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AN ASSESSMENT OF PRESCRIBED BURNING ON SOIL EROSION POTENTIAL IN THE MIXED HARDWOOD FORESTS OF THE OZARK HILLS IN SOUTHERN ILLINOIS

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By

Kyle Sterling Monroe

B.S., Southern Illinois University, 2007

A Thesis Submitted
in Partial Fulfillment of the Requirements for the
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THESIS APPROVAL

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Approved by:

Dr. Jon Schoonover
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Graduate School
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MAJOR PROFESSOR: Dr. Jon Schoonover

Prescribed fire has become a management tool utilized to restore or maintain the ecology of the mixed hardwoods ecosystem in the Ozark hills of southwestern Illinois. One effect of prescribed burning is consumption of fuel beds, including the litter layer that protects soil from erosion. Amount of sediment loss after prescribed burning in the steep topography of the Ozark hills is unknown. Erosion after prescribed burning could lead to increased soil loss and possibly stream sedimentation (Bladon etal., 2014). The objective of this research was to quantify the amount of sediment transport occurring on a watershed scale. Sediment yields were measured from five paired watersheds located in Trail of Tears State Forest in Union County, IL, USA from April 2009 into 2010. This location was selected because of the highly erodible loess soils and steeps slopes which present the highest probability of sediment transport following a prescribed burn treatment. One of the paired watersheds was randomly assigned as the control and the other assigned as the treatment. The treatment was a prescribed burn applied at standard burn prescription levels. Sediment loads were determined by collecting samples from a known volume of overland flow held in storage tanks below each watershed after rain events which produced runoff. The prescribed burn treatment significantly reduced the litter depth with 12.6%–31.5% litter remaining in the prescribed burn treatment watersheds. When data were combined across all watersheds, no significant differences were obtained between burn treatment and control watershed for total suspended solids and sediment concentrations or loads. The annual sediment losses varied between 1.41 to 90.54 $kg \cdot ha^{-1} \cdot year^{-1}$ in the four prescribed burn watersheds and 0.81 to 2.54 $kg \cdot ha^{-1} \cdot year^{-1}$ in the four control watersheds. Prescribed burn watershed 7 showed an average depth of soil loss of 4.2 mm, whereas control watershed 8 showed an average accumulation of sediments (9.9 mm), possibly due to steeper slopes. Prescribed burning did not cause a significant increase in soil erosion and sediment loss and can be considered acceptable in managing mixed hardwood forests of Ozark uplands and the Shawnee Hills physiographic regions of southern Illinois.

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I can honestly say that this has been one of the toughest obstacles in my life so far and I will never forget the memories made.

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CHAPTER 1

INTRODUCTION

Ecological studies have shown that wildfires have been a key factor in sustaining the composition of central hardwood forests (Abrams, 1992; Boerner, 1982; Boerner, 2000; Hutchinson, et al., 2005; Keyser, etal., 2017; Brose, etal., 2012). For this reason, land managers are using prescribed fire in mixed hardwood forested ecosystems to conserve or restore the ecology of that forest assemblage (Boerner, etal., 1999, Keyser, etal., 2017). However, fire has been associated with increased erosion rates in many different ecosystems throughout the United States (Boerner et al., 1999; Boerner, 2005; Robichaud, etal., 2007; Spigel & Robichaud, 2007). The implementation of prescribed fire may lead to an unnatural increase of erosion and sediment movement which could also lead to increased stream sedimentation (Blattel, 2005). If this is true, then it is possible that the practice of prescribed burning may be harmful to aquatic environments.

Human disturbance and modification of ecosystems has led to rising concern for the quality of water and aquatic environments (Harding, etal., 1998; Ryan & Meiman, 1996). Negative impacts on stream species associated with an increase in suspended solid loads have been extensively documented (Alexander & Hansen, 1986; Wood & Armitage, 1997). Stream degradation by sedimentation can include: increased turbidity, limited light penetration, reduction of primary productivity, change in channel morphology, and species decline (Wood & Armitage, 1997).

Studies throughout the United States have determined that runoff and erosion increase after the occurrence of fire (Boerner, 2000; Moffet, et al., 2007; Robichaud, et al., 2008; Spigel

& Robichaud, 2007). Information on erosion processes following prescribed fire in the Midwest, including southern Illinois is lacking. Prescribed fires that burn with lower intensity have been shown to leave more unconsumed vegetation, leaf litter, and duff which can reduce the sediment movement on the landscape (Woods & Balfour, 2008). This study will provide the opportunity to determine if the increased erosion and sediment movement is occurring in the mixed hardwood ecosystem of southern Illinois.

The study's specific objectives are to: 1) quantify the amount of sediment movement occurring on a watershed scale after the implementation of a prescribed fire; 2) contribute a better understanding of the effects of prescribed burning in the mixed hardwood ecosystem of southern Illinois; 3) provide recommendations to land managers based on research outcomes. The proposed study location was Trail of Tears State Forest located in the Ozark Hills of southern Illinois. This location was chosen because of the steep topography and highly erodible deep loess-cap soils that represent some of the most extreme site conditions in this area.

CHAPTER 2

LITERATURE REVIEW

Early European settlers recorded observing Native Americans using fire for clearing land, hunting and gathering, and warfare (Boerner, 2005; Van Lear & Waldrop, 1989; Ruffner & Groninger, 2006). As Europeans began settling across the United States, the trend of fire suppression began to emerge. The belief that fire interrupted the natural processes of an ecosystem really took hold in the late 1800's (Van Lear & Waldrop, 1989; Robertson & Heikens, 1994; Keyser, etal., 2017, Brose, etal., 2001). It was nearly 100 years later that land managers began to see that fire did not interrupt the natural process of an ecosystem but was a natural disturbance that could help maintain them (Blattel, 2005, Knapp, etal., 2015; Knoepp, etal., 2009; Ruffner & Groninger, 2006). In the eastern hardwoods of North America, lack of fire allowed mesophytic species to begin dominating the understory of oak-hickory forests (Abrams, 1992; Robertson & Heikens, 1994; Ozier, et al., 2006; Ruffner & Groninger, 2004). This change in species composition sparked land managers to begin reintroducing fire in the ecosystem with the implementation of prescribed burning (Boerner, et al., 1999; Knapp, etal., 2015, VanLear & Waldrop, 1989; Ruffner & Groninger, 2006). Various studies have shown that fire in certain areas and under certain conditions may be beneficial to the maintenance of certain types of plant communities and the perpetuation of certain plant species (Sweney & Biswell, 1961; Van Lear & Waldrop, 1989; Ruffner & Groninger, 2004; Boerner; Barnes & Van Lear, 1998; Abrams, 1992; Carril, 2009). Other studies have shown that the lack of fire has led to the establishment of non-desirable species and non-native invasive species (Shotola, etal., 2011; Albrecht & McCarthy, 2005; Barnes & Van Lear, 1998; Brose, etal., 2001). Now that prescribed fire is being so widely reintroduced there needs to be research to ensure that best management practices are taken into consideration for each ecosystem.

Wildfires tend to burn with higher intensity and severity. Prescribed fires are planned to take into consideration temperature and extent which usually produce fires that burn across the ground with low intensity and is much less severe on the environment (Blattel, 2005; Van Lear & Waldrop, 1989). Whether fire is wild or prescribed, it can still alter the hydrologic cycle in forest ecosystems, but the extent of their effects depends on several factors (Abrams, 1992; Boerner, 2000; Erickson & White, 2008; Robichaud, et al.). Along with burn severity and fire intensity, Spigel and Robichaud (2000) cite five other factors that influence the impacts of prescribed fire on a landscape: burn area, topography, soil properties, climate, and channel proximity.

Land managers set specific prescription levels when designing a prescribed burn plan. These prescription levels are designed to reduce the chance of an escape fire and yield the desired management outcome following the burn. Fire intensity and severity are terms that scale a fire as low, medium, or high. Prescription levels for prescribed burning are designed to keep the fire intensity and severity at a low to medium range (Blattel, 2005, Boerner, 2000). This range is typically determined by prescription levels and burn or post burn observations (flame length, fuel consumption, fire-scar height, etc.).

Research has shown that sediment movement after a fire can result in no change or have detrimental impacts on the surrounding environment (Swanson, 1981; Robichaud, 2000; Woods & Balfour, 2008; Bladon, etal., 2014). Studies with increased stream sedimentation appear to be linked to high intensity wildfires, slash burning, or prescribed burns in combination with other site disturbances that include installation of logging roads. A study by Rich (1962) of a wildfire in central Arizona concluded that there was an increase in erosion over the burned area caused by overland flow. The sediment that was eroded settled in the lower portion of the watershed that was unburned or continued down the watershed increasing stream sedimentation. Robichaud and Waldrop (1994) found that sediment yields from prescribed burns in high severity treatment areas were 40-times greater than prescribed burns in low-severity treatment areas of the Southern Appalachian Mountains. Beschta (1978) conducted a study to monitor long-term sediment movement following road construction, logging, and site preparation burning in the Oregon coast range. Surface erosion from the slash burn was determined to be the primary cause of increased sediment yields. In undisturbed forested ecosystems, precipitation falls onto an intact litter layer and then infiltrates into the duff layer and soil while generating little to no overland flow (Meginnis, 1953; Swanson, 1981). Conversely, rain that falls on a burnt forest floor, where the litter layer has been consumed or partially consumed, will have a greater chance of directly contacting mineral soil particles (Megahan & Molitor, 1975). Energy from rain droplets is transferred into the soil particles upon direct impact, leading to increased soil displacement. Overland flow occurs with rainfall intensity exceeds infiltration rates or the soil reaches saturation. Water flowing over the surface of the soil and has the potential to form sheet erosion, leading to sediment movement. It is possible that sheet erosion can lead to rill erosion (Robichaud, 2000). This can result in a significant amount of sediment movement that is not desired by land managers. Once fire consumes the duff layer, overland flow can increase and then flow with the path of least resistance or from higher to lower elevation (Spigel & Robichaud, 2007). This overall increase in sediment movement, according to Blattel (2005), will impact concentrations of sediments and nutrients in streams which can impact water quality.

Prescribed fires tend to burn at a relatively low intensity under mixed hardwood forest cover. Temperatures typically do not exceed 200 to 250 degrees Celsius (Boerner, 2000). Minimal subsurface heating of the soil occurs because of these low surface temperatures during prescribed burning (Erickson & White, 2008). Prescribed fires can consume much of the detritus layer on the soil surface at these temperatures exposing the soil (Phillips, etal., 2000). Without a duff layer, the soil has no insulated barrier to protect it from solar heating or from rainfall (Erickson & White, 2008). The consumption of organic matter increases nutrient availability that is then released into the soil (Erickson & White, 2008). Heating of soil particles can also alter the structure of the soil increasing erosion potential (Ralston & Hatchel, 1979; Phillips, etal., 2000). With a low subsurface temperature of prescribed burns under mixed hardwoods, there is a decreased chance that a drastic change in soil structure would occur (Sweeney & Biswell, 1961). This may lead to less sediment movement than has been observed in other ecosystems. Results of a study by Phillips, etal., in a mixed oak dominated forest, middle Tennessee, concluded that 35 years of prescribed burning on 5 year intervals had little long-term effect on the surface horizons, except for a significant decrease in the thickness of the A horizons. This study also found that these long-term period burns seemed to allow enough time for almost complete recovery of surface horizons (Phillips, etal., 2000).

In some cases, soils become water repellent, or hydrophobic, in response to fire. Hydrophobicity can occur when fires burn with very high surface temperatures that turn organic matter resins into a vapor which can diffuse into course textured soils. Theses vapors then are then cooled by the soil, filling the pore spaces with organic matter resins and creating a water tight seal (Erickson & White, 2008; DeBano, 1991; Robichaud, 2000). Hydrophobic soils tend to occur in areas with coarse-textured soil and a detritus layer containing fuels high in resin

(Boerner, 2005; Swanson, 1981; Shakesby, & Doerr, 2006). Hydrophobicity is not known to occur after fires occurring under mixed hardwood stands because they have lower surface temperatures and the organic matter does not typically seal soil pore space (Blattel, 2005). Research to determine if hydrophobic soils occur under mixed hardwood stands is lacking, but the current literature claims that chances are very unlikely (Boerner, etal 2000). Scharenbroch, etal., 2010 studied the effects of low-severity prescribed fires that occurred over a 23-year period in a mixed hardwood forest in north east Illinois. Hydrophobicity was not different in burned compared to unburned plots.

Related to sediment movement is the volatilization of nutrients and ash convection during a fire. In a review by Erickson and White (2008) the authors listed soil nutrient elements that are commonly affected by fire including nitrogen, sulfur, and phosphorus. According to Boerner (1982), nutrients in biomass can be "lost to the atmosphere, deposited as ash, or remain in incompletely burned vegetation or detritus" (p. 187). These remaining nutrients in ash and detritus can be transported in sediment movement. Fire has the ability to volatilize organic nitrogen (N) and sulfur (S) through the consumption of mixed hardwood forest litter (Ralston & Hatchell, 1971). This volatilization can occur at 200 degrees Celsius in N and S but significant losses don't occur until around 300 degrees Celsius (Boerner, 2000; Byram, 1959). The N and S that is volatilized can reach the atmosphere and return as acid rain potentially damaging forest vegetation and crops (Blattel, 2005). Acid rain from prescribed fire may or may not occur under central hardwoods, but a study in this region does not appear to be available. Nutrients in convected ash can travel in sediment down slope and into streams or leach into groundwater (Shakesby & Doerr, 2006). Soil nutrients that are released in response to a burn do not always produce negative impacts to an ecosystem (Woods & Balfour, 2008). The volatilization of organic matter to nutrients is a process that naturally replenishes the soil making nutrients available for uptake by trees and other vegetation (Erickson & White, 2008; Byram, 1959; Scharenbroch, etal., 2012).

Researchers have measured erosion using varying methods and procedures. Two types of methods used are laboratory or computer based modeling and field tests (Moffet et al., 2007). Modeling is a way of predicting soil erosion based on calculations of predetermined variables that cause the erosion (i.e., slope). There are several models that have been created and are used for different scenarios like forested watersheds or agricultural fields. The universal soil loss equation (USLE) and the water erosion prediction project (WEPP) are two examples. Field tests are completed when funding is available to pay for a labor-intensive erosion study. Methods of measuring sediment loss include collection with silt fence, profile measurements, cross sectional measure, and suspended sediment in water samples. All methods can be used effectively, some producing more accurate results on different landscapes.

Moffet et al. (2007) completed a study that compared the field test data and the WEPP model on sagebrush rangeland with steep slopes before and after a prescribed fire. The results concluded that rill erosion was the most prominent erosion process and that the WEPP model significantly underestimated the soil erosion for burned conditions. Another study by Soto & Diaz-Fierros (1998) used field test data and the WEPP model to determine erosion rates after prescribed burning on scrub-bearing hillslopes in northwest Spain. In this study, the WEPP model predicted what the authors call reasonable accuracy, but consistently underestimated erosion losses. Until a more accurate model is created to account for fire on a landscape, field tests still appear to be the most accurate option.

CHAPTER 3

METHODS

Study Area Description

The research was conducted at Trail of Tears State Forest located in Western Union County, five miles Northwest of Jonesboro, IL (Figure 3-1) Trail of Tears State Forest (TTSF) is just over 2000 hectares and is managed for timber, wildlife, ecosystem preservation, watershed protection, and recreation ("Trail of Tears", n.d.) (Figure 3-2). Research watersheds were located on the north side of State Forest Road, 2.25 miles west of the Highway 127 and State Forest Road intersection, Township 12 South, Range 2 West, Section 8 (Latitude 37.485504; Longitude -89.364989) (Figure 3-3). This location was selected for the study because of the steep topography of the loess covered Ozark hills which cover the majority of the forest. The Ozark hills present some of the most rugged terrain in Illinois and yield sites with high erosion potential due to deep loess which is relatively unconsolidated compared to soil from other parent material (Fenneman, 1938). The southern Illinois region and Union county are part of the central hardwood region of the United States (Figure 3-4). This region has been subjected to a wide range of silvicultural practices and disturbances, including wildfires and clearcutting for agricultural land use (Ozier, etal. 2006). Historically, due to frequent surface fires and periodic timber harvesting, Quercus and Carya species flourished in this region (Robertson & Heikens 1994; Ruffner & Groninger, 2004). However, the widespread suppression of fire and reduced timber harvesting in the past 100 years have led to increased dominance of shade tolerant mesophytic species (Ruffner & Groninger, 2006)

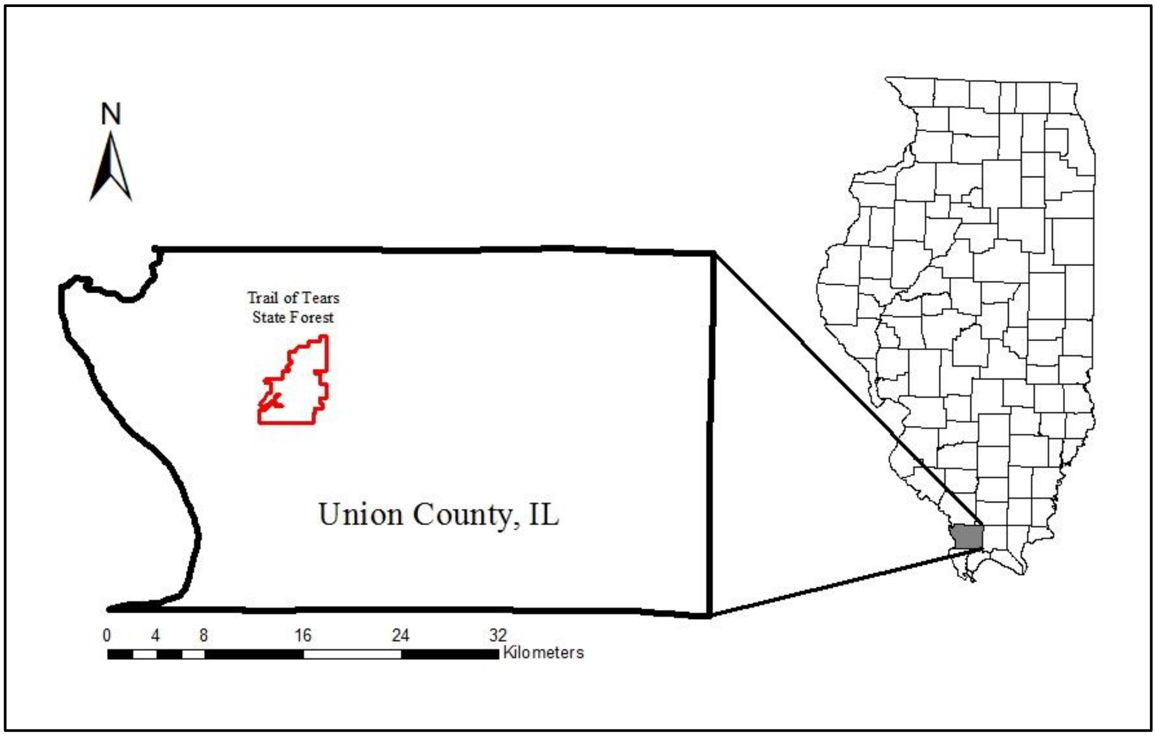

Figure 3-1. Map showing the location of Trail of Tears State Forest within Union County, IL.

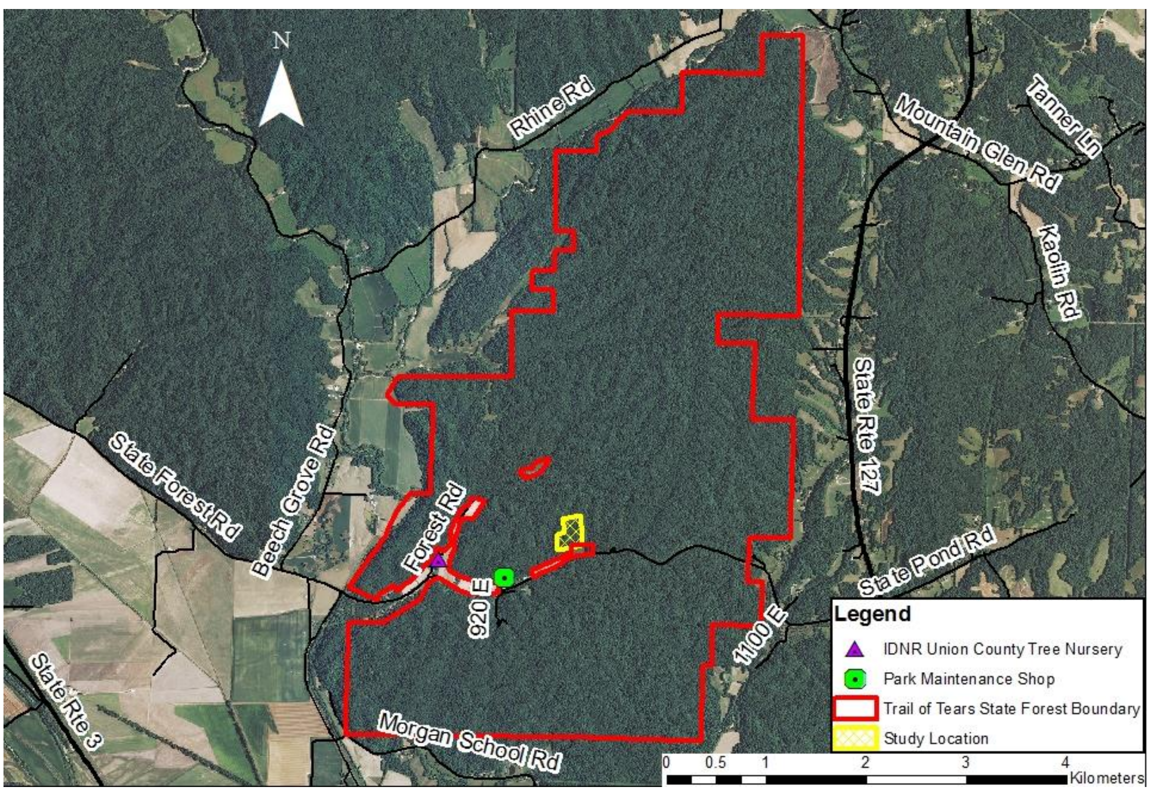

Figure 3-2. Map showing the study location within the ~2000 hectare Trail of Tears State Forest boundary.

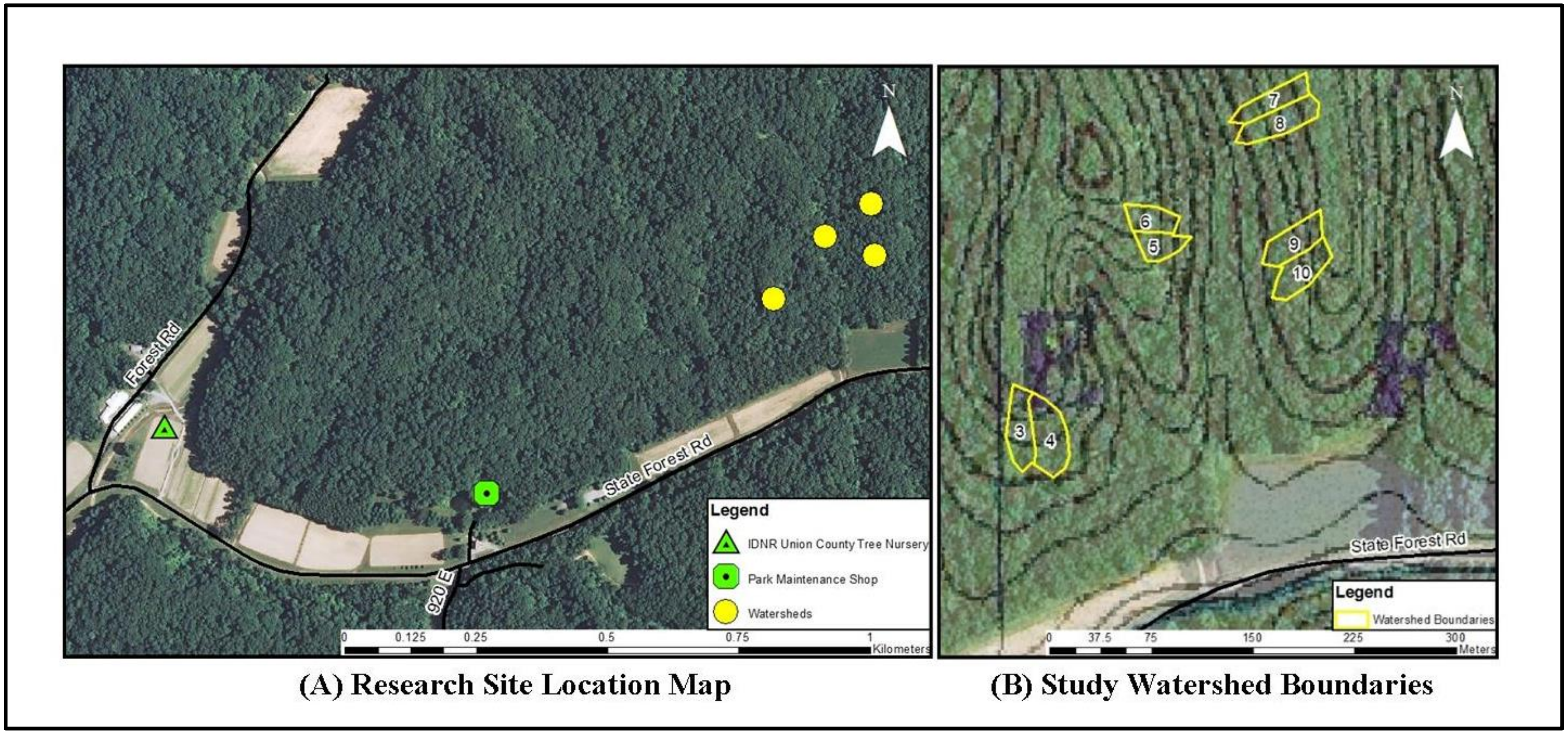

Figure 3-3. **(A)** Research site location at Trail of Tears State Forest in the Ozark hills of southern Illinois **(B)**. Map showing study watershed boundaries on a topographic map of Trail of Tears State Forest (Township 12 South, Range 2 West, Section 8) (Latitude 37.485504; Longitude -89.364989)

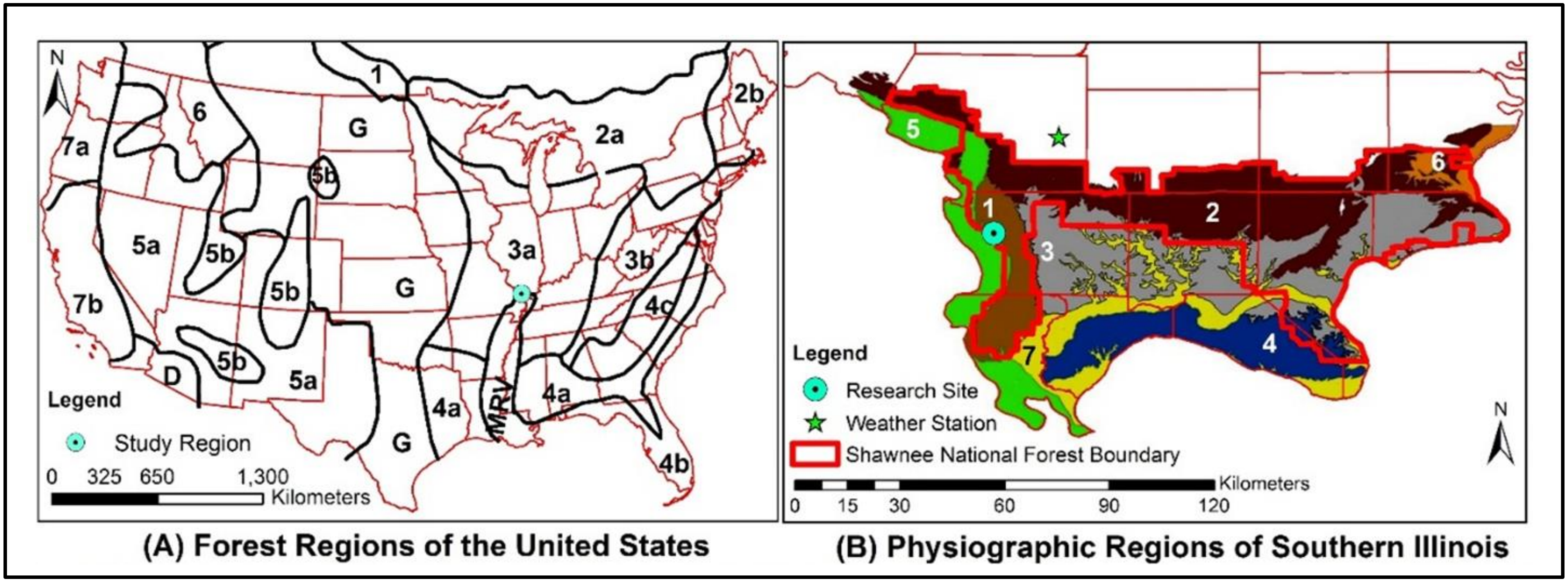

Figure 3-4. (**A**) Forest regions of the United States: (1) Northern Conifer-Hardwood forest, Aspen Parkland; (2a) Northern Hardwood-Conifer Forest (Sugar Maple-Yellow Birch-American Beech-White Pine Forest), Great Lakes Section; (2b) Northern Hardwood-Conifer Forest, New England Section; (3a) Central Hardwood Forest (Oak-Hickory and mesophytic elements), Plateaus section; (3b) Central Hardwood Forest, Appalachian Mountain section; (4a) Southeastern Pine-Hardwood Forest, Upper Coastal Plain; (4b) Southeastern Pine-Hardwood Forest, Lower Coastal Plain; (4c) Southeastern Pine-Hardwood Forest, Piedmont Plateau; (5a) Southwestern Juniper-Pinyon Savanna; (5b) Central and Southern Rocky Mountain Mixed Conifer Forest; (6) Northern Rocky Mountain Conifer Forest; (7a) Northern Coastal Conifer Forest; (7b) Sierra Nevada Mountain, Southern Coastal Conifer Forest. Other zones include grassland (G), desert (D), and the Mississippi River Valley (MRV). Adapted from Fralish and Franklin, 2002. (**B**) Physiographic regions of southern Illinois: (1) Illinois Ozark Hills; (2) Greater Shawnee Hills; (3) Lesser Shawnee Hills; (4) Cretaceous Hills; (5) Mississippi River Alluvial Plain; (6) Lower Ohio-Wabash Rivers Alluvial Plain; (7) Ohio-Cache Rivers Alluvial Plains

There are three soil series within the studied watershed boundaries, which include the Menfro silt loam, the Menfro-Clarksville complex, and the Clarksville-Menfro complex (Figure 3-5). There are two dominant soil series descriptions. The Menfro series is a silt loam and is classified as Fine-silty, mixed, superactive, mesic Typic Hapludalfs. The Clarksville series is a gravelly silt loam and is classified as Loamy-skeletal, siliceous, semiactive, mesic Typic Paleudults ("Web soil survey", n.d.). The climate of the region can be described as continental, with hot humid summers and cool to cold winters. The average temperature for the region is 13.8 °C, and average annual precipitation is 1163 mm (Ozier, etal., 2006)

Five paired watersheds were installed, which encompassed all aspects to include the microclimates that occur within the mixed hardwood ecosystem. Watersheds 1 & 2 (Pair 1) are north facing, watersheds 3 & 4 (Pair 2) face south, watersheds 5 & 6 (Pair 3) face east, watersheds 7 & 8 (Pair 4) face west, and watersheds 9 & 10 (Pair 5) also have a west aspect. Watersheds 7 & 8 are of steep topography and were specifically selected for this reason (Table 3-1). After the first few rain events, observations showed that karst topography was influencing the hydrologic behavior of watersheds 1 & 2 resulting in the removal of them from the study. Variables used to establish these similar characteristics include: slope (%), area (m^2), tree species composition and soil series.

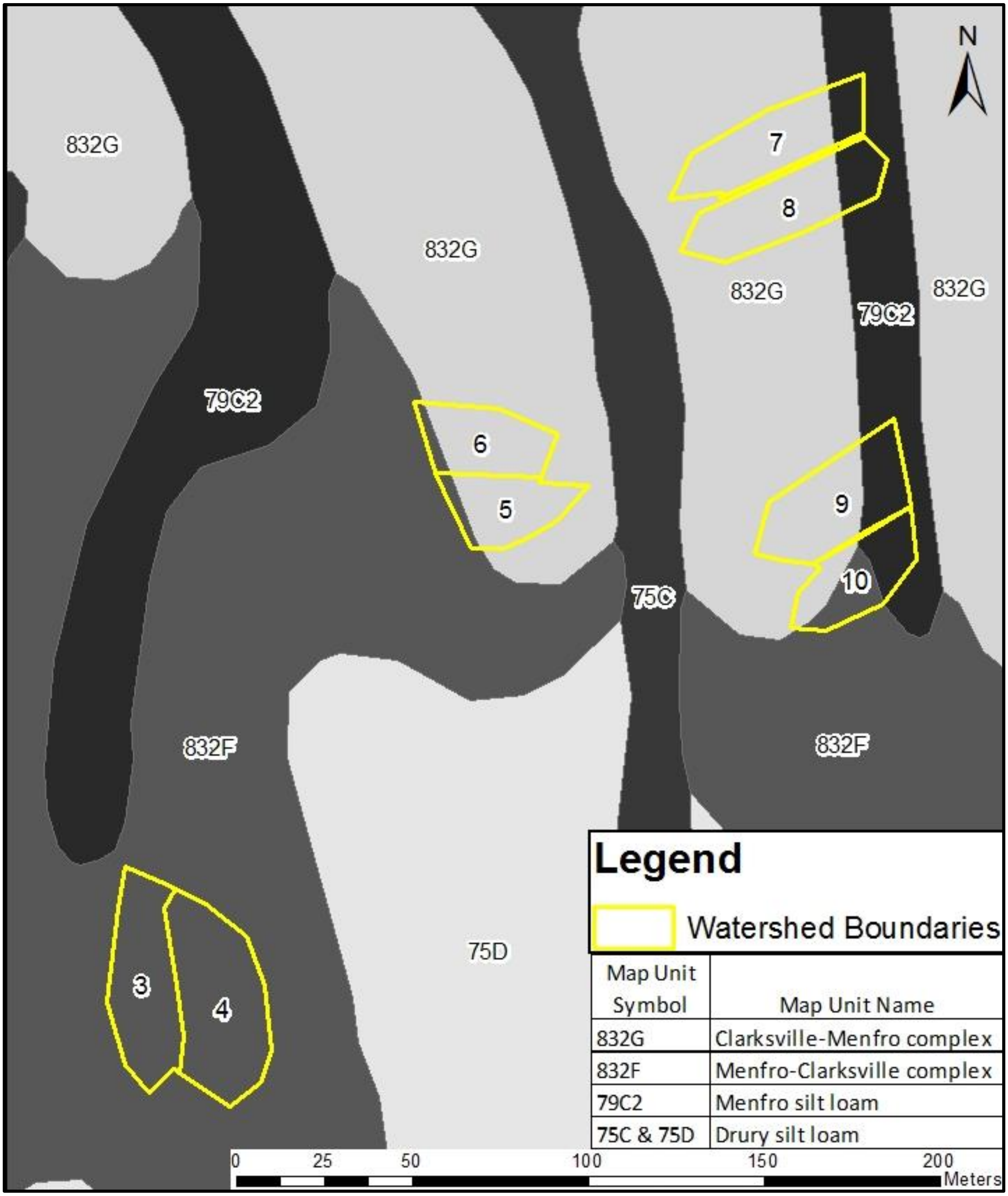

Figure 3-5. Map of official soil series within the studied watershed boundaries.

Table 3-1. Slope (%), Slope Range (%), Area (m^2), and Area (ha) of experimental watersheds at Trail of Tears State Forest.

Watershed	**Slope (%)**	**Slope Range (%)**	**Area (m^2)**	**Area (hectares)**
Unburned				
3	18.1	5.0-68.8	1083.2	0.11
6	21.3	3.4-44.7	640.9	0.06
8	24.8	2.2-58.3	1088.3	0.11
9	21.6	2.2-45.8	608.8	0.06
Burned				
4	18.6	0.1-42.9	1223.1	0.12
5	21.6	0.0-43.7	659.4	0.07
7	24.6	1.8-72.4	1030.5	0.10
10	18.9	1.7-42.8	914.3	0.09

Three weather stations near TTSF were used to calculate the mean temperature and mean precipitation for the region. The three locations of the weather stations are Cape Girardeau Municipal Airport (Cape Girardeau, MO), Grand Tower 2N (Grand Tower, IL), and the Carbondale Sewage Plant (Carbondale, IL). The average total rainfall in the region from 1971 through 2000 was 109.02 cm (45.92 in). The mean annual temperature in this region from 1971 through 2000 is 13.42 degrees C (56.15 degrees F). No data was available for the average mean temperature from the weather station in Grand Tower, IL (“Local climate”, n.d.). A tipping bucket rain gauge was also installed at TTSF to provide more site specific data during the study (Photograph 3-1).

Photograph 3-1. Tipping bucket rain gauge that was installed at the TTSF study location to provide site specific precipitation data.

Field Procedures

Pre Burn Data Collection

A Topcon ® total station was used to delineate watershed boundaries and calculate average watershed slopes by creating a digital elevation model (DEM) for each watershed (Appendix-1). The watershed boundaries were marked by walking their perimeter and hanging flagging along the boundary then delineated using GPS equipment and GIS software. Figure 3-5 shows an example of the DEM's created for paired watersheds 3 and 4.

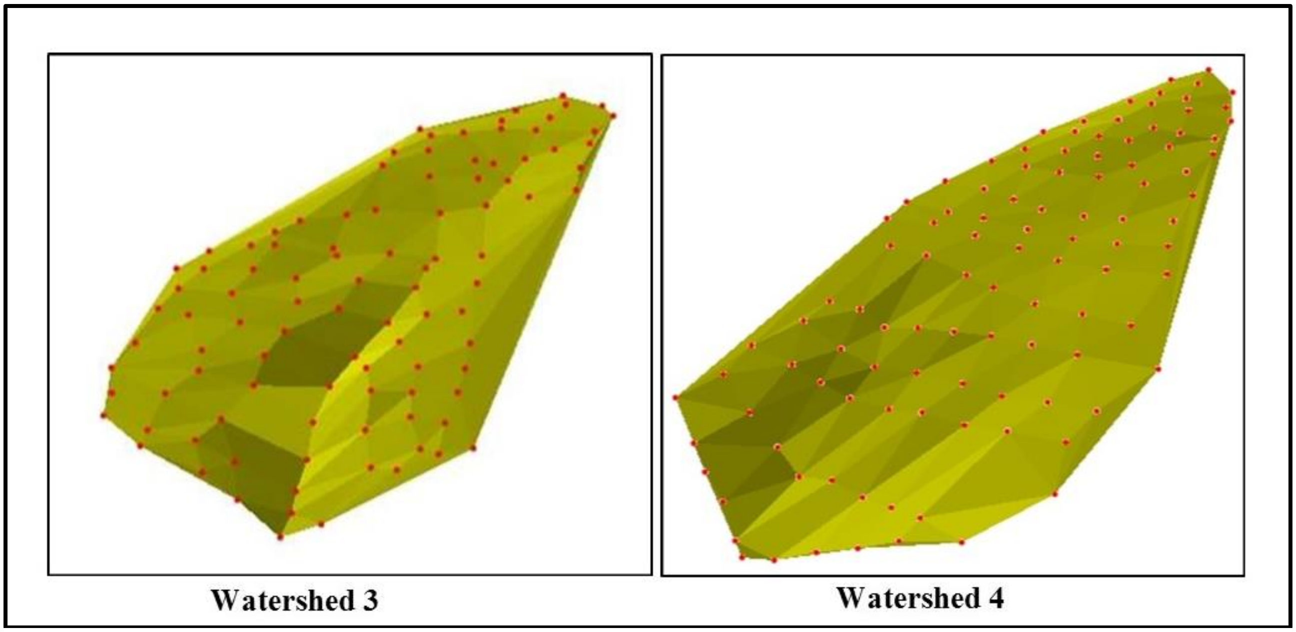

Figure 3-6. Watershed pair 3 & 4 digital elevation models (DEM).

Litter depths were taken at 30 cm upslope from each of the 18 erosion pins within each of the ten watersheds prior to the prescribed burn. The litter depth was used to determine if the paired watersheds have similar amounts of surface organic matter accumulation and to help quantify burn severity and burn intensity after the prescribed fire. Measurements were taken by placing a ruler into the leaf litter and measuring (centimeters) from the soil surface to the top of the highest leaf curl. Soil moisture (volumetric water content) was collected at 30 cm downslope of the 18 erosion pins within each of the ten watersheds prior to the prescribed fire. A Field Scout time-domain reflectometer (TDR) probe was used to determine pre-burn soil moisture on November 5, 2009. Soil moisture was taken again following the burn so that comparisons could be made between pre and post burn volumetric water content at a soil depth of six inches. Weather conditions (i.e. temperature, wind speed, humidity, time) was also monitored before and during the prescribed burn.

Installation of Sediment Collection Equipment

To assess scour and deposition 18 rebar erosion pins were installed randomly throughout the watersheds, including ridges, side slopes, and channels. Erosion pins were constructed from 9.5 mm rebar cut into 61 cm lengths, with 12.7 mm fender washers welded to the rebar in the center of the rebar. Rebar were pressed into the ground until the washer was flush with the surface of the soil (Photograph 3-2). The erosion pins were measured one year following the burn. Each watershed outlet was equipped with a 45 cm wide, galvanized metal flume that was fabricated by a local sheet metal shop in Carbondale, IL. To prevent water from bypassing the flume, 61 cm x 243 cm galvanized steel sheets were oriented with the long side on the ground and buried ~30 cm deep on each side of the flume. The sheets were buried at an angle and were connected to the front sides of the flume with screws and sealed with silicon (Photograph 3-3). At the downslope edge of the flume a 10-cm diameter pvc pipe with a 10-cm elbow was attached to a collar on the flume to route runoff into a 1150 L polyethylene tank. Each tank was calibrated and the side of the tank was labeled in 20 L intervals (Photograph 3-4). The tank was installed on a flat pad below the watershed outlet to allow the water from the pvc pipe to flow into the tank via gravity (Photograph 3-5). The technique for constructing each pad varied base on topography, but all functioned similarly. Some of the pads were created by digging into the hillside and creating a flat surface, while others were constructed by burying posts in the hillside and building a level platform on top to set the tank on (Photograph 3-6).

Photograph 3-2. Erosion pin installed flush with the soil surface.

Photograph 3-3. Installation of galvanized metal flume.

Photograph 3-4. Tanks were pre calibrated and labeled every 20 L to ensure accurate volume totals per storm event.

Photograph 3-5. Complete set up of flume and tank design.

Photograph 3-6. Installation on level tank platform and on leveled earthen surface.

The Prescribed Burn

The prescribed burn was performed on November 6, 2009 beginning at approximately 1100 am by SIU Fire Dawgs, an SIU student wildland fire crew lead by Dr. Charles Ruffner. The day before the fire, fire lines were installed using council rakes and backpack blowers, and then resurveyed the morning of the fire to ensure clean lines. A 10-hour fuel moisture stick that was located on-site was measured (weighed in grams) the morning of the burn to provide an accurate moisture content of 10-hour dead fuels. The TTSF is home to timber rattlesnakes, which are state threatened species. Prescribed burn staff completed a walkthrough of each watershed before ignition began in order to check downed logs and other potential snake hiding spots to prevent fire-related mortality. Watersheds ranged in slope from 18-25 %, so backing fires were used to improve the fire line (Table 4-2). Once fire lines were deemed sufficient, the ignition sequence was completed using a ring-head fire. During the burn, wind speeds ranged from 2-6 mph, the average relative humidity was 40%, and the air temperature was 23^{o}C. Mop-up was performed immediately following the burn where downed logs and standing dead trees could spread embers into unburned fuel across the line. The site was revisited the day after the burn to make certain that no fires reignited during the night.

Photograph 3-7. Example of how the backing fire was used to improve the fire line before continuing the ignition process by lighting the ring-head fire in watershed 4 on November 9, 2009.

Photograph 3-8. Photograph showing the completion of the ring-head fire ignition sequence in watershed 10.

Photograph 3-9. Photograph showing the completion of the prescribed burn treatment in Watershed 10.

Post Burn Data Collection

Post-fire data collected within each plot included: surface temperature of the fire, soil erosion or accumulation, total volume of overland flow collected, and total concentration and mass of suspended solids and sediment collected. To characterize burn severity and intensity, five hobo thermometers were buried in each watershed before the prescribed burn occurred and then data were downloaded following the burns (Appendix-2). The 18 preinstalled erosion pins in each watershed were measured one year after the burn to observe and quantify the extent of sediment erosion or accumulation at different locations within each watershed.

Vegetative Data Collection Procedures

Forest inventory plots were taken within all study watersheds to determine species composition by density (stems ha^{-1}), basal area (m^2 ha^{-1}), and relative density (%) (Appendix-3). Each watershed contained two sample plots that did not overlap each other. The two points which became plot center were randomly located within the watersheds. Each random point was used as the center for three nested plots of 3.05 meter, 7.62 meter, and 15.24 meter diameters (Fralish, 1994). Within each 15.24 meter diameter plot, species and diameter at breast height (dbh) were recorded for each tree greater than 9 cm dbh. The 7.62 meter diameter plots were used to determine sapling density of stems measuring 2 cm to 9 cm at dbh. The 3.05 meter diameter plots were used to determine seedling density by measuring stems less than 2 cm (Photograph 3-10).

Photograph 3-10. Example of seedling data collection within the 3.05 meter nested plot.

Water Sampling Procedures

The total volume of water leaving the mouth of the watershed was collected during each storm event. During very large rainfall events runoff collectors were disconnected from the flume once filled to prevent biased sediment export estimates. The total volume of the water collected in each tank was measured to estimate event loads. After each rain event, the tanks were stirred with a paddle to re-suspend organic material and sediment to create an even mixture. Each tank was mixed for one minute to reduce sampling bias. After the tank was completely mixed, a grab sample from the tank was collected and taken to the laboratory for analysis. After each rain event, tanks were drained and rinsed with clean water in preparation for the next rain event.

Lab Procedures

Water samples were analyzed for both total suspended solid and total suspended sediment (Appendix 3-4). Total suspended solids were determined using the U.S. Environmental Protection Agency method 160.2 (Keith, 1991). Water samples were agitated to re-suspend solids then suction filtered through a Whatman glass microfiber filter to separate the total residue non-filterable suspended solids from the water (Photograph 3-11). Filters were again oven-dried at 105 ^{o}C and then reweighed. Total suspended solids included both inorganic sediment and organic matter. To separate the sediment, samples were placed in a muffle furnace at 550 ^{o}C to combust the organic matter. Following combustion, the sample was again reweighed to determine the final mass of the inorganic sediment in the sample.

Photograph 3-11. Water samples were suction filtered through a Whatman glass microfiber filter to separate the total residue non-filterable suspended solids from the water.

Statistical Analysis

Data were collected from eight watersheds (i.e, 4 pairs), that consisted of a control watershed sharing a topographic divide with a treatment watershed. One watershed in each pair was randomly assigned as the control and the other the prescribed burn treatment. Total suspended solids and sediment were treated as dependent variables in an ANOVA model to test for differences among the watersheds. Within watershed pairs (i.e., pairs based on aspect), two-tailed, unequal variance TTESTs were used to determine difference between pairs during the pre and post treatment period. Dependent variables (i.e., TSS concentration, TSS mass, sediment concentration, sediment mass) were not normally distributed, thus log-transformations were performed in order to address normality assumptions for parametric tests. The log-transformations resulted in normal distributions for all variables. Pearson correlation coefficients were used to examine relationships between site characteristics (i.e., percent slope, litter depth, soil moisture, fire temperature), and rainfall variables (i.e., intensity, duration, and volume) with total suspended solids and sediment. One-way ANOVA models with a Pearson Correlation were used to assess differences between watershed litter depths, fire temperature, and soil moisture. Lastly, the influence of watershed aspect and the burn treatments were analyzed using a two-way ANOVA model. SAS was used for all statistical analyses and an alpha level of 0.05 was used to determine statistical differences (SAS Institute, Cary NC)

CHAPTER 4

RESULTS & DISCUSSION

Precipitation and Rainfall Intensity

The 30 year mean total annual rainfall in the region from 1971 through 2000 was 109 cm (45.9 in). During 2009 and 2010 there was 133 cm (52.2 in) and 100 cm (39.5 in) of precipitation, respectively. The total precipitation for the study period of September 21, 2009 through September 16, 2010 was 121 cm (47.5 in), which was only 4.1 cm (1.6 in) higher than the 30 year average. When broken into monthly totals, the month with the highest precipitation was October, 2009 (25.60 cm) and the month with the lowest precipitation was August, 2009 (3.28 cm) (Table 4-1). The total number of rainfall events during the study period was 85, 31 of which were large enough to produce runoff in at least one watershed. A total of 213 runoff samples were collected over the study period. One extreme runoff event, on October 30, 2009, was not included in the final analysis because all of the collection tanks overflowed prior to sampling. The event produced 1.82 in (4.62 cm) of rainfall and immediately followed a rain event two days prior, so antecedent soil moisture was high.

Rainfall intensity and duration of storm events were evaluated based on time of sampling (Appendix-4). Some of the sampling tanks continued to fill up after the storm event had ended. The lowest intensity storm event that produced runoff was recorded on 3/12/10 with an intensity of 0.0049 cm/hr. The highest intensity of 0.5266 cm/hr was recorded on 5/1/10 in watershed 5. The intensity for each watershed during this storm event varied based on time of sampling. Duration until sampling ranged from 1.016 hours in watershed 5 on 5/1/10 to 26.55 hours in watershed 7 & 10 on 3/21/10. Duration of storm event was also calculated at time of sampling. Pearson correlation determined that the mean volume of overland flow sampled per watershed was larger when rainfall duration (P = 0.01) was longer and intensity (P <.01) was higher. Pearson correlation coefficients were also used to determine if intensity and duration were correlated with TSS and sediment concentrations or mass loss. Of these variables, only the duration of the storm event compared to the TSS concentration was found to be statistically significant at (P = 0.04).

Table 4-1. Monthly precipitation totals during the study period (2009-2010) at Trail of Tears State Forest, IL.

Year	Month	Precipitation (cm)	Sampled Events
2009	September	7.16	1
2009	October	25.60	6
2009	November	3.84	2
2009	December	13.74	3
2010	January	5.97	2
2010	February	3.38	1
2010	March	13.97	4
2010	April	11.56	3
2010	May	13.84	3
2010	June	7.14	0
2010	July	7.26	0
2010	August	3.28	0
2010	September	8.59	1

The total precipitation and rainfall intensity was collected in a rain gauge located in an adjacent field to the research site. Several studies have shown that forest canopy storage, bark water storage capacity (BWSC), stemflow, and throughfall interception further reduce the total precipitation and rainfall within a forested ecosystem (Keim, etal., 2006; Trimble & Weizman, 1954; Helvey & Patric, 1965; Brown & Barker, Jr., 1979; Levia Jr. & Wubbena, 2006). Although the benefits of canopy storage and throughfall interception are reduced during the dormant season, the retention and interception of rainfall by the stems of woody vegetation still reduce total precipitation and rainfall intensity (Keim, etal., 2006; Levia Jr. & Wubbena, 2006).

These phenomena would explain why duration was a statistically significant factor when compared to TSS concentration ($P = .04$). The longer events saturated the vegetation, which then allowed the rain to reach the ground for an extended period. Less of the rainfall from shorter events would reach the ground and produce little if any overland flow.

Watershed Characteristics

Slope and Area

All delineated watershed pairs used in the study had similar physical characteristics. The average percent slopes were similar among the watersheds, with a 6.7 percent difference between the most gradual and the steepest slopes (Table 4-2). Watersheds 7 & 8 were selected to represent "extreme" slope conditions for the region. When removing these two watersheds, there is only a 3.5 percent difference in the average percent slope among the remaining watersheds. The watershed areas were also comparable, ranging from 640.9 m^2 to 1223.1 m^2 (Table 4-2).

Table 4-2. Physical characteristics of the 8 experimental watersheds at Trail of Tears State Forest.

Watershed	Slope (%)	Slope Range (%)	Area (m^2)	Area (hectares)
Unburned				
3	18.1	5.0-68.8	1083.2	0.11
6	21.3	3.4-44.7	640.9	0.06
8	24.8	2.2-58.3	1088.3	0.11
9	21.6	2.2-45.8	608.8	0.06
Burned				
4	18.6	0.1-42.9	1223.1	0.12
5	21.6	0.0-43.7	659.4	0.07
7	24.6	1.8-72.4	1030.5	0.10
10	18.9	1.7-42.8	914.3	0.09

Species Composition

Across all watersheds the three most dominant mature tree species (>9 cm) were *Acer saccharum* (28%), *Quercus alba* (20.5%), and *Quercus rubra* (12.9%). The three most prevalent sapling species (2-9 cm) were *Acer saccharum* (47.2%), *Fagus grandifolia* (20.8%), and *Ostrya virginiana* (7.5%). The most abundant seedlings (<2 cm) were *Fagus grandifolia* (11.3%), *Quercus alba* (11.3%), *Nyssa sylvatica* (10.5%), and *Ulmus americana* (10.5%) (Table 4-3) (Appendix 4-1). Species composition, including basal area, mature trees, seedlings, and saplings by watershed were not statistically significant independent variables that influenced the dependent variables (i.e., TSS concentration, TSS mass, sediment concentration, and sediment mass).

Table 4-3. Basal area and stem density summaries for the 8 experimental watersheds at Trail of Tears State Forest.

Watershed	**Aspect**	**Basal Area (m^2 ha^{-1})**	**Mature Trees ha^{-1} (>9 cm)**	**Saplings ha^{-1} (2-9 cm)**	**Seedlings ha^{-1} (<2 cm)**
Unburned					
3	South	31.1	411.5	794.5	9781.0
6	East	17.0	356.5	1096.5	4109.5
8	West	42.6	493.0	767.5	21918.0
9	West	31.3	384.0	877.5	13013.5
Burned					
4	South	54.6	493.5	109.5	10274.0
5	East	44.7	356.5	329.0	9589.0
7	West	38.1	548.0	438.5	5479.5
10	West	30.7	576.0	767.5	5479.5

Litter Depth

Litter depths were initially measured throughout each experimental watershed prior to the implementation of the prescribed burn and again post burn (Appendix-5). No statistical differences were found between mean litter depths between individual pre burned watersheds. Average pre burn litter depths were grouped by watershed aspect, which showed a significant difference between west facing watersheds (4.01 cm) compared to east (4.64 cm) and south (4.64 cm) facing watersheds (Figure 4-1). Although a statistically significant difference was documented between the watersheds by aspect, these data showed that the average litter depths between the watersheds were within 1.04 cm.

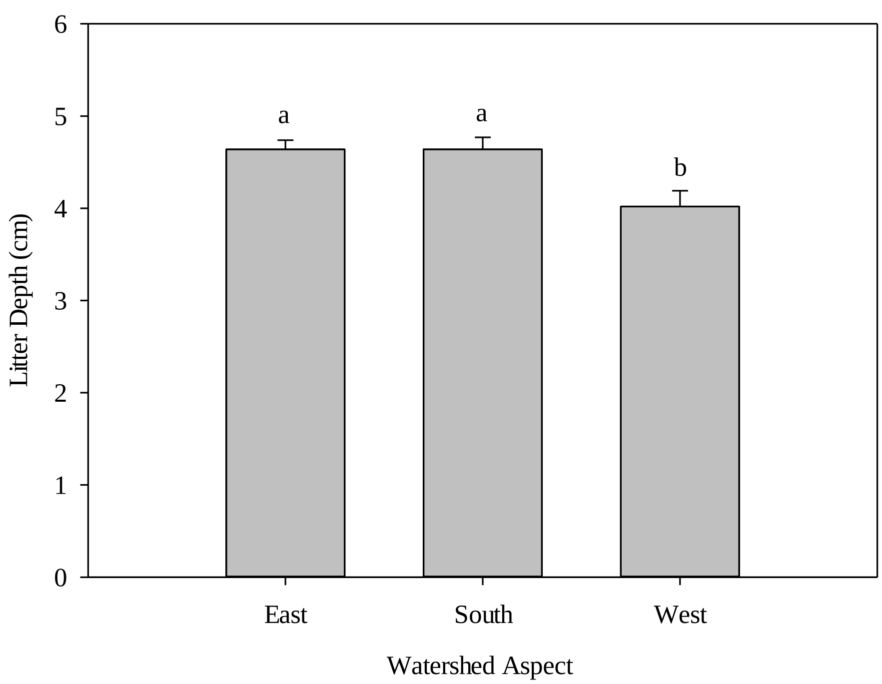

Figure 4-1. Mean (±1 standard error) pre burn litter depth based on watershed aspect.

Pre burn litter depths among all watersheds were similar (P > .01) (Table 4-4). Post burn litter depths were significantly different among control and treatment watersheds (P < .01) (Table 4-4). Litter depths in the control watersheds remained the same. The unconsolidated litter and fine fuels were mostly consumed in all burned watersheds, leaving the humus layer exposed (Table 4-4) (Photograph 4-1). The percent of litter depth remaining in treatment watersheds post burn had some variation. Watershed 4 had 12.6 percent of the litter remaining post burn, whereas watershed 5 was left with 13.0 percent, watershed 7 with 31.5 percent, and watershed 10 with 30.3 percent. Watershed 7 was very incised or V-shaped which caused leaf litter to accumulate in the channel. This leaf litter was compacted, held moisture, and was not fully consumed during the prescribed burn. This unconsumed litter explains why 31.5 percent of the litter remained post burn. Litter depths were not determined to have statistically significant impact on TSS concentration (P = 0.81), TSS mass (P = 0.19), sediment concentration (P = 0.65), or sediment mass (P = 0.21) loss. Prescribed burns generally leave portions of the forest floor intact because they rarely consume fuels uniformly over the entire area (Van Lear & Waldrop, 1989). A study in Arkansas by Moehring, etal., 1966 found that low intensity burns over a decade left 36 percent of the forest floor by weight intact. Boerner etal.(2000) conducted a prescribed burn in mixed hardwoods of southern Ohio which did not consume 60 percent (± 5 percent) of the unconsolidated leaf litter. Sweeney and Biswell (1961) concluded that 24 percent of the litter and 77 percent of the duff layer remained after four prescribed fires under California ponderosa pine, and that the remaining litter were sufficient to cover the soil. Treatment watersheds in this study exhibited similar results and had leaves, detritus, fine roots, sticks, and rocks remaining on the soil surface ~5 months post burn (Photograph 4-2).

Table 4-4. Average Pre- and Post-burn litter depth and soil moisture for experimental watersheds at Trail of Tears State Forest, IL.

Watershed	**Average Litter Depth (cm)**		**Average Soil Moisture (%)**†	
	Pre-Burn	Post-Burn	Pre-Burn	Post-Burn
Unburned				
3	4.50a††	.a†††	22.0ab††	22.2a††
6	4.66a	.a	25.2ab	24.0a
8	3.92a	.a	22.2ab	23.3a
9	3.73a	.a	24.0ab	24.0a
Burned				
4	4.77a	0.6b	26.3a	25.8a
5	4.63a	0.6b	19.8b	19.1a
7	4.13a	1.3b	24.9ab	22.6a
10	4.29a	1.3b	25.6ab	25.4a

†Volumetric Water Content
††Within a column, different letters represent significant differences at α=0.05.
†††Post burn litter depths in control watersheds were assumed the same and not remeasured due to short time window.

Photograph 4-1. Representation of litter consumption following the prescribed burn treatment in watershed 4 at Trail of Tears State Forest, IL.

Photograph 4-2. Watershed 4 close-up image taken on April 19, 2010, which shows leaves, detritus, fine roots, sticks, and rocks that remain ~5 months post burn.

Soil Moisture (Volumetric Water Content)

Soil moisture content was taken throughout each delineated watershed prior to the implementation of the prescribed burn and again post burn (Table 4-4) (Appendix-6). Soil moisture was very consistent throughout treatment and control watersheds. Pre burn soil moisture content was higher in watershed 4 (26.3 %) than 5 (19.8 %), but similar across all other watersheds ($P = 0.01$). There was no statistical difference ($P = 0.08$) between watersheds based on post burn soil moisture content. Volumetric water content did not significantly influence TSS concentration ($P = 0.15$), TSS mass ($P = 0.07$), sediment concentration ($P = 0.10$), and sediment mass ($P = 0.07$). Danielovich, etal., 1987 concluded that having adequate soil moisture is an important component when determining the consumption of leaf litter. Van Lear & Waldrop, (1989) stated that prescribed burns conducted when surface fuels are cured and soil moistures were high, provided advantages to soil protection.

Prescribed Burn

The prescribed burn for the study was performed on November 6, 2009. An *in situ* 10 hour fuel moisture stick was weighed at 109 grams, which is equivalent to a 10 hour fuel moisture content of 9 percent. Following the safety briefing, the initial firing began at 1100 CST and all study watershed burns were completed by 1300 CST. Weather conditions were monitored throughout the prescribed burn. Air temperatures ranged from 20.3 °C to 24.9 °C. Humidity started out at 43 percent, but dropped to 37 percent by the end of the prescribed burn. Winds were from the south to southwest at 2-6 mph (Table 4-4).

Table 4-5. Prescribed burn on-site weather conditions during the burn on November 06, 2009 at Trail of Tears State Forest, IL.

Time (CST)	**Temp (°F)**	**Temp (°C)**	**Humidity (%)**	**Wind Speed**	**Wind Direction**
1100	68.5	20.3	43	2-5	S-SW
1200	74.8	23.8	39	2	S
1300	76.8	24.9	37	4-6	S

The highest maximum temperature (281.6 ˚C) was in the West facing aspect of watershed 7. The lowest maximum temperature (191.8 ˚C) was in the West facing aspect of watershed 10. Similar average prescribed burn temperatures of 210 ˚C under mixed hardwoods in southern Ohio were recorded in a study by Boerner, etal. (2000). The average max temperatures of the fire in each of the four treatment watersheds were not statistically different from one another (P = .11) (Table 4-6). Since there were no statistical differences in max temperatures among watersheds, max temperatures were disregarded as an independent variable influencing total sediment loss.

Table 4-6. Max temperature (°C) at 30 cm above the soil surface for burned watersheds at Trail of Tears State Forest, IL.

Watershed	Max Temperature (°C)†	Aspect
4	207.4a††	South
5	218.6a	East
7	281.6a	West
10	191.8a	West

†Max Temperatures were taken from an average of five hobo thermometers placed throughout each watershed.
††Different letter within a column represent significant differences at $\alpha = 0.05$.

Total Suspended Solid and Total Sediment Concentration and Mass by Paired Watersheds

Total suspended solid concentrations include sediment and organic matter extracted during vacuum filtration from each sample. Pre burn total suspended solid concentrations were higher in all watersheds except watersheds 5 and 10 (Figure 5-2). Watersheds 5 and 10 underwent the prescribed burn treatment. Both of these watersheds slightly flattened out at the bottom before the placement of the flume. This could have resulted in reduced runoff velocities and allowed the TSS to settle before entering the flume (Liu, etal., 2000; Wu & Sidle, 1995). The highest pre burn TSS concentration was in watershed 3 (0.24g L^{-1}); however, only one pre burn sample was collected for watershed 3 on 10/7/09. The tank volume was only 4.5 liters of water following a 1.1 inch rain event, leading to a concentrated sample. The lowest pre burn concentration was in watershed 8 (0.03g L^{-1}). Watershed 8 likely received the lowest concentration of pre burn TSS because of the compacted layer of leaf litter that accumulated in the channel of this V-shaped drainage (Photograph 4-2). The leaf litter would help trap the smaller particles of detritus before it reached the flume or prevent the movement of the detritus layer (Sayer, 2005; Knapp, etal., 2005; Harmon, etal., 1986).

The highest post burn TSS concentration was in watershed 5 (0.25g L^{-1}). Watershed 5 had elevated pre (0.20 g L^{-1}) and post (0.25 g L^{-1}) burn TSS concentration levels compared to all other watersheds (± 95% confidence interval). Post burn sediment concentrations were significantly higher for watershed 5 compared to the other treatment watersheds. This indicates that the pre burn litter layer was not the only variable that influenced the TSS and sediment concentrations in Watershed 5. Observations during sample collections revealed a seep that existed directly above the flume of watershed 5. The seep was not noticed pre burn because of the leaf litter that was present. The elevated levels of TSS mass pre burn showed that the seep likely was present throughout the entire study. The Clarksville-Menfro soil complex make up the soils in the study watersheds. These soils are formed over karst, or a region comprised of porous limestone with many fractures and fissures (White, 1988). During rain events over karst landscapes, water percolates into the soil where it can then enter a chain of macropores, fractures, fissures, and sinkholes (Gale, 1984; Uchida, etal., 2001). Parallel movement of water, through soil macropores, is commonly referred to as 'pipeflow' or 'soil pipes' (Uchida, etal., 2001). Subsurface flow of water, or 'pipeflow' can in some instances return to the soil surface through a seep. Seeps, or springs with low flow rates, are formed from water and sediment that follow a natural course of voids in bedrock, then discharge or resurge to the soil surface (Reed, etal., 2010). Allochthonous sediments (sediments transported into a karst aquifer) and autochthonous sediments (sediments originating within a karst aquifer) (Peterson & Wicks 2003), that return to the surface through a seep would increase sedimentation (Krekeler etal., 1997; Mahler etal., 1999; Ryan & Meiman, 1995). The seep from the hillside of watershed 5 increased TSS mass and sediment by allowing subsurface sediment to resurface and enter the flume before having a chance to settle out within the watershed.

Watershed 7 & 8 both had the lowest levels of post burn concentrations of TSS (0.02g L^{-1}). (Figure 4-3). Since these paired watersheds received different treatments, the low levels of TSS concentration post burn were likely unrelated to the prescribed burn. Watershed 8 was a control, so the leaf litter remained throughout the watershed during the entire study period. The high moisture content of the compacted litter in the channel of watershed 7 prevented it from being consumed by the prescribed burn and thus creating a common denominator between the paired watersheds post burn. Both watersheds had a large amount of compacted litter in the thalweg of the drainage that would slow the overland flow and act as a filter, and suppress rill erosion (Sayer, 2005; Knapp, etal., 2005).


Photograph 4-3. Picture of watershed 7 on the left & 8 on the right, which show the incised or V-shaped channel with litter accumulation.

Watershed 10 resulted in higher TSS concentrations compared to paired watershed 9. No significant differences were found in TSS and sediment concentrations between watersheds 9 and 10 (Figure 4-3). Watershed 9 was a control watershed, but also had coarse woody debris that existed within the channel, acting as a dam. The woody debris was trapping TSS and sediment before it reached the flume (Photograph 4-3). This was a contributing factor that led to the low post burn TSS and sediment levels (Bilby & Likens, 1980; Knapp, etal., 2005; Naiman, etal., 2002; Harmon, etal., 1986; Swanson, 1981). In the publication, Ecology of Coarse Woody Debris (Harmon, etal., 1986), the authors discuss the importance of downed logs on the surface control of downslope movement of sediment and organic matter on forested hillslopes. In a review of fire on geomorphic processes, Swanson (1981), also discusses the importance of downed logs in forested ecosystems. In his review, Swanson describes TSS movement through a watershed and the importance of downed logs in slowing water and storing TSS. A study by Knapp, etal. (2005) evaluated coarse woody debris (CWD) abundance before and after prescribed burning. The study determined that prescribed burns reduce the size and length of CWD, but high moisture content prevented total consumption, allowing the CWD to still function as sediment dams and reduce erosion.

Photograph 4-4. Picture of coarse woody debris that is lying across the drainage of watershed 9.

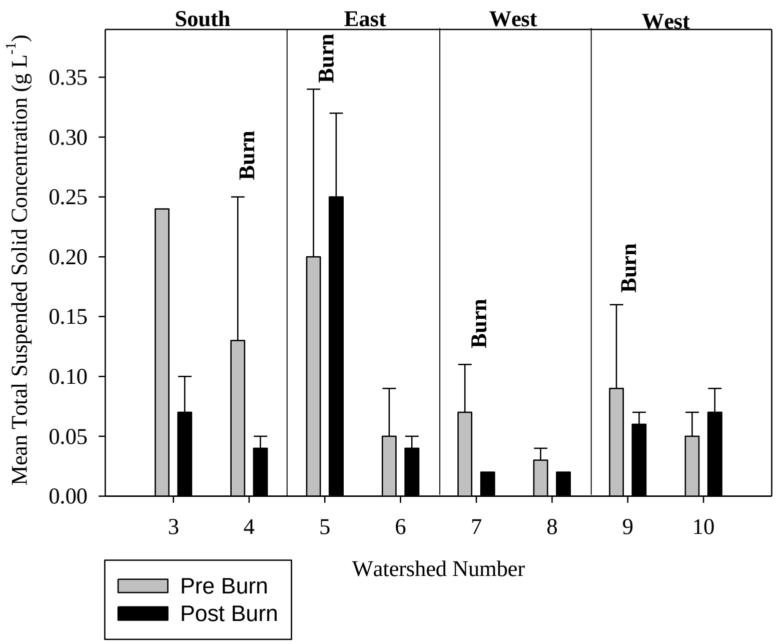

Figure 4-2. Mean (±1 standard error) pre and post burn total suspended solid concentration (g L^{-1}) by watershed at Trail of Tears State Forest.

The lowest total pre burn mean sediment concentration per watershed in watershed 8 (0.01g L^{-1}) and the highest is in watershed 5 (0.17g L^{-1}). Watershed 8 consistently received larger volumes of runoff than many of the other watersheds, which likely decreased concentration levels. The lowest total post burn mean sediment concentration is the same in watersheds 7 and 8 (0.01g L^{-1}). Similar to the pre burn levels, watersheds 7 and 8 received higher volumes of runoff than the other watersheds. These higher volumes would dilute the sample and yield lower concentration levels. The litter accumulation in the thalweg of the watershed could have acted as a filter, also decreasing sediment concentrations (Sayer, 2005; Knapp, etal., 2005). The highest total post burn sediment concentration is watershed 5 (0.23g L^{-1}). Both pre and post burn total sediment concentrations are elevated in watershed 5. This trend mimics the TSS concentration levels and points to the seep above the flume. The mean watershed 3 sediment concentration shows the same pattern as the mean TSS concentration, where the pre burn concentrations are higher than post burn. Another important finding in the mean post burn sediment concentrations is that two of the post burn, burned watersheds (4 & 7) are equal to or less than their paired (3 & 8), unburned watershed (Figure 4-3).

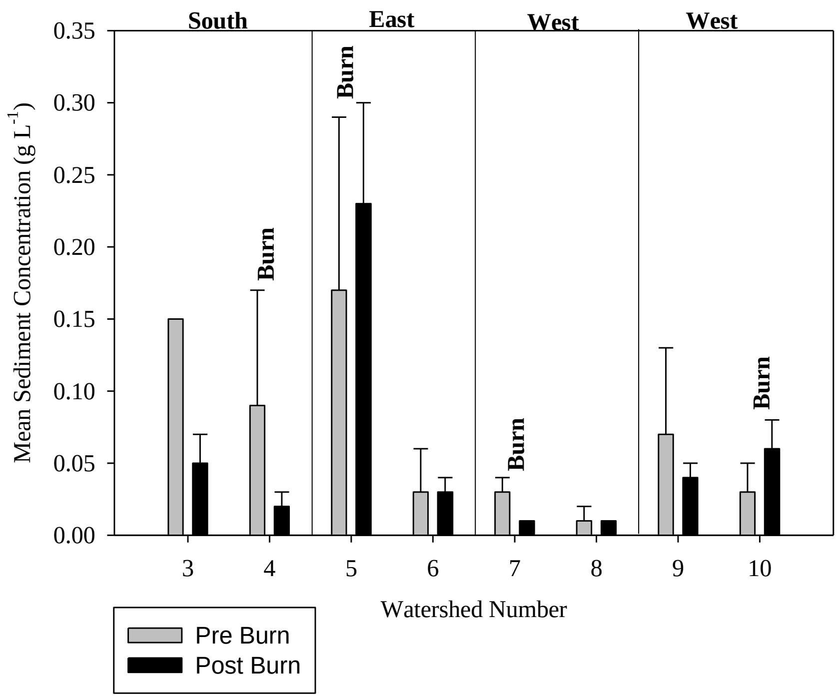

Figure 4-3. Mean (±1 standard error) pre and post burn total sediment concentration (g L^{-1}) by watershed at Trail of Tears State Forest, IL.

Pre burn TSS mass was lower than post burn TSS mass in all watersheds except watershed 8 (Figure 4-4.). The pre to post burn change in the mean TSS mass in watershed 8 was 1.14 grams, which is very minimal. Watershed 8 is V-shaped and had a large amount of leaf litter that accumulated in the channel. The litter layer could have filtered out the TSS and contributed to the only watershed having a slightly lower post burn TSS mass level (Sayer, 2005; Knapp, etal., 2005). The highest pre and post burn TSS mass was in watershed 5 at 40.22g pre burn and 291.20 g) post burn. This high pre and post burn mean TSS mass in watershed 5 is much higher than all other watersheds in the study. The high mean TSS mass totals reinforce the influence of ‘pipeflow’ and the seep directly above the flume as a primary contributing factor. The lowest pre burn TSS mass was in watershed 3 (1.08 g) and the lowest post burn TSS mass was in watershed 9 (6.48 g). Watersheds 3 received low volumes of overland flow which help explain why the TSS concentrations are high but the TSS mass is low.

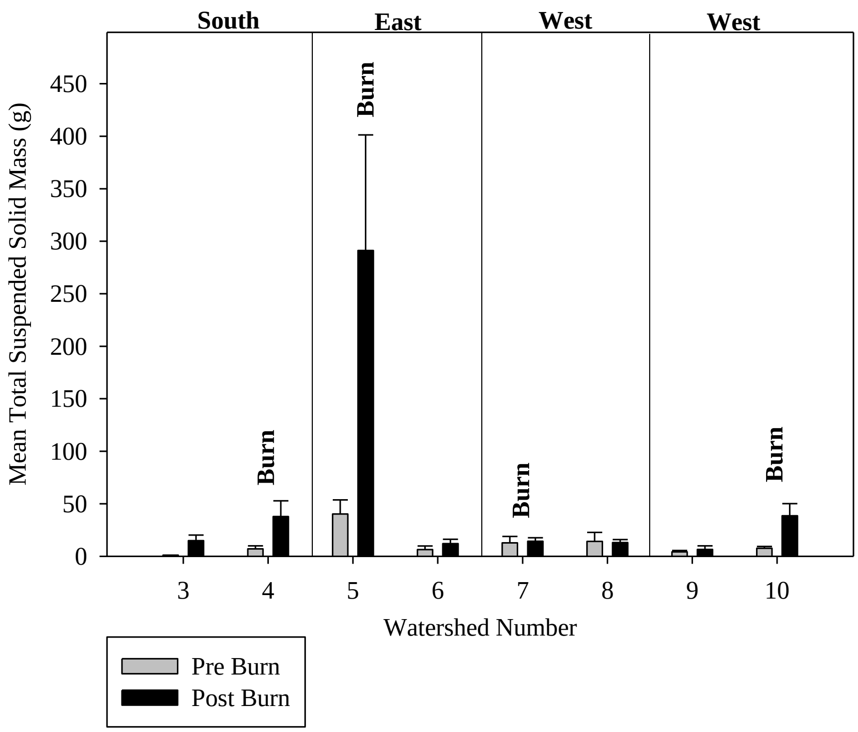

Figure 4-4. Mean (±1 standard error) pre and post burn total suspended solid mass (g) by watershed at Trail of Tears State Forest, IL.

Mean sediment mass by watershed for the study period was higher in all burned watersheds compared to its unburned paired watershed except for watershed 8 (Figure 4-5). The leaf litter accumulation in the drainage of watershed 8 is still the most likely reason for this trend. Watershed 5 is the highest in both pre (34.85 g) and post burn (273.53 g) sediment mass (Figure 4-5). The mean pre burn sediment mass in watershed 5 is 34.85 g, which is more than four times higher than the next closest pre burn mean of 6.43 in watershed 7. The mean post burn sediment mass in watershed 5 is 273.53 g, which is almost a full order of magnitude higher than the next closest post burn mean of 29.96 in watershed 10. This drastically larger pre and post burn mean sediment mass yields continue to point to the seep above the flume in watershed 5. The lowest pre burn mean sediment mass is watershed 3 (0.67g) and the lowest post burn mean sediment mass is watershed 9 (3.7g). The single pre burn water sample received in watershed 3 was small and resulted in the low sediment mass. The low post burn mean sediment rate in watershed 9 is contributed to the large dead woody material that was lying across the watershed (Bilby & Likens, 1980; Knapp, etal., 2005; Naiman, etal., 2002; Harmon, etal., 1986). (Photograph 4-3). The coarse woody debris acts as a natural dam that traps TSS and sediment from reaching the flume.

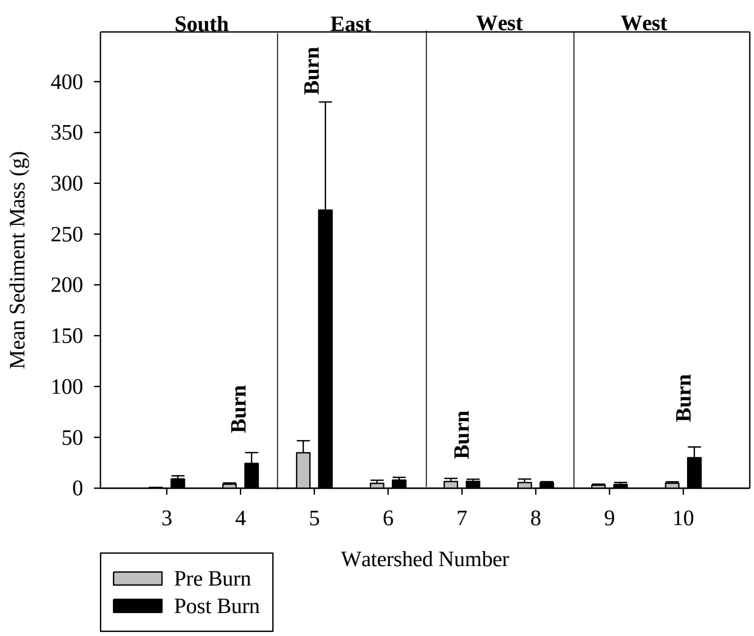

Figure 4-5. Mean (±1 standard error) pre and post burn total sediment mass (g) by watershed at Trail of Tears State Forest.

Total Suspended Solids and Total Sediments Combined by Prescribed Burn and Control

Total suspended solid mean concentration and mass in burned and unburned watersheds were similar for both pre and post burn outputs (TSS concentration pre burn P =.86; TSS concentration post burn P = .43; TSS mass pre burn P = .25; TSS mass post (P = .29)) (Table 4-7) This is also consistent in sediment concentration and mass with similar outputs both pre and post burn (sediment concentration pre burn P = .75; sediment concentration post burn P = .42; sediment mass pre burn P = .31; sediment mass post burn P = .31) (Table 4-8) Table 4-7 indicates that on average, the prescribed burn treatment increased the mean TSS concentration and mass, although they were not found to be statistically different. Mean sediment concentration and mass were also generally higher post burn, but not significantly different (Table 4-8).

Table 4-7. Mean (±1 standard error) total suspended solid concentration (g L^{-1}) and mass (g) between burn and unburned watersheds at Trail of Tears State Forest, IL.

Treatment Average	**Pre Burn TSS Concentration**	**Pre Burn TSS Mass**	**Post Burn TSS Concentration**	**Post Burn TSS Mass**
Burned	0.11±0.03a	16.89±7.87a	0.09±0.05a	95.50±65.47a
Unburned	0.10±0.04a	6.47±2.79a	0.04±0.01a	11.62±1.80a

† Within a column, different letters represent significant differences at α=0.05.

Table 4-8. Mean (±1 standard error) sediment concentration (g L^{-1}) and mass (g) between burn and unburned watersheds at Trail of Tears State Forest.

Treatment Average	**Pre Burn Sediment Concentration**	**Pre Burn Sediment Mass**	**Post Burn Sediment Concentration**	**Post Burn Sediment Mass**
Burned	0.08±0.03a	12.51±7.46a	0.08±0.05a	83.61±63.49a
Unburned	0.06±0.03a	3.43±1.06a	0.03±<0.01a	6.45±1.22a

† Within a column, different letters represent significant differences at α=0.05.

Total Suspended Solid and Sediment Movement During the Study Period

In general, TSS concentration and mass loss in burned watersheds were higher than unburned watersheds. Figure 4-6 represents the total amount of TSS mass and TSS concentration when all burned samples and unburned samples were combined per storm event. TSS concentration does not show as consistent of a pattern as TSS mass due to the high variability of organic matter and volume of water per watershed per storm event. This same trend in the data is shown in the total sediment concentration and mass for burned and unburned watersheds combined per storm event (Figure 4-7)

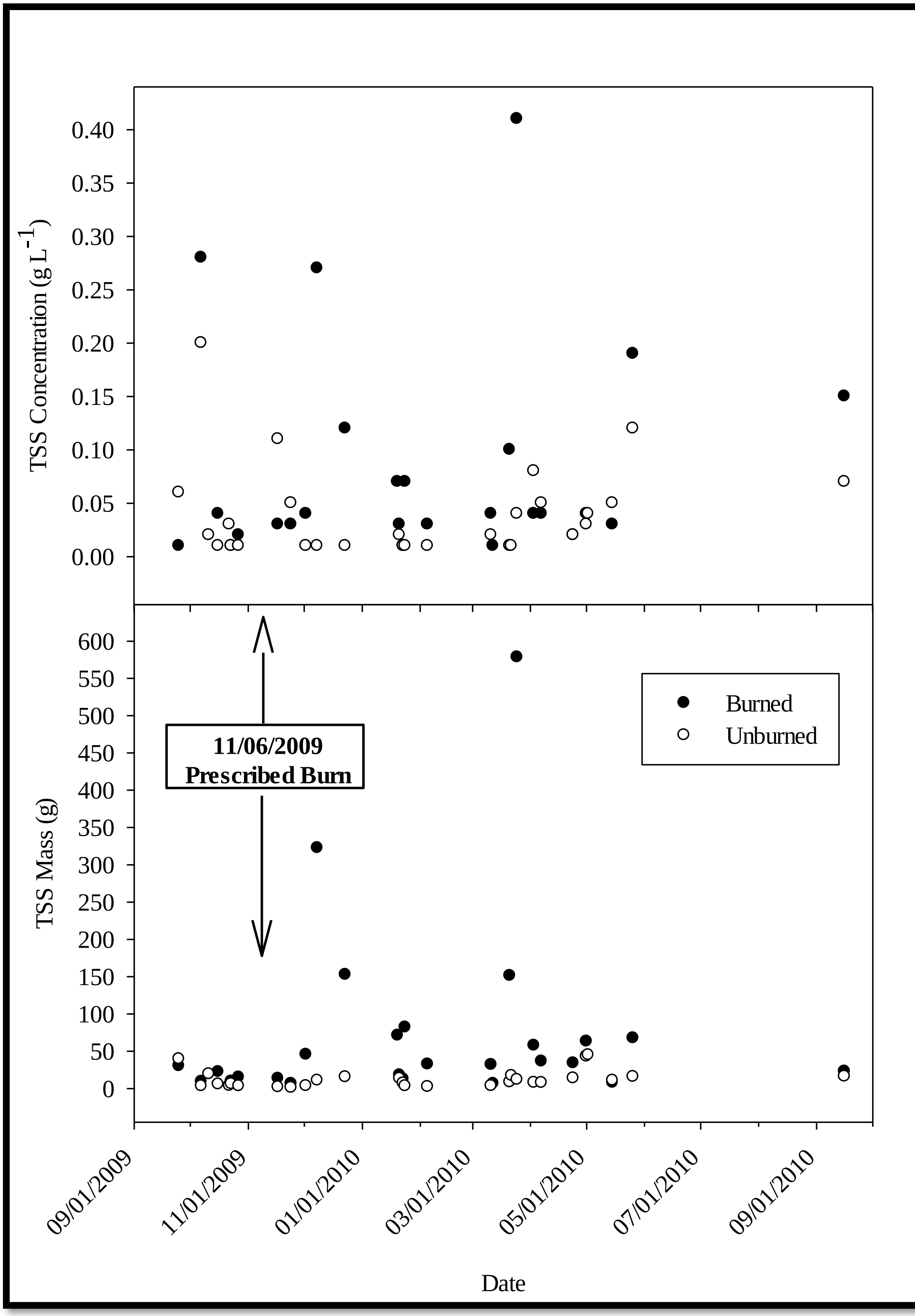

Figure 4-6. TSS loss for all burned and unburned watersheds combined per storm event

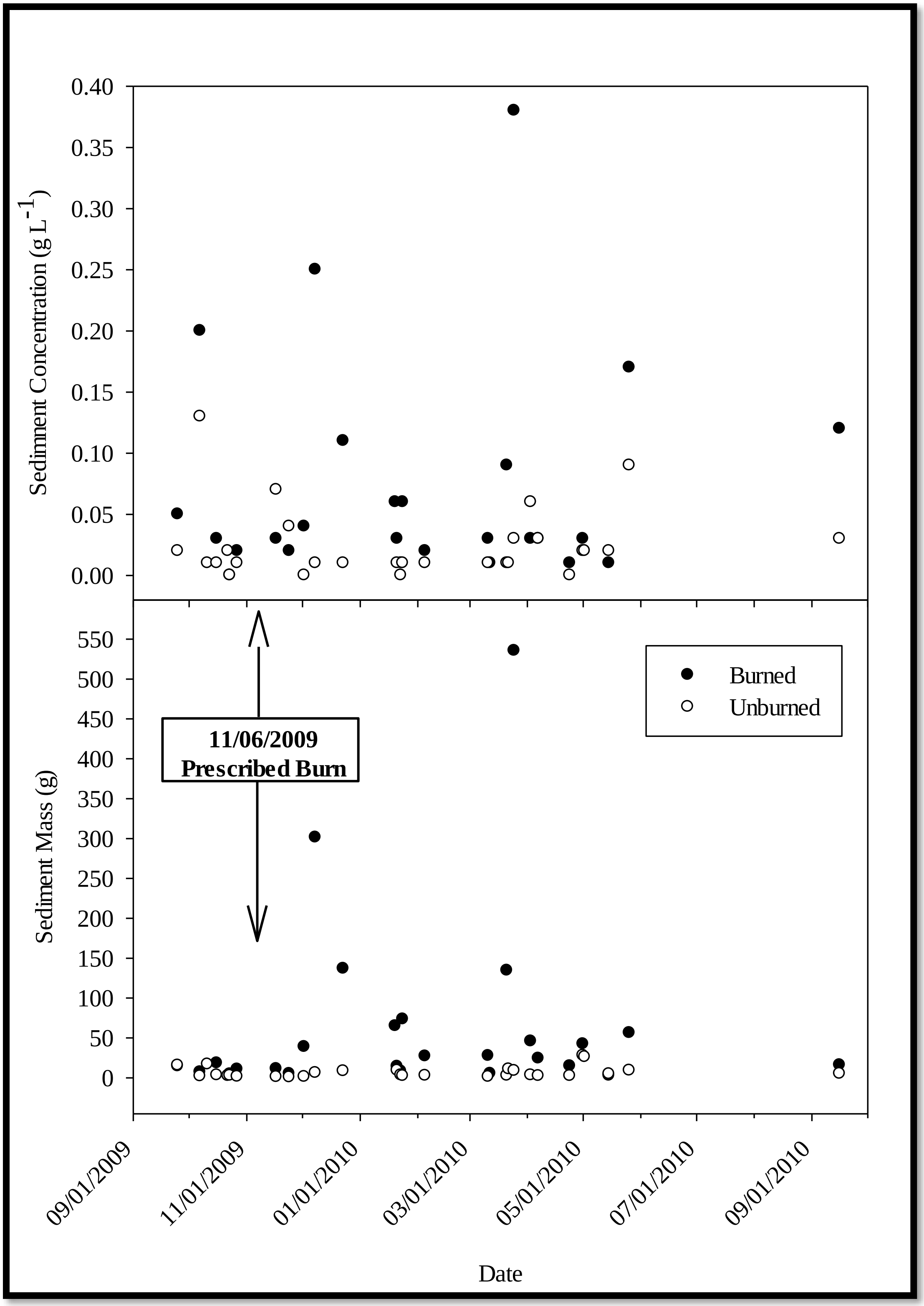

Figure 4-7. Sediment loss for all burned and unburned watersheds combined per storm event

Percent Change in TSS and Sediment Loss from Pre and Post Burn

A negative or zero percent change in TSS and sediment concentrations occurred in all unburned watersheds (Table 4-9). Burned watersheds were split with 4 and 7 having a negative percent change and 5 & 10 having a positive percent change in concentration and mass from pre and post burn. A larger number of samples post burn and storm events that produced higher volumes of runoff lead to the negative percent change in concentrations in the majority of the watersheds. Watersheds 5 & 10, both burned watersheds had positive percent changes in TSS and sediment concentrations following the prescribed burn treatment. The seep in watershed 5 was the only visual indicator that explained the increase in concentration levels. It is unclear why watershed 10 TSS and sediment concentrations increased.

All watersheds except watershed 8 had a positive percent change in TSS and sediment mass from pre burn to post burn storm event totals. Watershed 3, an unburned watershed, had the highest percent change in both TSS (1275%) and Sediment (1252%) mass. Only one pre burn sample of 4.5 liters was collected in Watershed 3. The sample was derived from a storm event that only produced a trickle into the collection tank. This low velocity trickle did not have enough energy to transport much TSS and yielded a sample with low TSS and sediment. Watershed 8 had the lowest percent change in TSS and sediment mass from pre to post burn, and was the only watershed to have a negative change in both TSS and Sediment mass pre to post burn. This again is likely due to the fact that this was a control watershed and the leaf litter accumulation in the thalweg of the watershed was acting as a filter. This phenomenon of the leaf litter in the thalweg acting as a filter seems to have a significant impact on TSS and sediment movement. Watershed 7 had unconsumed leaf litter and fresh leaf drop that accumulated in the channel (Photograph 5-1). Watershed 7 yielded the second lowest percent change in TSS and sediment mass, even though it was a treatment watershed (Table 4-9).

Table 4-9. Percent (%) change of Total Suspended Solids (TSS) and Sediment Concentration and Mass from Pre and Post Burned Storm Events.

	Concentration		Mass	
Watershed	% Change TSS	% Change Sediment	% Change TSS	% Change Sediment
Unburned				
3	-71	-67	1275	1252
6	-20	0.00	90	69
8	-33	0.00	-8	-5
9	-33	-43	54	26
Burned				
4	-69	-78	434	525
5	25	35	624	685
7	-71	-67	13	3
10	40	100	410	515

Study Period TSS and Sediment Loads

The pre burn TSS and sediment loads are much lower than post burn TSS and sediment loads in all watersheds, including the control watersheds (Table 4-10). This shows that an increase in TSS and sediment loss post burn was not only attributed to the prescribed burn. There may have been other factors that caused an increase in TSS and sediment loss. One major change from pre to post treatment sampling was that a portion of the post sampling period occurred during the dormant season. Canopy cover was not monitored during the study, but research has shown that canopy cover slows rainfall and can reduce rainfall intensity (Brown & Barker, 1979; Helvey & Patric, 1965; Trimble & Weizman, 1954). Transpiration and uptake of water by vegetation during the growing season would also decrease soil moisture levels and decrease the potential for overland flow to occur (Elliott, etal., 1999). Only 7 storm events over a two month period make up the pre burn sampling period where as the post burn sampling period contains 23 sampled storm events over a ten month period. The ten month post burn sampling period consisted of March, April, and May. These three months receive a large portion of annual rainfall, which held true during this study (Table 4-1). Not incorporating March through May in the pre burn sampling period likely contributed to lower TSS and sediment yields.

Table 4-10. Total suspended solid and sediment loads by watershed during the study period. The pre-burn period was between 09/01/2009 and 11/08/2009, and the post-burn period was between 11/06/2009 and 09/16/2010.

Watershed	TSS Pre-burn (g)	TSS Post-burn (g)	TSS Change (%)	Sediment Pre-burn (g)	Sediment Post-burn (g)	Sediment Change (%)
Unburned						
3	1.08	118.78	10861.30	0.67	72.49	10784.74
6	31.92	205.57	544.04	23.34	134.22	474.98
8	56.86	235.30	313.84	21.82	93.09	313.84
9	16.86	97.14	476.23	11.72	55.46	476.23
Burned						
4	21.28	681.83	3103.72	11.66	437.99	3103.72
5	120.65	5241.53	4244.48	104.56	4923.54	4244.48
7	50.88	258.92	408.89	25.71	119.65	408.89
10	30.23	655.69	2069.13	19.49	509.40	2069.13

Soil Erosion and Aggradation from Erosion Pin Data

Erosion pins were measured at the conclusion of the field study to evaluate the annual soil movement by watershed (Table 4-11). The erosion pin data in watershed 7 showed an average soil erosion of 4.2 mm. Conversely, watershed 8 had the highest aggradation of sediment (9.9 mm). Watersheds 7 and 8 were significantly different from each other and both are significantly different from the other watersheds, which are similar (P = .04). Watersheds 7 & 8 are paired watersheds that represent the steepest slopes. The soil loss in Watershed 7 could be attributed to the steep slopes accompanied by the loss of litter during the prescribed burn. The highest amount of soil aggradation in Watershed 8 is also likely due to the percent slope. Instead of the sediment being lost like in watershed 7, it is plausible that the litter allowed the sediment to move, but remained within the watershed. This movement of sediment within the watershed led to higher rates of aggradation than what was documented in the other watersheds. Watershed 9 had the lowest average change and lowest average range of sediment movement within the watersheds (Table 4-11). One observation that could have influenced these low rates of sediment movement was the debris of large dead trees that had fallen into the drainage (Photograph 4-3). This debris might have acted as sediment traps, which reduced the movement throughout the watershed (Bilby & Likens, 1980; Knapp, etal., 2005; Naiman, etal., 2002; Harmon, etal., 1986).

Table 4-11. Soil movement measured by erosion pins during the post burn study period in all study watersheds at Trail of Tears State Forest, IL.

Watershed	Average change per watershed (mm)†	Range (mm)†
Unburned		
3	2.6±1.9ab††	0 – 34.0
6	-1.3±1.2ab	-11.0 – 15.0
8	9.9±7.3b	-4.0 – 105.5
9	0.9±0.6ab	0 – 10.5
Burned		
4	1.8±2.5ab	-11.5 – 41.5
5	-2.7±1.6ab	-27.5 – 3.0
7	-4.2±1.9a	-29.5 – 6.5
10	-2.1±1.5ab	-14.5 – 10.5

†Negative numbers indicated soil loss and positive numbers indicate accumulation.
†† Different letter within a column represent significant differences at $\alpha = 0.05$.

Annual Sediment Loss

Projected losses were higher in the four burned watersheds compared to the unburned watershed pair (Table 4-12). Watershed 7 was the only burned watershed with projected sediment losses lower than any of the unburned watersheds, but still slightly higher than the paired watershed 8. Watershed 5 had a projected annual sediment loss of 90.54 kg ha^{-1} yr^{-1}, which is more than 13 times higher than the next closest projected annual loss, which occurred in watershed 10 at 6.76 kg ha^{-1} yr^{-1}. The projected erosion rates in this study are very low when compared to the agricultural and other land use studies in Table 4-13. Annual soil losses measured in row crops, grazing, and forests reported in Table 4-13 far exceed the soil loss averages in this study.

Table 4-12. Projected annual sediment loss during the post-burn phase of the project at Trail of Tears State Forest.

Watershed	Projected annual loss (kg)✝	Projected annual loss on an area basis (kg ha^{-1} yr^{-1})
Unburned		
3	0.09	0.81
6	0.16	2.54
8	0.11	1.04
9	0.07	1.10
Burned		
4	0.53	4.34
5	5.97	90.54
7	0.15	1.41
10	0.62	6.76

✝Projected annual losses were predicted based on the daily average sediment loss for the 301 days that made up the post burn sampling period. This average daily loss was used to predict the remaining 64 days to estimate the annual loss.

This study shows that prescribed burning does not cause a significant increase in soil loss, even on steep and friable soils, and these low levels of erosion should be considered acceptable in the mixed hardwood forests of southern Illinois. Additionally, reduction in erosion rates after prescribed burning will depend on how rapidly surface cover is re-established, as well as the precipitation received and intercepted by residual tree crowns (Trimble & Weizman, 1954). In a study conducted by Ursic (1970) in scrub oak forest in Mississippi, enough regrowth of understory resulted in normalizing runoff and sediment production over a 3-year post-burn period. Ursic (1970) reported that the maximum sediment yield was 6500 $kg{\cdot}ha^{-1}$ on two burned catchments during the first year after burning, 580 $kg{\cdot}ha^{-1}$ after two years, and 50 $kg{\cdot}ha^{-1}$ in the final year of study.

Table 4-13. Annual soil losses reported from different land use systems in the United States.

Reference	**Location**	**Land Use**	**Years** †	**Annual Precipitation (mm)**	**Soil Loss ($kg \cdot ha^{-1} \cdot year^{-1}$)**
Meginnis (1953)	Holly Springs, Mississippi	Scrub oak, burned	2	1620	740
		Oaks, unburned	2	1700	56
Daniel et al. (1943)	Guthrie, Oklahoma	Woodland burned annually	10	780	247
		Woodland unburned	10	780	22
Copley et al. (1944)	Statesville, North Carolina	Hardwood, burned semi-annually	9	1180	6904
		Hardwood, unburned	9	1180	4
Pope et al. (1946)	Tyler, Texas	Woodland, burned annually	9	1041	807
		Woodland unburned	9	1041	112
Ferguson (1957)	East Texas	Shortleaf-loblolly, single burn	1.5	-	471
		Shortleaf-loblolly, unburned	1.5	-	224
Ursic (1970)	North Mississippi	Scrub oak, burned	3	1323	568
		Scrub oak, unburned	3	1323	247
Schuman et al. (1973)	Treynor, Iowa	Corn, contour farming	3	778	25,310
		Corn, contour farming	3	774	16,600
		Bromegrass, rotational grazing	3	755	600
		Corn, level terraced farming	3	757	1330
Sharpley (1995)	Southern Plains of Oklahoma and Texas	Grass	>6	-	223
		Field crops, no-till	>6	-	564
		Field crops, reduced-till	>6	-	1275
		Field crops, conventional-till	>6	-	3574
		Peanut-Sorghum	>6	-	16,684

† Total number of years for soil loss monitoring.

Decision Tool for Land Managers in Southern Illinois

Land managers should use prescribed fire when possible for fuel reduction and site preparation where necessary. An important consideration is to maintain high moisture content in the humus layer during burning operations. Land managers set specific prescription levels when designing a prescribed burn plan. These prescription levels are designed to reduce the chance of an escaped fire and yield the desired management outcome following the burn. Fire intensity and severity are terms that scale a fire as low, medium, or high (Byram, 1959). Prescription levels for prescribed burning are designed to keep the fire intensity and severity at a low to medium range (Brose & Van Lear, 1998; Brose, etal., 2001). This low to medium range can be determined by post-burn observations which include flame length, fuel consumption, fire-scar height, etc. The prescribed burn for the study at TTSF was within the typical prescription range that is desired by land managers when burning in mixed hardwood forests of the central and eastern United States (Erickson & White, 2008; Knoepp, etal., 2009; Brose, etal., 2001; Loucks, etal., 2008). The timing of the burn (November 6, 2009) was within the standard dormant season prescribed burn period (Erickson & White, 2008). The maximum temperatures of the prescribed burn were comparable to the recorded temperatures of prescribed burns studied under other mixed hardwood forests (Knoepp, etal., 2009; Brose, etal., 2001; Loucks, etal., 2008; Scharenbroch, etal., 2012). Results from this research showed that the levels of TSS and sediment loss were not significantly different between control and prescribed burn watersheds. If all criteria of prescribed burning are met, the landowners of southern Illinois can use prescribed fires to manage their mixed hardwood forests without serious worry of soil loss.

CHAPTER 5

SYNTHESIS

Conclusion

The research findings provide valuable information regarding prescribed burning on steep topography in the forested Ozark hills of southern Illinois. Prescribed fires reduced the litter depth with no differences in soil moisture content due to prescribed burning. Only one watershed (watershed 5) showed some significant changes due to prescribed burning compared to other watersheds due to the presence of a seep. However, the TSS and sediment concentrations and loads were not increased significantly due to prescribed burning of mixed hardwood forests. Sediment transport in all watersheds and erosion potential after a prescribed fire can also be categorized as low, and land managers may use these data to burn more frequently or burn larger tracts. Slope and aspect were not influencing factors in regulating runoff after burning. In conjunction with similar antecedent soil moisture, if prescribed burning temperature does not exceed the recommended temperature observed in our study, then the humic horizon of the lower duff is not consumed, which protects soil from rain drops and throughfall. Prescribed fires can be recommended in southern Illinois for maintaining hardwood forests without increasing erosion risk under typical topography and precipitation years.

Management Limitations

Randomization

Like most studies, this study was subject to several limitations. The randomization of the study design was difficult. The first study design incorporated several watersheds through the specified area that would randomly be assigned as controls or treatments. The problem with this design is that the random choices for either the control or the treatment may not represent all aspects. It would also be difficult to compare one watershed to another if they were not similar. Therefore, the paired watershed design was selected. Most watersheds that were very similar were directly adjacent to one another. Although not random, it was a better option for this study's design.

Tank Size

Watershed characteristics were an important factor that influenced the sampling procedure for the study. The delineated size of the watersheds produced more runoff than anticipated, which altered the assumed sampling process. Collection tanks were unable to hold enough volume for many of the storm events that produced runoff. Instead of sampling at the end of the storm event, tanks were monitored throughout the storm event and sampled before the tanks overflowed so a known volume in the tank could be obtained and to prevent accumulation of sediment in the tank. The time the tanks were sampled was recorded so that duration and intensity of the storm event could be calculated up to the time of sampling.

Tank Sampling Bias

Another limitation was tank sampling bias. If the tanks are not mixed properly, sediment that settled to the bottom of the tank may remain and yield a sample that underestimates the amount of suspended sediment. To mitigate this problem, tanks were purchased that have a flat bottom and a large lid in the center to make mixing easier and more efficient. The mixing speed and mixing time of each tank was as consistent as possible; however, sample volume in the tank may have produced different uniformity of the mixture within the tank (i.e. mixing lower volumes was much easier than mixing tanks that were almost full).

Litter redistribution

The size of the treatment watersheds was relatively small, allowing for surrounding leaf litter from outside the study area to be wind-blown into the burned plots (Photograph 5-1). A small, likely insignificant, amount of litter reentered the burned watersheds following the prescribed fire, and could have potentially influenced the study results by underestimating TSS and sediment loads. Some of the litter was unconsumed by the fire and some fell from the trees after the fire. This phenomenon did not appear to greatly influence ground cover in most of the burned watersheds, but was worth noting in watershed 8 due to the topography of the watershed (Photograph 5-1).

Photograph 5-1. Photograph of litter that was transported via wind from outside treatment watershed 8.

Karst topography and 'pipeflow'

Karst topography and 'pipeflow' influenced infiltration and subsurface movement of water to a degree in certain watersheds. Initially, this led to the removal of watersheds 1 & 2, which also meant losing the only watershed pair that had a north facing aspect. Watershed 1 was receiving excessive flow from the karst topography, while watershed 2 was receiving little to no overland flow (Photograph 5-2). This shallow karst and/or 'pipeflow' influence also increased sediment loss in watershed 5, where subsurface flow re-surfaced directly above the flume. Watershed 3 also seemed to receive very low volumes of runoff that could have been influenced by the karst and/or 'pipeflow'.

Photograph 5-2. Photograph of a natural drain that was diverting runoff to subsurface flow and bypassing the flume in watershed 2.

Flume Design

Flumes were designed to divert overland flow into the holding tank for sampling. High water holding capacity, hydraulic conductivity, and porosity of forest soils (alfisols), especially in the karst soils of this study location allowed for shallow subsurface flow during storm events. Burying the flumes may have caused subsurface flow to resurface, and subsequently increased the overland flow that was collected during the study period (Photograph 5-3).

Photograph 5-3. Photo shows how corrugated metal sheets were buried to divert overland flow into the flume.

Study Design

In an ideal, paired-watershed study, the watersheds would have been calibrated for 3-4 years, or until a strong predictive model was created between the watersheds. Funding constraints limited our pre burn sampling window and prevented the study from utilizing automated water samplers. Ideally, each watershed would be equipped with a complete gaging station and an automated water sampler to capture sediment movement over the storm hydrograph while monitoring discharge. This would have provided the opportunity to create a more accurate sediment budget for each watershed.

Management Implications

The current study was performed at a site with highly erodible, loess-derived soils with very steep slopes to determine, under the most susceptible site characteristics, if prescribed burning had an impact on soil loss. Although the prescribed burn did show increases in sediment and TSS concentrations and mass, the severity of soil loss was not comparable to other more common land uses. The low estimated sediment and TSS loads calculated from this study are favorable towards using prescribed burning as a management tool in the mixed hardwoods of southern Illinois or similar soils and forest cover types. When burning at the prescription levels in this study, use caution when antecedent soil moisture is low, as this may lead to higher litter consumption than desired.

Recommendations for future research

A 3-4 year pretreatment sample collection period should precede the prescribed burn in order to create a strong predictive model between the watersheds. The post burn sampling period is recommended to monitor the influence of the prescribed burn on TSS and sediment loss and the trends of seasonal recovery post burn. Larger watersheds should be selected to prevent encroachment of windblown litter into the treatment watersheds. Larger watersheds would also allow for the use of a gauging station and ISCO automated water samplers at each watershed outlet. This would allow for samples to be collected throughout the entire storm event, including the tail of the hydrograph following the storm event. Monitoring a stream gaging station during the study would provide stream discharge and allow for the development of a sediment budget.

Sediment nutrient content and turbidity could be monitored in addition to TSS and sediment volumes. Lysimeters could also be added within the study watersheds to measure soil and water quality response to the prescribed burn. An evaluation of the tree species composition and understory plant species diversity before and after the prescribed burn would provide beneficial data on post burn vegetation response. The post burn vegetative response could also be evaluated as a potential factor in the reduction of TSS and sediment movement. A prescribed burn during the late winter or early spring should be replicated and results should be compared to the fall prescribed burn study.

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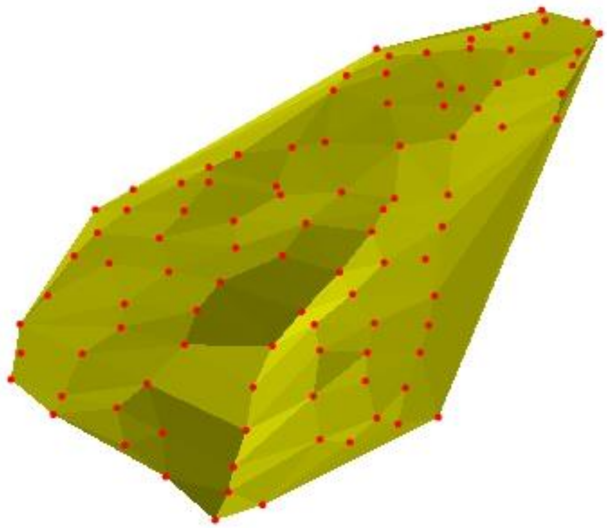
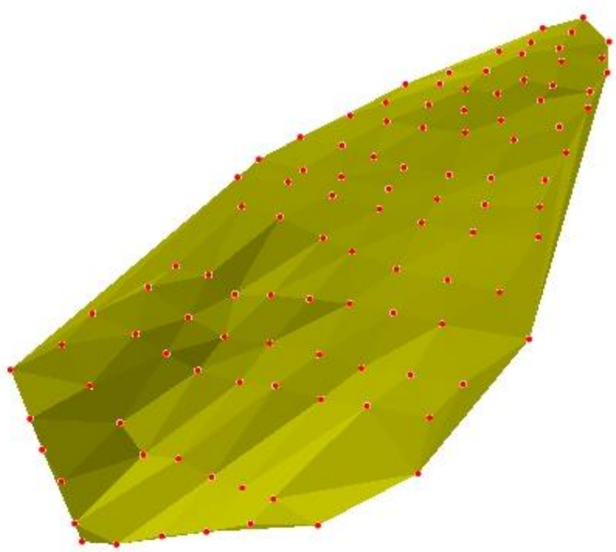
APPENDICES

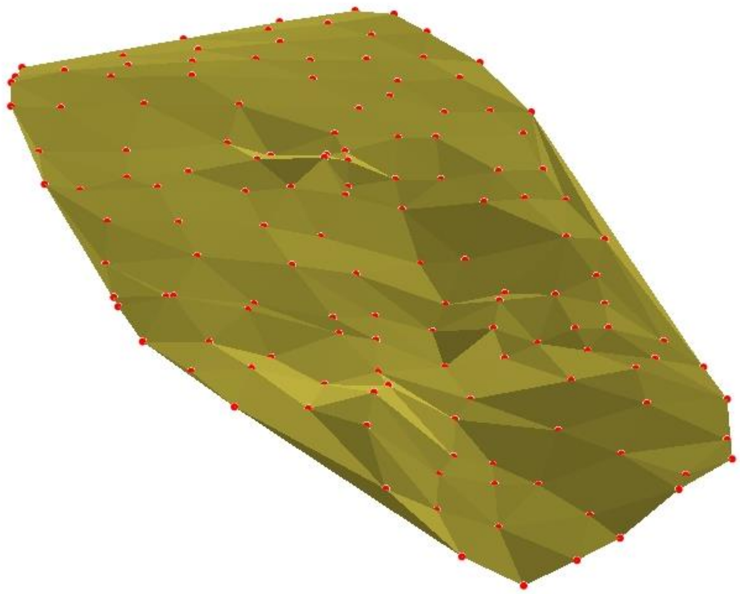
Appendix-1. Digital Elevation Models (A-H) created for each experimental watershed at Trail of Tears State Forest, IL.



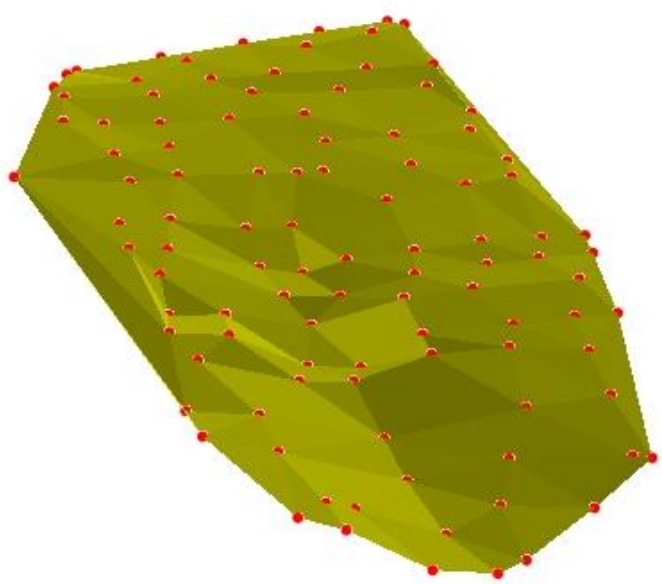
(A) Watershed 3 Digital Elevation Model



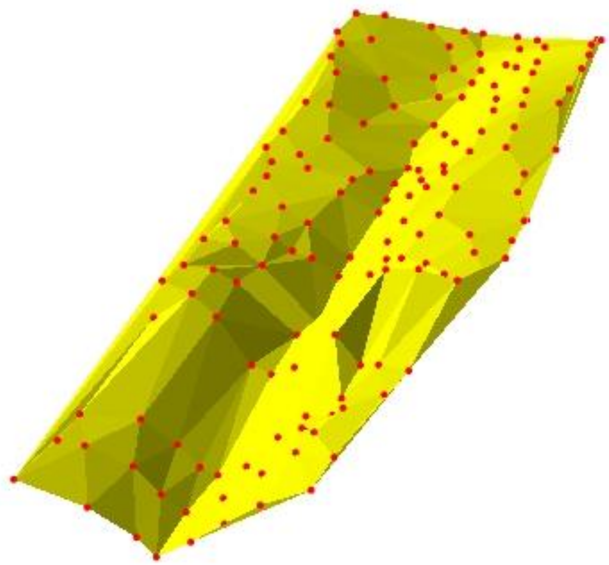
(B) Watershed 4 Digital Elevation Model



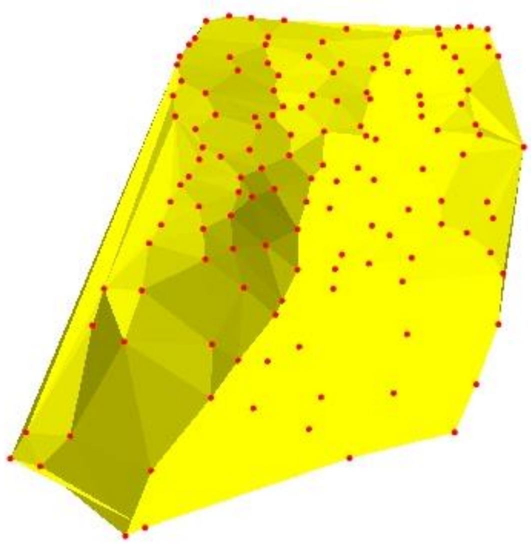
(C) Watershed 5 Digital Elevation Model



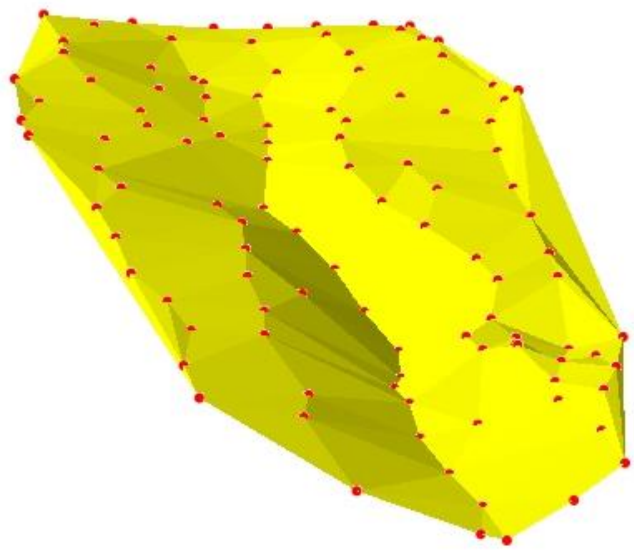
(D) Watershed 6 Digital Elevation Model



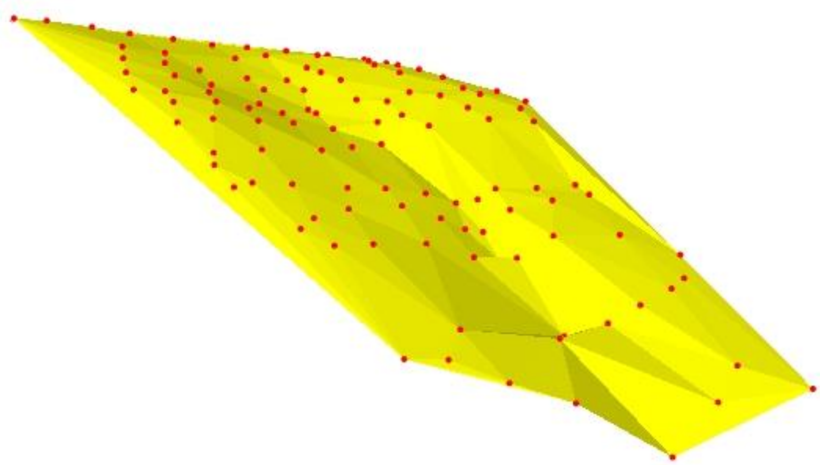
(E) Watershed 7 Digital Elevation Model



(F) Watershed 8 Digital Elevation Model



(G)Watershed 9 Digital Elevation Model



(H)Watershed 10 Digital Elevation Model

Appendix-2. Max Temperature from all HOBO Thermometers throughout treatment watersheds before averaging.

Watershed Number	Max_Temperature_C	Plot_Number
4	165.00	3
4	209.44	11
4	219.44	15
4	204.44	18
4	238.89	20
5	160.56	2
5	258.89	13
5	190.00	14
5	303.61	16
5	180.00	21
7	248.89	1
7	323.06	9
7	175.00	10
7	268.89	17
7	391.94	22
10	243.89	4
10	116.10	5
10	204.44	6
10	204.40	7
10	190.00	19

Appendix-3. Dominant tree species separated by size classes across all watersheds at Trail of Tears State Forest, IL.

Strata	Density (stems ha^{-1})	Basal Area (m^2 ha^{-1})	Relative Density (%)
Mature Overstory Trees (>9 cm)			
Acer saccharum	127	2.66	28 .0
Quercus alba	93	9.91	20.5
Quercus rubra	58	7.17	12.9
Carya glabra	45	4.30	9.8
Quercus velutina	45	9.87	9.8
Fagus grandifolia	41	0.98	9.1
Carya tomentosa	17	1.25	3.8
Cornus florida	10	0.15	2.3
Nyssa sylvatica	7	0.14	1.5
Amelanchier arborea	3	0.03	0.8
Carya ovata	3	0.15	0.8
Fraxinus americana	3	0.33	0.8
Saplings (2-9 cm)			
Acer saccharum	343		47.2
Fagus grandifolia	151		20.8
Ostrya virginiana	55		7.5
Carya glabra	41		5.7
Amelanchier arborea	27		3.8
Cercis canadensis	27		3.8
Carya ovata	14		1.9
Carya tomentosa	14		1.9
Fraxinus americana	14		1.9
Nyssa sylvatica	14		1.9
Sassafras albidum	14		1.9
Ulmus americana	14		1.9
Seedlings (<2 cm)			
Fagus grandifolia	1199		11.3
Quercus alba	1199		11.3
Nyssa sylvatica	1113		10.5
Ulmus americana	1113		10.5
Fraxinus americana	1027		9.7
Acer saccharum	942		8.9
Sassafras albidum	942		8.9
Quercus velutina	599		5.6
Asiminia triloba	514		4.8
Prunus serotina	514		4.8
Carya glabra	428		4.0
Quercus rubra	257		2.4
Carya tomentosa	171		1.6
Cercis canadensis	171		1.6
Liquidambar styraciflua	171		1.6
Ostrya virginiana	171		1.6
Morus alba	86		0.8

Appendix-4. Precipitation data collected from experimental watersheds per storm event at Trail of Tears State Forest, IL. (.) indicates that no sample was collected.

Watershed	Date	Precipitation Volume (cm)	Duration (hours)	Intensity (cm/hour)
3	09/25/09	.	.	.
4	09/25/09	.	.	.
5	09/25/09	.	.	.
6	09/25/09	.	.	.
7	09/25/09	0.3425	9.05	0.0378
8	09/25/09	0.3425	9.05	0.0378
9	09/25/09	.	.	.
10	09/25/09	.	.	.
3	10/07/09	0.5196	5.20	0.0999
4	10/07/09	0.5196	5.20	0.0999
5	10/07/09	0.5196	5.20	0.0999
6	10/07/09	0.5196	5.20	0.0999
7	10/07/09	0.5196	5.20	0.0999
8	10/07/09	0.5196	5.20	0.0999
9	10/07/09	0.5196	5.20	0.0999
10	10/07/09	0.5196	5.20	0.0999
6	10/11/09	1.4291	15.61	0.0915
3	10/16/09	0.4291	15.61	0.0274
4	10/16/09	0.4291	15.61	0.0274
5	10/16/09	0.4291	15.61	0.0274
6	10/16/09	0.4291	15.61	0.0274
7	10/16/09	0.4291	15.61	0.0274
8	10/16/09	0.4291	15.61	0.0274
9	10/16/09	0.4291	15.61	0.0274
10	10/16/09	0.4291	15.61	0.0274

9	10/22/09	0.3031	2.40	0.1263
6	10/23/09	0.5551	12.81	0.0433
10	10/23/09	0.5551	12.81	0.0433
4	10/27/09	0.3228	12.20	0.0264
5	10/27/09	0.3346	12.66	0.0264
3	10/27/09	.	.	.
6	10/27/09	0.3425	15.16	0.0225
7	10/27/09	0.3425	15.16	0.0225
8	10/27/09	0.3425	15.16	0.0225
9	10/27/09	0.3425	15.16	0.0225
10	10/27/09	0.3425	15.16	0.0225
3	11/17/09	1.0629	25.10	0.0423
4	11/17/09	1.0629	25.10	0.0423
5	11/17/09	1.0629	25.10	0.0423
6	11/17/09	1.0629	25.10	0.0423
7	11/17/09	1.0629	25.10	0.0423
8	11/17/09	1.0629	25.10	0.0423
9	11/17/09	1.0629	25.10	0.0423
10	11/17/09	1.0629	25.10	0.0423
3	11/24/09	.	.	.
4	11/24/09	0.1456	3.20	0.0455
5	11/24/09	0.1456	3.20	0.0455
6	11/24/09	0.1456	3.20	0.0455
7	11/24/09	0.1456	3.20	0.0455
8	11/24/09	0.1456	3.20	0.0455
9	11/24/09	0.1456	3.20	0.0455
10	11/24/09	0.1456	3.20	0.0455
4	12/02/09	0.3110	12.38	0.0251
5	12/02/09	0.3110	12.38	0.0251

3	12/02/09	0.3188	13.30	0.0239
6	12/02/09	0.3188	13.30	0.0239
7	12/02/09	0.3188	13.30	0.0239
8	12/02/09	0.3188	13.30	0.0239
9	12/02/09	0.3188	13.30	0.0239
10	12/02/09	0.3188	13.30	0.0239
3	12/08/09	0.3779	17.50	0.0215
4	12/08/09	0.2755	16.08	0.0171
5	12/08/09	0.2519	15.75	0.0159
6	12/08/09	0.3897	17.90	0.0217
7	12/08/09	0.2992	16.41	0.0182
8	12/08/09	0.3110	16.58	0.0187
10	12/08/09	0.3464	20.53	0.0168
9	12/08/09	0.4448	20.53	0.0216
3	12/23/09	0.1338	2.06	0.0647
4	12/23/09	0.1338	2.06	0.0647
5	12/23/09	0.1338	2.06	0.0647
6	12/23/09	0.1338	2.06	0.0647
7	12/23/09	0.1338	2.06	0.0647
8	12/23/09	0.1338	2.06	0.0647
9	12/23/09	0.1338	2.06	0.0647
10	12/23/09	0.1338	2.06	0.0647
4	01/20/10	0.2440	2.73	0.0893
5	01/20/10	0.2440	2.73	0.0893
3	01/21/10	0.5354	10.80	0.0495
6	01/21/10	0.5354	10.80	0.0495
7	01/21/10	0.3661	8.88	0.0412
8	01/21/10	0.3661	8.88	0.0412
9	01/21/10	0.5354	10.80	0.0495

10	01/21/10	0.3661	8.88	0.0412
4	01/23/10	0.1535	1.10	0.1395
7	01/23/10	0.1732	1.43	0.1208
8	01/23/10	0.1732	1.43	0.1208
3	01/24/10	0.1850	3.43	0.0538
5	01/24/10	0.1850	2.26	0.0816
6	01/24/10	0.2204	20.48	0.0107
9	01/24/10	.	.	.
10	01/24/10	0.2204	3.18	0.0692
3	02/05/10	.	.	.
4	02/05/10	0.1417	12.63	0.0112
5	02/05/10	0.1417	12.46	0.0113
6	02/05/10	0.2716	22.90	0.0118
7	02/05/10	0.1574	14.63	0.0107
8	02/05/10	0.1574	15.05	0.0104
9	02/05/10	0.2716	23.06	0.0117
10	02/05/10	0.1574	15.13	0.0104
3	03/11/10	.	.	.
4	03/11/10	0.2519	1.35	0.1866
5	03/11/10	0.2519	1.35	0.1866
6	03/11/10	0.2519	1.35	0.1866
7	03/11/10	0.2519	1.35	0.1866
8	03/11/10	0.2519	1.35	0.1866
9	03/11/10	0.2519	1.35	0.1866
10	03/11/10	0.2519	1.35	0.1866
3	03/12/10	.	.	.
4	03/12/10	0.0866	17.55	0.0049
5	03/12/10	0.0866	17.55	0.0049
6	03/12/10	.	.	.

7	03/12/10	.	.	.
8	03/12/10	.	.	.
9	03/12/10	.	.	.
10	03/12/10	.	.	.
3	03/22/10	.	.	.
4	03/21/10	0.2834	11.10	0.0255
5	03/21/10	0.2755	10.76	0.0255
7	03/21/10	0.3425	26.55	0.0129
8	03/21/10	0.3425	14.10	0.0242
9	03/21/10	0.7598	14.10	0.0538
10	03/21/10	0.3976	26.55	0.0149
6	03/22/10	0.7598	15.18	0.0500
4	03/25/10	0.4763	11.51	0.0413
5	03/25/10	0.4763	9.56	0.0497
7	03/25/10	0.4921	9.81	0.0501
8	03/25/10	0.4921	11.51	0.0427
10	03/25/10	0.5000	10.31	0.0484
3	03/25/10	0.5157	10.31	0.0499
6	03/25/10	0.5157	11.51	0.0447
9	03/25/10	0.5157	10.81	0.0476
3	04/03/10	.	.	.
4	04/03/10	0.2874	5.51	0.0520
5	04/03/10	0.2874	5.51	0.0520
6	04/03/10	0.2874	5.51	0.0520
7	04/03/10	0.2874	5.51	0.0520
8	04/03/10	0.2874	5.51	0.0520
9	04/03/10	0.2874	5.51	0.0520
10	04/03/10	0.2874	5.51	0.0520
3	04/07/10	.	.	.

4	04/07/10	0.2480	2.93	0.0845
5	04/07/10	0.2480	2.93	0.0845
6	04/07/10	0.2480	2.93	0.0845
7	04/07/10	0.2480	2.93	0.0845
8	04/07/10	0.2480	2.93	0.0845
9	04/07/10	.	.	.
10	04/07/10	0.2480	2.93	0.0845
3	04/24/10	.	.	.
4	04/24/10	0.4566	7.50	0.0608
5	04/24/10	0.4251	7.25	0.0586
6	04/24/10	0.5275	12.00	0.0439
7	04/24/10	0.5275	8.00	0.0659
8	04/24/10	0.5275	8.25	0.0639
9	04/24/10	0.5275	12.50	0.0422
10	04/24/10	0.5275	9.50	0.0555
3	05/02/10	0.7440	3.43	0.2167
4	05/01/10	0.6141	1.35	0.4549
5	05/01/10	0.5354	1.01	0.5266
6	05/01/10	0.7283	2.93	0.2483
7	05/01/10	0.6496	1.68	0.3859
8	05/01/10	0.6535	1.76	0.3699
9	05/01/10	0.7480	3.43	0.2178
10	05/01/10	0.7007	2.43	0.2879
3	05/15/10	.	.	.
4	05/15/10	.	.	.
5	05/15/10	.	.	.
6	05/15/10	.	.	.
7	05/15/10	0.0708	6.58	0.0107
8	05/15/10	0.0708	6.58	0.0107

9	05/15/10	.	.	.
10	05/15/10	.	.	.
3	05/26/10	0.1771	1.58	0.1118
4	05/26/10	0.1771	1.58	0.1118
5	05/26/10	0.1771	1.58	0.1118
6	05/26/10	0.1771	1.58	0.1118
7	05/26/10	0.1771	1.58	0.1118
8	05/26/10	0.1771	1.58	0.1118
9	05/26/10	0.1771	1.58	0.1118
10	05/26/10	0.1771	1.58	0.1118
3	09/16/10	.	.	.
4	09/16/10	0.2480	3.46	0.0715
5	09/16/10	0.2480	3.46	0.0715
6	09/16/10	0.2480	3.46	0.0715
7	09/16/10	0.2480	3.46	0.0715
8	09/16/10	0.2480	3.46	0.0715
9	09/16/10	0.2480	3.46	0.0715
10	09/16/10	0.2480	3.46	0.0715

Appendix-5. Pre and post burn litter depths (cm) for experimental watersheds at Trail of Tears State Forest, IL.

Watershed	Pre Burn (cm)	Post Burn (cm)
3	3.8	0.0
3	4.7	0.0
3	4.1	0.0
3	4.5	0.0
3	4.6	0.0
3	5.2	0.0
3	5.0	0.0
3	3.1	0.0
3	3.2	0.0
3	4.4	0.0
3	3.9	0.0
3	4.1	0.0
3	5.3	0.0
3	4.1	0.0
3	5.6	0.0
3	6.1	0.0
3	4.0	0.0
3	5.3	0.0
4	4.1	0.5
4	4.5	0.8
4	4.3	0.5
4	5.4	0.8
4	5.1	0.7
4	6.3	0.6
4	5.7	0.4
4	5.8	0.4
4	4.4	0.7
4	4.2	0.2
4	4.9	0.8
4	5.8	0.8
4	5.0	0.3
4	4.8	1.1
4	4.3	0.5
4	3.8	0.2
4	3.6	0.5
4	3.9	0.3
5	3.7	0.4
5	5.1	0.6
5	4.4	1.0
5	4.0	0.2
5	5.1	0.3
5	5.8	0.7
5	5.7	0.9
5	4.7	1.2
5	4.4	0.1
5	4.9	0.2
5	4.1	0.8
5	4.5	0.5
5	4.3	0.8
5	4.2	1.0
5	4.8	0.4
5	4.4	0.7
5	3.9	0.5
5	5.3	1.2
6	4.5	0.0
6	4.3	0.0
6	3.5	0.0
6	5.5	0.0
6	3.9	0.0
6	4.2	0.0
6	5.3	0.0
6	5.0	0.0
6	4.1	0.0
6	5.2	0.0
6	5.6	0.0
6	5.2	0.0
6	4.7	0.0
6	4.8	0.0
6	3.9	0.0

6	4.6	0.0
6	4.5	0.0
6	5.0	0.0
7	3.0	1.2
7	4.0	0.3
7	3.2	1.1
7	3.2	0.4
7	0.0	0.0
7	4.9	1.2
7	8.0	5.8
7	5.1	2.0
7	3.1	0.2
7	3.2	0.1
7	5.2	0.9
7	4.7	1.5
7	3.9	1.0
7	5.4	3.6
7	3.3	0.5
7	4.7	0.6
7	5.0	1.4
7	4.5	1.1
8	3.6	0.0
8	6.2	0.0
8	4.1	0.0
8	4.6	0.0
8	0.9	0.0
8	3.3	0.0
8	8.9	0.0
8	3.0	0.0
8	5.9	0.0
8	3.0	0.0
8	4.4	0.0
8	4.6	0.0
8	3.4	0.0
8	4.2	0.0
8	2.9	0.0
8	0.6	0.0
8	3.0	0.0

8	3.9	0.0
9	3.4	0.0
9	4.3	0.0
9	3.2	0.0
9	3.9	0.0
9	0.0	0.0
9	3.7	0.0
9	6.4	0.0
9	5.3	0.0
9	3.2	0.0
9	5.0	0.0
9	3.5	0.0
9	3.3	0.0
9	4.0	0.0
9	4.1	0.0
9	3.2	0.0
9	2.8	0.0
9	3.7	0.0
9	4.2	0.0
10	3.8	0.4
10	6.0	4.5
10	4.7	1.2
10	4.2	1.3
10	4.1	0.6
10	4.8	0.4
10	6.3	3.9
10	3.0	1.4
10	3.6	0.6
10	4.3	2.3
10	3.3	0.8
10	4.8	1.9
10	4.2	0.7
10	3.4	0.5
10	4.9	1.0
10	4.6	1.4
10	3.1	0.3
10	4.1	0.8

Appendix-6. Field Scout TDR Moisture Probe Soil Moisture Data collected throughout experimental watersheds at Trail of Tears State Forest, IL.

Rx Burn Time	Watershed	Volumetric Water Content
pre	3	19.9
pre	3	21.4
pre	3	16.3
pre	3	14.5
pre	3	12.0
pre	3	26.8
pre	3	38.0
pre	3	21.0
pre	3	25.0
pre	3	17.4
pre	3	26.1
pre	3	22.1
pre	3	17.8
pre	3	31.1
pre	3	21.0
pre	3	17.0
pre	3	14.2
pre	3	34.0
pre	4	25.4
pre	4	31.1
pre	4	26.1
pre	4	27.9
pre	4	26.4
pre	4	18.1
pre	4	27.9
pre	4	26.4
pre	4	25.7
pre	4	23.6
pre	4	26.4
pre	4	35.1
pre	4	25.0
pre	4	27.5
pre	4	28.3
pre	4	35.8
pre	4	18.5
pre	4	17.4
pre	5	12.3
pre	5	29.3
pre	5	21.0
pre	5	22.5
pre	5	18.9
pre	5	19.2
pre	5	11.6
pre	5	15.6
pre	5	13.1
pre	5	16.3
pre	5	22.5
pre	5	22.1
pre	5	21.0
pre	5	21.0
pre	5	17.4
pre	5	27.5
pre	5	24.6
pre	5	21.0
pre	6	28.3
pre	6	39.1
pre	6	30.8
pre	6	27.5
pre	6	30.4
pre	6	20.3
pre	6	29.7
pre	6	24.6
pre	6	22.1
pre	6	18.9
pre	6	23.9
pre	6	19.9
pre	6	29.0
pre	6	17.4
pre	6	26.1
pre	6	18.9
pre	6	19.9

pre	6	27.2
pre	7	29.0
pre	7	31.9
pre	7	18.9
pre	7	18.1
pre	7	22.5
pre	7	36.9
pre	7	25.0
pre	7	22.5
pre	7	26.8
pre	7	18.1
pre	7	24.6
pre	7	30.8
pre	7	21.0
pre	7	24.3
pre	7	24.3
pre	7	23.2
pre	7	24.3
pre	7	26.1
pre	8	10.9
pre	8	27.9
pre	8	14.5
pre	8	23.6
pre	8	20.3
pre	8	28.6
pre	8	36.2
pre	8	27.5
pre	8	14.9
pre	8	19.6
pre	8	19.6
pre	8	18.5
pre	8	14.5
pre	8	31.9
pre	8	21.4
pre	8	26.1
pre	8	22.1
pre	8	20.7
pre	9	19.2
pre	9	25.7
pre	9	15.2
pre	9	19.9
pre	9	7.6
pre	9	25.4
pre	9	31.1
pre	9	22.8
pre	9	19.2
pre	9	23.6
pre	9	30.4
pre	9	19.6
pre	9	30.1
pre	9	31.1
pre	9	29.0
pre	9	22.8
pre	9	25.4
pre	9	34.0
pre	10	26.1
pre	10	38.4
pre	10	30.4
pre	10	18.1
pre	10	22.1
pre	10	24.3
pre	10	22.8
pre	10	19.2
pre	10	25.0
pre	10	22.8
pre	10	27.2
pre	10	25.4
pre	10	30.8
pre	10	25.0
pre	10	15.6
pre	10	31.1
pre	10	26.1
pre	10	30.8
post	3	22.5
post	3	22.8
post	3	17.4
post	3	13.1
post	3	11.6
post	3	19.6
post	3	35.5

post	3	23.6
post	3	25.7
post	3	21.7
post	3	33.7
post	3	22.8
post	3	23.2
post	3	23.6
post	3	12.7
post	3	29.7
post	3	19.2
post	3	20.3
post	4	24.6
post	4	30.1
post	4	27.5
post	4	26.4
post	4	27.9
post	4	18.5
post	4	16.3
post	4	14.5
post	4	26.4
post	4	23.6
post	4	31.5
post	4	35.5
post	4	32.6
post	4	21.4
post	4	26.8
post	4	38.0
post	4	19.9
post	4	22.5
post	5	10.5
post	5	32.6
post	5	23.6
post	5	17.0
post	5	6.2
post	5	26.4
post	5	22.8
post	5	18.1
post	5	11.6
post	5	18.5
post	5	21.4

post	5	18.1
post	5	21.0
post	5	17.4
post	5	15.6
post	5	25.0
post	5	19.2
post	5	19.6
post	6	22.1
post	6	41.3
post	6	26.4
post	6	23.6
post	6	28.3
post	6	21.4
post	6	29.0
post	6	21.0
post	6	18.1
post	6	21.0
post	6	19.6
post	6	25.4
post	6	30.4
post	6	18.5
post	6	23.9
post	6	17.4
post	6	18.5
post	6	25.4
post	7	27.5
post	7	23.9
post	7	14.5
post	7	17.0
post	7	21.0
post	7	24.3
post	7	41.3
post	7	24.6
post	7	26.4
post	7	18.5
post	7	24.3
post	7	25.4
post	7	21.4
post	7	21.7
post	7	21.4

post	7	17.0
post	7	20.3
post	7	16.3
post	8	8.7
post	8	33.7
post	8	23.6
post	8	21.0
post	8	17.4
post	8	25.7
post	8	40.5
post	8	22.5
post	8	22.1
post	8	19.6
post	8	28.3
post	8	22.1
post	8	17.8
post	8	30.4
post	8	14.9
post	8	27.2
post	8	22.5
post	8	21.7
post	9	21.7
post	9	26.4
post	9	12.7
post	9	19.9
post	9	6.9
post	9	14.5
post	9	28.3
post	9	12.7
post	9	24.6
post	9	25.0
post	9	32.6
post	9	25.0
post	9	32.6
post	9	34.8
post	9	30.4
post	9	27.9
post	9	33.3
post	9	22.1
post	10	22.8
post	10	30.1
post	10	34.4
post	10	18.5
post	10	22.8
post	10	22.1
post	10	39.8
post	10	27.5
post	10	15.6
post	10	20.3
post	10	25.7
post	10	24.3
post	10	24.6
post	10	28.3
post	10	21.7
post	10	26.4
post	10	25.0
post	10	27.5

Appendix-7. Storm event sample data for experimental watersheds at Trail of Tears State Forest, IL. (.) indicates that sample was not collected or no sample was present.

Watershed	Storm Event Date	Rx Burn Time	Sample Collection Time (24 hour)	Tank Volume (L)	Total Suspended Solid Concentration (g/L)	Sediment Concentration (g/L)	Total Suspended Solid Mass (g)	Sediment Mass (g)
3	09/25/09	Pre	.	0	.	.	.	.
4	09/25/09	Pre	.	0	.	.	.	.
5	09/25/09	Pre	.	0	.	.	.	.
6	09/25/09	Pre	.	0	.	.	.	.
7	09/25/09	Pre	18:30	292	0.1028	0.0488	30.0176	14.2496
8	09/25/09	Pre	18:30	620	0.0636	0.0248	39.4320	15.3760
9	09/25/09	Pre	.	0	.	.	.	.
10	09/25/09	Pre	.	0	.	.	.	.
3	10/07/09	Pre	17:00	4.5	0.2408	0.1480	1.0836	0.6660
4	10/07/09	Pre	17:00	8.5	0.3704	0.2528	3.1484	2.1488
5	10/07/09	Pre	17:00	40	0.4748	0.4156	18.9920	16.6240
6	10/07/09	Pre	17:00	3.5	0.2196	0.1344	0.7686	0.4704
7	10/07/09	Pre	17:00	13	0.1620	0.0508	2.1060	0.6604
8	10/07/09	Pre	17:00	122	0.0372	0.0080	4.5384	0.9760
9	10/07/09	Pre	17:00	20	0.3120	0.2456	6.2400	4.9120
10	10/07/09	Pre	17:00	126	0.0936	0.0692	11.7936	8.7192
6	10/11/09	Pre	17:55	1169	0.0163	0.0143	19.1236	16.7915
3	10/16/09	Pre	21:00	0	.	.	.	.
4	10/16/09	Pre	21:00	505	0.0114	0.0067	5.7570	3.3835
5	10/16/09	Pre	21:00	940	0.0692	0.0606	65.0480	56.9640
6	10/16/09	Pre	21:00	120	0.0122	0.0075	1.4683	0.9097
7	10/16/09	Pre	21:00	1060	0.0126	0.0079	13.3931	8.4588
8	10/16/09	Pre	21:00	910	0.0101	0.0050	9.1982	4.5991
9	10/16/09	Pre	21:00	480	0.0125	0.0083	6.0009	4.0219

10	10/16/09	Pre	21:00	65	0.0686	0.0586	4.4590	3.8090
9	10/22/09	Pre	18:00	140	0.0256	0.0160	3.5840	2.2400
6	10/23/09	Pre	14:45	620	0.0094	0.0042	5.8546	2.6387
10	10/23/09	Pre	14:45	920	0.0102	0.0047	9.4217	4.4049
4	10/27/09	Pre	19:15	940	0.0131	0.0065	12.3769	6.1259
5	10/27/09	Pre	20:05	640	0.0572	0.0484	36.6080	30.9760
3	10/27/09	Pre	22:15	0	.	.	.	.
6	10/27/09	Pre	22:15	340	0.0138	0.0074	4.7028	2.5323
7	10/27/09	Pre	22:15	840	0.0063	0.0027	5.3625	2.3461
8	10/27/09	Pre	22:15	730	0.0050	0.0012	3.6894	0.8738
9	10/27/09	Pre	22:15	80	0.0129	0.0067	1.0320	0.5426
10	10/27/09	Pre	22:15	535	0.0085	0.0047	4.5539	2.5615
3	11/17/09	Post	0:58	5	0.2724	0.1968	1.3620	0.9840
4	11/17/09	Post	0:58	335	0.0093	0.0058	3.1155	1.9430
5	11/17/09	Post	0:58	635	0.0690	0.0604	43.8150	38.3540
6	11/17/09	Post	0:58	60	0.0456	0.0184	2.7360	1.1040
7	11/17/09	Post	0:58	40	0.0324	0.0190	1.2960	0.7600
8	11/17/09	Post	0:58	220	0.0107	0.0039	2.3700	0.8778
9	11/17/09	Post	0:58	5	0.1096	0.0758	0.5480	0.3790
10	11/17/09	Post	0:58	145	0.0289	0.0218	4.2041	3.1627
3	11/24/09	Post	16:09	0	.	.	.	.
4	11/24/09	Post	16:09	335	0.0063	0.0032	2.1105	1.0720
5	11/24/09	Post	16:09	625	0.0327	0.0271	20.4487	16.9575
6	11/24/09	Post	16:09	40	0.0179	0.0111	0.7182	0.4468
7	11/24/09	Post	16:09	3	0.0720	0.0320	0.2160	0.0960
8	11/24/09	Post	16:09	65	0.0219	0.0127	1.4264	0.8299
9	11/24/09	Post	16:09	4	0.1092	0.0840	0.4368	0.3360
10	11/24/09	Post	16:09	115	0.0200	0.0126	2.3000	1.4490
4	12/02/09	Post	20:05	1110	0.0186	0.0119	20.6460	13.2090

5	12/02/09	Post	20:15	1040	0.1278	0.1178	132.9120	122.5120
3	12/02/09	Post	21:07	0	.	.	.	.
6	12/02/09	Post	21:07	520	0.0060	0.0031	3.1200	1.6120
7	12/02/09	Post	21:07	1180	0.0085	0.0057	10.0441	6.7484
8	12/02/09	Post	21:07	1175	0.0051	0.0011	5.9925	1.2925
9	12/02/09	Post	21:07	70	0.0144	0.0066	1.0080	0.4620
10	12/02/09	Post	21:07	1160	0.0153	0.0103	17.7422	12.0338
3	12/08/09	Post	17:10	1100	0.0156	0.0099	17.2634	10.9725
4	12/08/09	Post	15:45	1180	0.0908	0.0711	107.1900	83.9629
5	12/08/09	Post	15:25	1200	0.9412	0.9016	1129.4400	1081.9200
6	12/08/09	Post	17:34	1120	0.0083	0.0051	9.2960	5.7120
7	12/08/09	Post	16:05	1140	0.0119	0.0062	13.6458	7.1261
8	12/08/09	Post	16:15	1160	0.0077	0.0031	8.9482	3.7027
10	12/08/09	Post	16:40	1200	0.0323	0.0263	38.7828	31.6008
9	12/08/09	Post	20:12	540	0.0127	0.0074	6.8947	4.0219
3	12/23/09	Post	17:00	1145	0.0220	0.0128	25.1900	14.6560
4	12/23/09	Post	16:10	1220	0.0442	0.0320	53.9240	39.0400
5	12/23/09	Post	16:20	1240	0.3728	0.3524	462.2720	436.9760
6	12/23/09	Post	18:05	1230	0.0101	0.0061	12.4328	7.5251
7	12/23/09	Post	16:30	1180	0.0216	0.0130	25.4880	15.3400
8	12/23/09	Post	16:35	1175	0.0114	0.0048	13.3950	5.6400
9	12/23/09	Post	19:41	700	0.0140	0.0070	9.800	4.9000
10	12/23/09	Post	16:50	1160	0.0584	0.0476	67.7440	55.2160
4	01/20/10	Post	19:00	600	0.0105	0.0066	6.3000	3.9600
5	01/20/10	Post	19:15	1080	0.1254	0.1164	135.4320	125.7120
3	01/21/10	Post	16:00	1120	0.0159	0.0101	17.8752	11.3210
6	01/21/10	Post	16:15	1150	0.0197	0.0153	22.6550	17.5950
7	01/21/10	Post	21:15	1220	0.0085	0.0050	10.3700	6.1000
8	01/21/10	Post	21:15	1140	0.0073	0.0038	8.3220	4.3320

9	01/21/10	Post	19:55	220	0.0188	0.0130	4.1360	2.8600
10	01/21/10	Post	21:20	420	0.0598	0.0521	25.1370	21.8971
4	01/23/10	Post	23:20	1100	0.0142	0.0099	15.6200	10.8900
7	01/23/10	Post	23:40	1100	0.0083	0.0047	9.1300	5.1700
8	01/23/10	Post	23:40	1120	0.0062	0.0028	6.9440	3.1360
3	01/24/10	Post	1:40	60	0.0126	0.0071	0.7581	0.4309
5	01/24/10	Post	0:30	1210	0.1134	0.1036	137.2140	125.3560
6	01/24/10	Post	18:15	380	0.0139	0.0103	5.2820	3.9140
9	01/24/10	Post	.	0	.	.	.	.
10	01/24/10	Post	1:25	920	0.0286	0.0228	26.3074	21.0459
3	02/05/10	Post	8:40	0	.	.	.	.
4	02/05/10	Post	6:30	1120	0.0063	0.0030	7.0560	3.3600
5	02/05/10	Post	6:20	1160	0.0904	0.0820	104.8640	95.1200
6	02/05/10	Post	17:00	400	0.0071	0.0036	2.8400	1.4400
7	02/05/10	Post	8:30	1030	0.0053	0.0016	5.4796	1.6438
8	02/05/10	Post	8:55	785	0.0037	0.0074	2.9233	5.8466
9	02/05/10	Post	17:10	60	0.0130	0.0058	0.7800	0.3480
10	02/05/10	Post	9:00	830	0.0139	0.0090	11.5909	7.5065
3	03/11/10	Post	4:08	0	.	.	.	.
4	03/11/10	Post	4:08	160	0.0127	0.0066	2.0428	1.0640
5	03/11/10	Post	4:08	985	0.1132	0.1028	111.5020	101.2580
6	03/11/10	Post	4:08	40	0.0180	0.0113	0.7235	0.4522
7	03/11/10	Post	4:08	425	0.0148	0.0060	6.2900	2.5500
8	03/11/10	Post	4:08	855	0.0094	0.0024	8.0370	2.0520
9	03/11/10	Post	4:08	20	0.0462	0.0294	0.9240	0.5880
10	03/11/10	Post	4:08	280	0.0248	0.0160	6.9440	4.4800
3	03/12/10	Post	17:00	0	.	.	.	.
4	03/12/10	Post	17:00	260	0.0017	0.0014	0.4420	0.3640
5	03/12/10	Post	17:00	515	0.0235	0.0194	12.1236	10.0003

6	03/12/10	Post	17:00	0	.	.	.	.
7	03/12/10	Post	17:00	0	.	.	.	.
8	03/12/10	Post	17:00	0	.	.	.	.
9	03/12/10	Post	17:00	0	.	.	.	.
10	03/12/10	Post	17:00	0	.	.	.	.
3	03/22/10	Post	7:49	0	.	.	.	.
4	03/21/10	Post	16:15	1580	0.0263	0.01623	41.6077	25.6371
5	03/21/10	Post	15:55	1605	0.3184	0.2980	511.0320	478.2900
7	03/21/10	Post	18:15	1260	0.0100	0.0030	12.6000	3.7800
8	03/21/10	Post	18:15	1500	0.0102	0.0030	15.3000	4.5000
9	03/21/10	Post	19:20	60	0.0168	0.0102	1.0080	0.6120
10	03/21/10	Post	19:20	1060	0.0366	0.0280	38.7960	29.6800
6	03/22/10	Post	19:10	1250	0.0135	0.0085	16.9575	10.6400
4	03/25/10	Post	17:15	1530	0.1762	0.1218	269.5860	186.3540
5	03/25/10	Post	17:30	1600	1.1396	1.1008	1823.3600	1761.2800
7	03/25/10	Post	18:00	800	0.0150	0.0056	12.0000	4.4800
8	03/25/10	Post	18:00	920	0.0120	0.0090	11.0400	8.2800
10	03/25/10	Post	18:30	640	0.3252	0.2948	208.1280	188.6720
3	03/25/10	Post	19:10	120	0.0348	0.0230	4.1760	2.7600
6	03/25/10	Post	19:10	520	0.0498	0.0386	25.8960	20.0720
9	03/25/10	Post	19:10	80	0.0648	0.0464	5.1840	3.7120
3	04/03/10	Post	6:33	0	.	.	.	.
4	04/03/10	Post	6:33	1370	0.0240	0.0120	32.8800	16.4400
5	04/03/10	Post	6:33	1520	0.1094	0.0978	166.288	148.6500
6	04/03/10	Post	6:33	155	0.0328	0.0222	5.0840	3.4410
7	04/03/10	Post	6:33	780	0.0134	0.0046	10.4520	3.5880
8	04/03/10	Post	6:33	1240	0.0126	0.0036	15.6240	4.4640
9	04/03/10	Post	6:33	10	0.1988	0.1556	1.9880	1.5560
10	04/03/10	Post	6:33	790	0.0258	0.0172	20.3820	13.5880

3	04/07/10	Post	20:03	0	.	.	.	.
4	04/07/10	Post	20:03	1175	0.0208	0.0060	24.4400	7.0500
5	04/07/10	Post	20:03	1220	0.0656	0.0528	80.0320	64.4160
6	04/07/10	Post	20:03	40	0.0836	0.0464	3.3440	1.8560
7	04/07/10	Post	20:03	330	0.0200	0.0052	6.6000	1.7160
8	04/07/10	Post	20:03	660	0.0172	0.0040	11.3520	2.6400
9	04/07/10	Post	20:03	0	.	.	.	.
10	04/07/10	Post	20:03	520	0.0644	0.0440	33.4880	22.8800
3	04/24/10	Post	.	0	.	.	.	.
4	04/24/10	Post	2:00	1590	0.0204	0.0072	32.4360	11.4480
5	04/24/10	Post	1:45	1550	0.0316	0.0192	48.9800	29.7600
6	04/24/10	Post	6:30	720	0.0220	0.0080	15.8400	5.7600
7	04/24/10	Post	2:30	1480	0.0180	0.0052	26.6400	7.6960
8	04/24/10	Post	2:45	1540	0.0148	0.0004	22.7920	0.6160
9	04/24/10	Post	7:00	165	0.0144	0.0004	2.3760	0.0660
10	04/24/10	Post	4:00	1420	0.0192	0.0064	27.2640	9.0880
3	05/02/10	Post	2:17	1200	0.0372	0.0216	44.6400	25.9200
4	05/01/10	Post	0:55	1520	0.0196	0.0064	29.7920	9.7280
5	05/01/10	Post	0:35	1580	0.0852	0.0732	134.6160	115.6560
6	05/01/10	Post	2:30	1560	0.0444	0.0292	69.2640	45.5520
7	05/01/10	Post	1:15	1490	0.0136	0.0008	20.2640	1.1920
8	05/01/10	Post	1:20	1540	0.0036	0.0048	5.5440	7.3920
9	05/01/10	Post	3:00	1570	0.0340	0.0192	53.3800	30.1440
10	05/01/10	Post	2:00	1620	0.0416	0.0260	67.3920	42.1200
3	05/15/10	Post	.	0	.	.	.	.
4	05/15/10	Post	.	0	.	.	.	.
5	05/15/10	Post	.	0	.	.	.	.
6	05/15/10	Post	.	0	.	.	.	.
7	05/15/10	Post	11:01	260	0.0292	0.0100	7.5920	2.6000

8	05/15/10	Post	11:01	200	0.0532	0.0228	10.6400	4.5600
9	05/15/10	Post	.	0	.	.	.	.
10	05/15/10	Post	.	0	.	.	.	.
3	05/26/10	Post	23:32	60	0.1252	0.0908	7.5120	5.4480
4	05/26/10	Post	23:32	300	0.0956	0.0680	28.6800	20.4000
5	05/26/10	Post	23:32	540	0.2956	0.2716	159.6240	146.6640
6	05/26/10	Post	23:32	35	0.2332	0.1876	8.1620	6.5660
7	05/26/10	Post	23:32	1170	0.0524	0.0336	61.3080	39.3120
8	05/26/10	Post	23:32	860	0.0492	0.0248	42.3120	21.3280
9	05/26/10	Post	23:32	60	0.0728	0.0492	4.3680	2.9520
10	05/26/10	Post	23:32	60	0.3264	0.3024	19.5840	18.1440
3	09/16/10	Post	.	0	.	.	.	.
4	09/16/10	Post	3:40	60	0.0660	0.0344	3.9600	2.0640
5	09/16/10	Post	3:40	60	0.4596	0.4108	27.5760	24.6480
6	09/16/10	Post	3:40	20	0.0608	0.0264	1.2160	0.5280
7	09/16/10	Post	3:40	460	0.0424	0.0212	19.5040	9.7520
8	09/16/10	Post	3:40	1450	0.0292	0.0080	42.3400	11.6000
9	09/16/10	Post	3:40	40	0.1076	0.0632	4.30400	2.5280
10	09/16/10	Post	3:40	860	0.0464	0.0312	39.9040	26.8320

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AN ASSESSMENT OF PRESCRIBED BURNING ON SOILS AND EROSION POTENTIAL IN THE MIXED HARDWOOD FORESTS OF THE OZARK HILLS IN SOUTHERN ILLINOIS

Major Professor: Dr. Jon E. Schoonover

Publications:

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Singh, G, Schoonover, J.E., Monroe, K.S, Williard, K.W.J., and Ruffner, C.M. 2017. Prescribed Burning and Erosion Potential in Mixed Hardwood Forests of Southern Illinois. *Forests. 8* 111-131