THE EFFECT OF DRYING AND DRYING TEMPERATURE ON SOIL ANALYTICAL TEST VALUES

By

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Bachelor of Science in Environmental Science

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Stillwater, Oklahoma

2013

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
July, 2015

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ACKNOWLEDGEMENTS

I would like to extend my utmost appreciation to my major advisor, Dr. Hailin Zhang, for providing me with valuable scientific knowledge and guidance throughout the past two years. I would not be where I am without his willingness to help and his dedication to his work and this project. I would also like to express my sincere gratitude to Dr. Brian Arnall and Dr. Chad Penn for their insightful instruction in and outside of the classroom. Furthermore, I want to thank Dr. Jackie Schroder for his contributions with the writing process, as well as Dr. Robert Miller at Colorado State University for providing me with the variety of soils for this project. Besides faculty, I would also like to recognize grad students Bruno Morandin and Josh Daniel for assisting me with numerous tasks and general information I might have needed throughout the two years.

In addition, I would like to note the assistance of Mike Kress and other staff of the Soil, Water, and Forage Analytical Laboratory with the extensive amount of lab work required for this project, and express a special thanks to them.

Finally, I must extend a well-deserved thank you to my parents, Tim and Ronda Mueller, as well as the rest of my family and friends, who have been very supportive of me throughout my education career and helping me strive for success.

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Date of Degree: JULY 2015

Title of Study: THE EFFECT OF DRYING AND DRYING TEMPERATURE ON SOIL ANALYTICAL TEST VALUES

Major Field: PLANT AND SOIL SCIENCE

Abstract: Variable drying temperatures during soil sample preparation may result in different results of the same sample. This project was conducted to determine the effect of drying and drying temperature on the results of common soil test analytes. Twenty-seven different soil samples from major agricultural regions of the U.S. were obtained and prepared for this study. The samples were hand ground to pass 2 mm sieve and divided into 6 portions. One of the 6 portions was kept at field moist condition, and the other 5 portions were dried at 25, 45, 65, 85 and 105°C overnight. Soil pH, and concentrations of ammonium-N, nitrate-N, plant available K, P, Ca, Mg, S, Cu, Fe, Zn, Mn, B, organic C, and total N were determined using standard methods. In general, sample drying increased the concentration of most analytes compared with the field moist samples. The impact of drying temperatures on K concentrations was variable : some soils were increased, or decreased, but others were unchanged. The contents of Fe, B, Zn, Mn, NH_4-N, and P, were increased by drying temperatures. The concentrations of Cu and Mg, however, were not consistently affected by drying temperatures. In addition, the initial field moist soil test values affected how drying temperatures impacted on the concentrations of NO_3-N, NH_4-N, Ca, organic C, and total N. Soil pH was affected differently, half of the samples decreased while the other half did not change by drying or drying temperature significantly. It is important for laboratories to use a standardized sample drying temperature to accurately characterize soils and make fertilizer recommendations.

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INTRODUCTION

Soil testing is widely used in the US and other developed countries to characterize soil and make fertilizer recommendations. However, there has not been a standardized drying temperature when samples are prepared for analysis in the U.S. In fact, many different temperatures ranging from air drying to oven drying at various degrees are used by different laboratories (Savoy, 2013) which may result in variable results of the same sample due to drying temperature differences. The most concerned nutrient due to the drying temperature effect is potassium (K) because it is a primary macronutrient and its release and fixation are dependent on clay mineralogy and drying temperature. If K test values are inaccurate, it may result in over or under applying K fertilizer for a particular crop not only affecting yields but also financial returns for the farmer. There have been many studies done on this topic, but the variability of the results found makes it difficult to determine if the test values are accurate compared to natural soil conditions. Some other factors that may change soil test values may include field conditions such as: moisture, temperature, soil type, soil mineralogy, and soil testing procedures. An additional concern is whether the initial nutrient concentrations of the soil will affect the release or fixation of nutrients after the drying process. To our knowledge, there is no comprehensive evaluation on how sample drying temperature affecting test results using soil samples from multiple regions. Most studies used soil samples from a local area. It is urgently needed to study how sample drying and drying temperature on soil test results using samples from a large geographical region in order to provide more reliable data to farmers.

Soil Testing Background

Soil test is a chemical process that provides a guideline for lime and fertilizer needs of soils when considered in conjunction with post-fertilizer management and cropping history (Thom et al., 2000). There are sixteen essential nutrients that plants need to grow, which include: carbon (C), hydrogen (H), and oxygen (O), nitrogen (N), phosphorus (P), K, Calcium (Ca), magnesium (Mg), sulfur (S), boron (B), chlorine (Cl), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), and zinc (Zn). All of these nutrients are essential for plant growth, so knowing the available levels of these nutrients in soils is the most reliable way to develop a balanced fertilizer program for the optimum yields. Soil testing provides a way to accurately estimate how much fertilizer or lime to apply. Under applying nutrients will hurt crop yields and over applying will increase production costs, negatively impact crop quality, and may increase the potential to harm the environment (Tucker, 1999.) Soil testing to determine fertility was first introduced in the 1840's by the work of Daubney in England using "active" and "dormant" terms to describe the solubility of the nutrients in soils (Anderson, 1960). The methodology for analyzing soils in Daubney's time was not advanced enough to make any accurate suggestions on fertility, which seemed to have caused the subject of soil testing to be set aside for many years (Anderson, 1960). Since the earlier years, soil testing has gradually advanced, giving us the ability to more accurately determine fertilizer and lime needs. Modern soil testing is now done mostly from automated instruments such as flow injection auto-analyzer and Inductively Coupled Plasma Spectrometer (ICP) to determine compounds or multiple elements in soil extracts simultaneously. These instruments make soil analysis more accurate and efficient. In addition to the advancement of analytical instruments, soil extraction methods have also evolved over the years. Currently, there are different methods used to extract the same nutrient to accommodate soil property variability or geographical differences. For example, plant available P in the soil can be extracted by Mehlich 3, Mehlich 1, Olsen, Bray-Kertz P-1, Bray P-2, AB-DTPA, water, and dilute salt methods (Lindsay and Norvell, 1978). However, it has become more popular to use one extractant for multiple elements to improve laboratory efficiency, for instance, Mehlich 1 and 3 can be used as an extractant for plant available P, K, Ca, and Mg; DTPA-sorbital extracting solution can be used for Fe, Zn, B, Cu, and Mn (Lindsay and Norvell, 1978); and AB-DTPA and Mehlich 3 for all major macro- and micro-nutrients and quantified by ICP simultaneously.

Soil Sample Preparation

The ideal situation for soil testing would be using undisturbed and unaltered either chemically or mechanically during soil sample preparation. Soil testing using undisturbed soils would provide the most accurate results as it would relate most closely to the natural setting of the soil; however, it is impractical to conduct soil testing with undisturbed samples efficiently. The sample preparation procedure begins with the drying and pulverizing process. For the ease and speed of soil testing, samples are dried and ground so that they are homogenized and easier to handle and store. Storing field-moist samples is much more difficult because they have to be kept in sealed containers or bags to maintain moisture content of the samples.

Drying allows for ease of use and also the ability to perform reruns if necessary. After drying and pulverizing, soil samples are normally sieved with a No. 10 or 2mm sieve for most soil analyses. Sieving the samples allows for removing roots and rocks, and having a uniform particle size to facilitate extraction. Because of aggregate sizes, it is important to homogenize each soil sample thoroughly before scooping or weighing the sample (Hoskins and Ross, 2009). The scooping and weighing process is usually determined by the preference of a lab. Scooping is much faster and it allows for samples to be analyzed much more quickly so it is commonly employed by commercial service labs. Scooping is also said to be able to compensate for differences in bulk density of different soil types (Hoskins and Ross, 2009). Weighing subsamples has been shown to be more accurate in most situations (Glenn, 1983). Schroder et al. (2009) found that repeatability relative standard deviation (RSDr) values for weighing were minimally more accurate than for scoping, and reproducibility relative standard deviation (RSDR) values were not significantly different between the 2 methods. Furthermore, results of weight-based samples are not affected by particle size and texture of the sample.

Drying is an important step of sample preparation

Sample drying is a common pretreatment in both public and private soil testing laboratories for most agricultural tests (Hoskins and Ross 2009; Gelderman and Mallarino, 2012). Drying allows more convenient sample handling, particularly sieving and mixing, and therefore analytical results from dried soil samples are expected to be more reproducible than those from field-moist samples. Dried soil samples are thought to be relatively stable with minimal change over time resulting from microbial or chemical reactions; they are often archived by testing laboratories at least for a short time in case retesting is warranted. Dried soil samples from field research projects may be archived for decades (Erich and Hoskins, 2011). There is, however, not a standard temperature that every lab uses to dry soils. Temperatures used for drying soil samples range from 32ºC (Mississippi) to 65ºC (OK, AR, TN) in the Southeast US (Savoy, 2013). Although some states use the same temperature, there is still a difference in drying time ranging from 12-72 hours, or until the drying process is complete (Savoy, 2013). Some references suggested that soil samples should not be dried over 40ºC (104ºF), because of the impact on nutrient extractability, especially K (Gelderman and Mallarino, 2012). Most labs use temperatures exceeding this recommended temperature (Savoy, 2013) although how much effect drying temperature has on different analytes is not well documented. Both drying temperature and duration would have the potential to change soil test results. Because the difference in drying temperature and the potential impact of drying on test results, it has been suggested to use field moist samples for routine analysis (Mallarino et al., 2012). However, the adoption of using field moist samples for testing has been very low due to practical issues encountered in fast paced service labs.

The Effect of Sample Drying on Soil Test Potassium

Many years of research has shown that the wetting and drying and also the freezing and thawing cycles of the soil has an effect on the transformations of K between exchangeable and nonexchangeable fractions (Mallarino et al., 2012). Soils initially high in exchangeable K may fix K upon drying while those with initially very low exchangeable K levels tend to release K upon drying (Mallarino et al., 2012). The equilibrium between these soil K pools is also affected by K additions and plant K removal from the soil. Therefore, the time of sampling interacting with these factors in the field or during sample handling at the laboratory may partially account for high temporal variation of soil test K (STK) levels (Mallarino et al., 2012). Potassium has been shown to have the highest variability when soil samples are dried (Attoe, 1947; Dowdy and Hutcheson, 1963; Scott and Bates, 1962; Burns and Barber, 1961). The drying of soil samples has been shown to increase exchangeable K, and also in some cases to cause fixation of K by the soils compared with analyzing field moist samples. Soil clay mineralogy is important for potassium exchangeability as well, since Montmorillonite and Vermiculite can cause fixation of K while Illite has the potential to release it (McLean and Watson, 1985; Dowdy and Hutcheson, 1963). It has also been shown that soils with a high STK levels greater than 250 mg/kg are more likely to fix K or extract less upon drying. In contrast, soils with low initial soil test K (<150 mg/kg) have the tendency to release more K upon drying (Attoe, 1947). In other words, drying could increase soil test K for low K soils but reduce STK for high K soils. It was found by Burns and Barber (1961) that varying moisture content in soil samples from 60 to100% moisture equivalent had no effect on non-exchangeable K at the drying temperatures of 1º to 80ºC, but there was an increase in exchangeable K for all of their samples with one exception. Scott and Bates (1962) found that when dried, exchangeable K increased, but when the dried soil was rewet with water exchangeable K decreased. They found in most cases for this to be true, as well as additions of other solutions and organic matter.

Iowa researchers in the 1960s and 1970s showed that soil K extracted from field-moist samples was better correlated with crop K uptake than K extracted from air-dried or oven-dried samples. A slurry method for P, K, and other nutrient test using field-moist soil samples was developed in the 1970s and was implemented in Iowa until 1988. The procedure was recommended by the North-Central Region Soil Testing Committee (NCR-13, Brown and Warncke, 1988; Eik and Gelderman, 1988). Field correlations for corn and soybean for the slurry K test were published by Mallarino et al. (1991a, 1991b). Based on comparisons of the amounts of soil K extracted using dried (35 to 40 ºC) and moist samples, the interpretation for the slurry K test was increased by a factor of 1.25 in Iowa (Mallarino et al. 2012). However, there is a renewed interest to use field moist samples by some private laboratories lately.

The Effect of Drying on Other Analytes

Despite the advantages of drying during soil preparation, it is known that drying soil samples alters soil pH and nutrient extractability (Van Erp. Houba et al., 2001; Turner and Haygarth, 2003; Bartlett and James, 1980; Gelderman and Mallarino, 2012). In general, drying increases the concentration of solutes, which may cause some elements to precipitate or increase sorption on soil surfaces. Rewetting dried soil samples disrupts soil aggregate structure and may expose additional organic matter and clay surfaces to solution. Air drying has been observed to increase extractable organic matter (Lundquist et al., 1999; Bartlett and James, 1980). In addition to disruption of aggregate structure and exposure of previously protected organic matter, at least two other mechanisms may contribute to this effect: death and lysing of microbial cells and alteration and disruption of organic bonds. Drying also increases surface acidity, which may affect the solubility of many nutrients, particularly micronutrients (Bartlett and James, 1980; Dowding et al., 2005). In some cases, this may affect subsequent solubility or extractability of phosphorus (P), copper (Cu), manganese (Mn), zinc (Zn), and other nutrients over time, even in dry storage (Bartlett and James, 1980).

Turner and Haygarth (2003) found large differences in bicarbonate-extractable P (organic and inorganic) between field-moist and air-dried soil samples. They noted that although their findings were significant for research studies of P cycling, the differences had little soil-testing significance because correlations between plant growth and soil-test P levels were established using air-dry soil samples. Searle and Sparling (1987) had similar findings for P, and also noted that air drying caused no significant change in extractable sulfate content. Among the micronutrients, Mn is the most affected by drying. Generally, there is an increase in extractable Mn upon drying, caused by the reduction of insoluble manganese oxides to a soluble form (Bartlett and James, 1980).

Venterink et al. (2002) showed that extractable nitrate increased from almost zero in the initial soil cores to an average of 120 mg N m^{-2} in wet soil cores and 690 mg N m^{-2} in dried soil cores, after 27 days of incubation.

The objective for this study was to determine if drying and drying temperatures have significant impacts on common soil test values using soil samples collected from multiple states and represented a wide range of soil types and geographical regions.

MATERIALS AND METHODS

Twenty-seven samples (numbered 1 to 27) from different regions of the United States were chosen for this study. The locations of the samples are shown in Figure 1. Most of the samples were from the corn and soybean belt and some from the Pacific Northwest and the south central US. The samples were collected and archived by the Agricultural Laboratory Proficiency (ALP) for its sample exchange program. The samples had been frozen in plastic bottles since they were collected at the natural field moisture until the preparation for this study.

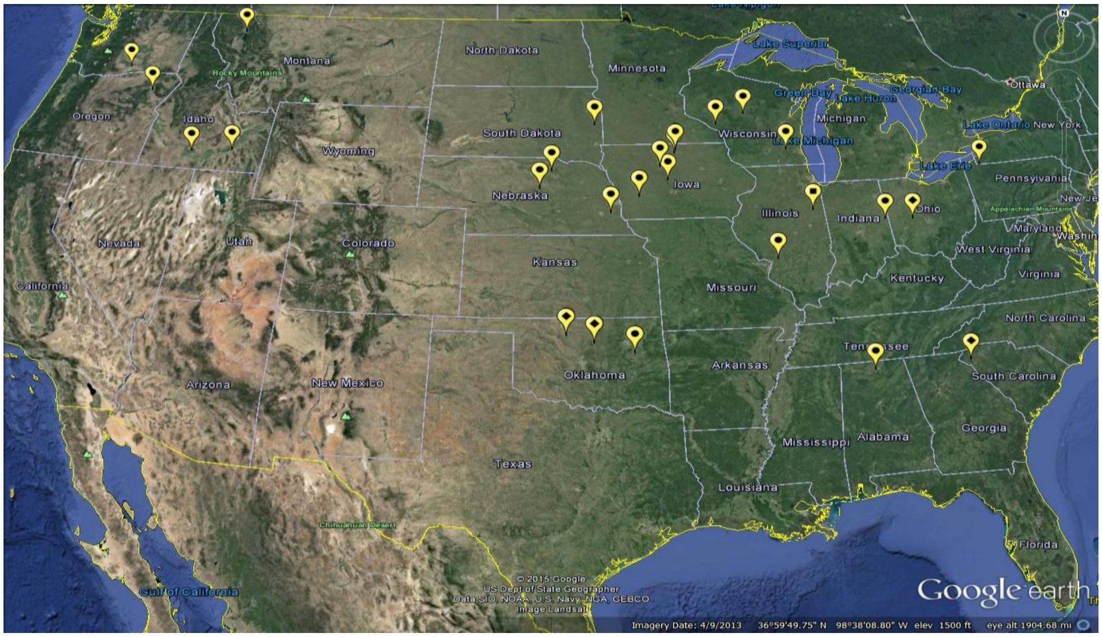

Figure 1. Locations of the twenty-seven soils across the U.S.

The soil samples were brought out of the freezer to thaw. After the soils were allowed to thaw, they were crushed by hand and then sieved to pass through a 2mm sieve. Each individual soil sample was then separated equally by weight into six separate containers for different drying temperature treatments (6 X 27 = 162 individual containers). The subsamples were numbered 1- 162, labeled with their respective soil I.D. and with the drying temperature: field moist, 25ºC, 45ºC, 65ºC, 85ºC, or 105ºC. The field moist samples were put into sealed containers to maintain moisture and stored in the refrigerator between analyses. The rest of the samples were separated into their temperature groups and dried at the assigned temperature. The drying lasted for 24 hours in a forced air oven at the preset temperature except for the 25ºC samples which were let dry at ambient temperature until dry. Each individual sample was then tested three times for NH_4-N, NO_3-N, macronutrients, micronutrients, SO_4-S, organic carbon (OC) and total nitrogen (TN), and pH. Soil texture was also determined for all 27 air dried soil samples.

Soil pH was measured in a 1:1 soil to water suspension with a pH meter and a combination electrode (Thomas, 1996). The soil NO_3-N and NH_4-N determination involved extracting nitrate and ammonium from soil samples with 1.0 M KCl (Kachurina et al., 2000). Ammonium and nitrate in the extracts were simultaneously measured on a flow-injection analyzer. The ammonium was analyzed using the salicylate method, and the nitrate was measured using the cadmium reduction method. Briefly, 25 ml of KCl extracting solution was added to 5g of soil and shaken for 30 minutes. The samples were then filtered with pre-folded filter paper and analyzed by the LaChat instrument.

Sulfate (SO_4-S) was extracted from the samples with 0.008 M calcium phosphate. Twenty-five mls of calcium phosphate extractant were added to 5g of sample and the samples were shaken for 30 minutes. The samples were then filtered and quantified by an ICP.

Macronutrients K, Ca, Mg, and P were extracted by the Mehlich 3 method (Mehlich, 1984). Twenty ml of Mehlich 3 solution was added to 2g of soil in Erlenmeyer flasks, shaken for 5 minutes at 210 rpm. The samples were then immediately filtered and analyzed by an ICP.

Micronutrients Fe, Zn, Cu, and Mn are normally analyzed using the DTPA Method (Lindsay and Norvell, 1978). The DTPA-Sorbitol extraction is a quantitative method for estimating bioavailability of Fe Cu Mn and Zn in soils. With the addition of sorbitol, this extraction can also be used for measuring boron in soils (Miller et al., 2001). Twenty mls of DTPA-sorbitol extracting solution was added to 10g of soil sample, shaken for 2 hours on a rotary shaker at 250 rpm. After shaking, samples were immediately filtered through two layers of filter paper. Samples were allowed to filter for at least 2 hours and then were analyzed by an ICP.

Soil organic carbon and total nitrogen were analyzed on a LECO TruSpec CN Analyzer. A brief principle of the dry combustion method is described below. Soil samples wrapped in tin foil are dropped into a hot furnace (950°C) and flushed with oxygen for very rapid and complete combustion. The products of combustion are passed through a secondary furnace (afterburner, 850°C) for further oxidation and particulate removal. Moisture is then removed with a filter and a thermoelectric cooler. The gases are collected in the ballast. Carbon is measured as the gases pass through the CO_2 infrared detector. Finally, the gases fill the 3cc aliquot loop and are carried by the helium flow through hot copper to remove oxygen and change NOx to N_2. The N_2 flows through Lecosorb and Anhydrone to remove carbon dioxide and water, respectively. A thermal conductivity cell is used to determine the nitrogen content.

Soil texture was determined by the hydrometer method (Bouyoucos, 1928). This method determines percentages of sand, silt, and clay content. Corrections for viscosity and temperature are made by use of an analytical blank and by adjusting the time for the final hydrometer reading based on a temperature table.

Statistical Analysis

All statistical analyses were performed with SAS Version 9.4 (SAS Institute, Cary, NC). Differences in response variables were assessed with analysis of variance methods assuming a two-factor factorial (soil and temperature) in a randomized complete block design. Simple effects of temperature given soil are investigated with protected planned contrasts and pairwise multiple comparisons using a 0.05 level of significance. Means and standard errors are reported where appropriate.

RESULTS AND DISCUSSION

Table 1 shows some basic properties of all twenty-seven soils that were used in this study. Soil pH, clay content, organic matter content, soil test K, P, Mg and Ca ranged from 3.8 to 7.8, 5 to 34%, 0.5 to 5%, 45 to 916 mg kg^{-1}, 4 to 209 kg^{-1}, 65 to 986 kg^{-1}, and 256 to 11351 kg^{-1}, respectively. A wide variety of soil samples ensures that the results will represent wide geographical regions and conditions.

Table 1. The names of all the soils used, their abbreviations and basic properties.

Classification	I.D.	State	pH	Clay %	OM %	K mg/kg	P mg/kg	Mg mg/kg	Ca mg/kg
Canisteo clay loam	BAD	IA	7.5	31.3	5.1	125	33.5	502	11351
Marshall silty clay loam	Elkorn	IA	5.9	30.0	3.0	232	53.8	835	4573
Lester loam	HAR-B	IA	5.3	10.0	1.1	77	56.8	159	829
Webster silty clay loam	LIN	IA	6.8	12.5	1.4	251	57.0	284	1770
Saude loam	MAR-2	IA	5.6	20.0	1.9	136	35.6	261	2121
Abernathy silt loam	ATH	AL	5.9	32.5	0.6	172	28.1	66	1175
Cecil sandy loam	CLE2	SC	4.8	15.0	0.6	45	15.3	108	480
Virgil silt loam	DEG	WI	6.9	17.5	2.6	95	33.5	663	2310
Gale silt loam	TAY	WI	4.8	20.0	0.9	120	39.0	391	1328
Withee silt loam	W-8	WI	7.1	12.5	1.8	66	27.4	624	1939
Miami silt loam	TAY2	IN	6.9	25.0	1.2	165	9.5	547	1700
Casco-Miami-Fox complex	JUS-OH	OH	7.5	33.8	1.3	154	3.9	740	2517
Chautauqua silt loam	CHA	NY	5.2	15.0	3.6	139	37.8	225	1837
Virden-Fosterburg silt loam	HAR	IL	5.0	27.5	3.1	119	50.6	479	2930
Del Rey silt loam	USI	IL	4.7	15.0	1.4	77	11.3	97	256
Pivot loamy sand	ON2	NE	4.7	10.0	1.2	197	69.5	122	739
Otoe silty clay loam	JMLF	NE	5.1	30.0	1.8	191	13.3	513	2629
Ipage loamy fine sand	BUR	NE	3.8	5.0	0.8	248	83.4	69	413
Purdam silt loam	DRI	ID	6.5	20.0	0.5	163	89.1	647	2252
Delco loam	TAB	ID	7.7	12.5	0.9	894	152.6	359	4031
Psys gravelly silt loam	LGE	OR	6.1	27.5	3.5	868	67.7	987	4414
Quincy loamy fine sand	GUY	WA	7.1	5.0	0.5	354	209.4	187	1764
Barnes-Buse loams	SP1	SD	4.7	15.0	2.1	78	46.8	310	2043
Pond Creek silt loam	LAH	OK	6.9	26.3	1.1	282	33.8	522	2412
Kirkland silt loam	STIL	OK	4.8	20.0	0.7	133	42.2	244	919
Taloka silt loam	HASK	OK	7.5	12.5	1.3	85	51.7	99	2412
Creston silt loam	CRE	MT	7.8	13.8	3.3	338	62.9	322	6610
Min.			3.8	5.0	0.5	45	4.0	65	256
Max.			7.8	34.0	5.0	916	209.0	986	11351
Avg.			6.0	19.1	1.8	215	52.4	384	2509

The Effect of Drying on Exchangeable Potassium

Soil test K (STK) was affected by drying and drying temperatures differently. Some samples showed an increasing trend as drying temperature increased, some decreasing, and others had no differences. Therefore, the 27 soil samples were separated into three different groups based on how exchangeable K values were affected by temperature. Figure 2 shows how exchangeable K values decreased as drying temperature increased from air drying to 105°C. Of the 27samples, seven (LIN, CHA, BUR, TAB, LGE, GUY, and CRE) had a decreasing trend in extractable K when dried and as drying temperature increased. Six of these 7 soils had a field moist soil test potassium (STK) value of 250mg/kg (0.64 meq. per 100g) or greater, and the 7th (CHA) soil had a value of 140mg/kg. A total of 7 out of the 27 soils had field moist STK higher than 250 mg/kg, and 6 were in this group and one (LAH) in the “no change” group. This clearly suggests that drying soil samples reduced K extractability for samples with initial high STK levels. This finding confirms similar discoveries in many other studies (more discussion below).

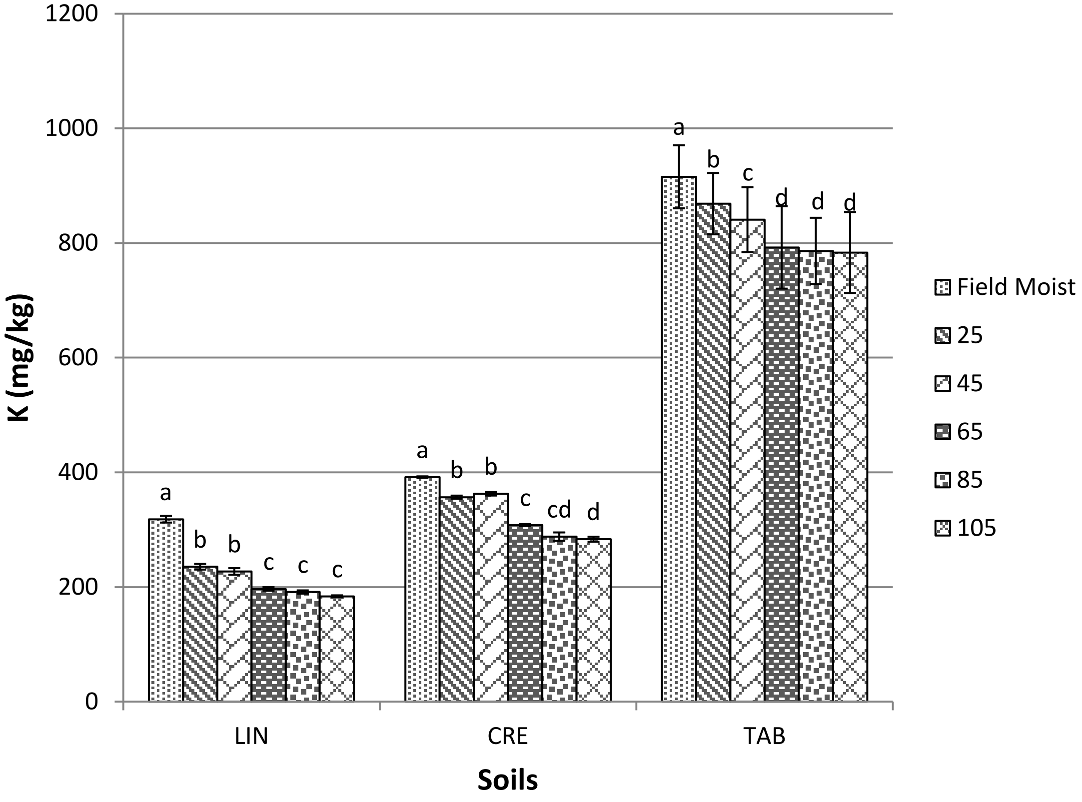

Figure 2. Representative soil samples showing a decreasing trend of exchangeable K as drying temperature increased. Seven out of the total 27 soil samples had similar trends and 6 of the 7 had initial STK above 250 mg/kg (different letters indicate statistical difference at p=0.05).

In contrast to the decreasing trend shown in Figure 2, Figure 3 shows the increasing exchangeable K trend when samples were dried and as drying temperature increased. There were only four of the twenty-seven soils that displayed this increasing trend (BAD, ON2, JMLF, and DRI). Field moist STK values for this group ranged from 102-208mg/kg. This increasing trend is probably due to K release upon drying when initial STK are low. This artificial STK increase may put K deficient soils into adequate category. The unfertilized soils in the work of Attoe (1947) had low STK values ranging from 86-245 lbs/ac for non-dried and 101-283 lbs/ac for the dried soils. They found 4-58% STK increase due to drying. Dowdy and Hutcheson (1963), Erich and Hoskins (2011), and Gelderman and Mallarino (1998) also stated that soils with low STK in their work released K upon drying.

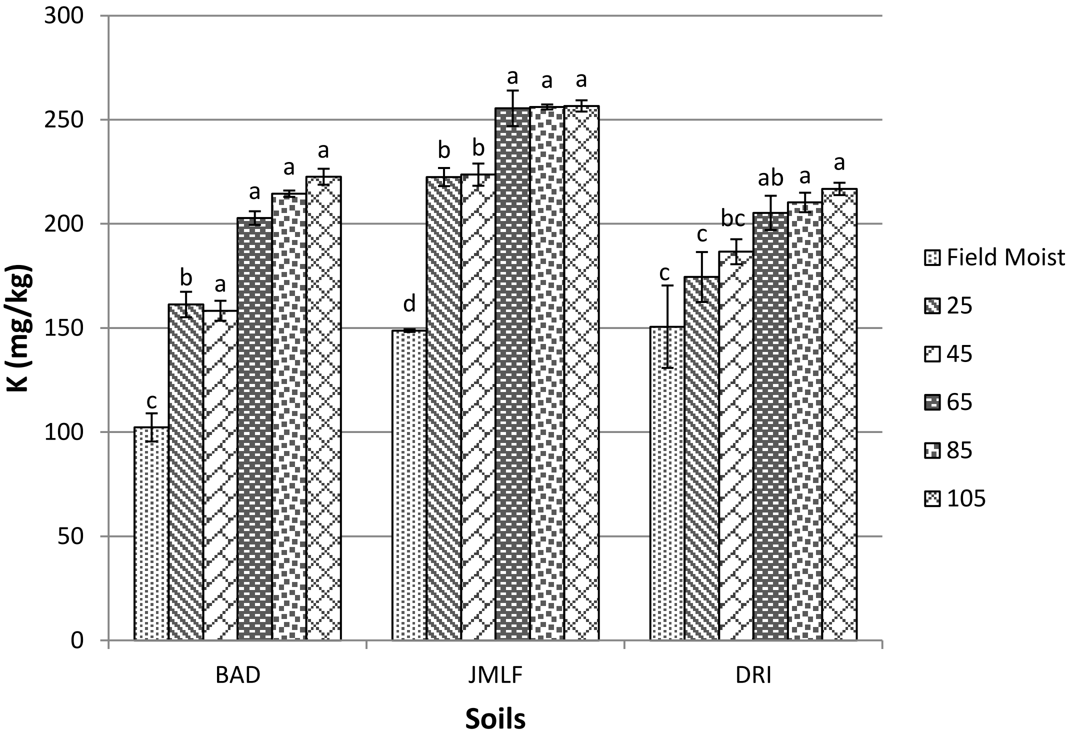

Figure 3. Soil test K as impacted by drying and drying temperature for representative samples. All soils with this trend had initial soil test K less than 250 mg/kg (different letters indicate statistical difference at p=0.05).

The remaining sixteen soils exhibited no change in exchangeable K when dried or as drying temperature increased. Results of 3 representative samples in this group are shown in Figure 4. The no-change of STK occurred to samples with low, medium and high initial STK values. The criteria set for “low,” “medium,” and “high” values in this study is on a generalized basis of the data set for that particular analyte. These terms are not meant to indicate deficiency or sufficiency for fertilizer recommendations. Based on our results, it can be said with confidence that soils with a field moist/initial STK value of 250mg/kg or greater generally will decrease exchangeable K concentration upon drying due to potential K fixation. Continuing fixation will occur after air drying, but the decrease in concentration is not linear and is highly variable from soil to soil. The soils in this group only continued fixation of exchangeable K for treatments of 25˚C, 45˚C, and 65˚C, with no more occurring at the 85˚C and 105˚C treatments. As for soils with exchangeable K values below 250mg/kg, the trends are highly variable, as there were sixteen soils that showed no significant difference from drying or from the increase in drying temperature including some samples with very high and very low initial STK.

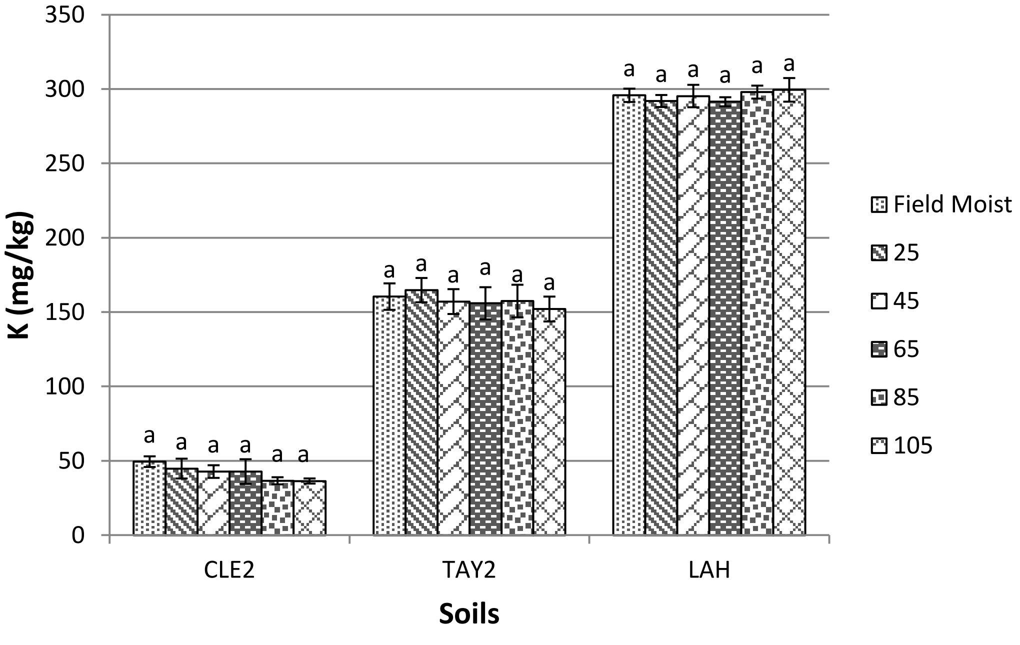

Figure 4. Sixteen of the 27 samples showed no change in exchangeable K upon drying and as drying temperature increased. Three samples representing low, medium and high initial STK are shown (the same letters indicate no statistical differences).

The inconsistencies in the STK values in this study that were affected by drying and drying temperatures have a number of possibilities for the mechanisms behind them. At the top of the list we attribute these inconsistencies to clay mineralogy and how it affects the soil chemistry of the entire soil system. Commonly 2:1 minerals such as smectites, vermiculites, illites, and micas are considered to be a factor in the fixation and release of K ions (Essington, 2003). Micaceous clays have been said to be important in the non-exchangeable and mineral K forms for plant uptake because they are subject to biological weathering in the rhizosphere (Hinsinger et al., 1991). As shown by Mengel et al. (1998) sand and silt sized muscovite and biotite have the potential to be a significant source of plant-available K in studies of 14 Alfisols. Potassium feldspars are also believed to play a role with the rest of these primary minerals to be a high source of K for sandy Ultisols of the Atlantic coastal plain (Parker et al., 1989). Layered minerals of 2:1 type are more likely to interact with soil solution because they have greater surface charges than 1:1 minerals such as Kaolinite. Dowdy and Hutcheson (1963) suggested that vermiculite probably fix K when soils are dried. In contrast higher amounts of illite and montmorillonite released K in their study. When these minerals are saturated with K, the charge on the K ions will shrink the d-spacing or the space between the mineral layers closer together and trap or fix K. Drying has also been found to increase fixation by pulling out water from the interlayer and collapsing the mineral structure even further (Essington, 2003). As the clay minerals are rehydrated, they tend to release K back into soil solution. In many studies, soil moisture, along with a seasonal effect can have a significant positive effect on the exchangeability of K in the soil especially in winter months (Blakemore, 1966; Childs and Jencks, 1967). These changes could be due to the leaching of K from crop residues as well as the conversion from non-exchangeable to exchangeable K through valence dilution (Khan et al., 2013). It is well known that K in the soil is a very active and unpredictable nutrient given all of the factors that affect its exchangeability. Studies by Dowdy and Hutcheson (1963), Erich and Hoskins (2011), and Gelderman and Mallarino (1998) have demonstrated that if a soil has a high initial STK, STK is decreased after the soil is dried. On the other hand, if a soil has a low initial STK, drying will result in a higher STK. This study confirms the findings with high initial STK, but for the 27 soils tested, the low initial STK soils were inconsistent and only 4 displayed an increasing trend after drying. Attoe (1947) used 10 different soils to test the differences of STK between unfertilized and fertilized soils when dried. The fertilized soils received 450mg/kg of K had very high STK ranging from 421-750mg/kg and the unfertilized soils had STKs from 38-271mg/kg. The fertilized soils fixed K in all of the ten soils after being dried, while the unfertilized soils showed an increase or release in exchangeable K in all but one of the soils. Dowdy and Hutchison (1963) presented a study showing the K fixation of 6 soils used by Cook and Hutcheson (1960) that represented low, medium, and high concentrations of K. Those 6 soils were then leached with K_2SO_4 if they fell below an STK of 0.5 me. per 100g of soil and $CaSO_4$ for soils above an STK of 0.5 me. per 100g of soil to find out the difference between the original and leached soil after a 7 day period of equilibrium. Their results showed that the soils with a high initial STK value fixed potassium over the 7-day period as soil moisture content decreased. Our results are generally consistent with those finding since 6 of 7 soils with above the 250mg/kg initial STK had a decreasing trend as drying temperature increased. The results of an extensive study by Kahn et al. (2013) suggested that soil K testing did not provide a scientific basis for fertilizer management because of variability of STK over time and upon drying. They performed many studies on K soil testing and fertility and found that K was too unpredictable to provide an accurate soil test analysis. In one of the studies, where a Drummer soil that was void of K fertilizer for 14 years was air dried and dried at 105˚C, they determined STK biweekly for 4 years for both temperatures. The STK values were significantly different between air-dried and oven dried at 105˚C and varied drastically with or without drying over those 4 years, and the variations became larger after harvest when soil sampling normally takes place. All of these findings suggest the complexity of K exchangeability in soils. It is recommended to take soil clay mineralogy into consideration in order to better understand the mechanisms why soil test K vary with sampling time and change after samples dried.

The effect of drying on extractable phosphorus, calcium, magnesium and sulfur

There were two different trends of soil test P (STP) as influenced by drying and drying temperature: STP increasing as drying temperature increasing and no significant changes (Figure 5). The W-8 soil represents 21 out of the 27 soils that showed an increase trend in extractable P, especially when the drying temperatures reached 65˚C where the changes were more dramatic when drying temp was greater than 65˚C. All of the soils in this group were very similar to one another in trend. The ATH soil represents the group of remaining six soils (ATH, CLE2, JUS-OH, DRI, GUY, and STIL) which had no significant changes from drying or drying temperature. Turner and Haygarth (2001) found that comparable amounts of phosphorus were solubilized when 29 samples of permanent grassland soil samples were dried at temperatures of 15 and 30˚C. However, samples dried at 30˚C were much faster to solubilize than those were dried at

15˚C. They also found a highly significant relationship between extractable P increase and the soil microbial phosphorous level. These findings are similar to this study as there was an increase in P solubility (STP) at temperature of 65-85˚C, which further indicates that a higher drying temperature will result in more extractable P for some soils. Soil microbial P contribution at higher drying temperatures could possibly lead to higher extractable P for this study as well. There have been many studies that have reported significant increases in P concentrations when soils have been dried or rewetted (Turner et al., 2003). Much of the differences in P solubility have been accredited to the chemical and physical aspects of drying as it breaks down or disrupts organic matter. Increased STP has also been found from rewetting soils through microbial compounds releasing P by lysis (Searle and Sparling, 1987; Turner and Haygarth, 2001; Bartlett and James, 1980). Blackwell et al. (2010) also observed that air dried soils could kill up to 70% of the microbial biomass in the soil which could be a large source of soluble P. The disruption of soil aggregates and organic colloid cracking will also release with the increase in extractability of the non-biomass and exposes new soils surfaces for microbial attack (Wu and Brookes, 2005). This will also allow for these nutrients to be changed into a more labile pool contributing to the flush of nutrient mineralization and solubilization (Gordon et al., 2008).

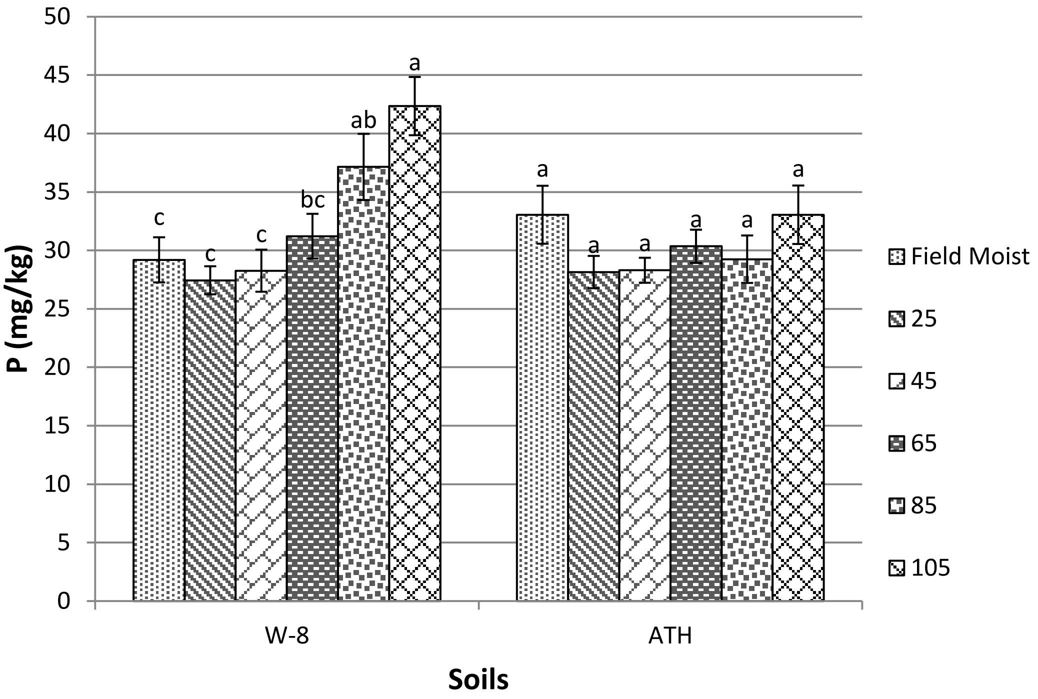

Figure 5. The effect of drying and drying temperature on soil test phosphorus. The W-8 soil represents 21 samples with an increasing trend while the ATH soil represents the group of 6 soils with no significant changes upon drying (different letters indicate statistical difference at p=0.05).

The extractable Ca of some soil samples was not affected by drying and drying temperature, but others were slightly decreased by drying temperature (Figure 6). Of the twenty-seven soils, only five of them (BAD, HAR, TAB, LGE, and CRE) exhibited a decreasing trend in concentration as soils were dried and continued to decrease as temperature increased, which are represented by the HAR and BAD soils in Figure 6. These five soils all had the initial extractable Ca greater than 3000mg/kg. The decreasing trend in extractable Ca for this group of soils stopped at 65˚C, and no further decreasing was observed when dried at 85˚C and 105˚C. All of the remaining soils had field moist extractable Ca concentrations below 3000mg/kg and showed no changes upon drying or as drying temperature increased. The agronomic critical value for Ca is about 375 mg/kg, so the decrease upon drying for those high Ca soils has no practical implication. In other words, no Ca will be recommended for those Ca-rich soils. The fixation may occur in these soils due to clay mineralogy. If a clay mineral such as vermiculite dominates these soils, the high concentrations could cause these minerals to be saturated with Ca. Therefore, when these soils are dried, Ca will become fixed in the mineral innerlayer and not be available for plant uptake (Essington, 2003).

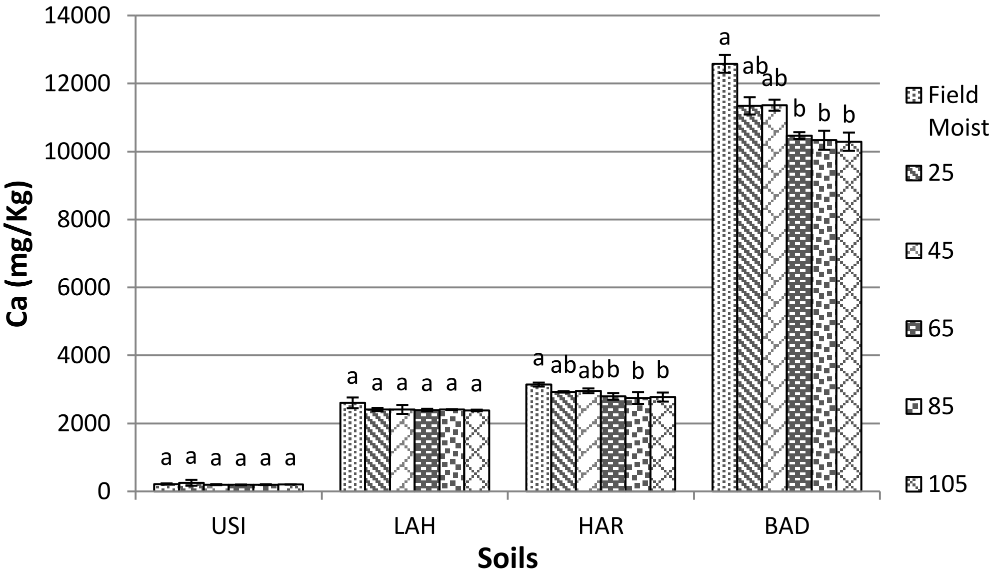

Figure 6. The effect of drying and drying temperature on soil extractable Ca values for soils with different field moist Ca levels (different letters indicate statistical difference at p=0.05).

Extractable magnesium can be divided into two groups: one with a decreasing trend due to drying and increasing in drying temperature and one with no significant changes (Figure 7). Eleven of the 27 soils had a decreasing trend in concentration from drying and increasing drying temperature. These 11 soils varied greatly in initial soil test Mg concentrations, ranging from 253-1031mg kg^{-1}. There was no change found in the remaining 16 soils, although the initial soil test Mg still exhibited a wide range from 72-545 mg kg^{-1}. It is unclear why some soils behaved differently from others when dried. Erich and Hoskins (2011) stated that drying had small and insignificant changes in the two soils that were used in their study. There has been very little research done on the effects of drying on Mg.

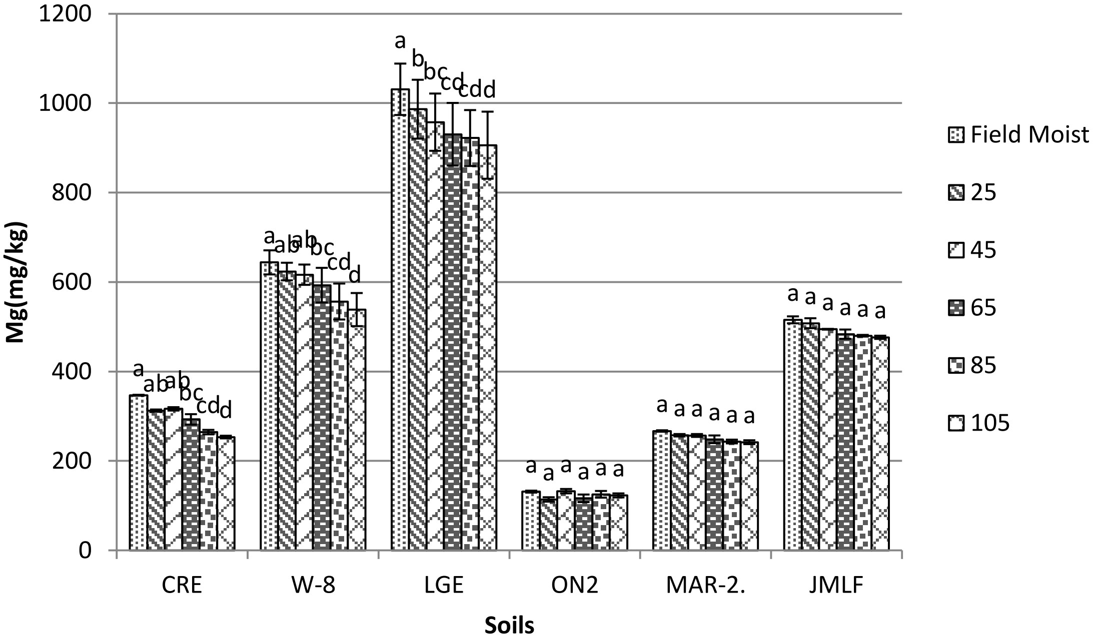

Figure 7. Extractable Mg values of some soils were decreased by drying and as drying temperature increased while others had no significant changes (different letters indicate statistical difference at p=0.05).

Clear trends for extractable S were observed for the five samples tested (Figure 8). The extractable S increased when dried and as drying temperature increased except for 4 soils from 25 to 45˚C. Sharp increases occurred to all samples from 65 to 85˚C, and from 85 to 105˚C drying. The mechanism of why extractable S was increased by drying or as drying temperature increased is not clear. It may be due to enhanced decomposition of soil organic matter or increased solubility of sulfur compounds. There are not many studies that tested the effects of drying on extractable sulfur. However, David et al. (1982) determined that drying organic samples at 65˚C increased the concentration of total extractable sulfur and sulfate sulfur. David et al. (1989) later confirmed the findings of the first study that oven drying soil samples at 65˚C did cause increases in extractable sulfate. In contrast, another study by Shen et al. (1992) found that drying had no significant impact on extractable sulfur. The results from this study clearly show that extractable sulfur has the tendency to increase when soil samples are dried.

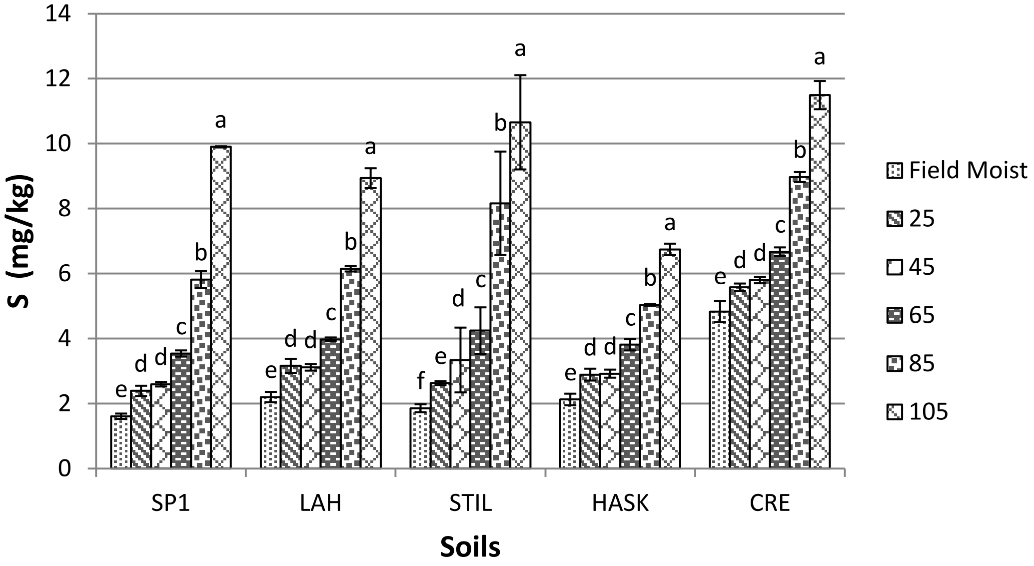

Figure 8. Soil test S as impacted by drying and drying temperature for representative samples (different letters indicate statistical difference at p=0.05).

The effect of soil sample drying and drying temperature on extractable micronutrient concentrations

Manganese (Mn), boron (B), zinc (Zn), iron (Fe) and copper (Cu) were the five micronutrients evaluated for this study and all of them showed increasing trends by drying and drying temperature. As shown in Figure 9, Mn concentrations in 25 of the 27 soils were increased by drying and increasing drying temperatures. As drying temperature increased, concentrations of manganese also increased, and the values for the 85˚C and 105˚C treatments were significantly higher than that of the 65˚C treatments. The soils that were dried at 105˚C had a much higher concentrations than those that were tested using field moist samples. On average the concentrations increased by 85% from the field moist to 105˚C across all soils that showed significant differences. Figure 9 shows the typical increasing trend of 3 samples that were induced by drying and drying temperature. Bartlett and James (1980) also found Mn solubility was greatly affected by drying and attributed the increased release to the disruption and partial oxidation of organic matter. However, the other 2 soils from the 27 had no changes in concentration from drying or increasing drying temperature. Many other studies have been completed with the very same results as this study. Boken (1952), Kelley and McGeorge (1913), McCool (1934), Heintze (1946), and Fujimoto and Sherman (1945) tested soil samples at field moist, air dried and dried at higher temperatures and found significant increases in extractable Mn when soil samples were dried. However, Fujimoto and Sherman (1945) showed decreases in extractable Mn for 5 of 28 soils but others were increased. It is clear from years of studies that extractable Mn does increase with drying and drying temperatures.

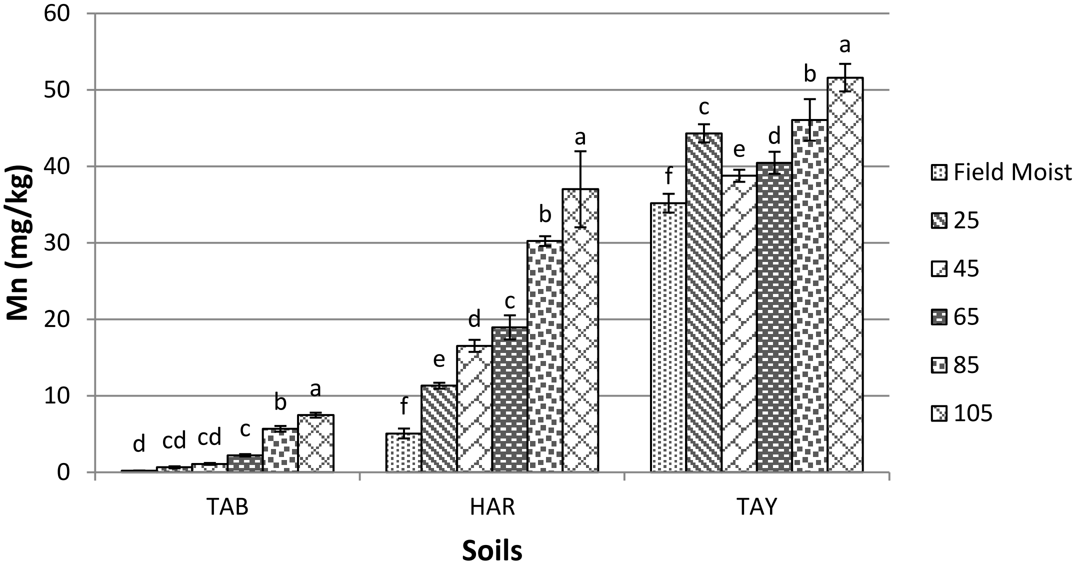

Figure 9. Extractable manganese was increased by drying and drying temperature. Twenty-five of the 27 soil samples had the increasing trend (different letters indicate statistical difference at p=0.05) and 2 had no changes (not shown).

The effect of drying and drying temperature on extractable B is shown in Figure 10. Out of the 27 soil samples, boron concentrations of 26 soils were significantly increased, and the 27th soil showed no change. Boron from field moist samples ranged from 0-0.75mg/kg. Given the low concentrations of boron, these changes are significant given that the critical value for boron for most plant growth is about 0.2mg/kg. Therefore, the changes induced by drying could affect B recommendation especially when different labs use different temperatures to dry soil samples. Figure 10 illustrates the trend of 3 of the 27 soils which give a good representation of the entire group. There were some variations on the magnitude of increases across all soils and all temperature treatments, although all of the dried soils showed an increase over the field moist soil. BUR was the only soil that displayed no change as drying and drying temperature increased. The reason is unknown why it did not behave the same as the other 26 soils. Few studies have been conducted to study the effect of drying and drying temperature on Boron, but Fleming (1980) found that as soil dries B availability decreased and plant deficiencies might occur. No other publications to our knowledge directly test the relationship. While this is contradictory to this study, more research and testing should be done to study the drying effects on B concentrations to accurately determine what occurs during the drying process.

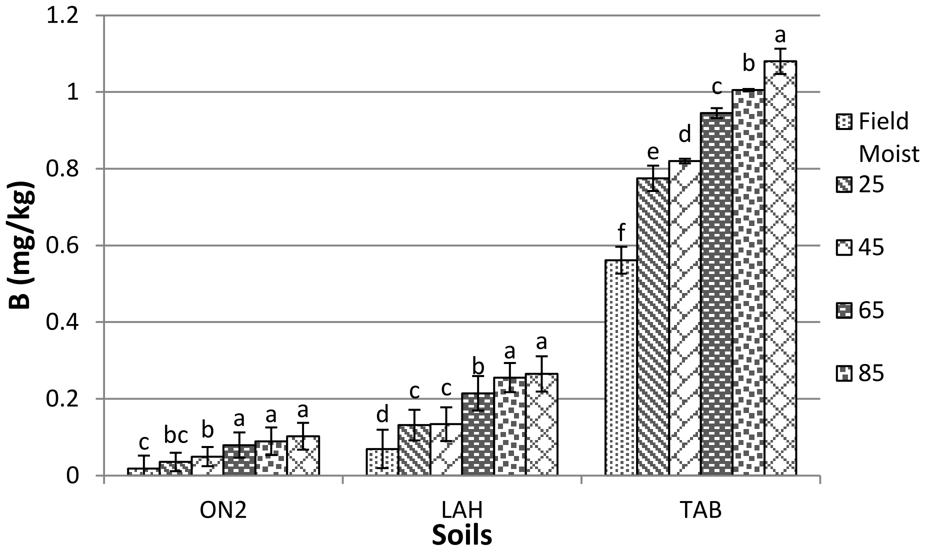

Figure 10. The effect of drying and drying temperature on extractable B. Three representative samples show the increasing trend for 26 of the 27 soils studied (different letters indicate statistical difference at p=0.05)

Soil test Zn values increased in 21 out of the 27 soils as samples were dried and as drying temperature increased. Figure 11 shows the typical trend for soil extractable Zn as impacted by drying. The initial field moist extractable Zn concentrations ranged from 0.3-4.5mg/kg. The remaining six soils (HAR-B, ATH, CLE2, TAY, JUS-OH, and USI) exhibited no change from drying or increasing drying temperature. It is unclear why these six did not behave in the same manner as the majority of the group. The initial extractable Zn concentrations in these six soils ranged from 0.6-1.86mg/kg, which were not very different from the soils affected by drying treatment. It is clear that a standardized drying temperature is needed in order for different laboratories to produce consistent test results with respect to Zn and several other nutrients. This study is in agreement with Leggett and Argyle (1983), Shuman (1980), and Tome et al. (1996) who all found extractable Zn were increased as soils were dried.

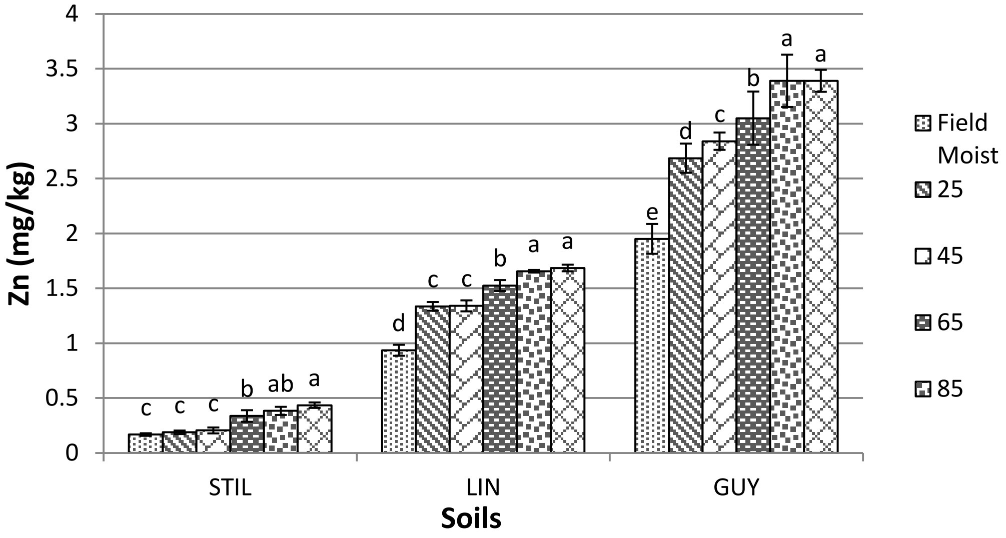

Figure 11. Soil extractable zinc as affected by sample drying and drying temperature for selected samples. Twenty-one of the 27 soils showed the similar increasing trend (different letters indicating significant difference at p=0.05) and the other 6 soils had no significant change (data not shown).

The effect of drying and drying temperature on extractable Fe of selected soils is shown in Figure 12. The trends of iron results were very similar to those of zinc, as 23 of the 27 soils increased when they were dried and as drying temperature increased. Field moist extractable Fe values ranged from 0.5-188mg/kg. Field moist values for the remaining 4 soils ranged from 0.6-112 mg/kg. It is not certain why these soils did not follow the same trend as the other 23 soils. As with Zn many others found significant increases among micronutrients including Fe after soil samples were dried (Leggett and Argyle, 1983; Shuman, 1980; and Tome et al., 1996).

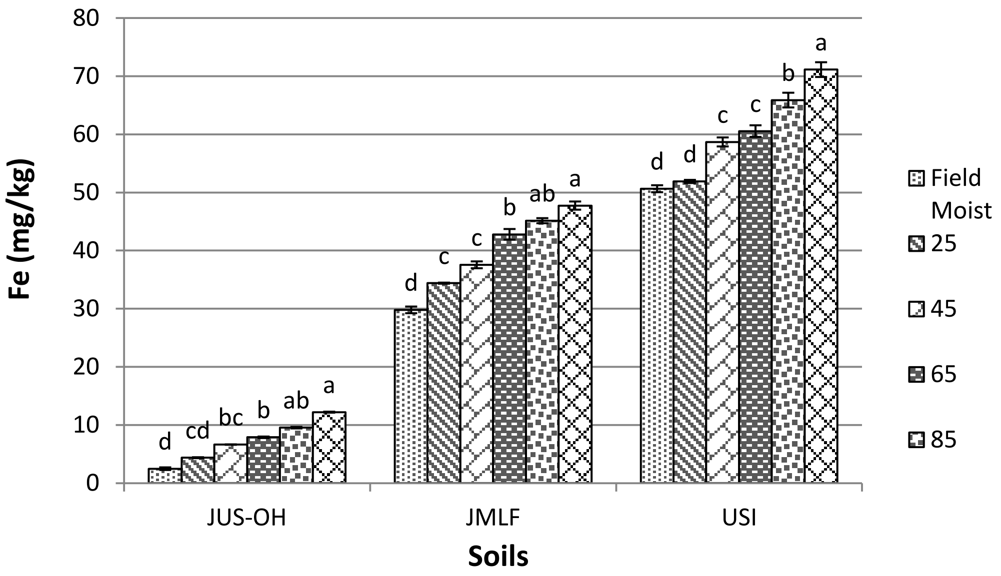

Figure 12. Soil extractable Fe as affected by sample drying and drying temperature for selected samples. Twenty-three of the 27 soils showed the similar increasing trend (different letters indicating significant difference at p=0.05

There were 4 different Cu trends that were observed: increasing, increasing then decreasing, fluctuating (up-down-up), and no change due to drying and increasing drying temperature. The first three trends are shown in Figure 13. Eight soils followed the increasing trend, 6 increased then decreased, 5 had a fluctuating trend, and 8 showed no significant change. The inconsistencies in extractable Cu cannot be interpolated clearly. There are not very many sources available for the effect that drying has on Cu extractability. Leggett and Argyle (1983) did report, however, that extractable Cu showed small increase after being dried. More research is needed to determine the drying effect on extractable Cu.

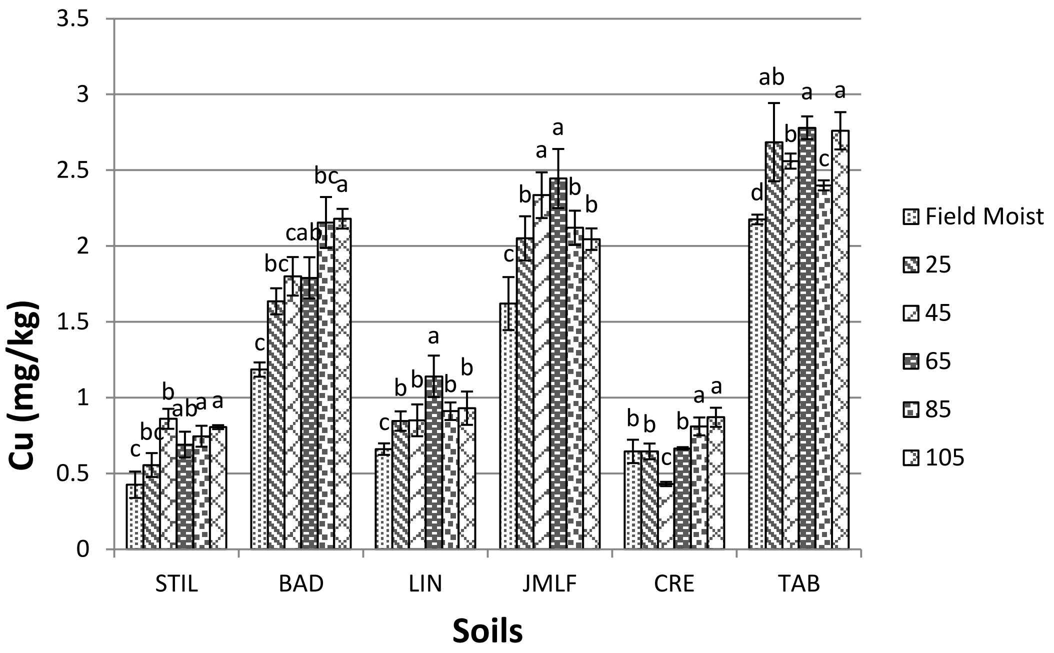

Figure 13. Representative samples for extractable copper showing increasing trends, increasing then decreasing, and no clear pattern as drying temperature increased (Different letters indicate statistical difference at p=0.05).

Based on the results from this study, it can be said that micronutrients Mn, B, Zn, and Fe all become more soluble from drying, and the solubility continues to increase as drying temperature increases. This artifact needs to be addressed by the soil test community in order to provide consistent and more reliable recommendations to farmers.

The Effect on Ammonium-nitrogen and Nitrate-nitrogen

The impact of drying and drying temperature on soil exchangeable ammonium can be separated into two groups: the first group consisted of 19 soils that exhibited an increasing trend with drying and as drying temperature increased and the other group showed a fixation then release trend (Figure 14). The dividing point for the 2 groups seemed to be at about 2 mg/kg extractable NH_4-N. As shown in Figure 14, the first group had an increasing trend with the initial NH_4-N values of less than 2 mg/kg (TAB and MAR-2 soil), and the other group had u-shaped pattern with the initial NH_4-N values greater than 2 mg/kg (ON2 and USI soil). The increasing trend of group one seemed to be very consistent across the 19 soils. Concentrations increased in the field moist, 25, 45, and 65˚C temps when dried, but sharp increases in exchangeable NH_4-N values occurred when the soils were dried at 85 and 105˚C, thus high drying temperatures need to be avoided. The increase from the original field moist NH_4-N to that dried at 105˚C was greater than 100%. The 8 soils in Group 2 had a different trend. From field moist to being dried at 65˚C, these soils fixed NH_4-N and then began to release it once samples were dried at 85˚C and 105˚C. Similar to K, the types of clay mineralogy and drying temperature affects ammonium fixation and releases. Wiltshire and Du Preez (1993) had very similar results as they reported that NH_4-N levels were significantly increased after samples were dried at a temperature of 100˚C for 24 hours. They also noted very little change in temperatures below 100 ˚C. Frye and Hutcheson (1981) reported that oven drying increased NH_4-N release from soils and that oven drying at 110°C released even more NH_4-N. Also in the study of Nina and Sigunga (2012), increases in NH_4-N concentrations were reported and attributed to organic and other inorganic sources such as ammonium phosphate compounds that were decomposed during heating and ammonium releases from soil exchange sites. Nina and Sugunga (2012) also stated that there were moderate ammonium increases when soils were air dried as well. Nelson and Bremner (1972) supported this evidence by finding that both air drying and oven drying increased exchangeable NH_4-N.

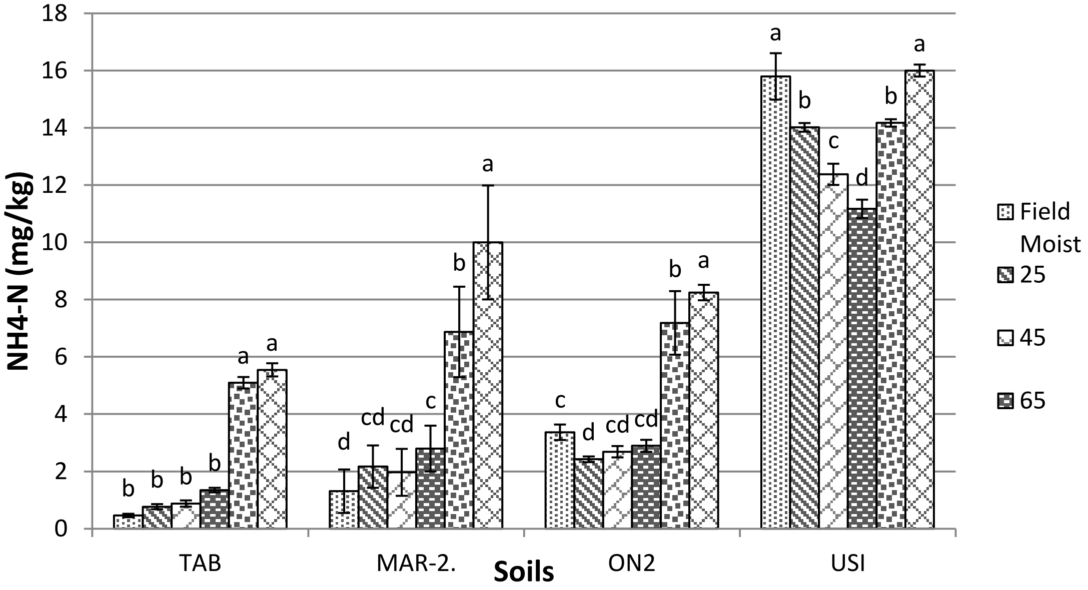

Figure 14. The impact of drying and drying temperature on soil extractable ammonium-nitrogen. Soils TAB and MAR-2 represent the trend of 19 soils and soils ON2 and USI represent trend of the remaining 8 soils.

For soil extractable nitrate, 6 of the 27 soils decreased in concentration as drying temperature increased. These soils were all the soils with initial field moist extractable NO_3-N value greater than 85mg/kg. Figure 15 shows the two groups, one representing the 6 soil with a decreasing trend and with over 85mg/kg initial nitrate-N, and the other representing the 21 soils that exhibited no change due to drying or increasing drying temperature. It can be concluded that soils with a high initial nitrate concentration will decrease in value as drying temperature increases. All of the remaining twenty-one soils showed variation in field moist extractable NO_3-N concentration and did not have significant statistical differences. The group with nitrate values below 85mg/kg was highly variable and inconsistent with respect to drying temperature for this study. Other studies such as Nina and Sagunda (2012) found that NO_3-N concentrations decreased when samples were dried at 70 and 100˚C compared to the same soils air dried that exhibited higher NO_3-N concentrations. Nina and Sagunda (2012) attributed the higher drying temperature losses to reduced microbial activity because of water loss and high temperatures. Linn and Doran (1984) found that soil moisture contents of below 10% water filled pore space resulted in low microorganism activity. The increases in NO_3-N for air dried samples were thought to occur due to enhanced mineralization because of increased temperature. Selmer-Olsen et al. (1971) reported that NO_3-N increased with time at 20°C. In a study by Witlshire and Du Preez (1993) it was found that NO_3-N concentrations remained almost constant after drying for all soils tested, which is consistent with the majority of the soils in this study.

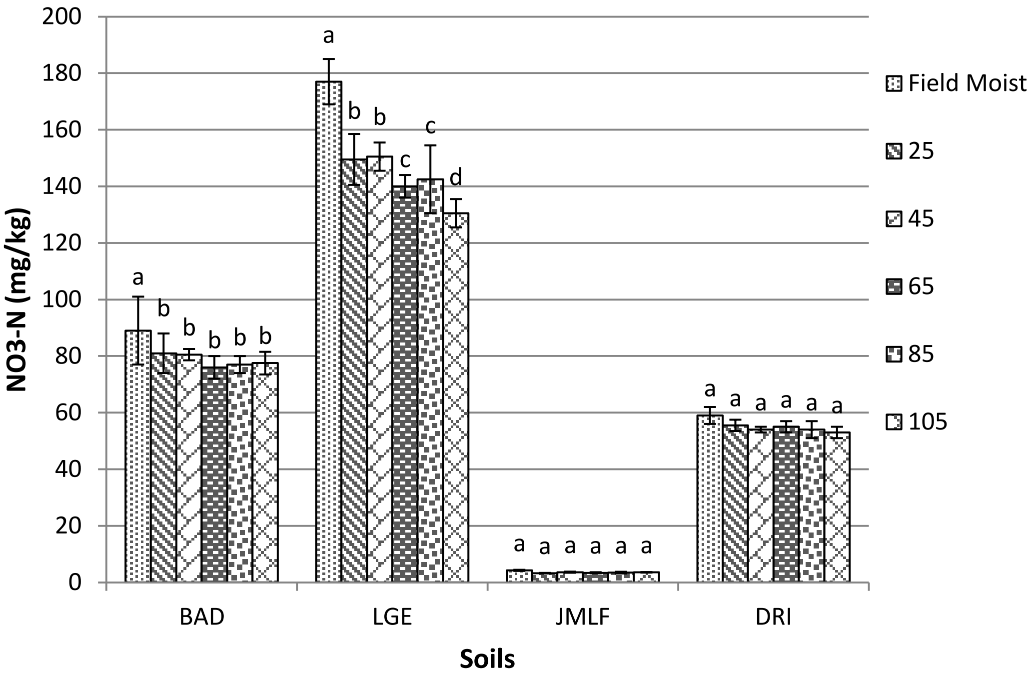

Figure 15. The effect of drying and drying temperature on NO_3-N. (Soils BAD and LGE represent the group with a decreasing trend and initial NO_3-N values over 85mg/kg and soils JMLF and DRI represent soils with no change and below 85mg/kg initial NO_3-N).

Impact of Drying on Total Nitrogen and Organic Carbon

Drying had no effects on the total N (TN) of some soils but decreased total nitrogen for other soils (Figure 16). Out of the twenty-seven soils, eight soils had a decreasing trend with drying and increasing drying temperature, and one soil had an increasing trend. Out of these eight soils, there were six with an initial field moist TN values greater than 0.2%, and all having a decreasing total N concentration with increasing drying temperature. One soil in all twenty-seven had an initial field moist TN value of greater than 0.2% that did not decrease in total N with increasing drying temperature. Therefore, total nitrogen can be assumed to have a decreasing trend when initial field moist values are greater than 0.2% when drying temperature is increased. It could be partially attributed to ammonium-N loss as discussed earlier; however, more research should be done to identify the mechanism of TN reduction due to drying.

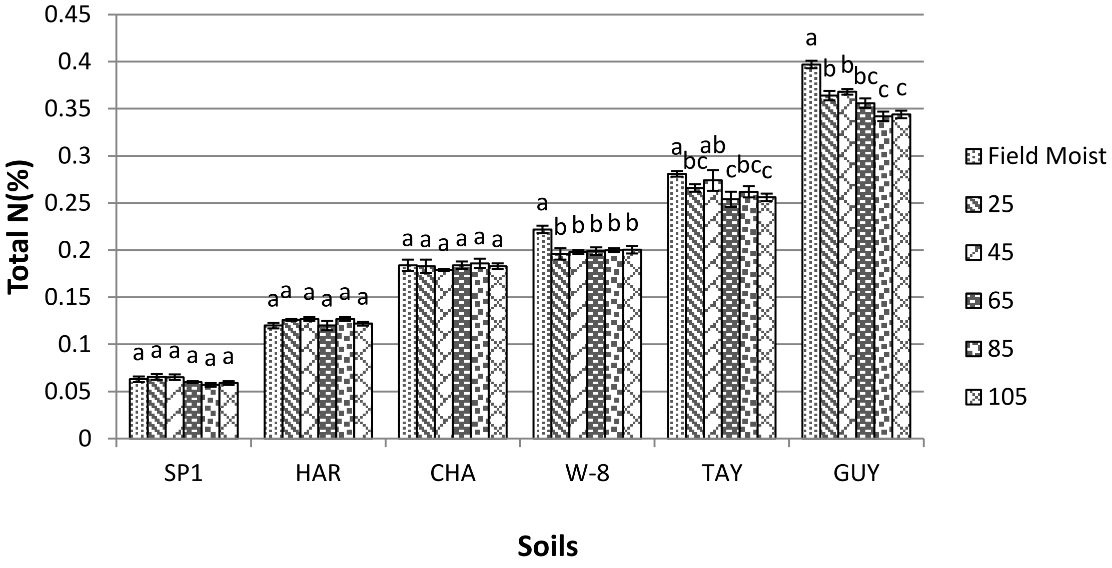

Figure 16. The impact of drying and drying temperature on soil total nitrogen determined by the dry combustion method. Soils W-8, TAY, and GUY represent the group with no changes (with field moist total N values below 0.2%). SP1, HAR, and CHA represent the other group with a decreasing trend and higher initial total N.

The impact of sample drying and drying temperature on organic carbon (OC) content determined by the dry combustion method is shown in Figure 17. Eight of the 27 soils had decreased OC with drying and drying temperature, and these 8 soils all had the initial field moist OC values above 2%. All other soils with field moist OC below 2% did not show any significant differences or trends due to sample drying or with drying temperature increases. The impact of drying and drying temperature on OC was similar to that on TN: only samples contained high amount of TN or OC subjected to losses due to drying and drying temperature increases. This is because both TN and OC are associated with soil organic matter.

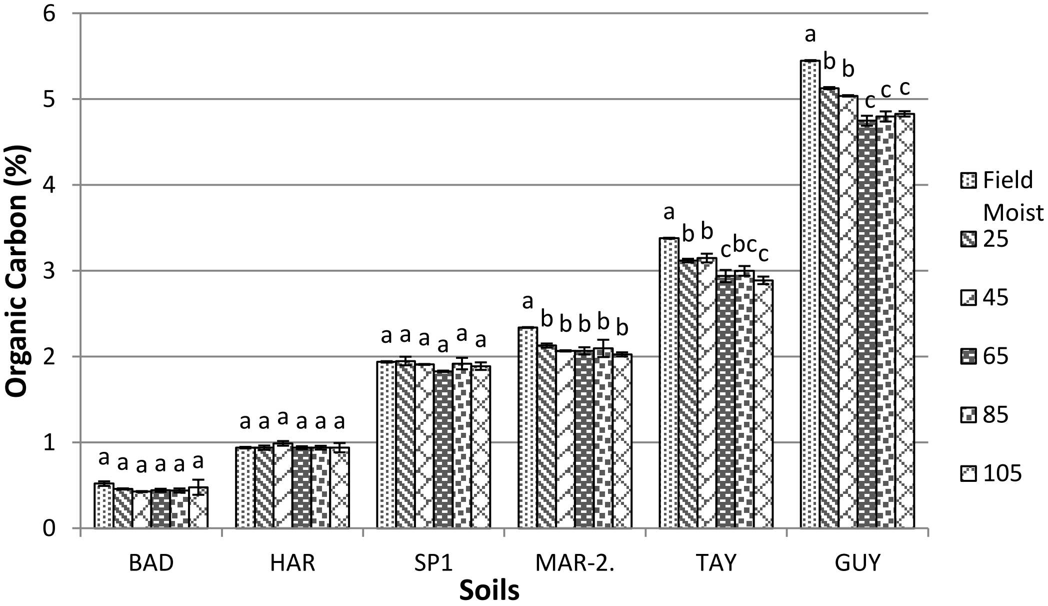

Figure 17. The impact of drying and drying temperature on soil organic carbon determined by the dry combustion method. Soils BAD, HAR, and SP1 represent the group with no changes (with field moist organic C values below 2%). MAR-2, TAY, and GUY represent the other group with a decreasing trend.

Little published information is available on the effect of drying and drying temperatures on TN and TOC. The instruments used to determine total nitrogen and organic carbon quantify all forms of N and C in the soil, so theoretically TN and OC should not be affected by sample preparation unless some components of N and C get lost during drying. Due to this fact, we do not expect significant changes to occur in these two analytes. Losses on the higher concentrated soils could be due to volatilization of ammonia and volatile carbon sources in the soils.

Effect of drying on soil pH

Drying had a mixed effect on pH values for the soils in this study. Thirteen soils displayed a decreasing trend while the other 14 soils were not affected by drying. Figure 18 shows the effect of drying on two soils representing the 2 separated trends. Har-B represents the group of soils with a decreasing trend upon drying and as drying temperature increased. The pH was decreased by 0.1 to 0.57 unit from field moist to air dried samples and the reduction was more obvious at higher drying temperatures. The effect of sample drying on soil pH has been shown in previous studies. Erich and Hoskins (2011) showed a decrease in pH for both of the Maine soils they tested and attributed the pH reduction to increased surface acidity. Bartlett and James (1980) also credited the increasing surface acidity to the decrease in soil pH. However, they also had mixed results on the drying effect using a limed and non-limed soil from Peru. Bartlett and James (1980) speculated that the changes in pH could be due to changing activities of Ca, Mg, Al, OH^-, P, CO_2, and organic associated protons. Dowding et al. (2005) used attenuated total reflectance Fourier transform infrared (ATR-FTIR) spectroscopy to specifically study the increase in surface acidity of clay films during the drying process and found that there is an acidifying effect when soils are dried. Sumner (1963) also stated that pH levels could be decreased by drying if a soil was rich in sulfur. The author claimed that S tends to be converted into its oxidized forms as samples are dried and the sulfur dioxide may dissolve in the soil solution to produce sulfuric acid which will in turn decrease soil pH. Therefore, the effect of sample drying of soil pH is dependent on soil characteristics.

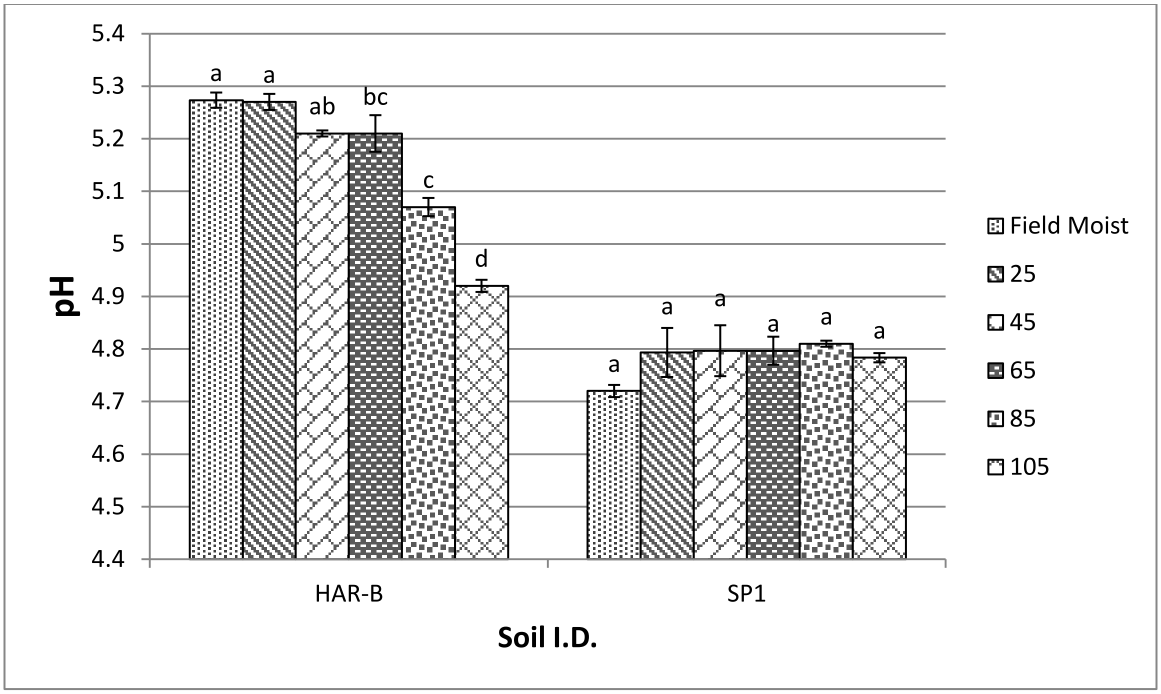

Figure 28. The impact of drying and drying temperature on soil pH. HAR-B represents the 13 soils with a decreasing trend due to drying and increased drying temperature, and SP1 represents 14 soils with no effect by drying the samples.

The Effect of Soil to Solution Ratio on Mehlich 3 Extraction

Given the wide range of drying temperatures used in this study, different amounts of dry weight samples were used for extraction since the same amount of samples with different moisture contents was extracted with the same amount extractant. This changed the soil to solution ratios slightly, which might affect extraction efficiency for some analytes. For example, the Mehlich 3 extraction uses 2g of soil to 20ml of extracting solution with a soil to solution ratio of 1:10. The field moist soils had a soil to solution ratio smaller than that of the air dried soils. The samples dried at higher temperature would have a soil to solution ratio greater than that of the air-dried sample. Although the final results were corrected for predetermined moisture, we wanted to be sure that the small variation of soil to solution ratio did not affect our interpretation of the data, and we tested another small set of samples with different soil to solution ratios for the Mehlich 3 extraction. Five field moist soils were selected and each soil was extracted using 2, 2.2, 2.4, and 2.6 grams of soil and 20ml solution. Therefore, the “as is” soil to solution ratios were 1:10, 1:9, 1:8.3, and 1:7.7, respectively. Corrected to dry-weight the actual soil to solution ratios are about 1:12.5, 1: 11.5, 1:10.8, and 1:10.2 with the last one being the standard ratio. From the trial we found that initial soil test values of P, K and others (Table 2) increased as soil mass increased. However, once the values were corrected back to dry weight they were decreased slightly as the soil to solution ratio increased (more soil) significantly based on statistical analysis (Table 2). The decrease was significant from 2.2 to 2.4 grams. This test confirms even with a correction factor that soil to solution ratios should have been taken into consideration when performing analysis on this study. The difference due to differences in soil to solution ratio, however, was less much less than the difference induced by drying and drying temperatures. For example, the extractable P decreased by 9mg/kg due to soil to solution ratios, but it was increased by 25mg/kg due to drying. This is just one example from the study, but this can be seen throughout although some gaps may be greater than others depending on soil or analytes. The findings from our trial are consistent with the work of Fuhrman et al. (2005) that performed a study with multiple soil to solution ratios to determine how water-soluble phosphorus would be affected. However, they found that a smaller soil to solution ratio would result in significantly larger water extractable P values, but our results were less significant. Similar findings were also found in the case of Chapman et al. (1997) who determined that as their soil to solution ratios decreased, the amount of P extracted per unit weight of soil increased as well.

Table 2. Potassium (K) and phosphorus (P) extracted by Mehlich 3 with various soil to solution ratios. Corrected values were compared with 4 different masses for each soil. Different letters indicate a significant difference at $p<0.05$

Potassium (K)

Soil I.D.	Moisture %	Grams	Rep 1	Rep 2	Rep 3	Mean	Mean mg/kg	Corrected new	Sig Dif p<0.05
BAD	19.4	**2.0**	188.8	184.4	183.9	185.7	92.9	115.2	A
	19.4	**2.2**	200.0	198.5	199.4	199.3	99.7	112.4	A
	19.4	**2.4**	208.0	210.8	211.5	210.1	105.1	108.6	B
	19.4	**2.6**	223.3	226.2	227.5	225.7	112.8	107.7	B
Elkhorn	14.9	**2.0**	416.0	413.0	424.3	417.8	208.9	245.3	A
	14.9	**2.2**	456.2	447.2	443.4	448.9	224.5	239.7	AB
	14.9	**2.4**	484.1	482.1	483.5	483.2	241.6	236.5	B
	14.9	**2.6**	519.1	516.0	525.4	520.2	260.1	235.0	B
HAR	20.5	**2.0**	213.3	204.5	200.9	206.2	103.1	129.7	A
	20.5	**2.2**	213.9	209.5	208.1	210.5	105.3	120.3	B
	20.5	**2.4**	229.4	233.1	230.1	230.9	115.4	121.0	B
	20.5	**2.6**	241.1	250.5	246.1	245.9	123.0	118.9	B
LGE	23.7	**2.0**	1089.6	1085.8	1092.6	1089.3	544.7	713.7	A
	23.7	**2.2**	1172.5	1176.5	1166.5	1171.8	585.9	697.9	B
	23.7	**2.4**	1264.4	1267.3	1279.8	1270.5	635.2	693.6	BC
	23.7	**2.6**	1369.3	1367.0	1360.9	1365.7	682.9	688.2	C
STIL	12.1	**2.0**	258.1	255.4	258.5	257.4	128.7	146.4	A
	12.1	**2.2**	276.8	279.1	280.7	278.9	139.4	144.2	A
	12.1	**2.4**	298.3	302.3	304.8	301.8	150.9	143.0	AB
	12.1	**2.6**	317.1	324.3	310.8	317.4	158.7	138.8	B

Phosphorous (P)

Soil I.D.	Moisture %	Grams	Rep 1	Rep 2	Rep 3	Mean	Mean mg/kg	Corrected new	Sig Dif p<0.05
BAD	19.4	**2.0**	66.0	55.4	54.3	58.6	29.3	36.3	A
	19.4	**2.2**	63.3	56.2	66.2	61.9	31.0	34.9	AB
	19.4	**2.4**	56.6	59.1	69.0	61.6	30.8	31.8	AB
	19.4	**2.6**	54.5	58.7	57.5	56.9	28.4	27.1	B
Elkhorn	14.9	**2.0**	91.9	89.5	90.1	90.5	45.3	53.1	A
	14.9	**2.2**	91.4	88.7	91.2	90.4	45.2	48.3	B
	14.9	**2.4**	92.8	94.1	94.5	93.8	46.9	45.9	C
	14.9	**2.6**	101.9	101.3	98.6	100.6	50.3	45.4	C
HAR	20.5	**2.0**	85.7	85.3	84.9	85.3	42.6	53.6	A
	20.5	**2.2**	83.5	82.4	83.7	83.2	41.6	47.6	B
	20.5	**2.4**	81.7	81.3	81.3	81.4	40.7	42.7	C
	20.5	**2.6**	79.6	79.4	81.2	80.1	40.0	38.7	D
LGE	23.7	**2.0**	121.3	118.7	119.9	120.0	60.0	78.6	A
	23.7	**2.2**	124.9	126.0	120.0	123.7	61.8	73.6	B
	23.7	**2.4**	129.0	128.2	130.6	129.3	64.6	70.6	BC
	23.7	**2.6**	141.8	140.1	136.6	139.5	69.7	70.3	C
STIL	12.1	**2.0**	77.5	77.2	76.0	76.9	38.4	43.7	A
	12.1	**2.2**	79.7	79.5	82.0	80.4	40.2	41.6	B
	12.1	**2.4**	83.3	84.9	84.7	84.3	42.2	40.0	C
	12.1	**2.6**	88.2	89.5	86.1	87.9	44.0	38.5	C

The Effects of Drying on All Soils and All Analytes

Table 3 summarizes the significance levels of all analytes for all the soils affected by drying and drying temperature. We can compare soil to soil, soil to analytes, and also analytes within each soil more closely. As shown in Table 3, 4 soils (BAD, Elkhorn, CHA, and HAR) showed a significant effect from drying for almost all analytes; and micronutrients, P and ammonium-N had significant effects by drying for all most all soils. This information offers clues for future studies in identifying mechanisms of the drying effects.

Table 3. The significance levels (P-values) of all analytes affected by drying temperature for all 27 soils. Values of <0.05 indicate significant, and <0.01 highly significant.

Soil	Fe	Zn	B	Cu	Mn	NO3-N	TN	OC	K	P	Mg	Ca	NH-4	pH	S
BAD	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0007	<.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.3121	
Elkorn	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<.0001	<.0001	0.0179	0.141	<0.0001	<0.0001	0.024	<0.0001	0.0002	
HAR-B	0.1222	0.2675	<0.0001	0.697	<0.0001	1	0.289	0.0935	0.9837	<0.0001	0.9563	0.9952	<0.0001	<.0001	
LIN	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.6568	0.4191	0.6766	<0.0001	0.0022	0.1443	0.9558	<0.0001	0.0023	
2-Mar	<0.0001	<0.0001	<0.0001	0.1128	<0.0001	0.9754	0.8266	0.7432	0.9819	<0.0001	0.7911	0.9071	<0.0001	0.0016	
ATH	0.0102	0.6582	<0.0001	0.8863	<0.0001	0.8231	0.0267	0.7797	0.5699	0.3941	0.9667	0.9892	<0.0001	0.1861	
CLE2	0.0923	0.0781	0.0042	0.5503	<0.0001	0.0573	0.0032	0.1204	0.8431	0.1802	0.8811	1	<0.0001	0.2275	
DEG	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.5295	0.5899	<0.0001	0.9735	<0.0001	<0.0001	0.767	<0.0001	<0.0001	
TAY	<0.0001	0.7249	<0.0001	<0.0001	<0.0001	0.7919	0.8478	0.9889	0.0907	0.0005	0.4508	0.9994	<0.0001	0.1917	
W-8	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.9404	0.9604	0.9936	0.8693	<0.0001	<0.0001	0.9986	<0.0001	<0.0001	
TAY2	<0.0001	<0.0001	<0.0001	0.0423	<0.0001	0.9864	0.9849	0.4714	0.9114	0.0049	<0.0001	0.9973	<0.0001	<0.0001	
JUS-OH	<0.0001	0.0523	<0.0001	0.0092	<0.0001	0.9601	0.1545	0.0503	0.1725	0.0956	<0.0001	0.9938	<0.0001	<0.0001	
CHA	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<.0001	<.0001	<0.0001	<0.0001	<0.0001	0.0417	0.3097	<0.0001	0.8058	
HAR	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0536	0.0016	<0.0001	0.0582	<0.0001	0.0125	0.0143	<0.0001	0.3862	
USI	<0.0001	0.6446	.0.481	0.9776	<0.0001	1	0.7862	0.8005	0.8128	<0.0001	0.999	0.9972	<0.0001	<0.0001	
ON2	0.0033	<0.0001	<0.0001	0.3151	0.1715	0.8902	0.1376	0.1443	<0.0001	<0.0001	0.9137	0.9909	<0.0001	0.1703	
JMLF	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.9997	0.0026	0.3134	<0.0001	<0.0001	0.2651	0.9872	<0.0001	<0.0001	
BUR	<0.0001	<0.0001	<0.0001	0.5183	0.9558	0.4144	0.326	0.0826	0.0226	0.0251	0.9958	0.9891	<0.0001	0.5931	
DRI	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.5108	0.5721	0.9805	<0.0001	0.3787	0.0002	0.1791	<0.0001	0.3609	
TAB	0.4505	<0.0001	<0.0001	<0.0001	<0.0001	<.0001	0.66	0.9635	<0.0001	<0.0001	0.5481	0.0124	<0.0001	0.6314	
LGE	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<.0001	0.7183	0.0127	<0.0001	<0.0001	<0.0001	0.0062	<0.0001	0.0751	
GUY	<0.0001	<0.0001	<0.0001	0.021	<0.0001	0.8858	0.8428	0.8997	<0.0001	0.0618	0.9939	0.5637	<0.0001	0.1711	
SP1	0.0553	<0.0001	<0.0001	0.2446	<0.0001	<.0001	0.0053	0.0037	0.5143	<0.0001	0.931	0.938	<0.0001	0.7061	<0.0001
LAH	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.7622	0.2558	0.9835	0.9749	0.0066	0.4038	0.4733	<0.0001	0.0078	<0.0001
STIL	0.0011	<0.0001	<0.0001	<0.0001	<0.0001	0.9928	0.8757	0.971	0.8866	0.0612	0.9547	0.9985	<0.0001	0.0017	<0.0001
HASK	<0.0001	<0.0001	<0.0001	0.0018	<0.0001	0.3196	0.2764	0.5104	1	0.0473	0.9739	0.8357	<0.0001	0.0044	<0.0001
CRE	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.3783	<.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.6858	<0.0001

Clay Mineralogy

Soil clay mineral compositions are suspected to affect soil test K (STK) levels when samples are dried, but it is unclear how exactly clay mineralogy impacting STK. Therefore, 6 of the 27 soil samples in this study (BAD, JMFL, Elkhorn, HAR, CHA, and TAB) were analyzed for clay composition by x-ray diffraction (XRD) spectrometer. These samples were chosen based off of STK values and analysis. The STK of BAD and JMFL soils showed an increasing trend with increasing drying temperature, the Elkhorn and HAR soils exhibited no change, and CHA and TAB soils showed a decreasing trend with increasing drying temperature. Suspensions of these 6 soils were decanted after settling for 4 hours. They were then evaporated to dryness and ground with a mortar and pestle for mineralogical analysis. The samples were then sent to IMR Labs in Louisville, KY to have XRD analysis performed on them. The samples were analyzed on XRD using a powder mount and the percentages major clay minerals after quartz was excluded from calculation to emphasize the importance of clays having close relationship to K are presented in Table 4. All four of the soils that exhibited STK changes, either increasing or decreasing, were dominated by mica. The soils that did not change STK due to drying temperature were dominated by an illite-montmorillonite mixed clay mineral. Those observations are based on a very small set of samples; more extensive mineralogical analysis should be performed to understand how clay mineralogy affects STK after samples are dried.

Table 4. Clay mineral composition of selected soils.

Soil	Clay Mineralogy	Percentage		Soil	Clay Mineralogy	Percentage
BAD	Mica	46%		**JMFL**	Mica	56%
	Illite-Montmorillonite	22%			Illite-Montmorillonite	26%
	Kaolinite	15%			Kaolinite	9%
	Illite	10%			Illite	5%
	Illite-Smectite	6%				
Elkhorn	Illite-Montmorillonite	62%		**HAR**	Illite-Montmorillonite	45%
	Illite	20%			Illite	36%
	Kaolinite	8%			Mica	11%
	Mica	7%			Kaolinite	6%
	Illite-Smectite	4%				
CHA	Mica	76%		**TAB**	Mica	51%
	Illite-Montmorillonite	14%			Illite-Montmorillonite	19%
	Illite-Smectitie	7%			Kaolinite	14%
					Illite-Smectite	11%
					Illite	5%

CONCLUSIONS

The impact of sample drying and drying temperature on common soil analytes was evaluated using 27 soils representing a wide range of soil properties and geographic regions of the US. Drying soil samples generally increased the concentrations of most analytes, and concentrations tend to keep increasing as drying temperature increased. Potassium (K) had varied outcomes due to drying and increasing drying temperature with increasing, decreasing, and unchanging trends. Clay mineralogy should be studied to determine if it is connected to changes in K concentrations due to drying. Micronutrients Fe, B, Zn, and Mn, as well as NH_4-N, and P, were increased by drying temperatures. The concentrations of Cu and Mg, however, were not consistently affected by drying temperatures. In addition, high initial field moist soil test values determined how drying impacted the concentrations of NO_3-N, NH_4-N, Ca, organic C, and total N. Some soil pH was reduced but most were not affected by drying or drying temperature.

Due to the impact of drying and drying temperature on routine soil test results, it is important for laboratories to use a standardized sample drying temperature to accurately make fertilizer recommendations. Although testing field moist samples are close to rooting environment, it may not be practical for fast paced production laboratories. More field plant response calibration needs to be conducted if field moist samples are used to test for plant available nutrients.

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APPENDICES

Appendix 1. Potassium (K) concentrations as affected by increasing drying temperature for all 27 soils.

Soil	Field Moist	25˚C	45˚C	65˚C	85˚C	105˚C	P-Value
BAD	102.47 (6.761)	161.38 (5.872)	158.34 (4.88)	202.84 (3.119)	214.59 (1.354)	222.68 (4.006)	<0.0001
Elkorn	241.47 (4.081)	251.52 (2.756)	256.12 (5.658)	255.35 (3.741)	267.55 (5.744)	268.07 (3.643)	0.141
HAR-B	77.51 (5.852)	76.78 (8.041)	76.88 (4.423)	76.09 (3.549)	79.05 (5.438)	83.9 (11.909)	0.9837
LIN	318.27 (5.688)	235.28 (4.894)	227.1 (5.851)	196.95 (3.052)	191.35 (2.642)	183.76 (1.847)	<0.0001
MAR-2	133.53 (0.545)	132.53 (3.043)	129.38 (4.323)	127.16 (5.376)	128.09 (5.737)	126.34 (4.843)	0.9819
ATH	174.52 (13.962)	172.13 (15.465)	165.19 (13.521)	162.59 (12.623)	159.1 (11.512)	157.84 (9.973)	0.5699
CLE2	49.54 (3.594)	44.84 (6.606)	42.9 (4.099)	42.82 (8.305)	36.59 (2.266)	36.41 (1.606)	0.8431
DEG	94.51 (8.792)	95.21 (6.072)	95.77 (5.978)	101.38 (7.376)	98.89 (4.977)	102.06 (7.089)	0.9735
TAY	113.54 (9.889)	119.78 (7.428)	126.43 (8.895)	137.79 (7.196)	137.25 (6.678)	139.71 (6.322)	0.0907
W-8	60.25 (9.427)	65.78 (2.582)	67.96 (3.842)	71.7 (4.063)	71.76 (4.345)	72.53 (3.954)	0.8693
TAY2	160.52 (8.941)	164.85 (8.243)	157.08 (8.343)	155.96 (10.885)	157.48 (10.886)	152.19 (8.539)	0.9114
JUS-OH	142.16 (18.428)	153.72 (7.268)	154.83 (7.193)	164.23 (8.492)	165.17 (6.351)	168.26 (7.486)	0.1725
CHA	140.17 (5.631)	138.65 (8.947)	127.42 (4.264)	104.93 (3.521)	98.83 (2.936)	97.35 (4.954)	<0.0001
HAR	108.39 (5.324)	118.62 (6.544)	119.05 (5.91)	133.49 (5.553)	135.78 (3.443)	135.62 (2.423)	0.0582
USI	77.78 (4.093)	77.25 (2.844)	75.59 (4.975)	69.18 (1.957)	66.62 (2.667)	66.73 (2.161)	0.8128
ON2	208.55 (3.524)	236.45 (2.591)	242.68 (5.361)	251.87 (3.69)	266.44 (5.72)	268.07 (3.643)	<0.0001
JMLF	148.93 (0.72)	222.66 (4.409)	223.73 (5.325)	255.46 (8.398)	256.06 (1.151)	256.78 (2.775)	<0.0001
BUR	266.46 (3.054)	253.98 (6.047)	248.26 (3.905)	247.86 (3.661)	243.3 (7.343)	227.78 (29.656)	0.0226
DRI	150.71 (19.777)	174.5 (11.997)	186.62 (6.022)	205.23 (8.13)	210.18 (4.628)	216.8 (2.817)	<0.0001
TAB	914.04 (35.695)	894.22 (59.103)	864.58 (38.171)	857.12 (53.244)	850.8 (62.156)	861.88 (46.678)	<0.0001
LGE	915.37 (55.006)	868.38 (53.596)	841.04 (56.6)	792.26 (71.875)	786.08 (57.839)	783.37 (70.572)	<0.0001
GUY	368.87 (18.445)	333.76 (4.021)	327.3 (6.637)	315.99 (11.451)	313.86 (7.152)	311 (4.99)	<0.0001
SP1	71.37 (5.49)	78.44 (7.637)	75.94 (5.007)	87.44 (4.705)	86.85 (4.918)	88.42 (0.155)	0.5143
LAH	295.8 (4.508)	291.91 (3.942)	295.41 (7.475)	291.41 (3.084)	298.05 (4.444)	299.47 (8.03)	0.9749
STIL	132 (6.667)	133.42 (8.483)	131.71 (9.015)	138.36 (4.344)	140.58 (5.34)	142.41 (9.841)	0.8866
HASK	85.91 (3.267)	85.23 (5.02)	87.11 (5.842)	87.16 (5.051)	87.14 (4.367)	85.75 (3.843)	1
CRE	391.67 (1.184)	356.64 (2.831)	362.64 (3.042)	307.98 (1.551)	287.89 (7.427)	283.26 (4.485)	<0.0001

Appendix 2. Phosphorous concentrations as affected by increasing drying temperature for all 27 soils.

Soil	Field Moist	25˚C	45˚C	65˚C	85˚C	105˚C	P-Value
BAD	29.62 (1.911)	34.95 (1.712)	34.09 (0.242)	39.06 (1.812)	44.49 (2.32)	54.71 (1.546)	<0.0001
Elkorn	50.39 (4.295)	54.78 (0.367)	56.58 (0.863)	59.3 (0.178)	65.46 (3.412)	77.33 (0.272)	<0.0001
HAR-B	56.94 (2.243)	56.75 (4.741)	57.74 (4.823)	61.38 (3.088)	66.85 (5.532)	74.75 (5.243)	<0.0001
LIN	61.86 (0.697)	57.67 (0.725)	59.91 (1.902)	59.52 (0.989)	64.71 (1.491)	69.44 (0.514)	0.0022
MAR-2	35.58 (0.386)	37.05 (0.685)	36.83 (0.401)	40.55 (1.376)	50.4 (0.65)	62.7 (1.631)	<0.0001
ATH	33.06 (2.476)	28.14 (1.384)	28.3 (1.065)	30.36 (1.423)	29.26 (2.03)	33.05 (2.468)	0.3941
CLE2	16.36 (3.388)	15.31 (4.318)	15.39 (3.47)	17.96 (2.673)	18.65 (2.535)	22.48 (2.56)	0.1802
DEG	35.35 (2.625)	33.45 (3.379)	34.79 (2.316)	36.91 (2.236)	43.35 (1.23)	47.84 (2.946)	<0.0001
TAY	40.99 (6.699)	39.02 (3.434)	40.68 (2.235)	43.56 (1.928)	46.13 (3.352)	51.78 (3.641)	0.0005
W-8	29.19 (1.929)	27.44 (1.198)	28.26 (1.79)	31.21 (1.913)	37.13 (2.826)	42.34 (2.485)	<0.0001
TAY2	9.34 (1.03)	9.46 (1.316)	11.6 (0.721)	11.76 (2.61)	12.84 (2.953)	20.34 (1.515)	0.0049
JUS-OH	5.04 (0.47)	3.94 (0.751)	5.93 (0.855)	6.64 (0.321)	8.33 (1.682)	12.39 (0.782)	0.0956
CHA	56.75 (4.347)	37.81 (4.208)	38.07 (4.604)	42.48 (3.164)	51.12 (2.885)	68.44 (5.693)	<0.0001
HAR	66.14 (2.591)	50.58 (1.228)	54.29 (2.089)	54.08 (1.829)	66.18 (2.231)	87.46 (2.837)	<0.0001
USI	10.04 (0.718)	11.32 (1.531)	10.47 (0.169)	13.02 (0.18)	18.54 (0.746)	24.28 (0.537)	<0.0001
ON2	67.94 (1.278)	57.6 (3.118)	70.47 (2.932)	66.05 (5.529)	77.12 (6.796)	83.09 (1.875)	<0.0001
JMLF	16.69 (0.135)	18.14 (0.815)	16.92 (0.132)	21 (1.082)	29.73 (0.709)	41.94 (0.088)	<0.0001
BUR	82.89 (2.975)	80.89 (4.094)	80.51 (1.689)	82.48 (3.56)	86.61 (2.902)	89.52 (2.154)	0.03
DRI	89.21 (2.661)	85.01 (6.281)	84.53 (5.016)	85.62 (7.168)	86.06 (5.433)	89.88 (7.521)	0.3787
TAB	181.1 (4.968)	152.6 (7.511)	147.33 (4.944)	148.11 (4.07)	147.27 (7.668)	148.82 (7.909)	<0.0001
LGE	72.11 (12.53)	67.69 (10.892)	68.26 (8.086)	70.31 (4.787)	76.27 (7.104)	83.07 (9.131)	<0.0001
GUY	206.45 (5.348)	199.83 (4.155)	198.1 (4.162)	201.51 (5.631)	199.8 (3.741)	197.69 (5.467)	0.0618
SP1	68.26 (25.667)	46.82 (6.318)	45.9 (8.041)	50.87 (9.548)	61.42 (9.44)	75.19 (10.943)	<0.0001
LAH	30.04 (2.825)	31.42 (3.284)	30.88 (1.925)	34.21 (1.432)	36.22 (0.738)	40.46 (0.529)	0.0066
STIL	42.1 (1.438)	42.15 (1.429)	43.39 (0.546)	44.49 (0.942)	47.55 (1.303)	50.03 (2.247)	0.0612
HASK	55.44 (9.475)	51.72 (8.331)	52.44 (9.269)	55.83 (7.579)	58.45 (9.387)	60.21 (7.405)	0.0473
CRE	70.55 (3.554)	64.19 (0.571)	65.93 (1.212)	67.92 (0.56)	77.99 (0.88)	87.94 (2.242)	<0.0001

Appendix 3. Calcium (Ca) concentrations as affected by increasing drying temperature for all 27 soils.

Soil	Field Moist	25˚C	45˚C	65˚C	85˚C	105˚C	P-Value
BAD	12579.37 (262.302)	11344.79 (254.556)	11363.09 (163.112)	10468.49 (101.134)	10332.32 (280)	10290.5 (269.272)	<0.0001
Elkorn	4662.61 (206.31)	4572.72 (153.357)	4416.54 (126.351)	4358.23 (68.504)	4346.61 (114.422)	4302.46 (45.467)	0.024
HAR-B	838.43 (59.984)	829.35 (58.928)	802.88 (18.883)	774.81 (2.384)	789 (43.877)	789.32 (45.594)	0.9952
LIN	1871.84 (39.307)	1769.9 (146.446)	1759.71 (104.875)	1797.02 (107.146)	1777.5 (116.592)	1776.81 (158.478)	0.9558
MAR-2	2198.43 (122.861)	2120.72 (134.794)	2201.05 (150.837)	2098.27 (161.644)	2101.98 (91.523)	2103.1 (108.251)	0.9071
ATH	1211.93 (42.14)	1174.72 (83.022)	1192.68 (67.461)	1153.26 (85.034)	1154.99 (69.598)	1129.65 (78.806)	0.9892
CLE2	497.98 (21.649)	480.48 (75.482)	485.91 (62.704)	487.52 (34.951)	472.43 (55.075)	473.12 (38.048)	1
DEG	2393.51 (135.844)	2309.59 (191.573)	2290.93 (207.055)	2214.56 (152.138)	2236.84 (67.562)	2270.78 (81.448)	0.767
TAY	1320.45 (30.137)	1328.28 (45.102)	1304.37 (41.16)	1295.89 (38.366)	1290.39 (35.35)	1325.26 (100.979)	0.9994
W-8	1970.74 (106.634)	1938.91 (84.171)	1953.56 (77.157)	1950.9 (159.813)	1918.96 (163.505)	1924.74 (138.895)	0.9986
TAY2	1707.61 (70.901)	1699.97 (49.806)	1666.14 (54.47)	1692.64 (68.81)	1682.2 (49.669)	1648.7 (36.593)	0.9973
JUS-OH	2493.17 (57.706)	2516.78 (105.561)	2442.57 (78.5)	2497.17 (160.005)	2468.94 (103.037)	2499.95 (74.282)	0.9938
CHA	2026.25 (19.837)	1837.31 (51.873)	1835.62 (99.653)	1750.05 (81.081)	1779.92 (91.247)	1827.42 (74.019)	0.3097
HAR	3145.4 (58.593)	2930.08 (21.047)	2961.42 (70.799)	2798.06 (98.846)	2751.03 (173.543)	2777.13 (133.22)	0.0143
USI	219.14 (18.949)	256.44 (87.579)	202.09 (15.442)	195.59 (10.047)	202.43 (12.569)	206.97 (7.018)	0.9972
ON2	709.11 (47.782)	738.57 (75.442)	750.23 (35.875)	784.36 (40.072)	717.8 (34.709)	713.42 (65.437)	0.9909
JMLF	2701.38 (137.534)	2628.54 (90.597)	2656.41 (141.161)	2686.24 (110.031)	2644.47 (146.66)	2701.22 (172.273)	0.9872
BUR	458.28 (57.717)	412.82 (31.154)	395.71 (25.64)	423.09 (61.064)	386.04 (22.097)	375.68 (42.345)	0.9891
DRI	1961.22 (852.78)	2251.64 (128.747)	2218.3 (179.929)	2195.37 (156.178)	2224.49 (179.671)	2233.32 (128.623)	0.1791
TAB	4302.64 (219.404)	4031.24 (397.182)	3944.13 (190.726)	3935.5 (264.514)	3895.95 (307.526)	3930.97 (198.574)	0.0124
LGE	4631.64 (393.694)	4413.7 (343.093)	4309.2 (375.992)	4238.77 (296.147)	4264.91 (287.605)	4193.61 (337.348)	0.0062
GUY	1758.34 (134.965)	1764.48 (163.199)	1636.72 (103.461)	1661.41 (93.569)	1589.5 (151.227)	1771.61 (286.111)	0.5637
SP1	2113.01 (201.527)	2043.03 (94.032)	2001.87 (104.728)	2001.85 (94.037)	2006.27 (99.009)	2004.62 (46.991)	0.938
LAH	2606.85 (158.742)	2411.86 (48.22)	2415.72 (132.425)	2394.68 (39.307)	2409.64 (12.323)	2382.75 (25.934)	0.4733
STIL	967.18 (91.024)	918.73 (78.472)	912.34 (86.992)	921.76 (53.75)	934.3 (48.511)	930.67 (6.909)	0.9985
HASK	2554.97 (236.87)	2411.82 (214.565)	2502.32 (279.207)	2436.66 (222.733)	2425.42 (170.364)	2422.76 (283.08)	0.8357
CRE	7245.73 (516.973)	6610.28 (452.053)	6855.36 (526.358)	6423.02 (706.289)	6463.83 (681.036)	6677.76 (662.65)	<0.0001

Appendix 4. Magnesium (Mg) concentrations as affected by increasing drying temperature for all 27 soils.

Soil	Field Moist	25˚C	45˚C	65˚C	85˚C	105˚C	P-Value
BAD	535.95 (4.039)	504.68 (11.46)	492.93 (5.082)	467.65 (5.509)	458.25 (7.944)	446.79 (4.527)	<0.0001
Elkorn	886.61 (16.149)	853.03 (13.081)	856.03 (19.362)	769.65 (6.446)	786.56 (11.609)	773.29 (10.673)	<0.0001
HAR-B	159.31 (7.404)	159.07 (12.88)	152.08 (3.758)	147.7 (4.957)	147.43 (11.24)	143.55 (6.734)	0.9563
LIN	315.63 (3.509)	289.86 (7.683)	289.43 (5.095)	274.65 (1.315)	272.51 (2.01)	266.1 (1.037)	0.1443
MAR-2	267.45 (1.594)	257.92 (2.78)	257.13 (3.212)	248.91 (8.596)	243.96 (4.246)	242.27 (4.39)	0.79
ATH	72.16 (3.771)	65.62 (4.659)	63.44 (4.727)	60.58 (4.532)	57.03 (4.529)	55.79 (2.585)	0.97
CLE2	115.28 (6.712)	108.01 (15.914)	106.23 (10.279)	107.9 (11.08)	95.2 (8.367)	94.01 (9.198)	0.88
DEG	681.77 (20.302)	663.48 (41.255)	664.33 (41.382)	624.57 (36.518)	601.24 (21.534)	604.78 (35.833)	<0.0001
TAY	397.21 (3.139)	391.32 (8.887)	395.02 (19.955)	386.23 (15.193)	373.34 (12.086)	362.86 (17.892)	0.45
W-8	644.32 (26.949)	623.77 (19.747)	616.8 (22.701)	593.29 (38.797)	556.72 (40.213)	538.89 (36.952)	<0.0001
TAY2	552.12 (18.97)	546.5 (19.814)	524.46 (16.498)	520.4 (34.522)	503.3 (36.249)	463.33 (21.149)	<0.0001
JUS-OH	741.14 (24.53)	740.33 (42.883)	695.64 (52.657)	697.41 (49.567)	665.93 (50.603)	648.14 (47.944)	<0.0001
CHA	252.61 (3.881)	225.45 (9.552)	217.81 (8.968)	205.63 (4.863)	197.93 (5.414)	196.23 (6.156)	0.0417
HAR	509.82 (9.112)	479.17 (11.126)	486.26 (1.756)	459.45 (9.302)	454.76 (15.39)	445.13 (9.526)	0.0125
USI	100.33 (5.733)	97.16 (5.659)	96.41 (3.568)	95.04 (4.142)	94.09 (5.871)	91.96 (5.607)	0.999
ON2	131.64 (2.283)	114.1 (4.905)	132.68 (4.915)	116.78 (8.484)	125.84 (7.568)	123.16 (4.584)	0.9137
JMLF	515.68 (7.893)	508.24 (11.064)	494.65 (0.807)	483.86 (10.418)	480.46 (1.885)	476.81 (3.577)	0.2651
BUR	74.58 (6.073)	68.81 (3.323)	67.41 (3.341)	67.34 (1.752)	65.99 (3.309)	62.98 (8.41)	0.9958
DRI	559.05 (238.267)	647.22 (21.338)	637.08 (29.637)	622.39 (30.267)	623.43 (37.477)	624.25 (29.579)	0.0002
TAB	380.92 (37.147)	359.31 (49.938)	355.22 (33.911)	352.57 (40.508)	345.97 (39.747)	349.64 (42.304)	0.5481
LGE	1031.44 (57.557)	986.52 (65.796)	957.8 (63.96)	930.73 (69.966)	922.44 (62.47)	906.12 (74.996)	<0.0001
GUY	185.24 (4.472)	176.94 (2.519)	176.78 (3.208)	176.84 (3.506)	175.98 (2.329)	172.69 (4.266)	0.9939
SP1	316.93 (25.002)	310.43 (9.196)	306.66 (15.657)	303.74 (14.459)	300.9 (12.941)	296.66 (5.888)	0.931
LAH	545.11 (41.584)	521.79 (22.232)	526.35 (25.175)	516.06 (12.537)	511.97 (15.879)	504.51 (19.527)	0.4038
STIL	253.85 (11.192)	243.97 (13.258)	241.11 (14.176)	244.18 (4.595)	237.13 (5.275)	235.71 (11.714)	0.9547
HASK	106.68 (4.468)	98.89 (6.037)	101.88 (5.59)	96.75 (5.723)	93.51 (6.035)	90.91 (7.124)	0.9739
CRE	347.22 (1.006)	312.39 (2.64)	316.64 (3.866)	293.32 (11.66)	264.91 (5.063)	253.51 (2.981)	<0.0001

Appendix 5. Sulfur concentrations as affected by increasing drying temperature for the five soils tested.

Soil	Field Moist	25˚C	45˚C	65˚C	85˚C	105˚C	P-Value
SP1	1.61 (0.082)	2.38 (0.157)	2.59 (0.07)	3.54 (0.094)	5.81 (0.264)	9.89 (0.019)	<0.0001
LAH	2.2 (0.159)	3.16 (0.217)	3.11 (0.102)	3.97 (0.059)	6.14 (0.081)	8.93 (0.306)	<0.0001
STIL	1.85 (0.122)	2.63 (0.061)	3.34 (0.996)	4.24 (0.715)	8.16 (1.589)	10.65 (1.446)	<0.0001
HASK	2.12 (0.179)	2.89 (0.183)	2.91 (0.123)	3.8 (0.175)	5.03 (0.025)	6.74 (0.176)	<0.0001
CRE	4.83 (0.324)	5.57 (0.118)	5.79 (0.099)	6.67 (0.135)	8.96 (0.154)	11.48 (0.432)	<0.0001

Appendix 6. Manganese (Mn) concentrations as affected by increasing drying temperature for all 27 soils.

Soil	Field Moist	25˚C	45˚C	65˚C	85˚C	105˚C	P-Value
BAD	0.41 (0.371)	0.69 (0.043)	2.19 (0.171)	4.67 (0.242)	10.59 (0.851)	19.38 (0.832)	<0.0001
Elkorn	0.73 (0.175)	3.29 (0.136)	7.86 (0.064)	8.08 (2.061)	13.69 (2.856)	19.26 (2.362)	<0.0001
HAR-B	34.72 (2.108)	48.06 (4.321)	46 (3.362)	46.71 (2.397)	49.81 (4.345)	54.01 (3.593)	<0.0001
LIN	0.79 (0.111)	3.68 (0.033)	4.67 (0.098)	4.39 (0.162)	11.92 (0.371)	13.18 (0.434)	<0.0001
MAR-2	2.44 (0.399)	10.58 (0.157)	11.83 (0.287)	11.98 (0.636)	23.16 (2.257)	26.68 (2.367)	<0.0001
ATH	3.03 (1.074)	5.1 (0.969)	6.34 (0.805)	10.62 (1.379)	14.07 (1.697)	16 (2.567)	<0.0001
CLE2	3.37 (0.707)	9.86 (0.306)	8.6 (0.639)	9.91 (0.67)	14.63 (1.591)	19.24 (1.098)	<0.0001
DEG	1.25 (0.421)	5 (0.289)	6.99 (0.433)	7.3 (0.574)	22.2 (2.73)	25.28 (0.107)	<0.0001
TAY	35.16 (1.231)	44.3 (1.192)	38.75 (0.791)	40.45 (1.442)	46.05 (2.724)	51.59 (1.797)	<0.0001
W-8	0.76 (0.223)	4.31 (0.175)	3.78 (0.193)	6.28 (0.348)	12.67 (0.319)	17.36 (0.194)	<0.0001
TAY2	0.93 (0.108)	4.68 (0.264)	3.65 (0.146)	6.24 (0.307)	10.44 (0.747)	14.7 (0.62)	<0.0001
JUS-OH	0.72 (0.227)	2.07 (0.035)	2.66 (0.152)	3.99 (0.119)	6.93 (0.337)	10.74 (0.84)	<0.0001
CHA	11.17 (0.655)	43.37 (1.95)	30.62 (1.11)	44.88 (0.848)	61.89 (3.347)	79.97 (4.396)	<0.0001
HAR	5.06 (0.646)	11.3 (0.388)	16.51 (0.788)	18.93 (1.576)	30.22 (0.636)	36.99 (4.968)	<0.0001
USI	17.34 (0.492)	22.24 (0.626)	19.8 (0.712)	22.02 (1.605)	28.46 (1.408)	34.62 (0.894)	<0.0001
ON2	7.63 (0.406)	8.15 (0.201)	7.33 (0.349)	8.14 (0.573)	8.17 (0.334)	9.49 (0.712)	0.1715
JMLF	6.32 (0.864)	14.69 (0.281)	13.11 (0.309)	15.22 (0.734)	21.18 (0.769)	28.2 (1.25)	<0.0001
BUR	7.74 (0.194)	7.12 (0.31)	6.96 (0.248)	7.3 (0.268)	7.2 (0.016)	7.46 (0.192)	0.9558
DRI	0.6 (0.085)	6.23 (0.245)	2.45 (0.23)	2.97 (0.179)	5.42 (0.187)	6.7 (0.522)	<0.0001
TAB	0.18 (0.018)	0.64 (0.135)	1.08 (0.123)	2.21 (0.15)	5.67 (0.375)	7.46 (0.321)	<0.0001
LGE	1.48 (0.217)	9.19 (0.726)	21.58 (0.73)	9.3 (0.444)	26.49 (0.455)	25.66 (0.221)	<0.0001
GUY	0.23 (0.11)	1.28 (0.047)	0.63 (0.032)	1.92 (0.066)	2.97 (0.177)	3.69 (0.166)	<0.0001
SP1	16.8 (1.01)	49.09 (1.274)	55.31 (1.248)	45.1 (0.889)	63.48 (1.67)	80.43 (1.905)	<0.0001
LAH	0.84 (0.313)	1.02 (0.035)	2.31 (0.099)	10.88 (0.612)	18.78 (0.633)	19.44 (0.851)	<0.0001
STIL	4.32 (0.404)	9.69 (0.992)	13.24 (0.79)	16.87 (0.375)	19.17 (0.396)	22.3 (0.575)	<0.0001
HASK	0.61 (0.094)	0.71 (0.08)	0.56 (0.138)	10.68 (0.184)	17.14 (0.559)	19.84 (1.269)	<0.0001
CRE	0.39 (0.067)	0.34 (0.031)	0.35 (0.073)	4.21 (0.054)	14.06 (0.485)	16.37 (0.873)	<0.0001

Appendix 7. Zinc (Zn) concentrations as affected by increasing drying temperature. Means and (Standard error) are reported.

Soil	Field Moist	25˚C	45˚C	65˚C	85˚C	105˚C	P-Value
BAD	0.46 (0.041)	0.54 (0.007)	0.62 (0.03)	0.72 (0.099)	0.77 (0.047)	0.75 (0.01)	<0.0001
Elkorn	0.59 (0.027)	0.81 (0.028)	0.88 (0.025)	1 (0.01)	1.07 (0.029)	1.15 (0.01)	<0.0001
HAR-B	0.35 (0.014)	0.38 (0.036)	0.42 (0.014)	0.4 (0.042)	0.45 (0.085)	0.43 (0.026)	0.2675
LIN	0.93 (0.049)	1.33 (0.04)	1.34 (0.052)	1.52 (0.049)	1.65 (0.012)	1.68 (0.029)	<0.0001
MAR-2	0.4 (0.017)	0.53 (0.027)	0.59 (0.027)	0.61 (0.052)	0.65 (0.076)	0.68 (0.041)	<0.0001
ATH	0.28 (0.015)	0.24 (0.019)	0.29 (0.036)	0.29 (0.009)	0.31 (0.018)	0.29 (0.055)	0.6582
CLE2	0.44 (0.018)	0.5 (0.029)	0.5 (0.038)	0.49 (0.027)	0.54 (0.038)	0.56 (0.02)	0.0781
DEG	0.83 (0.043)	0.96 (0.03)	0.92 (0.047)	1.13 (0.073)	1.18 (0.064)	1.29 (0.077)	<0.0001
TAY	0.92 (0.034)	0.86 (0.036)	0.91 (0.044)	0.9 (0.015)	0.89 (0.054)	0.9 (0.018)	0.7249
W-8	0.41 (0.012)	0.5 (0.008)	0.56 (0.043)	0.7 (0.036)	0.78 (0.015)	0.83 (0.022)	<0.0001
TAY2	0.38 (0.03)	0.37 (0.023)	0.46 (0.031)	0.47 (0.02)	0.52 (0.013)	0.58 (0.038)	<0.0001
JUS-OH	0.34 (0.058)	0.35 (0.056)	0.39 (0.011)	0.42 (0.022)	0.4 (0.006)	0.45 (0.022)	0.0523
CHA	1.24 (0.026)	1.31 (0.024)	1.46 (0.067)	1.72 (0.042)	1.91 (0.083)	1.91 (0.03)	<0.0001
HAR	0.86 (0.067)	1.08 (0.048)	1.05 (0.038)	1.27 (0.029)	1.38 (0.015)	1.39 (0.04)	<0.0001
USI	0.72 (0.005)	0.68 (0.012)	0.67 (0.02)	0.68 (0.06)	0.72 (0.047)	0.71 (0.039)	0.6446
ON2	2.28 (0.123)	2.77 (0.04)	2.94 (0.232)	3.23 (0.285)	3.21 (0.037)	3.78 (0.174)	<0.0001
JMLF	0.57 (0.088)	0.7 (0.032)	0.92 (0.074)	1.1 (0.034)	1.2 (0.048)	1.37 (0.012)	<0.0001
BUR	1.25 (0.12)	1.39 (0.098)	1.71 (0.056)	2.09 (0.021)	2.49 (0.148)	3.02 (0.147)	<0.0001
DRI	0.76 (0.103)	0.91 (0.028)	1 (0.021)	1.09 (0.077)	1.2 (0.061)	1.2 (0.076)	<0.0001
TAB	1.24 (0.032)	1.54 (0.085)	1.68 (0.031)	1.94 (0.022)	2.14 (0.031)	2.63 (0.063)	<0.0001
LGE	1.71 (0.03)	2.45 (0.051)	2.56 (0.044)	2.72 (0.021)	3.11 (0.017)	3.17 (0.056)	<0.0001
GUY	1.95 (0.136)	2.68 (0.132)	2.83 (0.078)	3.04 (0.241)	3.38 (0.023)	3.38 (0.1)	<0.0001
SP1	0.53 (0.061)	0.87 (0.057)	0.85 (0.055)	1.04 (0.045)	1.14 (0.01)	1.23 (0.048)	<0.0001
LAH	0.75 (0.033)	0.92 (0.058)	0.94 (0.065)	1.24 (0.05)	1.31 (0.01)	1.39 (0.059)	<0.0001
STIL	0.16 (0.011)	0.18 (0.016)	0.2 (0.027)	0.33 (0.053)	0.38 (0.037)	0.43 (0.025)	<0.0001
HASK	0.17 (0.02)	0.2 (0.024)	0.18 (0.017)	0.3 (0.011)	0.32 (0.013)	0.35 (0.012)	<0.0001
CRE	0.54 (0.049)	0.65 (0.065)	0.5 (0.011)	0.88 (0.03)	0.96 (0.068)	1.02 (0.02)	<0.0001

Appendix8. Iron (Fe) concentrations as affected by increasing drying temperature for all 27 soils. Means and (standard error) are reported.

Soil	Field Moist	25˚C	45˚C	65˚C	85˚C	105˚C	P-Value
BAD	0.67 (0.227)	1.56 (0.082)	1.96 (0.033)	5.31 (0.131)	7.35 (0.136)	8.3 (0.085)	<0.0001
Elkorn	17.92 (2.583)	22.43 (1.654)	24.11 (3.175)	29.83 (1.941)	33.66 (2.818)	34.36 (1.993)	<0.0001
HAR-B	30.29 (2.886)	29.79 (6.286)	33.3 (3.916)	32.65 (3.16)	31.3 (5.335)	33.22 (5.112)	0.1222
LIN	11.21 (1.556)	20.33 (1.379)	20.57 (1.64)	26.73 (2.101)	28.46 (2.06)	30.5 (3.008)	<0.0001
MAR-2	19.69 (2.258)	23.47 (3.72)	25.93 (1.985)	24.87 (3.9)	25.54 (5.753)	28 (4.759)	<0.0001
ATH	1.39 (0.229)	1.73 (0.404)	2.61 (0.416)	3.89 (0.812)	5.49 (1.262)	6.27 (1.94)	0.0102
CLE2	20.91 (3.693)	22.11 (2.354)	21.72 (2.899)	21.81 (3.482)	23.64 (3.205)	25.25 (3.157)	0.0923
DEG	9.8 (1.589)	16.78 (1.122)	15.82 (1.25)	23.91 (2.664)	25.84 (2.026)	27.24 (1.678)	<0.0001
TAY	26.78 (2.683)	32.31 (2.171)	34.86 (1.261)	37.39 (0.915)	36.46 (1.032)	39.4 (0.472)	<0.0001
W-8	5.43 (0.602)	10.62 (0.273)	12.05 (0.776)	18.76 (0.999)	22.3 (1.267)	24.63 (1.27)	<0.0001
TAY2	3.03 (0.364)	5.07 (0.261)	6.68 (0.369)	8.96 (0.244)	11.27 (0.332)	13.77 (1.008)	<0.0001
JUS-OH	2.47 (0.575)	4.36 (0.092)	6.62 (0.591)	7.87 (0.917)	9.53 (0.435)	12.2 (0.705)	<0.0001
CHA	93.9 (5.594)	94.39 (6.991)	98.29 (8.3)	102.09 (6.342)	98.63 (8.478)	100.59 (4.644)	<0.0001
HAR	36.26 (2.799)	43.33 (3.341)	42.69 (1.705)	49.81 (2.693)	52.28 (2.037)	54.75 (3.062)	<0.0001
USI	50.64 (3.38)	51.92 (3.004)	58.72 (2.997)	60.56 (1.54)	65.9 (2.065)	71.14 (1.752)	<0.0001
ON2	21.58 (2.194)	24.58 (1.067)	25.49 (2.249)	26.88 (2.731)	25.05 (0.847)	27.93 (1.725)	0.0033
JMLF	29.79 (4.047)	34.39 (3.307)	37.55 (1.915)	42.79 (1.385)	45.14 (1.933)	47.75 (1.281)	<0.0001
BUR	34.5 (9.37)	30.32 (2.83)	33.93 (4.533)	32.01 (3.878)	30.09 (5.918)	27.32 (1.824)	<0.0001
DRI	2.57 (0.648)	4.81 (0.342)	6.2 (0.412)	7.77 (0.785)	9.34 (1.229)	10.45 (1.441)	<0.0001
TAB	0.28 (0.083)	0.9 (0.068)	1.23 (0.06)	2.1 (0.108)	2.68 (0.205)	3.19 (0.11)	0.45
LGE	9.96 (0.315)	14.76 (0.18)	15.11 (0.554)	21.15 (0.822)	24.91 (1.091)	27.47 (0.931)	<0.0001
GUY	3.4 (0.537)	7.04 (0.856)	8.84 (0.719)	9.75 (1.437)	11.54 (0.205)	11.73 (1.015)	<0.0001
SP1	56.2 (5.593)	54.71 (3.78)	54.58 (3.299)	58.35 (0.794)	58.48 (2.922)	56.11 (0.695)	0.0553
LAH	2.72 (0.325)	3.76 (0.415)	3.73 (0.724)	6.56 (0.398)	8.27 (0.219)	9.98 (0.594)	<0.0001
STIL	9.2 (0.548)	9.97 (1.826)	10.92 (1.712)	12.26 (1.682)	13.37 (1.365)	15.53 (0.427)	0.0011
HASK	4.08 (0.151)	6.55 (0.435)	4.76 (0.045)	12.67 (0.347)	14.72 (0.426)	16.49 (0.901)	<0.0001
CRE	2.24 (0.437)	3.43 (0.122)	2.58 (0.207)	6.45 (0.161)	7.94 (0.52)	8.65 (0.483)	<0.0001

Appendix 9. Copper (Cu) concentrations as affected by increasing drying temperature for all 27 soils. Means and (standard error) are reported.

Soil	Field Moist	25˚C	45˚C	65˚C	85˚C	105˚C	P-Value
BAD	1.18 (0.047)	1.63 (0.085)	1.8 (0.127)	1.78 (0.135)	2.15 (0.167)	2.17 (0.065)	<0.0001
Elkorn	0.66 (0.064)	1.1 (0.069)	1.16 (0.081)	1.17 (0.04)	1.2 (0.051)	1.34 (0.034)	<0.0001
HAR-B	0.46 (0.014)	0.5 (0.059)	0.57 (0.022)	0.52 (0.084)	0.53 (0.043)	0.51 (0.064)	0.697
LIN	0.65 (0.037)	0.84 (0.063)	0.84 (0.105)	1.13 (0.137)	0.91 (0.057)	0.93 (0.11)	<0.0001
MAR-2	0.18 (0.021)	0.3 (0.018)	0.31 (0.02)	0.34 (0.049)	0.32 (0.036)	0.37 (0.032)	0.1128
ATH	0.52 (0.037)	0.45 (0.035)	0.48 (0.052)	0.47 (0.006)	0.52 (0.04)	0.46 (0.075)	0.8863
CLE2	0.63 (0.045)	0.74 (0.029)	0.71 (0.076)	0.69 (0.048)	0.72 (0.066)	0.76 (0.056)	0.5503
DEG	1.08 (0.086)	1.51 (0.041)	1.32 (0.016)	1.48 (0.282)	1.34 (0.099)	1.6 (0.097)	<0.0001
TAY	1.52 (0.054)	1.78 (0.073)	2.02 (0.229)	1.79 (0.089)	1.73 (0.234)	1.47 (0.008)	<0.0001
W-8	0.75 (0.037)	0.7 (0.068)	0.88 (0.148)	1.03 (0.162)	1.11 (0.191)	1.01 (0.089)	<0.0001
TAY2	1.07 (0.121)	0.96 (0.074)	1.14 (0.09)	1.09 (0.102)	1.12 (0.119)	1.18 (0.057)	0.0423
JUS-OH	0.87 (0.131)	0.94 (0.16)	0.98 (0.015)	1 (0.045)	0.99 (0.027)	1.13 (0.046)	0.0092
CHA	4.27 (0.016)	4.27 (0.181)	4.77 (0.517)	4.23 (0.095)	4.25 (0.291)	4 (0.19)	<0.0001
HAR	0.89 (0.068)	1.07 (0.047)	0.94 (0.018)	1.17 (0.036)	1.2 (0.037)	1.21 (0.057)	<0.0001
USI	0.54 (0.007)	0.57 (0.024)	0.55 (0.015)	0.54 (0.044)	0.56 (0.022)	0.52 (0.002)	0.9776
ON2	0.21 (0.027)	0.3 (0.011)	0.33 (0.04)	0.32 (0.034)	0.31 (0.009)	0.37 (0.017)	0.3151
JMLF	1.62 (0.174)	2.05 (0.146)	2.33 (0.151)	2.44 (0.195)	2.11 (0.113)	2.04 (0.07)	<0.0001
BUR	0.7 (0.06)	0.77 (0.024)	0.79 (0.015)	0.84 (0.026)	0.75 (0.028)	0.79 (0.022)	0.5183
DRI	2.07 (0.304)	2.83 (0.046)	2.88 (0.094)	2.92 (0.2)	2.96 (0.017)	2.84 (0.069)	<0.0001
TAB	2.17 (0.032)	2.68 (0.258)	2.55 (0.05)	2.78 (0.075)	2.39 (0.032)	2.75 (0.123)	<0.0001
LGE	1.14 (0.032)	1.65 (0.065)	1.63 (0.124)	1.68 (0.085)	1.77 (0.033)	1.82 (0.066)	<0.0001
GUY	0.87 (0.103)	0.88 (0.032)	0.93 (0.036)	0.93 (0.068)	1.01 (0.024)	1.08 (0.017)	0.021
SP1	1.16 (0.114)	1.24 (0.141)	1.13 (0.057)	1.27 (0.031)	1.25 (0.069)	1.21 (0.036)	0.2446
LAH	0.56 (0.009)	0.7 (0.059)	0.72 (0.073)	0.87 (0.036)	0.89 (0.024)	0.9 (0.038)	<0.0001
STIL	0.42 (0.086)	0.55 (0.079)	0.58 (0.066)	0.68 (0.085)	0.74 (0.069)	0.8 (0.013)	<0.0001
HASK	0.28 (0.018)	0.37 (0.014)	0.28 (0.006)	0.45 (0.001)	0.46 (0.009)	0.52 (0.019)	0.0018
CRE	0.64 (0.077)	0.64 (0.051)	0.43 (0.013)	0.66 (0.008)	0.81 (0.058)	0.86 (0.063)	<0.0001

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Appendix 10. Ammonium Nitrogen (NH_4-N) concentrations as affected by increasing drying temperature for all 27 soils. Means and (standard error) are reported.

Soil	Field Moist	25˚C	45˚C	65˚C	85˚C	105˚C	P-Value
BAD	1 (0.968)	2.32 (0.969)	2.54 (1.103)	5.91 (1.328)	10.67 (2.071)	12.63 (1.605)	<0.0001
Elkorn	0.9 (0.868)	1.58 (0.226)	2.73 (0.758)	4.02 (0.545)	8.28 (0.679)	13.27 (0.666)	<0.0001
HAR-B	6.16 (0.86)	6.22 (0.847)	5.7 (0.587)	5.94 (0.912)	9.04 (1.029)	11.45 (2.165)	<0.0001
LIN	0.99 (0.548)	1.43 (0.688)	1.53 (0.697)	1.97 (0.603)	4.77 (0.913)	6.14 (0.99)	<0.0001
MAR-2	1.3 (0.759)	2.16 (0.742)	1.97 (0.821)	2.8 (0.804)	6.87 (1.576)	10 (1.989)	<0.0001
ATH	1.41 (0.923)	1.7 (0.842)	1.53 (0.785)	2.06 (0.789)	8.9 (0.534)	12.24 (0.764)	<0.0001
CLE2	2.11 (0.813)	1.35 (0.615)	1.68 (0.724)	1.88 (0.947)	4.75 (0.869)	5.15 (0.652)	<0.0001
DEG	0.6 (0.149)	2.41 (0.651)	3.09 (0.851)	3.74 (0.753)	6.29 (0.637)	7.92 (0.85)	<0.0001
TAY	3.63 (0.661)	4.1 (0.742)	3.62 (0.273)	4.29 (0.344)	7.57 (0.859)	9.9 (0.914)	<0.0001
W-8	0.64 (0.35)	1.62 (0.489)	1.97 (0.579)	2.71 (0.701)	7.88 (0.164)	9.81 (1.148)	<0.0001
TAY2	0.67 (0.375)	1.11 (0.362)	1.07 (0.328)	1.59 (0.687)	4.64 (0.299)	6.22 (1.763)	<0.0001
JUS-OH	0.83 (0.633)	1.27 (0.683)	1.31 (0.64)	1.78 (0.868)	4.55 (0.79)	7.06 (0.906)	<0.0001
CHA	26.97 (1.178)	22.27 (1.286)	23.31 (1.592)	18.38 (1.088)	19.6 (1.404)	24.16 (1.218)	<0.0001
HAR	1.09 (0.786)	2.38 (0.792)	2.57 (0.044)	3.13 (0.069)	10.11 (0.636)	17.63 (1.313)	<0.0001
USI	15.8 (0.811)	14.01 (0.151)	12.37 (0.374)	11.17 (0.32)	14.17 (0.127)	16 (0.208)	<0.0001
ON2	3.37 (0.274)	2.42 (0.104)	2.69 (0.198)	2.89 (0.21)	7.18 (1.113)	8.24 (0.265)	<0.0001
JMLF	0.63 (0.148)	1.74 (0.115)	1.73 (0.054)	2.63 (0.168)	9.58 (0.765)	10.65 (0.2)	<0.0001
BUR	2.21 (0.108)	1.53 (0.071)	1.25 (0.081)	1.48 (0.118)	5.98 (0.575)	5.36 (0.617)	<0.0001
DRI	0.55 (0.083)	0.96 (0.062)	1.13 (0.104)	1.45 (0.122)	4.88 (0.165)	7.34 (0.336)	<0.0001
TAB	0.46 (0.06)	0.77 (0.091)	0.88 (0.109)	1.36 (0.079)	5.09 (0.204)	5.53 (0.232)	<0.0001
LGE	0.54 (0.218)	1.37 (0.07)	1.52 (0.114)	2.34 (0.136)	9.66 (0.949)	13.03 (0.243)	<0.0001
GUY	0.57 (0.168)	0.69 (0.187)	0.84 (0.14)	0.98 (0.125)	3.59 (0.247)	4.92 (0.104)	<0.0001
SP1	4.89 (0.11)	3.86 (0.059)	3.84 (0.081)	3.75 (0.049)	8.75 (0.248)	11.4 (0.893)	<0.0001
LAH	0.47 (0.202)	1.23 (0.082)	1.39 (0.083)	1.96 (0.055)	4.4 (0.157)	6.6 (0.418)	<0.0001
STIL	0.57 (0.258)	1.29 (0.138)	1.76 (0.118)	1.58 (0.016)	3.54 (1.235)	7.35 (1.235)	<0.0001
HASK	0.63 (0.039)	1.71 (0.132)	3.25 (0.275)	3.81 (0.111)	5.27 (0.338)	8.15 (0.652)	<0.0001
CRE	0.54 (0.21)	1.81 (0.294)	4.13 (0.751)	5.61 (0.621)	6.69 (0.223)	7.92 (0.078)	<0.0001

Appendix 11. Nitrate nitrogen (NO_3-N) concentrations as affected by increasing drying temperature for all 27 soils. Means and (standard error) are reported.

Soil	Field Moist	25˚C	45˚C	65˚C	85˚C	105˚C	P-Value
BAD	89.34 (12.664)	81.4 (7.386)	80.53 (2.571)	76.21 (4.414)	77.12 (3.525)	77.76 (4.604)	0.0007
Elkorn	126.93 (19.236)	115.47 (10.912)	115 (5.251)	108.09 (1.437)	110.46 (4.643)	108.98 (5.861)	<.0001
HAR-B	2.3 (0.102)	1.92 (0.019)	2.09 (0.03)	2.09 (0.167)	2.05 (0.085)	2.03 (0.068)	1
LIN	21.83 (3.01)	17.24 (0.482)	17.49 (0.564)	18.48 (1.637)	16.72 (1.187)	17.54 (1.811)	0.6568
MAR-2	28.14 (0.944)	26.5 (0.595)	26.21 (0.672)	26.09 (0.25)	25.44 (0.595)	25.92 (0.388)	0.9754
ATH	27.04 (1.621)	25.37 (0.282)	25.75 (0.936)	22.48 (1.823)	24.8 (1.084)	24.49 (0.268)	0.8231
CLE2	37.08 (0.086)	34.55 (1.348)	42.2 (2.155)	36.64 (4.375)	34.39 (7.581)	32.42 (6.558)	0.0573
DEG	38.04 (1.868)	33.92 (2.033)	32.54 (1.856)	33.43 (1.767)	33.4 (0.338)	32.34 (1.096)	0.5295
TAY	44.67 (0.66)	43.13 (0.791)	43.15 (0.867)	42.47 (0.759)	41.53 (0.368)	40.01 (0.737)	0.7919
W-8	33.05 (0.166)	30.84 (0.715)	31 (1.098)	30.58 (0.219)	30.49 (0.733)	29.6 (0.478)	0.9404
TAY2	17.41 (0.472)	16.23 (0.68)	16.16 (0.549)	15.96 (0.715)	15.59 (0.489)	14.95 (0.448)	0.9864
JUS-OH	16.04 (0.809)	14.22 (0.286)	14.01 (0.409)	13.7 (0.278)	13.51 (0.43)	13.04 (0.535)	0.9601
CHA	161.28 (1.862)	156.55 (24.029)	142.59 (9.924)	151.14 (15.342)	139.66 (2.51)	138 (4.149)	<.0001
HAR	57.8 (0.674)	52.28 (1.163)	56.27 (0.971)	54.24 (3.682)	49.56 (2.397)	49.65 (1.018)	0.0536
USI	0.75 (0.082)	0.73 (0.053)	0.72 (0.058)	0.74 (0.054)	0.74 (0.06)	0.76 (0.027)	1
ON2	21.69 (2.469)	20.12 (1.434)	22.16 (3.322)	22.75 (2.829)	21.58 (0.808)	19.19 (2.018)	0.8902
JMLF	4.27 (0.249)	3.24 (0.155)	3.57 (0.204)	3.42 (0.22)	3.49 (0.285)	3.56 (0.127)	0.9997
BUR	51.45 (1.229)	49.86 (1.262)	49.73 (1.519)	48.29 (2.072)	48.64 (2.636)	44.65 (1.688)	0.4144
DRI	59.37 (3.01)	55.76 (2.586)	54.2 (1.66)	55.04 (2.487)	54.31 (2.705)	53.4 (2.422)	0.5108
TAB	90.22 (17.032)	71.8 (5.136)	69.62 (5.098)	71.34 (7.608)	69.53 (7.433)	69.9 (1.812)	<.0001
LGE	177.27 (7.693)	149.49 (8.905)	150.75 (5.415)	140.12 (4.758)	142.53 (12.614)	130.69 (4.983)	<.0001
GUY	38.93 (1.224)	36.3 (0.875)	37.23 (0.243)	36.27 (1.809)	37.42 (1.742)	34.94 (1.037)	0.8858
SP1	117.11 (4.471)	101.79 (7.495)	106.31 (5.582)	105.94 (9.441)	111.29 (5.032)	105.25 (16.71)	<.0001
LAH	19.53 (0.563)	15.49 (0.437)	16.95 (0.26)	15.83 (0.846)	15.7 (0.528)	15.02 (0.553)	0.7622
STIL	4.38 (0.873)	2.94 (0.162)	3.12 (0.089)	2.7 (0.371)	2.63 (0.654)	2.38 (0.195)	0.9928
HASK	17.47 (1.411)	15.33 (0.571)	18.58 (1.325)	13.71 (0.529)	17.02 (3.472)	11.98 (0.044)	0.3196
CRE	33.37 (8.421)	32.9 (1.369)	36.39 (1.822)	33.17 (5.931)	29.59 (0.316)	30.65 (1.315)	0.3783

Appendix 12. Total nitrogen (TN) concentrations as affected by increasing drying temperature for all 27 soils. Means and (standard errors) are reported.

Soil	Field Moist	25˚C	45˚C	65˚C	85˚C	105˚C	P-Value
BAD	0.19 (0.001)	0.17 (0.009)	0.17 (0.009)	0.16 (0.006)	0.16 (0.002)	0.16 (0.004)	<.0001
Elkorn	0.14 (0.029)	0.12 (0.007)	0.12 (0.001)	0.11 (0.002)	0.12 (0.002)	0.12 (0.005)	<.0001
HAR-B	0.05 (0.003)	0.05 (0.002)	0.04 (0.004)	0.05 (0.002)	0.04 (0.002)	0.04 (0.004)	0.289
LIN	0.06 (0.001)	0.06 (0.005)	0.06 (0.005)	0.06 (0.004)	0.07 (0)	0.06 (0.003)	0.4191
MAR-2	0.08 (0.001)	0.08 (0.003)	0.08 (0.001)	0.08 (0)	0.08 (0.005)	0.08 (0.004)	0.8266
ATH	0.04 (0.001)	0.04 (0.003)	0.04 (0.001)	0.03 (0.006)	0.03 (0.007)	0.03 (0.007)	0.0267
CLE2	0.02 (0.007)	0.02 (0.01)	0.03 (0.002)	0.03 (0.007)	0.03 (0.004)	0.03 (0.004)	0.0032
DEG	0.09 (0.003)	0.09 (0.007)	0.09 (0.002)	0.08 (0.002)	0.08 (0.006)	0.09 (0.004)	0.5899
TAY	0.05 (0.003)	0.06 (0.001)	0.06 (0.002)	0.06 (0.005)	0.06 (0.002)	0.06 (0.001)	0.8478
W-8	0.09 (0.005)	0.09 (0.006)	0.08 (0.001)	0.09 (0.004)	0.09 (0.005)	0.09 (0.002)	0.9604
TAY2	0.05 (0.004)	0.05 (0.003)	0.05 (0.001)	0.05 (0.002)	0.05 (0.001)	0.05 (0.007)	0.9849
JUS-OH	0.07 (0.005)	0.06 (0.004)	0.06 (0.003)	0.06 (0.006)	0.06 (0.007)	0.06 (0.005)	0.1545
CHA	0.19 (0.004)	0.18 (0.005)	0.18 (0.003)	0.17 (0.005)	0.17 (0.005)	0.17 (0.004)	<.0001
HAR	0.14 (0.002)	0.13 (0.003)	0.13 (0.01)	0.12 (0.008)	0.13 (0.005)	0.12 (0.004)	0.0016
USI	0.05 (0.002)	0.05 (0.001)	0.04 (0.005)	0.05 (0.003)	0.05 (0.004)	0.05 (0.003)	0.7862
ON2	0.05 (0.006)	0.05 (0.002)	0.05 (0.003)	0.05 (0.015)	0.05 (0.002)	0.05 (0.002)	0.1376
JMLF	0.08 (0.003)	0.08 (0.006)	0.08 (0.003)	0.07 (0.008)	0.08 (0.005)	0.07 (0.006)	0.0026
BUR	0.04 (0.002)	0.04 (0.001)	0.04 (0.001)	0.04 (0.003)	0.04 (0.002)	0.04 (0)	0.326
DRI	0.04 (0.002)	0.04 (0.006)	0.04 (0.005)	0.04 (0.004)	0.04 (0.005)	0.04 (0.005)	0.5721
TAB	0.05 (0.002)	0.05 (0.002)	0.04 (0.003)	0.04 (0.004)	0.04 (0.006)	0.04 (0.003)	0.66
LGE	0.14 (0.013)	0.14 (0.007)	0.14 (0.014)	0.14 (0.009)	0.14 (0.005)	0.14 (0.009)	0.7183
GUY	0.03 (0.003)	0.03 (0.002)	0.03 (0.002)	0.03 (0.001)	0.02 (0.001)	0.02 (0.001)	0.8428
SP1	0.11 (0.004)	0.09 (0.005)	0.09 (0.001)	0.09 (0.007)	0.1 (0.002)	0.1 (0.004)	0.0053
LAH	0.05 (0.002)	0.05 (0.003)	0.05 (0.003)	0.05 (0.004)	0.05 (0.002)	0.05 (0.003)	0.2558
STIL	0.03 (0.001)	0.04 (0.003)	0.04 (0.002)	0.04 (0.002)	0.04 (0.001)	0.03 (0.008)	0.8757
HASK	0.06 (0.005)	0.06 (0.001)	0.06 (0.002)	0.06 (0.001)	0.06 (0.002)	0.06 (0.002)	0.2764
CRE	0.14 (0.002)	0.13 (0.007)	0.14 (0.004)	0.12 (0.002)	0.12 (0.006)	0.12 (0.001)	<.0001

Appendix 13. Organic carbon (OC) concentrations as affected by increasing drying temperature for all 27 soils. Means and (standard errors) are reported.

Soil	Field Moist	25˚C	45˚C	65˚C	85˚C	105˚C	P-Value
BAD	2.72 (0.088)	2.56 (0.054)	2.52 (0.044)	2.37 (0.023)	2.4 (0.044)	2.41 (0.031)	<0.0001
Elkorn	1.56 (0.043)	1.5 (0.011)	1.51 (0.035)	1.42 (0.065)	1.46 (0.02)	1.47 (0.027)	0.0179
HAR-B	0.54 (0.026)	0.53 (0.009)	0.49 (0.053)	0.5 (0.044)	0.45 (0.029)	0.44 (0.027)	0.0935
LIN	0.71 (0.044)	0.7 (0.045)	0.68 (0.019)	0.66 (0.046)	0.73 (0.019)	0.7 (0.013)	0.6766
MAR-2	0.97 (0.006)	0.97 (0.027)	0.95 (0.005)	0.91 (0.007)	0.95 (0.051)	0.94 (0.008)	0.7432
ATH	0.36 (0.012)	0.31 (0.019)	0.31 (0.018)	0.32 (0.021)	0.31 (0.025)	0.31 (0.011)	0.7797
CLE2	0.32 (0.016)	0.32 (0.004)	0.38 (0.067)	0.41 (0.033)	0.35 (0.05)	0.39 (0.068)	0.1204
DEG	1.38 (0.112)	1.28 (0.327)	1.14 (0.136)	1.22 (0.261)	1.16 (0.225)	1.1 (0.038)	<0.0001
TAY	0.47 (0.007)	0.47 (0.024)	0.49 (0.049)	0.46 (0.024)	0.47 (0.021)	0.47 (0.012)	0.9889
W-8	0.88 (0.015)	0.89 (0.039)	0.87 (0.034)	0.87 (0.02)	0.89 (0.045)	0.88 (0.013)	0.9936
TAY2	0.52 (0.022)	0.59 (0.069)	0.52 (0.028)	0.53 (0.027)	0.53 (0.012)	0.56 (0.021)	0.4714
JUS-OH	0.77 (0.066)	0.64 (0.034)	0.67 (0.063)	0.67 (0.119)	0.7 (0.109)	0.66 (0.051)	0.0503
CHA	2.08 (0.139)	1.79 (0.024)	1.79 (0.078)	1.74 (0.072)	1.7 (0.023)	1.72 (0.079)	<0.0001
HAR	1.69 (0.024)	1.55 (0.022)	1.57 (0.067)	1.46 (0.101)	1.49 (0.056)	1.44 (0.058)	<0.0001
USI	0.68 (0.086)	0.69 (0.02)	0.67 (0.027)	0.73 (0.058)	0.69 (0.089)	0.7 (0.019)	0.8005
ON2	0.52 (0.045)	0.59 (0.044)	0.52 (0.044)	0.54 (0.163)	0.59 (0.045)	0.51 (0.031)	0.1443
JMLF	0.91 (0.008)	0.89 (0.041)	0.87 (0.021)	0.81 (0.035)	0.87 (0.032)	0.86 (0.025)	0.3134
BUR	0.49 (0.066)	0.37 (0.015)	0.38 (0.013)	0.41 (0.01)	0.39 (0.018)	0.41 (0.005)	0.0826
DRI	0.27 (0.002)	0.26 (0.002)	0.25 (0.008)	0.24 (0.004)	0.24 (0.006)	0.25 (0.002)	0.9805
TAB	0.45 (0.025)	0.44 (0.002)	0.42 (0.037)	0.41 (0.028)	0.42 (0.031)	0.43 (0.018)	0.9635
LGE	1.77 (0.128)	1.73 (0.032)	1.73 (0.076)	1.68 (0.021)	1.63 (0.026)	1.68 (0.061)	0.0127
GUY	0.26 (0.026)	0.22 (0.008)	0.21 (0.007)	0.22 (0.005)	0.22 (0.006)	0.23 (0.006)	0.8997
SP1	1.17 (0.017)	1.06 (0.017)	1.03 (0.007)	1.03 (0.042)	1.04 (0.071)	1.01 (0.058)	0.0037
LAH	0.54 (0.008)	0.52 (0.026)	0.53 (0.025)	0.52 (0.01)	0.51 (0.007)	0.53 (0.031)	0.9835
STIL	0.35 (0.012)	0.34 (0.001)	0.31 (0.017)	0.34 (0.024)	0.33 (0.007)	0.33 (0.021)	0.971
HASK	0.65 (0.014)	0.65 (0.041)	0.66 (0.032)	0.6 (0.057)	0.61 (0.038)	0.61 (0.036)	0.5104
CRE	1.79 (0.029)	1.66 (0.033)	1.76 (0.049)	1.6 (0.049)	1.59 (0.068)	1.59 (0.042)	<0.0001

Appendix 14. pH values from all 27 soils as drying temperature increases.

Soil	Field Moist	25˚C	45˚C	65˚C	85˚C	105˚C
BAD	7.6	7.5	7.5	7.7	7.6	7.7
Elkorn	5.8	5.9	5.8	5.9	5.7	5.8
HAR-B	5.3	5.3	5.2	5.1	5.1	4.9
LIN	6.8	6.8	6.7	6.7	6.6	6.7
MAR-2	5.6	5.6	5.6	5.6	5.6	5.5
ATH	6	5.9	5.9	5.8	5.8	5.8
CLE2	4.8	4.8	4.8	4.8	4.7	4.8
DEG	6.9	6.9	6.8	6.8	6.7	6.6
TAY	4.7	4.8	4.7	4.7	4.7	4.7
W-8	7.1	7.1	7	7	6.8	6.7
TAY2	6.9	6.9	6.9	6.8	6.6	6.5
JUS-OH	7.5	7.5	7.4	7.3	7.2	7.1
CHA	5.2	5.2	5.2	5.2	5.2	5.2
HAR	5	5	5.1	5	5	5
USI	4.8	4.7	4.6	4.5	4.4	4.3
ON2	4.8	4.7	4.8	4.7	4.8	4.7
JMLF	5.2	5.1	5.1	5.1	5.1	5
BUR	3.8	3.8	3.8	3.8	3.9	3.9
DRI	6.4	6.5	6.5	6.5	6.5	6.5
TAB	7.7	7.7	7.6	7.8	7.7	7.7
LGE	6.1	6.1	6.1	6.1	6.1	6
GUY	7.1	7.1	7	7	7.1	7
SP1	4.7	4.7	4.7	4.7	4.8	4.8
LAH	7	6.9	6.9	6.9	6.9	6.8
STIL	4.8	4.8	4.8	4.8	4.8	4.8
HASK	7.6	7.5	7.5	7.5	7.5	7.4
CRE	7.9	7.8	7.8	7.8	7.8	7.8

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