this pattern, EBC and ECEC were significantly greater in unburned sites than low/medium and high burn sites in both horizons, meaning that fire decreases the ECEC of soils, probably through the loss of soil OM, decreasing capacity to retain and supply nutrient cations for plant nutrients growth. The percent base saturation was significantly lower in the low/medium and high burn sites compared to the reference and unburned sites. A decrease in %BS, which represents the proportion of acids to bases on soils exchange surfaces, leads to a more acidic environment due to the relative increase in Al is present on soil exchange surface than base cations (Cai et al., 2011), as seen in the significantly decreased soil pH. Al significantly increased in burned areas, with values more than doubling from non-burned sites to burned sites in both horizons. Al has been shown to increase post-fire, with the release attributed to changes in nutrient release and ash deposition (Kong et al., 2018). Additionally, a decrease in base cations and organic matter can lead to Al mobilization, which is furthermore more soluble in acidic conditions (Elliott et al., 2012; Lydersen et al., 2014). Soil exchangeable Al presence has been shown to increase with increasing burn severity and higher fire temperature (Pereira et al., 2010). Gibbsite ($Al(OH)_3$) has been found to be noticeably reduced at temperatures exceeding 600°C, and studies have indicated the increased presence of Al^{3+} ion compared to $Al(OH)^{2+}$ with increasing temperature (Moller et al., 2006; Certini, 2005). Al was the major source of the increased total acidity in burned areas, which led to the significant decrease in percent base saturation in tandem with the decrease in EBC at burned sites. Additionally, at the pH range of the burned sites, below 4.4 in both horizons, Al ion (Al^{3+}) is present in a high proportion and is toxic to many plant species. With the spike in Al ion, vegetation in burned areas could be hindered (Rout et al., 2001). No increase in Al was noted for stream samples post-fire.

The ratio of carbon to nitrogen (C/N) was significantly higher in low/medium and high burn areas as compared to reference and unburned sites in both soil horizons. A significant decrease in percent N was evident in burned areas for the B soil horizon. Changes in the percent C and percent N in the A/O horizon from the wildfire were inconsistent, which could be due to the more exposed nature of the top soil layer. I hypothesized that the percent C, N, and S would decrease in burned areas. The only significant decrease noted was the percent N in the B soil horizon. The TS tended to decrease with increasing burn severity, however, not significantly. The lack of significance could be due to the much smaller sample size tested for this parameter.

The organic matter, expected to be lower in burned areas, did decrease in low/medium and high burn areas, however, not significantly or by great margins. The unburned and reference sites had similar percentages of organic matter throughout the study area. Other studies, in the eastern and western United States have reported significantly decreased organic matter (Elliot et al., 2012; Bormann et al., 2008; Baird et al., 1999; Murphy et al., 2006). Because soil sampling began in 2018, there were over 18 months between the fire and sampling which could have allowed organic matter to build up in burned areas.

Of the 6 soil sites with historic soil data available, one site was located within the burn footprint (RP3). A two-way contingency analysis on all the soil parameters tested on both groups was performed, and no site displayed a significant difference pre- to post-fire. However, the lowest p-value (0.086) was evident at the one burned soil site, which fell in the low/medium classification. The limited data from the Grell (2010) study did not provide the statistical power to adequately interpret the two datasets. Additionally, the Road Prong and Walker Camp Prong sites were only added to the sampling scheme for 2019 collections, increasing the period post-fire, opportunity for environmental change and time between the historical data.

The stream pH, ANC and conductivity decreased significantly post-fire at all sites, including those with burned area in the watershed and the two reference sites (73 and 74). An increase in stream base cations was expected to occur due to releases from soils. It was expected that changes in stream chemistry would be short-lived as mobile solutes produced from the wildfire are flushed from the watersheds and as nutrients are assimilated by re-growing vegetation recovers. Exchangeable base cations in soils decreased significantly in unburned areas, but did not significantly change at sites within burned areas. This finding was contrary to my hypotheses. Years of acid deposition have led to elevated stores of S in soils. It was expected that this S to be released as sulfate into streams when burned. However, the stream samples did not show large differences post-fire. Sulfate decreased significantly post-fire at both reference sites, and 2 of 3 sites with burn area. Sulfate has been shown to decrease in base-poor environments, with large S stores, as was seen in a wildfire study on base-poor Norwegian lakes, where sulfate decreased up to 93% (Lyderson et al., 2014), however no real trend or extreme decreases were seen. All sites, including the two reference sites, tended to decrease, however not by large measures. Stream pH was not predicted to change post-fire, as increases in sulfate stream export were anticipated to be balanced by increases in base cation export. However, post-fire pH changes were statistically significant, with a maximum decrease of 0.4 units among sampled sites. There are a variety of other factors that could impact pH over such a large area, and time frame, including other atmospheric deposition and underlying geologic factors (Flum et al., 1995).

An increase in ammonium in streams directly following the fire was hypothesized (Earl & Blinn, 2003). On the contrary, ammonium concentrations were significantly lower post-fire at all burned sites, whereas it did not change significantly at the two unburned control sites. In soil samples, ammonium was not significantly different between burn severity levels, however, it tended to be lower in burned areas. Nitrate decreased significantly post-fire at 2 of 3 burned sites, and 1 of the 2 reference sites. This inconsistency in changes could be due to potential atmospheric fallout (e.g. smoke, ash) in areas surrounding the footprint of the burn (Earl & Blinn, 2003). The only parameter that remained similar to pre-fire levels at all sites was chloride, which is generally not impacted by wildfire (Bayley et al., 1992; Schindler et al., 1980).

Examining the impacts of the CT2 fire compared to studies of western US wildfires was a goal of this project. The response to the CT2 fire exhibited some of the same impacts as observed in wildfires in the west, however, some parameters showed contrasting patterns. The CT2 resulted in significant decreases in percent N and organic matter soil as observed in western fires of similar magnitude (Murphy et al., 2006; Bormann et al., 2008). Bormann et al. (2008) noted dramatic (50%) decreases in percent total soil C post-fire, when compared to pre-fire observations. Due to the lack of pre-fire C data pre-fire, I cannot make a direct comparison to this observation. However, observed no significant difference between soil C concentrations in burned sites, unburned sites or reference sites. Bormann et al. (2008) also reported a significant decrease in soil percent N post-fire. Again, pre-fire N data were not available for comparison, however, in the B soil horizon there was a significant decrease in N concentrations in burned soil as compared to unburned and reference soil.

The most notably contrasting pattern from the CT2 wildfire in comparison to effects reported for western fires was for the soil and stream pH. The CT2 fire resulted in significant decreases in the pH of both soils and streams. In western areas of the US, increases in water pH are typically noted post-fire, attributed to the ash released from fires entering waterways (Waskom et al., 2014; Earl & Blinn, 2003). The impacts are typically short-lived as the ash is flushed downstream and the pH then returns to pre-fire values with time. A study in Canada, in a similarly base-poor environment, reported that following a wildfire in 1980 the area experienced a decrease in lake pH lasting at least two years after the fire (Bayley et al., 1992).

It was hypothesized that the stream impacts would be short-lived as ash would be anticipated to be readily transported from the burned watershed via stream runoff (Bayley et al., 1992; Knoepp et al., 2009). Streams were expected to experience a flux pulse response in chemistry, due to greater ion loads from nutrient loss on catchment lands entering streams as runoff just after the fire, which would quickly be transported from the area and further diluted by rain events and mixing of drainage from non-burned catchments. Smaller scale studies have shown that ash input into streams can impact water quality for as little as 24 hours (Earl & Blinn, 2003), or up to weeks (Cushing & Olson, 1963). The CT2 fire, as a much larger event with greater ash deposition, could have impacts to streams for a longer period. However, the GRSM National Park typically receives considerably more precipitation than most areas prone to large scale wildfire, such as in the West, which could cause a quicker return to baseline stream water quality conditions. Some water quality parameters did have a noticeable change in response to the fire, such as a decrease in pH. These effects became diminished and no longer significant within the first few weeks post-fire. With relatively few samples collected over a coarse interval (minimum of two weeks apart) immediately after the fire, the duration of stream impacts are difficult to characterize. More frequent sampling would have needed in the weeks following the fire to accurately quantify the stream impacts. One possible explanation of export of S and N are the hydrology and this rapid flush of ions with impacts being short-lived as ions are transported out of streams, waters comingle and precipitation occurs (Cushing & Olson, 1963; Earl & Blinn, 2003; Knoepp et al., 2013). Another explanation is the volatilization of S and N because of the fire temperature. N can begin volatilizing from organic matter at 200°C (Neary et al., 1999). Temperatures of 400°C have been shown to release 35-50% of sulfur to the gas phase during volatilization of herbaceous biomass (Knudsen et al., 2004). Wildfire typically burns surface soils at a temperature of 800°C or greater, with a flashpoint of 300°C, the temperature at which wood will catch fire (Natural Resources Canada, 2019). The CT2, especially in high burn areas, far exceeded temperatures susceptible to S and N volatilization.

The soil impacts from fire seems to have been more lasting and marked. In contrast, stream responses were transient. Stream chemistry changes were only anticipated for smaller streams within the burn footprint, due to dilution when waters mix from larger unburned watersheds. The site with the largest percent of watershed area burned (site 26 – 99.79% burned) exhibited the largest changes in concentrations of nearly all parameters measured post-fire. In contrast, Site 66 with the largest watershed area of the sites studied had 16.67% area burned, and generally experienced the smallest changes in measured stream solutes. The site at the highest elevation (site 74) generally had the highest greatest stream solute concentrations, or among the highest value, post-fire for all parameters measured. Factors such as percentage of the watershed impacted by wildfire, topography, geology, fire-intensity, ratio of catchment are to stream size and hydrological conditions impact post-fire water quality, creating large variability among watershed responses (Lyderson, 2014).

The CT2 wildfire caused a decrease in the soil pH of burned lands, due to a decrease in exchangeable base cations present. This coincided with an increase in Al in the soils in burned areas, which can be toxic to sensitive plant species. Ammonium in soils was significantly lower in burned areas and in streams that receive runoff from burned land. The streams in and around the burn area saw a significant decrease in pH, conductivity, and ANC post-fire when compared to historical stream data, however, this increase in acidity and ion concentration remains unexplained. Increased acidity may be due to some unmeasured anion or possibly to an increase in organics acids. The increase in conductivity from elevated ion concentrations was not observed in either anions or cations, thus dissolved metal such as iron could be a contributor. These changes were evident in reference sites as well as burn sites and continued or remained steady post-fire, making it difficult to attribute them to purely due to the wildfire occurrence. Wildfire events are rarely studied in base-poor environments, like the GRSM National Park. The incidence of large wildfires has increased rapidly in the US since the mid-1980s (Westerling et al., 2006). Climate change is predicted to further increase the occurrence and severity of wildfires due to increases in drought conditions. Climate change will likely lead to a longer fire season in the southern Appalachia (EPA, 2016; Liu et al., 2012). Potential for increased incidence, and predictions of a longer fire season, make this fire characterization important going forward.

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VI. APPENDICIES

A. APPENDIX A. SOIL DATA

Table A1. *Soil characteristics per sampling site. Soil horizons available for sampling, indication of exurban (outside National Park boundaries) or natural (inside National Park boundaries) and soil type.*

Site ID	Burn Level	Urban/Natural	Soil Horizon(s) Available	Soil Type
DUD	High Burn	Urban	B	Junaluska-Cataska complex
FCM	High Burn	Natural	B	Cataska-sylco complex
LCM	High Burn	Natural	B	Cataska-sylco complex
NMT	High Burn	Urban	B	Cataska-sylco complex
NS4	High Burn	Natural	B	Rock Outcrop-Luftee complex
SCM	High Burn	Natural	B	Cataska-sylco complex
TCL	High Burn	Urban	B	Soco-Stecoah complex
FCL	Low/Med Burn	Urban	A/O, B	Soco-Stecoah complex
GCL	Low/Med Burn	Urban	B	Soco-Stecoah complex
LGB	Low/Med Burn	Natural	B	Junaluska-Brasstown complex
NEON	Low/Med Burn	Natural	A/O	Spivey-Santeetlah-Nowhere complex
RGB	Low/Med Burn	Natural	B	Junaluska-Brasstown complex
RP3	Low/Med Burn	Natural	A/O, B	Luftee-Anakeesta complex
WIN	Low/Med Burn	Urban	A/O, B	Rosman-Reddies-Urban land complex
BGB	Unburned	Natural	A/O, B	Soco-Stecoah complex
CANEY	Unburned	Urban	A/O, B	Cataska-sylco complex
LOVE	Unburned	Urban	A/O, B	Rosman-Reddies-Urban land complex
PL441	Unburned	Natural	A/O	Dellwood-Smokemont complex
RS441	Unburned	Natural	A/O, B	Dellwood-Smokemont complex
NS1	Unburned	Natural	A/O, B	Luftee-Anakeesta complex
NS2	Unburned	Natural	A/O, B	Spivey-Santeetlah-Nowhere complex
NS3	Unburned	Natural	A/O, B	Spivey-Santeetlah-Nowhere complex
SKI	Unburned	Urban	A/O, B	Rock outcrop-Unicoi complex
RP1	Reference	Natural	A/O, B	Ditney-Unicoi complex
RP2	Reference	Natural	A/O, B	Breakneck-Pullback complex
SGL	Reference	Natural	A/O, B	Spivey-Santeetlah-Nowhere complex
TREE	Reference	Urban	A/O, B	Rosman-Reddies-Urban land complex
WCP1	Reference	Natural	A/O, B	Luftee-Anakeesta complex
WCP2	Reference	Natural	A/O, B	Ditney-Unicoi Complex
WCP3	Reference	Natural	A/O, B	Ditney-Unicoi Complex

Table A2. *Soil taxonomic classification in GRSM National Park.*

Soil Name	**Taxonomic Classification**
Anakeesta	Loamy-skeletal, isotic, frigid Humic Dystrudepts
Brasstown	Fine-loamy, mixed, subactive, mesic Typic Hapludults
Breakneck	Fine-loamy, isotic, frigid Humic Dystrudepts
Cataska	Loamy-skeletal, mixed, semiactive, mesic, shallow Typic Dystrudepts
Dellwood	Sandy-skeletal, mixed, mesic Oxyaquic Dystrudepts
Ditney	Coarse-loamy, mixed, semiactive, mesic Typic Dystrudepts
Junaluska	Fine-loamy, mixed, subactive, mesic Typic Hapludults
Luftee	Loamy-skeletal, isotic, frigid Humic Dystrudepts
Nowhere	Loamy-skeletal, isotic, acid, mesic Typic Humaquepts
Pullback	Loamy, isotic, frigid Humic Lithic Dystrudepts
Reddies	Coarse-loamy over sandy or sandy-skeletal, mixed, superactive, mesic Oxyaquic Dystrudepts
Rosman	Coarse-loamy, mixed, superactive, mesic Fluventic Humic Dystrudepts
Santeetlah	Fine-loamy, isotic, mesic Humic Dystrudepts
Smokemont	Sandy-skeletal, mixed, mesic Fluventic Humic Dystrudepts
Soco	Coarse-loamy, mixed, active, mesic Typic Dystrudepts
Spivey	Loamy-skeletal, isotic, mesic Humic Dystrudepts
Stecoah	Coarse-loamy, mixed, active, mesic Typic Dystrudepts
Sylco	Loamy-skeletal, mixed, active, mesic Typic Dystrudepts
Unicoi	Loamy-skeletal, mixed, semiactive, mesic Lithic Dystrudepts

B. APPENDIX B. HISTORICAL DATA

Table B1. *Grell (2010) soil data averages for Walker Camp Prong (WCP) and Road Prong (RP) sites. The averages include sites indicated as WCP1, WCP2 and WCP3, and RP1, RP2, and RP3. Data from the thesis of Mary Ann Grell titled* Soil Chemistry Characterization of Acid Sensitive Watersheds in the Great Smoky Mountains National Park.

Watershed	**Soil Layer**	**Average pH$_{H2O}$**	**Average pH$_{CaCl2}$**	**Average LOI %**	**Average Na Cmol$_c$/kg dry soil**	**Average K Cmol$_c$/kg dry soil**	**Average Mg Cmol$_c$/kg dry soil**	**Average Ca Cmol$_c$/kg dry soil**	**Average Total Exchangeable Base Cations Cmol$_c$/kg dry soil**	**Average Exchangeable Nitrate Cmol$_c$/kg dry soil**	**Average Exchangeable Ammonium Cmol$_c$/kg dry soil**	**Average Exchangeable Sulfate Cmol$_c$/kg dry soil**	**Average Total Acidity Cmol$_c$/kg dry soil**	**Average Effective Cation Exchange Capacity Cmol$_c$/kg dry soil**	**Average Total Base Saturation %**
WCP1	A/O	5.20	4.67	20.36	0.07	0.16	1.12	7.00	8.34	0.27	0.04	0.09	0.57	8.91	93.65
WCP2	A/O	4.48	3.90	9.98	0.01	0.24	0.32	1.49	2.05	0.23	0.02	0.04	3.97	6.22	33.02
WCP3	A/O	4.97	4.42	11.38	0.01	0.21	0.57	4.47	5.26	0.29	0.03	0.03	1.15	6.41	82.07
RP1	A/O	4.37	3.83	11.89	0.02	0.23	0.40	1.45	2.10	0.21	0.03	0.03	4.53	6.63	31.71
RP2	A/O	4.32	3.65	13.74	0.02	0.17	0.30	1.68	2.17	0.25	0.04	0.03	4.73	6.90	31.46
RP3	A/O	3.64	3.04	48.69	0.03	0.32	0.60	2.03	2.98	0.42	0.05	0.08	12.45	15.43	19.30
WCP1	B	5.25	4.59	9.51	0.04	0.05	0.29	1.53	1.92	0.09	0.01	0.11	1.12	3.23	59.43
WCP2	B	4.67	4.20	5.82	0.01	0.08	0.08	0.43	0.60	0.1	0.01	0.05	2.72	3.14	19.27
WCP3	B	5.54	4.85	7.01	0.02	0.13	0.27	3.50	3.92	0.13	0.01	0.04	1.18	5.09	76.91
RP1	B	4.67	4.18	6.42	0.01	0.08	0.10	0.28	0.47	0.06	0.01	0.02	2.54	3.02	15.74
RP2	B	4.60	4.01	6.51	0.01	0.07	0.07	0.29	0.45	0.07	0.01	0.03	3.08	3.53	12.74
RP3	B	4.45	4.19	13.32	0.01	0.05	0.05	0.09	0.21	0.05	0.01	0.08	2.45	2.66	7.89

C. APPENDIX C. MAPS

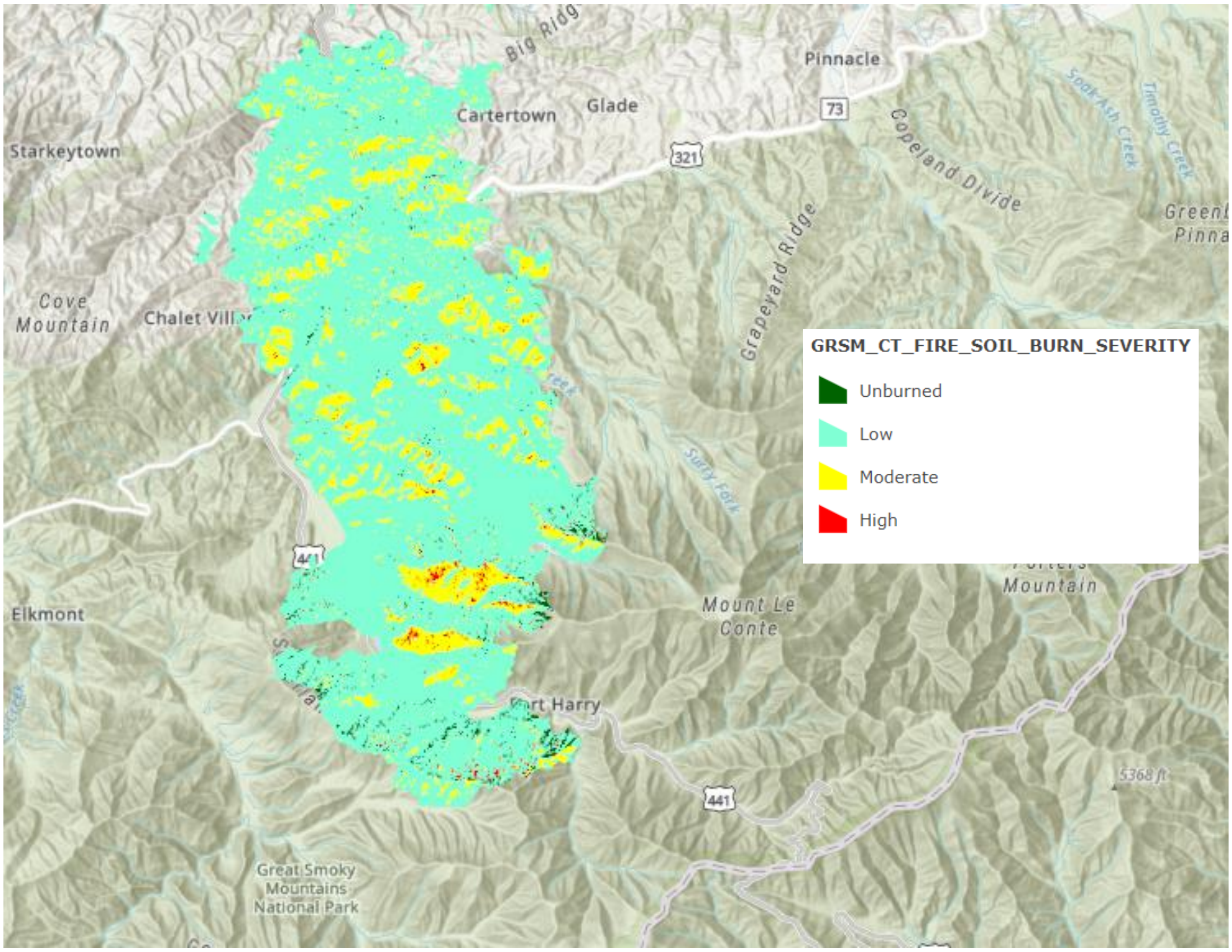
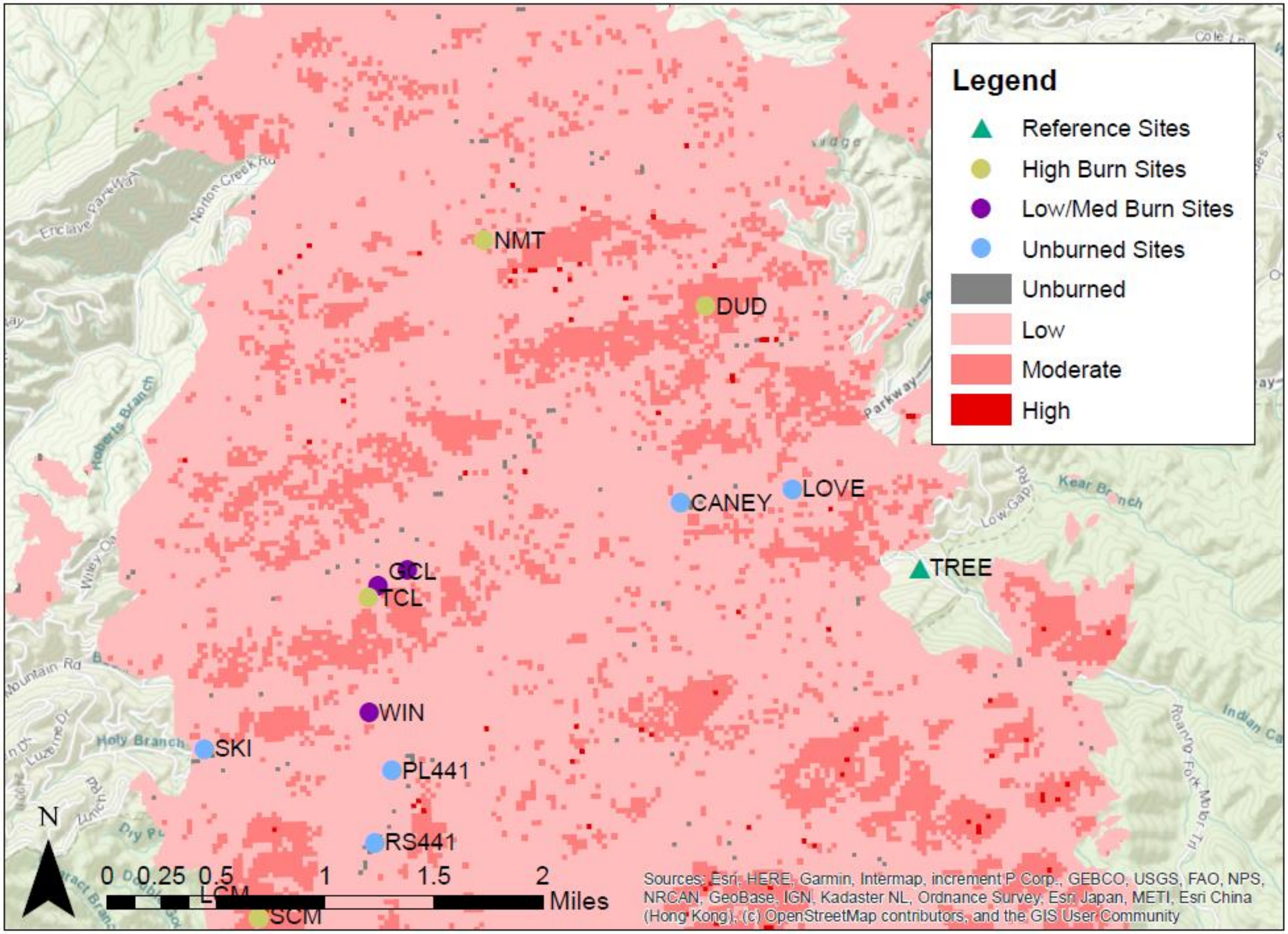
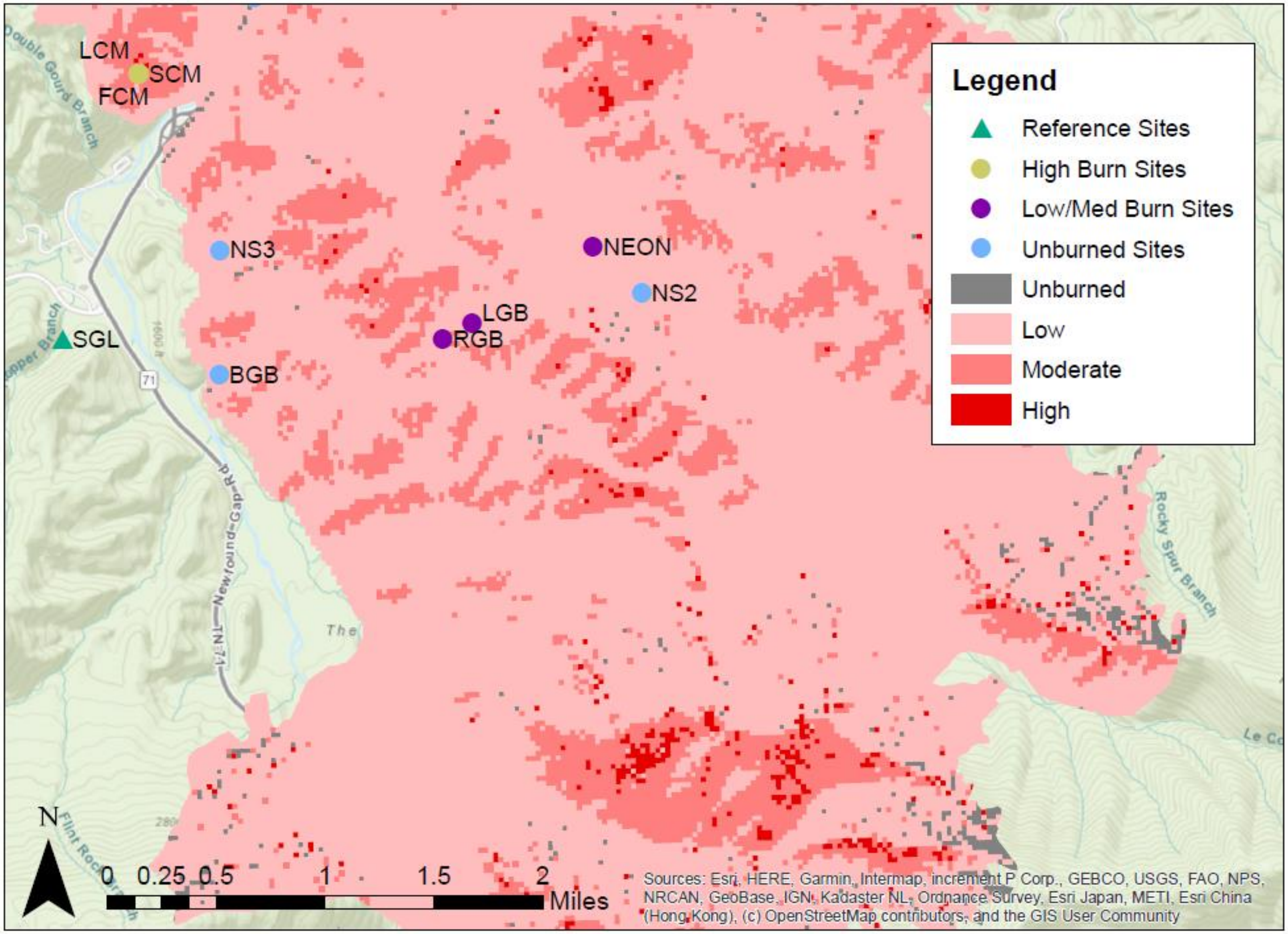


Figure C1. *Great Smoky Mountains National Park Soil Burn Severity Resulting from Chimney Tops 2 Fire GIS Layer. Esri, NASA, NGA, USGS | Great Smoky Mountains Natl Park, State of North Carolina DOT, Esri, HERE, Garmin, METI/NASA, USGS, EPA, NPS, USDA | BAER Team; Great Smoky Mountains National Park.*



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

Figure C2. *Map of urban sites, those outside of the National Park boundary, with each burn level represented.*



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

Figure C3. *Map of the original natural sites sampled, excluding RS441 and PL441 (included in map A3). Sites within the National Park that were sampled in 2018. Additionally, sites NS2 and NS3, sampled in 2019.*

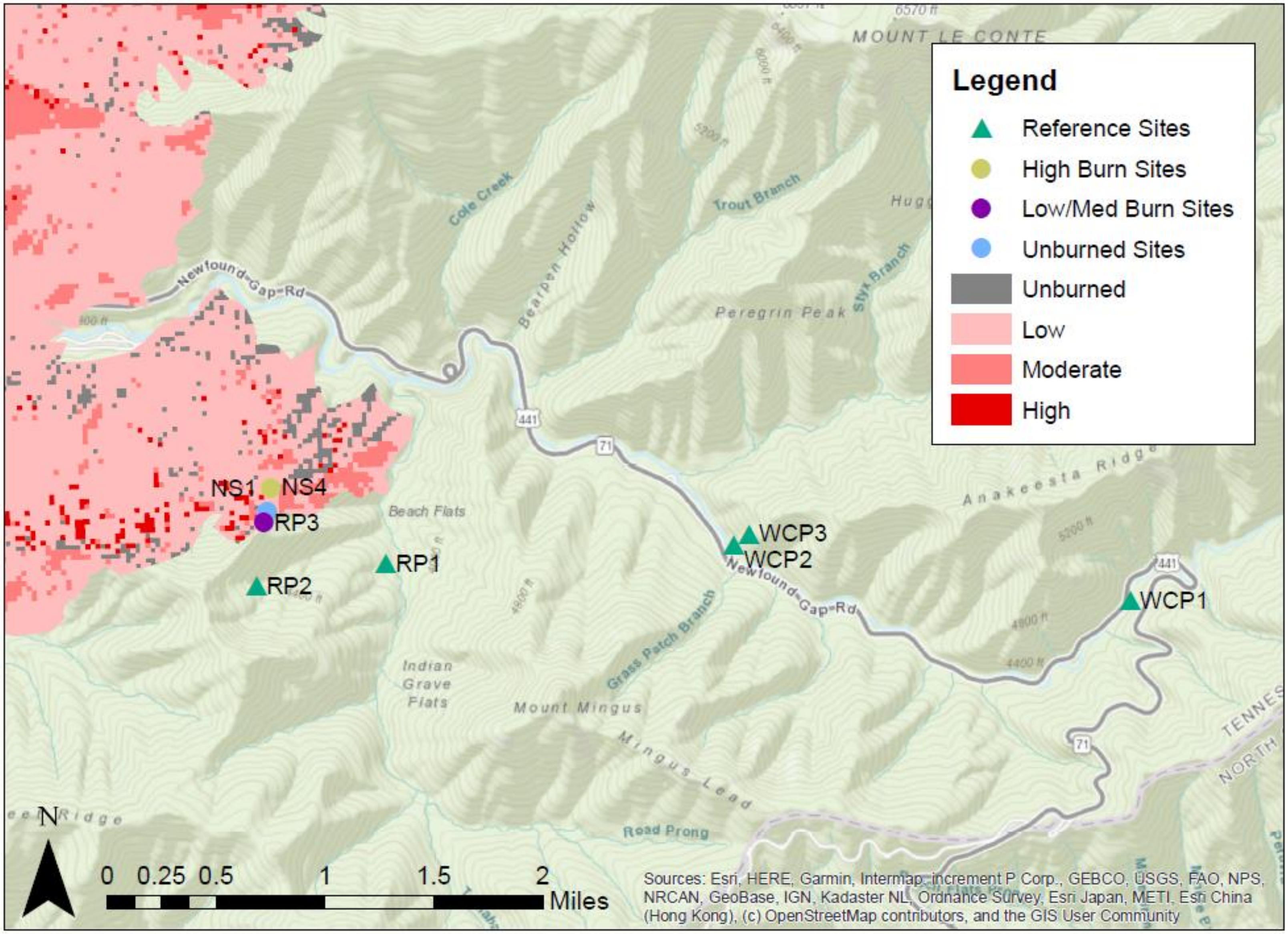
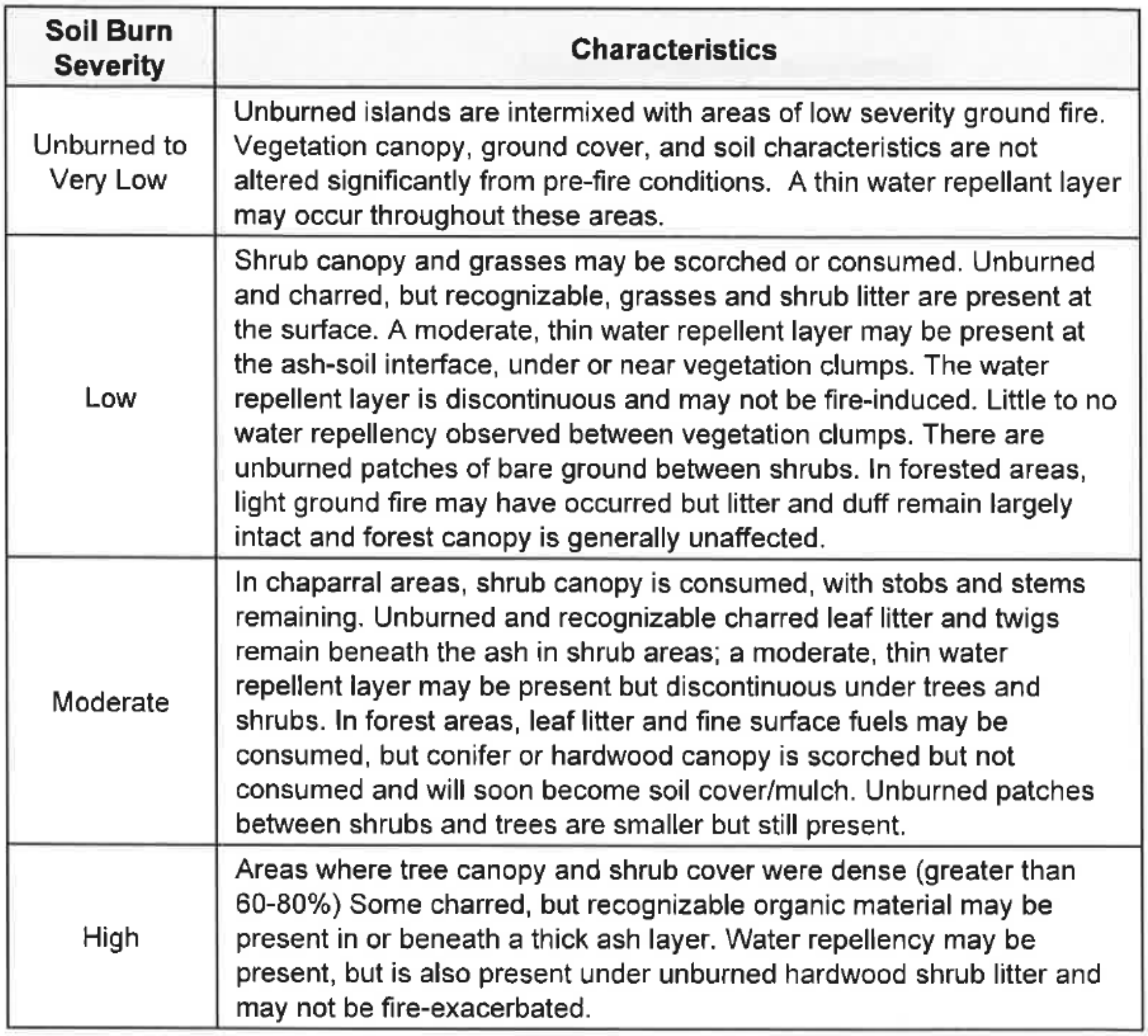


Figure C4. *Map of sites sampled in 2019, with all burn levels represented. The RP and WCP sites are those with historical data from a 2010 study within the park by Mary Ann Grell.*

D. APPENDIX D: BAER CLASSIFICATION

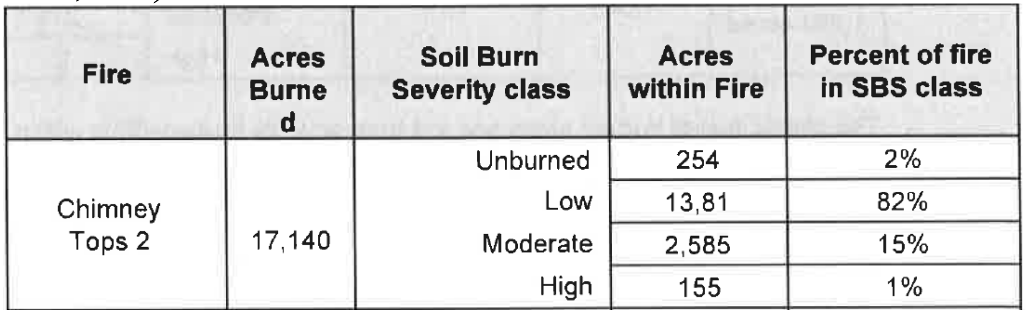
A Burned Area Reflectance Classification (BARC) map was created displaying the CT2 Fire. This map was modified significantly by the ground survey BAER team in order to more accurately represent the local post-burn conditions. The ground visits for validation focused on hillslope conditions, pre-burn vegetation communities, geologic types, soil classifications and vegetation burn severity. Table D1 displays the classification system used for the soil burn severities. Low and moderate soil burn levels were the dominate severity throughout the burn area, Table D2. This is thought to be due to the large amount of litter and duff accumulated in the park area on the soil surface that acted as a buffer to soil heating and kept the severity from increasing. Table D3 shows the major watersheds impacted and the area burned, percent watershed burned as well as the distribution of soil burn severity within each watershed.

Table D1. *General characteristics of the soil burn severity classes used to characterize the burn area by survey team (US Forest Service BAER, 2017).*



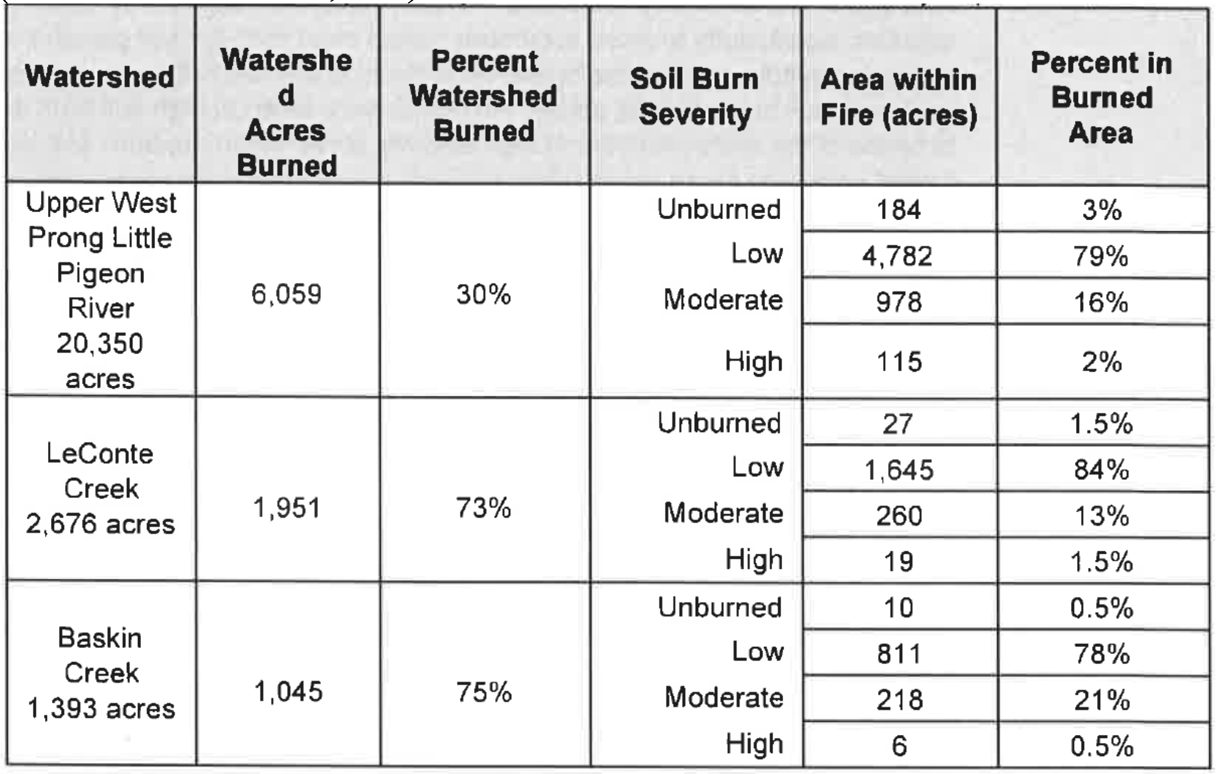
Soil Burn Severity	Characteristics
Unburned to Very Low	Unburned islands are intermixed with areas of low severity ground fire. Vegetation canopy, ground cover, and soil characteristics are not altered significantly from pre-fire conditions. A thin water repellant layer may occur throughout these areas.
Low	Shrub canopy and grasses may be scorched or consumed. Unburned and charred, but recognizable, grasses and shrub litter are present at the surface. A moderate, thin water repellent layer may be present at the ash-soil interface, under or near vegetation clumps. The water repellent layer is discontinuous and may not be fire-induced. Little to no water repellency observed between vegetation clumps. There are unburned patches of bare ground between shrubs. In forested areas, light ground fire may have occurred but litter and duff remain largely intact and forest canopy is generally unaffected.
Moderate	In chaparral areas, shrub canopy is consumed, with stobs and stems remaining. Unburned and recognizable charred leaf litter and twigs remain beneath the ash in shrub areas; a moderate, thin water repellent layer may be present but discontinuous under trees and shrubs. In forest areas, leaf litter and fine surface fuels may be consumed, but conifer or hardwood canopy is scorched but not consumed and will soon become soil cover/mulch. Unburned patches between shrubs and trees are smaller but still present.
High	Areas where tree canopy and shrub cover were dense (greater than 60-80%) Some charred, but recognizable organic material may be present in or beneath a thick ash layer. Water repellency may be present, but is also present under unburned hardwood shrub litter and may not be fire-exacerbated.

***Table D2**. Acres of Soil Burn Severity (SBS) Classes in the Chimney Tops 2 Fire (US Forest Service BAER, 2017).*



Fire	Acres Burned	Soil Burn Severity class	Acres within Fire	Percent of fire in SBS class
Chimney Tops 2	17,140	Unburned	254	2%
		Low	13,81	82%
		Moderate	2,585	15%
		High	155	1%

***Table D3.** Acres of Soil Burn Severity Class by Modeled Watershed in the Chimney Tops 2 Fire (US Forest Service BAER, 2017).*



Watershed	Watershed Acres Burned	Percent Watershed Burned	Soil Burn Severity	Area within Fire (acres)	Percent in Burned Area
Upper West Prong Little Pigeon River 20,350 acres	6,059	30%	Unburned	184	3%
			Low	4,782	79%
			Moderate	978	16%
			High	115	2%
LeConte Creek 2,676 acres	1,951	73%	Unburned	27	1.5%
			Low	1,645	84%
			Moderate	260	13%
			High	19	1.5%
Baskin Creek 1,393 acres	1,045	75%	Unburned	10	0.5%
			Low	811	78%
			Moderate	218	21%
			High	6	0.5%

E. APPENDIX E. SOIL ANALYSIS METHODS

Soil pH

The water pH and salt pH were taken on all samples (Thomas, 1996). Approximately 5 grams of field moist soil were added to 50 mL plastic centrifuge tubes. A 1:2 (weight: volume) ratio was used, adding respectively either 10 mL DI water or 0.01 M calcium chloride solution. The pH of the slurry was then measured using a pH meter.

Moisture Content

Soil moisture content was measured gravimetrically by drying 5 grams of field moist soil in an aluminum cup at 105°C to constant weight. The cup containing soil was weighed before and after drying, and moisture content was calculated by subtracting the final dry weight from the initial weight and determining a moisture percentage (Hart et al., 1994).

Organic Matter Content

The loss-on-ignition (LOI) method was used to determine the soils organic matter content. The LOI is assumed to be equal to organic matter content in most surface soils (Nelson and Sommers, 1996). Aluminum cups were places in a muffle oven at 400°C for two hours and weighed. Next, 1 to 3 grams of air dried soil, previously sieved to a diameter less than 0.2 mm, were added to the cup and placed in the oven at 105°C for 24 hours. The weight of these samples after subtracting the cup weight, W_{105}, was measured and the samples were placed back in the muffle oven at 400°C for 16 hours. The ignited sample weight, W_{400}, is calculated by subtracting the cup weight. The organic matter content of the soil samples was calculated using the following equation:

$$LOI\ \% = \frac{W_{105} - W_{400}}{W_{105}} * 100$$

Exchangeable Base Cations

Exchangeable base cations, which include: sodium (Na), potassium (K), calcium (Ca) and magnesium (Mg), were determined by the use of an extractant: 1 M NH_4Cl. 5 grams of air dry soil were added to approximately 50 mL extractant in a centrifuge tube. The slurry was shaken at 200 rpm for 3 hours in a reciprocating shaker, followed by 10 minutes in a centrifuge at 5000 rpm. The slurry was then filtered through 0.45 micrometer membrane filters and the filtered leachate was analyzed by ICP for Na, K, Ca, and Mg. Exchangeable Al and Fe were tested at the same time using the filtered leachate via ICP analysis (Sims, 1996).

Exchangeable Ammonium, Nitrate, and Sulfate

The extractant used for exchangeable ammonium, sulfate and nitrate was 0.01 M KCl. 5 grams of air dry soil were added to a 50 mL plastic centrifuge with 50 mL 0.01 M KCl. The slurry was shaken at 200 rpm for 3 hours in a reciprocating shaker and centrifuged at 5000 rpm for 10 minutes. The leachate was filtered through a 0.45 micrometer membrane filter and the filtered leachate was tested on IC for ammonium (NH_4), nitrate (NO_3) and sulfate (SO_4) (Cronan & Schofield, 1990; Stams & Marnette, 1990).

Total Acidity, Effective Cation Exchange Capacity, and Percent Base Saturation

Total acidity (TA) was calculated using a direct titration method. 5 grams of air dry soil were added to 50 mL of 1 M KCl in a centrifuge tube. The slurry was shaken at 200 rpm in a reciprocating shaker for 30 minutes, then centrifuged at 5000 rpm for 10 minutes. After centrifugation, the slurry was filtered through Buchner funnels using no. 42 Whatman filter paper. 25 mL of filtrate was transferred to a conical flask. Three drops of a solution made from 100 mL ethanol and 1 gram phenolphthalein were then added to the flask. The filtrate, with the phenolphthalein drops, was manually titrated using 0.1 M NaOH until the first permanent pink endpoint was observed (Sumner and Miller, 1996).

The total acidity is calculated using the equation as follows:

$$TA = \frac{100MA(x - y)}{W}$$

Where M is the molarity of NaOH, A is the aliquot factor (A = 2 = 50mL/25mL), y is the amount of NaOH used for the blank (mL), x is the amount of NaOH used in titration (mL), and W is the weight of soil in grams. The resulting units are cmol_c/kg dry soil. This TA value was used to determine the effective cation exchange capacity (ECEC).

The ECEC is defined as the sum of the cations a soil can adsorb at its native pH (Sumner and Miller, 1996). The equation is as follows:

$$\text{ECEC} = \text{Ca} + \text{Mg} + \text{Na} + \text{K} + \text{TA} + \text{NH}_4$$

The percent base saturation (%BS) represents the percentage of soil exchange sites occupied by base cations (Brandy and Weil, 2008). The percent base saturation was calculated by dividing the total exchangeable base cations by the effective cation exchange capacity:

$$\%BS = \frac{Na + K + Mg + Ca + NH_4}{ECEC}$$

Total Sulfur

Total sulfur (TS) was determined by thermal oxidation of soil samples. Less than one gram of dry soil was added to 25:1 sodium bicarbonate and silver oxide mixture at 550°C for four hours (Eivazi et al., 1988; Rossete et al., 2008). Residues were cooled in the oven and then transferred with minimum DI water to a flask, where the carbonate content was neutralized with minimum volume of HCl. Pure N gas in a pure stream was passed through the extract to remove any carbon dioxide traces. Resulting extract was analyzed on ICP for TS.

Percent Total Nitrogen and Percent Total Carbon

The total percent N and percent C were measured at the Colorado Plateau Stable Isotope Laboratory (CPSIL). $\delta^{15}N$, $\delta^{13}C$, %C, %N and C/N were measured in continuous-flow mode using a Thermo-Finnigan Delta^{plus} Advantage gas isotope-ratio mass spectrometer interfaced with a Costech Analytical ECS4010 elemental analyzer (Werner & Brand, 2001).

F. APPENDIX F: PEARSON CORRELATION

Correlations among Soil Chemistry Parameters

A Pearson correlation was used to compare soil parameters to one another in both soil horizons (Table 10, 11, 12 & 13). TA and pH were significantly correlated at both reference and low/medium burn severity levels in the A/O and B horizons ($p<0.01$). In both horizons, the reference sites had a significant ($p<0.01$) correlation between pH and EBC, as well as between EBC and individual base cations. Both horizons and burn levels showed a significant ($p<0.01$) correlation between the following pairs of parameters: EBC and ECEC ($p<0.01$), %C and %N ($p<0.01$), and C/N and TA ($p<0.01$). Nitrate and ammonium were significantly correlated in all cases aside from the B horizon of reference sites. Correlations that were noted only in the A/O horizon included pH and OM content ($p<0.01$), as well as OM and TA ($p<0.01$). In low/medium sites, the OM was correlated to EBC ($p<0.01$), and additionally in low/medium sites, more commonly than in reference sites, individual base cations were significantly correlated.

Table F113. *Correlations among soil chemistry parameters for reference sites in the A/O horizon. Significant correlations appear in bold (*p<0.01), N = 40.*

Parameter	pH	TA	EBC	ECEC	%BS	OM	SO$_4$	Na	K	Mg	Ca	Al	NO$_3$	NH$_4$	C	N
pH																
TA (cmol$_c$/kg)	**-0.500***															
EBC (cmol$_c$/kg)	**0.535***	-0.018														
ECEC (cmol$_c$/kg)	**0.443***	0.153	**0.985***													
BS (%)	**0.659***	**-0.388**	**0.739***	**0.703***												
OM (%)	**-0.676***	**0.745***	-0.289	-0.158	**-0.509***											
SO$_4$ (cmol$_c$/kg)	0.211	-0.019	**0.369**	**0.361**	0.269	-0.131										
Na (cmol$_c$/kg)	0.095	0.010	**0.317**	**0.315**	0.042	-0.133	0.142									
K (cmol$_c$/kg)	**0.391**	-0.026	**0.606***	**0.595***	**0.693***	**-0.387**	**0.418***	0.222								
Mg (cmol$_c$/kg)	**0.525***	0.003	**0.578***	**0.572***	**0.789***	**-0.313**	0.241	0.216	**0.719***							
Ca (cmol$_c$/kg)	**0.320**	-0.037	0.187	0.179	**0.544***	-0.182	0.126	0.206	**0.599***	**0.758***						
Al (cmol$_c$/kg)	**-0.664***	**0.493***	-0.137	-0.051	**-0.539***	**0.550***	-0.007	0.205	-0.198	**-0.371**	-0.289					
NO$_3$ (cmol$_c$/kg)	-0.189	**0.329**	-0.195	-0.131	-0.176	0.224	-0.203	**-0.344**	-0.177	0.035	-0.038	-0.081				
NH$_4$ (cmol$_c$/kg)	-0.133	0.122	-0.149	-0.124	-0.118	0.178	-0.205	**-0.362**	-0.225	-0.045	-0.143	-0.085	**0.675***			
C (%)	0.013	0.189	0.110	0.122	0.037	**-0.377**	**0.400**	0.228	0.074	0.252	-0.190	-0.084	-0.242	**-0.334**		
N (%)	-0.041	0.099	0.195	0.197	0.185	**-0.322**	**0.584***	0.145	0.115	0.075	-0.293	0.032	-0.306	**-0.335**	**0.950***	
C/N	0.049	**0.457***	-0.086	-0.050	**-0.395**	**-0.444***	-0.128	**0.393**	0.027	**0.600***	0.105	-0.299	0.105	-0.170	**0.638***	**0.412***

*TA = total acidity, EBC = exchangeable base cations, ECEC = effective cation exchange capacity, BS = base saturation, OM = organic matter content.

Table F214. *Correlation among soil chemistry parameters for reference sites in the B horizon. Significant correlations appear in bold (*p<0.01), N = 40.*

Parameter	**pH**	**TA**	**EBC**	**ECEC**	**%BS**	**OM**	**SO$_4$**	**Na**	**K**	**Mg**	**Ca**	**Al**	**NO$_3$**	**NH$_4$**	**C**	**N**
pH																
TA (cmol$_c$/kg)	**-0.766***															
EBC (cmol$_c$/kg)	**0.556***	**-0.452***														
ECEC (cmol$_c$/kg)	0.254	-0.024	**0.903***													
BS (%)	-0.050	**0.476***	0.282	**0.619***												
OM (%)	-0.168	0.228	0.227	**0.364**	-0.092											
SO$_4$ (cmol$_c$/kg)	0.002	0.028	**0.389**	**0.450***	**0.494***	0.086										
Na (cmol$_c$/kg)	-0.019	-0.110	0.022	-0.029	-0.189	-0.189	**0.669***									
K (cmol$_c$/kg)	0.212	-0.286	0.097	-0.029	**-0.336**	0.057	-0.232	0.014								
Mg (cmol$_c$/kg)	**0.461***	**-0.420***	0.107	-0.083	**-0.599***	-0.151	-0.206	0.159	**0.796***							
Ca (cmol$_c$/kg)	**0.619***	**-0.451***	0.281	0.098	**-0.519***	-0.237	-0.060	0.180	**0.458***	**0.774***						
Al (cmol$_c$/kg)	**-0.528***	**0.357**	-0.289	-0.152	**0.507***	-0.203	**0.326**	0.124	-0.213	**-0.386**	**-0.407***					
NO$_3$ (cmol$_c$/kg)	0.102	0.057	**0.382**	**0.455***	0.022	0.293	0.271	0.035	**-0.466***	-0.255	-0.155	-0.251				
NH$_4$ (cmol$_c$/kg)	0.024	0.009	**0.413***	**0.468***	-0.239	**0.556***	-0.137	**-0.315**	**0.447***	0.241	0.224	-0.286	0.251			
C (%)	**-0.504***	**0.474***	0.104	0.156	-0.277	**-0.382**	**0.378**	0.301	-0.124	-0.158	0.035	**0.358**	-0.133	0.034		
N (%)	**-0.337**	0.198	0.209	0.230	**-0.433***	-0.007	0.112	0.171	0.106	-0.035	0.214	0.090	-0.130	**0.337**	**0.887***	
C/N	**-0.471***	**0.728***	-0.086	-0.005	**0.658***	**-0.832***	**0.493***	0.308	-0.303	-0.145	-0.170	**0.617***	-0.140	**-0.416***	**0.633***	0.234

*TA = total acidity, EBC = exchangeable base cations, ECEC = effective cation exchange capacity, BS = base saturation, OM = organic matter content.

Table F315. *Correlation among soil chemistry parameters for low/medium burn sites in the A/O horizon. Significant correlations appear in bold (*p<0.01), N = 34.*

Parameter	**pH**	**TA**	**EBC**	**ECEC**	**%BS**	**OM**	**SO_4**	**Na**	**K**	**Mg**	**Ca**	**Al**	**NO_3**	**NH_4**	**C**	**N**
pH																
TA (cmol$_c$/kg)	**-0.796***															
EBC (cmol$_c$/kg)	-0.112	0.040														
ECEC (cmol$_c$/kg)	**-0.362**	**0.360**	**0.947***													
BS (%)	0.096	-0.290	**0.763***	**0.618***												
OM (%)	**-0.696***	**0.580***	**0.483***	**0.638***	0.119											
SO_4 (cmol$_c$/kg)	-0.055	0.058	-0.023	-0.003	0.008	-0.051										
Na (cmol$_c$/kg)	**-0.373**	**0.448***	**0.431**	**0.547***	**0.366**	0.229	0.205									
K (cmol$_c$/kg)	-0.270	**0.344**	**0.432**	**0.515***	0.331	0.160	-0.104	**0.601***								
Mg (cmol$_c$/kg)	**-0.533***	**0.617***	**0.526***	**0.690***	0.294	**0.504***	-0.047	**0.684***	**0.867***							
Ca (cmol$_c$/kg)	-0.312	**0.451***	**0.448***	**0.563***	0.268	0.273	-0.056	**0.648***	**0.922***	**0.934***						
Al (cmol$_c$/kg)	-0.294	0.096	0.269	0.282	0.271	**0.368**	0.007	0.161	0.006	0.167	-0.039					
NO_3 (cmol$_c$/kg)	0.043	-0.025	-0.182	-0.178	-0.250	-0.033	-0.113	-0.206	-0.180	-0.143	-0.146	-0.276				
NH_4 (cmol$_c$/kg)	-0.059	-0.042	-0.258	-0.255	-0.291	0.093	-0.069	**-0.400**	-0.272	-0.202	-0.218	-0.215	**0.797***			
C (%)	-0.319	0.018	-0.248	-0.279	0.053	-0.328	-0.193	**0.432**	0.028	0.177	0.114	-0.063	-0.051	0.039		
N (%)	-0.258	-0.067	-0.212	-0.258	0.068	-0.303	-0.227	0.292	-0.149	0.063	-0.002	-0.080	0.103	0.177	**0.946***	
C/N	**-0.572***	**0.344**	-0.333	-0.295	-0.152	-0.274	0.063	**0.355**	**0.458***	0.321	0.285	-0.077	**-0.417**	**-0.356**	0.335	0.034

*TA = total acidity, EBC = exchangeable base cations, ECEC = effective cation exchange capacity, BS = base saturation, OM = organic matter content.

Table F416. *Correlation among soil chemistry parameters for low/medium burn sites in the B horizon. Significant correlations appear in bold (*p<0.01), N = 34.*

Parameter	**pH**	**TA**	**EBC**	**ECEC**	**%BS**	**OM**	**SO$_4$**	**Na**	**K**	**Mg**	**Ca**	**Al**	**NO$_3$**	**NH$_4$**	**C**	**N**
pH																
TA (cmol$_c$/kg)	**-0.588***															
EBC (cmol$_c$/kg)	-0.097	0.013														
ECEC (cmol$_c$/kg)	**-0.584***	**0.942***	**0.349**													
BS (%)	**0.475***	-0.071	-0.231	-0.145												
OM (%)	-0.008	-0.056	**0.504***	0.117	-0.157											
SO$_4$ (cmol$_c$/kg)	-0.235	0.125	0.173	0.175	-0.259	0.114										
Na (cmol$_c$/kg)	-0.128	-0.095	0.198	-0.022	0.072	0.083	-0.074									
K (cmol$_c$/kg)	-0.285	0.249	**0.412**	0.372	0.112	0.191	0.078	**0.631***								
Mg (cmol$_c$/kg)	-0.149	-0.015	0.291	0.084	0.226	0.273	-0.132	**0.757***	**0.801***							
Ca (cmol$_c$/kg)	-0.061	0.151	**0.494***	0.308	0.302	**0.464***	-0.006	**0.580***	**0.786***	**0.815***						
Al (cmol$_c$/kg)	**-0.572***	**0.624***	0.262	**0.664***	-0.148	-0.137	0.143	**0.378**	**0.618***	**0.397**	0.322					
NO$_3$ (cmol$_c$/kg)	-0.022	0.163	-0.030	0.143	-0.101	0.078	**0.863***	-0.218	-0.106	-0.239	-0.084	0.064				
NH$_4$ (cmol$_c$/kg)	-0.125	0.041	0.275	0.131	-0.101	**0.368**	**0.570***	0.094	0.175	0.140	0.274	0.125	**0.624***			
C (%)	0.078	0.041	**0.803***	0.329	0.102	**0.457***	0.036	0.125	**0.379**	0.321	**0.432**	0.185	-0.111	0.164		
N (%)	0.109	-0.260	**0.721***	0.003	0.090	**0.586***	0.165	0.259	**0.411**	**0.463***	**0.494***	-0.050	-0.025	**0.368**	**0.769***	
C/N	-0.145	**0.491***	-0.048	**0.465***	0.021	-0.289	-0.190	-0.197	-0.104	-0.280	-0.147	0.331	-0.144	-0.304	0.105	-0.521

*TA = total acidity, EBC = exchangeable base cations, ECEC = effective cation exchange capacity, BS = base saturation, OM = organic matter content.

VII. VITA

Salley Anne Reamer was born in Columbia, South Carolina to Anne Carroll Reamer and Joseph Warren Reamer on January 30, 1996. She attended Satchel Ford Elementary School in Columbia, SC from 2002 – 2007 , Crayton Middle School from 2007 – 2010 , and AC Flora High School from 2010 – 2014. She then went on to attend Clemson University in the Calhoun Honors College and graduated with a bachelor's of science in Environmental Engineering in 2018. During her time at Clemson University, Salley was a member of the American Water Works Association chapter and participated in undergraduate research in the Department of Chemistry for two years and the Department of Environmental Engineering for one year. She participated in a National Science Foundation Undergraduate Research Program at the State University of New York at Buffalo and completed internships at Santee Cooper electric utility in South Carolina and an environmental consulting firm in the Water Resources group. Salley then accepted a graduate research assistantship at the University of Tennessee, Knoxville, in the Department of Civil and Environmental Engineering in August of 2018. During graduate school her main responsibilities were to carry out soil chemistry and water quality research in the Great Smoky Mountains National Park following the Chimney Tops II Wildfire. Salley will graduate in May 2020 with her graduate degree in Environmental Engineering with an emphasis in water resources from The University of Tennessee, Knoxville.