PINE

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SOIL AN-D NUTRIENT LOSS FOLLOWING SITE PREPARATION BURNING

by

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Summary:

Sediment loss and nutrient concentrations in runoff were evaluated to determine the effects of site preparation burning on a recently harvested loblolly pine (*Pinus taeda* L.) site in east Texas. Sediment and nutrient losses prior to treatment were approximately the same from control plots and pretreatment burn plots. Nutrient analysis of runoff samples indicated that the prescribed burn caused increased losses of N, P, K, Ca, and Mg from treatment plots. Preliminary results indicate a significant increase in sediment concentration and sediment loss following the prescribed burning application. The data indicate a gradual decline in sediment loss and nutrient concentration over time from treatment plots with respect to control plots. Sediment loss following treatment was within the range of sediment loss for an undisturbed forest in the south.

Erosion, Sediment, Nutrients, Prescribed Burning

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INTRODUCTION

Prescribed burning applications are frequently used in southern pine ecosystems during site preparation as an effective management tool. Site preparation burning is primarily used to reduce forest fuel loads, control competitive hardwood understory species, and prepare harvested sites for pine regeneration (Schoch and Binkley, 1986). However, little information is available about the effects of site preparation burning on soil erosion and nutrient loss from harvested loblolly pine (*Pinus taeda* L.) stands.

The impact of prescriid burning on soil and nutrient losses are related to several factors including timing, intensity, and frequency of prescribed burns. Fire affects soil physical properties that are dependent on organic matter including soil structure, aggregation, and pore space (Knoepp and Swank, 1993). In addition, Knoepp and Swank (1993) found that the impact of tire on soil physical properties depends on both the severity (heat penetration into the soil) and intensity (above ground temperature) of the fire. Prescribed fires can also affect nutrient loss pathways such as volatilization, ash convection, runoff, wind and soil erosion, and leaching of fire-released nutrients (Schoch and Binkley, 1986). Nitrogen (N) is an essential nutrient for southern pine and its availability often limits productivity in forest ecosystems (Vose and Swank, 1993). Total ecosystem N is generally decreased by fire due to the volatilization of N contained in wood, leaf material, and the forest floor (Knoepp and Swank, 1993). Changes in soil physical properties and nutrient cycling caused by prescribed fire might have adverse effects on long-term productivity and should be considered during management activities. Site characteristics including vegetation cover, soil erodibility, and steepness of slope can influence the rate of soil and nutrient loss caused by prescribed burning applications.

Research pertaining to soil and nutrient loss as a result of prescribed fire shows large variations among the findings. For example, Tiedemann et al. (1979) found that high intensity fires produced increased soil erosion, while Knoepp and Swank (1993) found that fires characterized as high intensity and light severity seldom resulted in excessive erosion. In many cases, it is difficult to detect the effects of site preparation burning on soil loss due to the other influential factors that cause erosion during site preparation operations. Van Lear and Danielovich, (1988) observed a significant increase in soil erosion caused by logging activities, which overshadowed the impact of prescribed burning on soil erosion Other studies have shown noticeable differences in erosion patterns following prescribed fires. Swift et al. (1993) found that prescribed fires created potential erosion sources of bare soil exposed by smoldering logs. The consumption of organic matter during fires converts nutrients into more soluble forms resulting in increased concentrations of nutrients in the mineral soil (Kodama and Van Lear, 1980). Van Lear and Danielovich, (1988) found that nutrient content in sediment was high in burn plots, but total quantities of nutrient being lost from the site were small due to low erosion rates.

This study was initiated to evaluate the effects of site preparation burning on soil and nutrient losses on a harvested loblolly pine site in east Texas. The objectives of the study were to quantify soil loss, sediment concentration, and nutrient (N, P, K, Ca, Mg, and S) concentrations in runoff following site preparation burning.

MATERIALS AND METHODS

Study Site

Six bordered erosion plots consisting of three treatment and three control plots were located in northwest Angelina County in east Texas, approximately 11 km west of Lufkin. The area is characterized by a humid subtropical climate with normal annual precipitation and temperature of 107 cm and 19 °C, respectively. The dominant soil series is Rosenwall, with slopes ranging from one to five percent. Soils are classified as clayey, mixed, thermic Aquic Hapludults with sandy loam A horizons up to 10 cm thick and a clay texture Bt horizon. These soils are moderately well drained, with medium runoff and slight to moderate erosion potential (Dolezel; Soil Conservation Service, 1988). Vegetation prior to clear-cut harvesting during the fall of 1998 was loblolly pine. Herbicide application was applied aerially to the site in the spring of 1999. Erosion plots were installed shortly after the herbicide application, one month prior to the site preparation burn.

The experimental design consisted of three replicated pairs of erosion plots, 1.8 meters by 2.4 meters in length. Each replicated pair consisted of one treatment plot, prescribed fire, and one control plot. The flumes were covered to prevent detached soil particles from entering by ways other than overland flow. Total runoff volume from each plot was transported down slope into two separate 120-liter containers using 4-inch PVC pipes with a two-way splitter attached to the terminal end. Runoff from small storm events was collected in two 5-liter utility pails suspended underneath the PVC pipes within the 120-liter containers. Precipitation at the site was recorded using a tipping bucket rain gage and three standard rain gages with one gage located at each paired plot.

Treatment

The study site was burned on August 1, 1999. Fire was excluded from a random plot within each replicated pair to serve as a control. Fire lines were constructed around the perimeter of each control plot prior to the burn During the event of the fire, control plots were covered with saturated blankets to prevent the vegetation from burning. No evidence of tire was observed in control plots following the prescribed burn. Treatment plots were burned by removing the plot borders to expose the vegetation to the fire. The flumes were left intact during the prescribed burn to prevent any disturbances that might have occurred from the removal and reinstallation of the flume. Treatment plots were representative of the site burn and experienced similar fire characteristics noted throughout the site. The fire was characterized as low intensity and light severity, with maximum temperatures ranging from 200 °C to 300 °C.

Sample Collection and Analysis

Total runoff from each storm event was stored in two 120-liter collectors in order to calculate runoff volume and collect samples for sediment and nutrient analysis. Sediment that settled in the flumes was collected after each storm as part of the total sediment loss. Representative sub-samples of total runoff volume were collected using l-liter plastic bottles. Runoff samples were usually collected within 24 hours of each storm event to minimize evaporative loss and volatilization of nutrients. Samples for anion (NO_3^-, PO_4^{-3}, and SO_4^{-2}) analysis were stored at 4 °C until analyzed, normally within 24 hours. Runoff samples analyzed for cation (NH_4^+, K^+, Ca^{+2}, and Mg^{+2}) concentrations were preserved with concentrated sulfuric acid to a pH < 2 and stored at 4 °C for no more than 28 days.

Sediment in runoff samples was filtered by vacuum filtration. Glass fiber filter paper was used to filter out suspended clay particles. Sediment collected from runoff samples and the flumes were oven-dried at 105 °C and recorded on a dry weight basis. Organic matter content in the sediment was determined by igniting the organic matter at 530 °C (loss on ignition) and weighing the remaining inorganic fractions. Sediment was not analyzed for nutrient content.

Nutrient (NO_3^-, NH_4^+, PO_4^{-3}, K^+, Ca^{+2}, Mg^{+2}, and SO_4^{-2}) concentrations in the runoff samples were analyzed using a Dionex ion chromatograph. The method for anion analysis was based on a Dionex method for the analysis of 13 anions with isocratic elution (Dionex Institute Inc., 1996). The method developed for cation analysis was based on a Dionex method for the isocratic elution of ammonium, alkali metals, and alkaline earth metals (Dionex Institute Inc., 1995).

Significant differences between control and treatment plots were determined with a paired t-test at a significance level of 0.05. An independent paired t-test was conducted for each storm event to determine significant differences in total soil loss, sediment concentration, runoff volume, and nutrient loss. Homogeneity of variances was tested with a folded F statistic. When variances were not homogeneous, an approximate t-test and Satterthwaite's approximation for computing degrees of freedom were used (SAS Institute Inc., 1998). Nutrient loss was estimated by converting nutrient concentration (mg L^{-1}) to weight (mg) using the total volume of runoff from each plot. Estimates for soil and nutrient losses per hectare were extrapolated based on the mean average for the control and treatment plots.

RESULTS

Pretreatment

Average sediment concentration in runoff prior to the prescribed burn was approximately the same for control plots (384 mg L^{-1}) and pretreatment burn plots (387 mg L“). No significant differences were detected in sediment concentration prior to treatment. Small variations in sediment concentration were observed among the individual plots. Total sediment loss, including both organic and inorganic fractions, was not significantly different between control (12.2 kg ha^{-1}) and pretreatment burn plots (10.4 kg ha-‘). Slight variations in sediment loss were detected among the three-paired plots, but not within the individual pairs. Nutrient concentration in runoff prior to treatment remained constant and fairly uniform throughout the plots, with the exception of phosphate (PO_4^{-3}). Total nutrient loss in runoff was small with no significant differences detected among the paired or individual plots. Due to the droughty conditions that existed, pretreatment sample collection and analysis consisted of only two storm events. Although the number of pretreatment events was limited, results indicated strong similarities in the measured parameters.

Post-treatment

Sediment concentration. -- During the first 9 months following treatment, average sediment concentration in runoff was greater from burn plots (400 mg L^{-1}) than control plots (195 mg L^{-1}). The maximum sediment concentration of 1410 mg L^{-1} (data not shown) occurred during the first storm event that followed the site preparation burn. Sediment concentration in runoff was significantly greater ($p = 0.0182$) from burn plots than control plots (Table 1). Four storm events occurring shortly after the burn produced a significant difference in sediment concentration among the treatment and control plots. However, the storm event that occurred on April 4 produced a significantly higher sediment concentration in control plots compared to burn plots (Figure 1). Variation in sediment concentration was small among the three replicated pairs and within the individual paired plots. Levels of sediment concentration could not be related to the volume of runoff or amount of precipitation.

Table 1. Sediment loss, sediment concentration, and runoff for 14 storm events (1999-2000) in east Texas.

Storm Event	Precipitation (mm)	Runoff (mm)		Sediment Concentration (mg L^{-1})		Organic Sediment (kg ha^{-1})		Inorganic Sediment (kg ha^{-1})		Total Sediment (kg ha^{-1})	
		Control	Burn	Control	Burn	Control	Burn	Control	Burn	Control	Burn
7/13	13	0.2	0.1	453	462	1.2	1.3	5.5	4.4	6.7	5.6
7/22	9	0.1	0.2	314	310	0.9	0.6	4.5	4.3	5.4	4.8
8/1	Prescribed Burn Applied										
9/8	17	0.2	0.2	348	658	1.3	*3.4	7.0	9.1	8.3	12.5
9/29	36	2.8	6.1	272	*680	4.8	26.7	17.5	53.8	22.3	80.6
10/8	49	9.2	9.5	276	*893	13.7	*43.4	31.3	*90.1	45.0	*133.6
10/30	31	4.5	9.9	79	181	2.3	7.4	8.3	14.4	10.7	21.9
12/12	30	12.9	12.4	73	73	1.9	5.2	10.0	11.2	11.9	16.3
1/10	18	0.3	0.3	45	65	0.2	0.6	1.0	2.0	1.1	2.6
1/28	19	0.3	0.6	24	*136	0.1	1.5	0.4	*2.6	0.5	4.1
2/18	13	1.1	1.3	183	*567	1.7	6.0	4.5	8.6	6.2	14.6
2/23	15	0.3	0.6	107	313	1.0	2.2	2.2	6.2	3.2	8.4
3/21	21	4.9	4.6	44	118	1.4	3.3	2.9	6.5	4.3	9.8
3/26	18	3.0	2.9	27	40	0.6	0.4	1.7	2.7	2.3	3.1
4/3	49	14.5	10.9	*34	25	4.9	3.9	2.2	4.4	7.1	8.3

• Significant at the 0.05 level.

Note: Storms with precipitation less than 12.7 mm (0.5 in.) not shown, except 7/22.

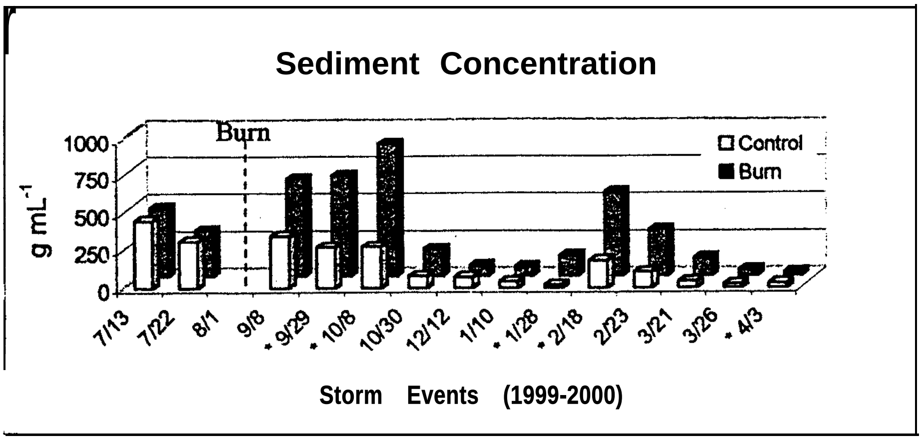

Figure 1. Sediment concentration.
* Significant difference at the 0.05 level.
Note: Storms with precipitation less than 12.7 mm (0.5 in.) not shown, except 7/22.

Sediment loss. -- Total sediment loss during the first 9 months following treatment was 140 kg ha^{-1} and 348 kg ha^{-1} for control and treatment plots, respectively. Sediment loss was significantly greater ($p = 0.0413$) from burn plots than from control plots (Table 1). The greatest sediment loss occurred during the storm event on Oct. 8, accounting for nearly 40% of the total sediment loss from treatment plots (Table 1). Although cumulative sediment loss was significantly greater in treatment plots, only one storm event on Oct. 8 produced a significant difference in sediment loss between treatment and control (Figure 2). The organic and inorganic fractions of the total sediment loss remained relatively constant following treatment, except for the first storm event. Analysis of the first storm event indicated that sediment from the burn plots was 56% organic matter. In general, organic matter constituted approximately 33% and 28% of the total sediment loss from the burn and control plots, respectively (Figure 3). Variation in sediment loss from the three replicated burn plots increased after treatment (Figure 4). Sediment loss from the burn plot in replicate 3 was approximately 290% and 110% greater than the other two burn plots on Sept. 29 and Oct. 8, respectively. After the first 3 months, differences in sediment loss between control and treatment gradually decreased with respect to time.

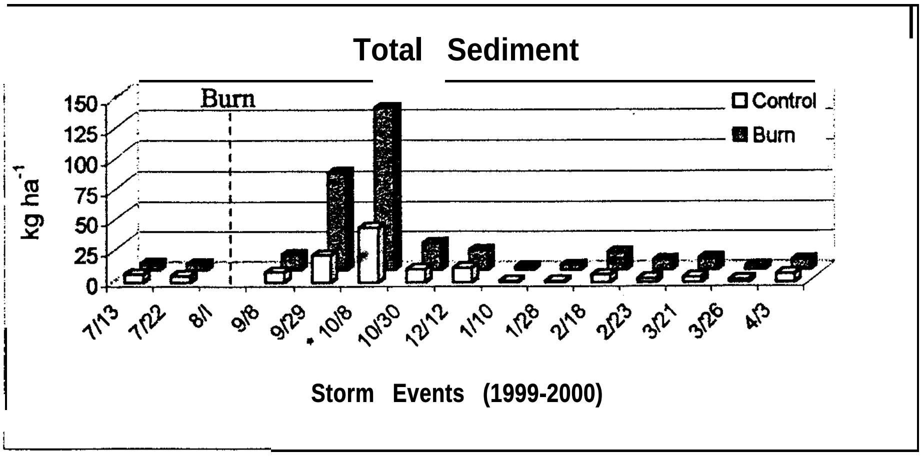

Figure 2. Total Sediment.
* Significant difference at the 0.05 level.
Note: Storms with precipitation less than 12.7 (0.5 in.) not shown. except 7/22.

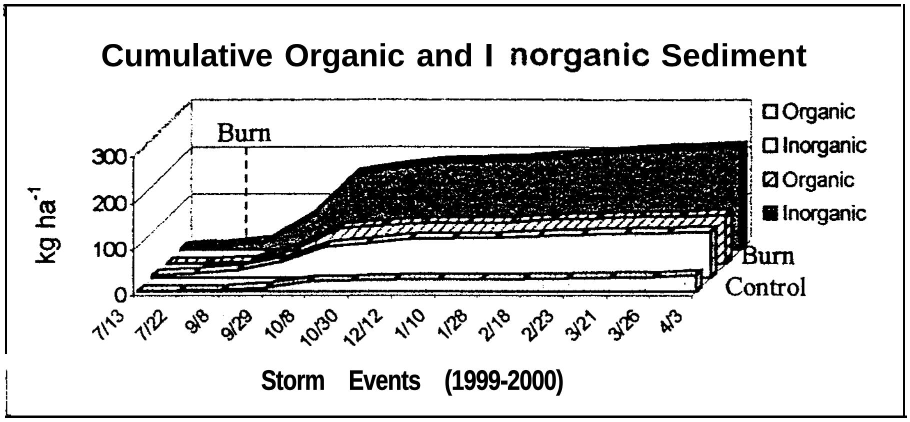

Figure 3. Cumulative organic and inorganic sediment.
Note: Storms with precipitation less than 12.7 (0.5 in.) not shown, except 7/22.

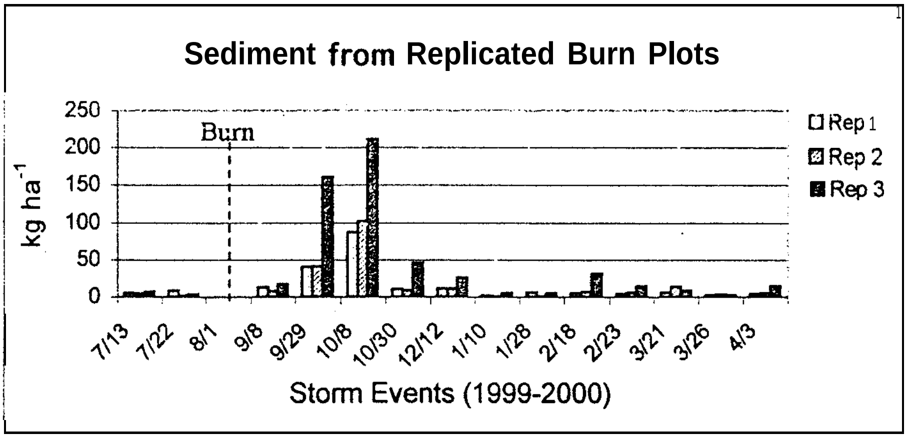

Figure 4. Sediment from replicated burn plots.
Note: Storms with precipitation less than 12.7 (0.5 in.) not shown, except 7/22.

Nutrient loss. -- Nutrient analysis of runoff indicated that the burning treatment caused an increased loss of inorganic nitrogen (N) from burn plots (Table 2). Total inorganic N loss from runoff following treatment was 2.3 kg ha^{-1} for control and 4.4 kg ha^{-1} for burn. Nitrate (NO_3^-) constituted approximately 86% of the total inorganic N loss from treatment and control plots. The remaining 14% of the total inorganic N was composed of ammonium (NH_4^+). No nitrites were detected in runoff. Nitrate and ammonium loss greatly increased during the first 3 months after the burn and gradually decreased with respect to time (Figure 5). Maximum NO_3^- concentration was greater in burn plots (57 mg L^{-1}) than control plots (33 mg L^{-1}). Nitrate concentration from burn plots increased after treatment and gradually decreased back to the pretreatment levels (Figure 6). Although total inorganic N loss from burn plots increased by 91% with respect to control, no significant statistical differences were detected between burn and control plots. Variation in total inorganic N loss was quite high between the replicated pairs due to the variability in N concentration and amount of runoff volume. No significant differences were detected on an individual storm basis. The large variation in total inorganic N between each plot combined with the small number of degrees of freedom in this study decreased the probability of finding any significant differences.

Table 2. Total ammonium (NH_4^+) and nitrate (NO_3^-) nitrogen loss for 12 storm events (1999-2000) in east Texas.

storm Event	Precip (mm)	NO_3^- - N (g ha^{-1})		NH_4^+ - N (g ha-‘)		Total Inorganic N (g ha^{-1})	
		Control	Burn	Control	Burn	Control	Burn
7/13	13	0.9	0.5	3.1	1.9	4.0	2.4
7/22	9	0.3	0.4	1.7	1.5	2.0	1.9
8/1	------------------------------ Prescribed Burn Applied ------------------------------						
9/8	17	1.1	2.0	2.9	4.2	4.0	6.2
9/29	36	67.1	163.1	28.4	177.6	95.5	340.7
10/8	49	757.2	904.7	243.6	308.4	1000.8	1213.2
10/30	31	604.4	1757.8	1.8	137.2	606.2	1895.0
12/12	30	545.8	796.7	0.0	0.0	545.8	796.7
1/28	19	1.0	9.2	0.0	0.0	1.0	9.2
2/18	13	11.9	14.2	0.0	0.0	11.9	14.2
2/23	15	2.3	5.6	0.0	0.0	2.3	5.6
3/21	21	21.0	6.9	0.0	0.0	21.0	9.6

* Storms with precipitation less than 12.7 mm (0.5 in.) not shown, except 7/22.

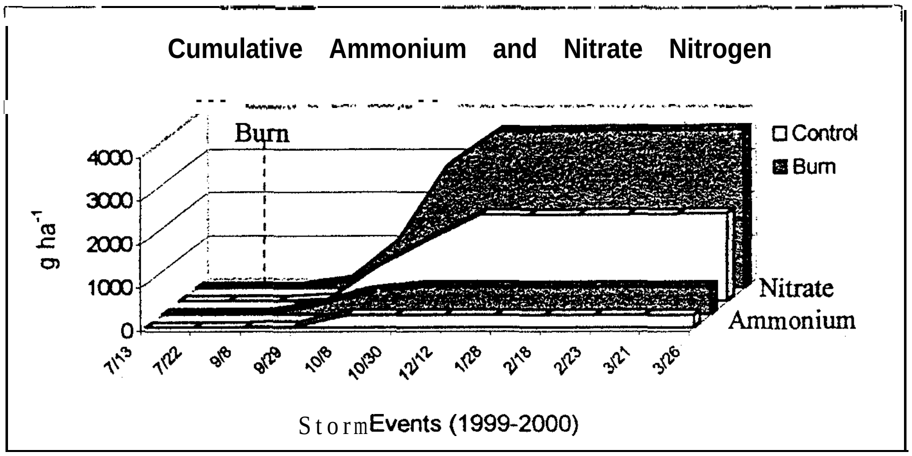

Figure 5. Cumulative ammonium and nitrate nitrogen.
Note: Storms with precipitation less than 12.7 mm (OS-in) not shown, except 7/22.

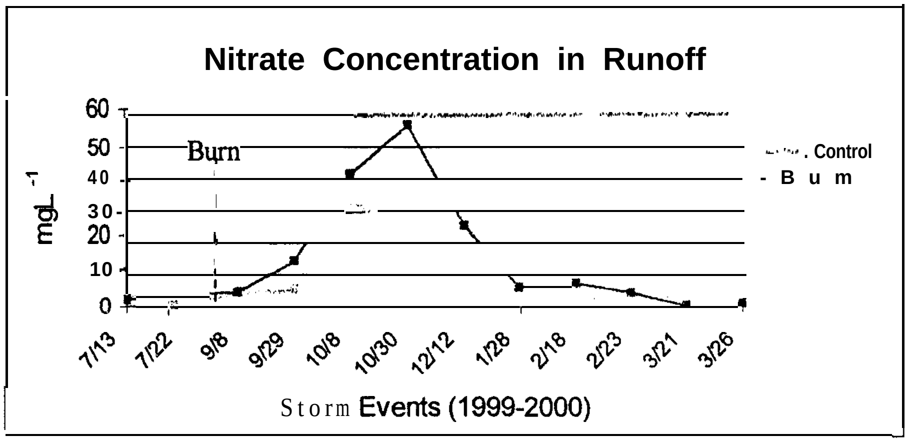

Figure 6. Nitrate concentration in runoff.
Note: Storms with precipitation less than 12.7 mm (0.5-in) not shown, except 7/22.

Nutrient (PO_4^{-3}, K^+, Mg^{+2}, and Ca^{+2}) analysis in runoff, not including N, indicated that site preparation burning caused an increase in nutrient loss. Phosphate (PO_4^{-3}) loss was extremely small relative to all other nutrients (Figure 7). Sulfate (SO_4^{-2}) concentration was not affected by the burn with a total loss of 1.2 kg ha^{-1} for both control and treatment plots. Burn plots lost more calcium (Ca^{+2}) than any other nutrient during the first 9 months following treatment (Table 3). Calcium loss was 2.2 kg ha^{-1} and 5.7 kg ha^{-1} from control and burn plots, respectively. Burn plots lost 3.8 kg ha^{-1} of potassium (K^+) and 1.7 kg ha^{-1} of magnesium (Mg^{+2}), approximately twice the quantity lost from the control plots. However, no significant statistical differences in nutrient loss were indicated between the control and treatment plots for PO_4^{-3}, K^+, Mg^{+2}, Ca^{+2}, and SO_4^{-2}. Variations in nutrient concentrations were large among the replicated burn and control plots, with the exception of SO_4^{-2}. Large variation in nutrient concentration and the small number of degrees of freedom in this study decreased the probability of finding significant differences among the control and treatment plots.

Table 3. Nutrient loss for 12 storms events (1999-2000) in east Texas.

storm Event	Precip (mm)	PO_4^{-3} - P (g ha^{-1})		K^+ (g ha^{-1})		Ca^{+2} (g ha^{-1})		Mg^{+2} (g ha^{-1})		SO_4^{-2} (g ha^{-1})	
		Control	Burn	Control	Burn	Control	Burn	Control	Burn	Control	Rum
7/13	13	0.9	0.0	35.0	24.0	15.5	8.9	4.2	3.5	3.7	2.2
7/22	9	0.0	0.0	16.8	14.1	3.3	6.1	1.6	1.8	0.9	1.0
8/1	Prescribed Burn Applied										
9/8	17	0.0	0.5	16.2	44.9	11.2	35.1	3.1	13.8	3.1	10.0
9/29	36	0.5	39.8	249.3	744.4	151.1	823.9	45.9	202.8	24.2	126.4
10/8	49	27.0	0.0	849.5	997.4	726.8	1573.4	272.1	384.5	564.1	236.1
10/30	31	0.0	0.0	420.3	1439.2	773.9	2451.3	253.1	758.9	99.1	283.4
12/12	30	0.0	0.0	240.0	261.2	251.8	344.6	80.4	105.1	227.4	195.1
1/28	19	0.0	0.0	0.5	7.8	0.9	14.8	0.2	4.3	6.0	17.0
2/18	13	0.0	0.0	31.4	83.1	15.5	30.7	39.8	101.5	24.7	85.1
2/23	15	0.0	0.0	10.2	54.0	3.1	38.4	7.4	25.2	8.0	27.6
3/21	21	1.0	0.0	145.8	98.0	276.9	360.4	47.2	47.2	120.6	97.1

Note: Storms with precipitation less than 12.7 mm (0.5 in.) not shown, except 7/22.

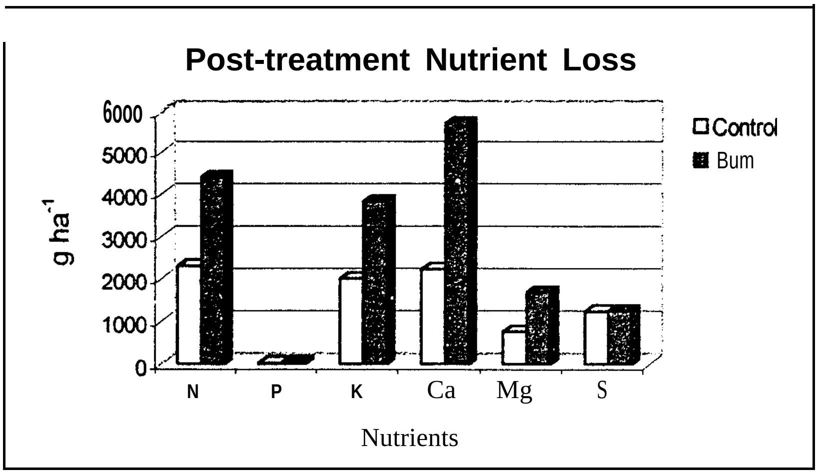

Figure 7. Post-treatment nutrient loss.

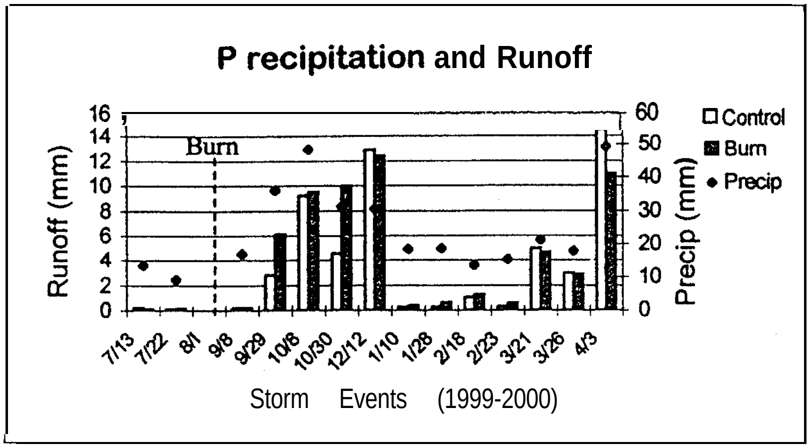

Figure 8. Precipitation and runoff.
Note: Storms with precipitation less than 12.7 mm (0.5-in) not shown, except 7/22.

<u>Runoff</u> -- Total runoff volume for the 18-storm events that occurred after treatment was 12% greater in treatment plots than control plots (Table 1). The site preparation burn did not significantly affect runoff volume. However, two storm events (i.e. Sept. 29 and Oct. 30) produced twice the volume of runoff in treatment plots compared to control (Figure 8). Percent runoff for the majority of storm events ranged from 1 to 10%. However, the highest percent runoff was recorded on Dec. 12 during an intense storm event that produced 42% runoff.

<u>Temporal trends</u>. -- The results from the 18 storm events that were evaluated after treatment indicate that site preparation burning had the greatest effect on sediment and nutrient loss during the first 3 months (Table 4). Sediment concentration gradually decreased 3 months following treatment. However, both control and burn plots experienced a similar trend causing the difference to remain relatively constant. Sediment lost from burn plots greatly decreased with respect to control 3 months following treatment. Total inorganic N loss from burn plots was 102% and 66% greater than control plots for O-3 months and 3-6 months after treatment, respectively. At 6-9 months, control plots lost 28% more inorganic N than burn plots. Similar trends were observed, although not as drastic, for all nutrients analyzed except for sulfate.

Table 4. Pretreatment and post-treatment sediment concentration, sediment loss, and macronutrient loss summarized for 20 storm event (1999-2000) in east Texas.

	Average Sediment Concentration (mg L^{-1})		Total Sediment (kg ha^{-1})		Macronutrients					
					Total Inorganic N (g ha^{-1})		PO_4^{-3} - P (g ha“)		K^+ (g ha^{-1})	
	Control	Bum	Control	Bum	Control	Bum	Control	Bum	Control	Bum
Pretreatment	384	386	12.2	10.4	6.4	4.3	0.9	0.0	51.8	38.1
Post-treatment										
3-months	439	766	94.7	258.5	1709.6	3459.2	27.7	40.3	1565.3	3269.6
6-months	62	221	20.7	39.7	552.1	914.7	0.1	4.7	253.2	292.3
g-months	84	213	24.9	49.5	46.1	35.6	1.1	0.0	191.0	257.8

DISCUSSION

Sediment Concentration

Site preparation burning caused a significant increase in sediment concentration from treatment plots. Extreme dry conditions persisted for 1 month following burn treatment and probably affected the maximum sediment concentration (1410 mg L^{-1}) from the first storm event. Wind blown sediment might have accumulated in the flumes in both treatment and control plots during the dry period, increasing the sediment concentration in the runoff for that particular event. The gradual decrease in sediment concentration (766 mg L^{-1} to 213 mg L^{-1}) from 3-9 months following treatment corresponds to the vegetation regrowth that took place on site. Blackburn et al. (1986) noted a similar decrease in sediment concentration (2 119 mg L^{-1} to 167 mg L^{-1}) one year following site preparation burning in a harvested shortleaf pine (*Pinus echinuta* Mill.) stand in east Texas. By 9 months following treatment, sediment concentration was slightly higher in control plots compared to burn plots. This was due to the excessive vegetation regrowth in the burn plots, which consisted of grasses, wild flowers, open-field weeds, and woody sprouts. Van Lear and Danielovich, (1988) found that the biomass of shrub and herbaceous vegetation in burned plots was approximately twice that of control plots after one growing season. By 9 months, sediment concentration returned to average, which is suggested to be 61 mg L^{-1} for small undisturbed southern pine watersheds (Ursic, 1979).

Sediment Loss

Total sediment loss was significantly greater from burn plots than control plots. Large variations among the replicated treatment plots can be related to the percent of soil exposed by fire and the slight differences in slopes. The burn plot in replicate 3 accounted for the largest fraction of sediment that constituted the total sediment loss. The quantity of sediment lost from burn plot replicate 3 was greatest due to the larger area of exposed soil and the slightly steeper slope. Organic matter content in the sediment was high, approximately 30%, for both control and treatment plots. Van Lear and Danielovich, (1988) found similar results with high organic matter content in sediment (17-22%) following site preparation burning. The percent of organic matter content in the sediment from burn plots during the first storm event was relatively high at 56%. This increase might have occurred from partially charred organic fragments that were suspended in the runoff immediately following treatment. Swift et al. (1993) found that the initial sediment collected after the burn was mainly light charcoal particles later followed by fibrous fragments of forest floor. Although significant increases were detected in sediment loss for a short period after the burn the total amount of sediment loss was relatively small compared to some site preparation activities, Sediment loss following treatment was within the range of sediment loss (trace to 717 kg ha^{-1} yr^{-1}) for undisturbed forests in the south (Yoho, 1980).

Nutrient Loss

Burning slightly increased nutrient (NO_3^-, NH_4^+, PO_4^{-3}, K^+, Mg^{+2}, and Ca^{+2}) concentration in runoff. Elevated levels of nutrient concentration peaked 3 months following the burn and gradually decreased with respect to control. Knoepp and Swank, (1993) found elevated levels of NO_3^- and NH_4^+ to persist for 1 year and 8 months after prescribed burning, respectively. Levels of NH_4^+ in runoff remained elevated for only 3-4 months in this study, similar to the findings of Klopatek et al. (1990). The duration of elevated inorganic N response is influenced by timing of burning, environmental conditions, and variability in N immobilization rates (Knoepp and Swank, 1993). The nitrate concentration in the runoff from control plots increased slightly after the burn treatment. This increase was probable caused by wind blown sediment contamination in control plots, which occurred during the dry period immediately following the burn. Differences in the amount of nutrient loss between control and burn plots were more apparent than the differences found in the nutrient concentrations. This resulted from the additive effect that runoff volume has on the nutrient loss when converting concentration to total nutrient loss. Total inorganic N loss in runoff was relatively small compared to other pathways of N loss (i.e. volatilization). Up to 250 kg ha^{-1} N can be volatilized during an effective site preparation burn of a stem-only harvested loblolly pine stand (Tew et al., 1986). By 5 months, inorganic N inputs from rainfall alone may compensate for the amount of inorganic N loss in runoff. These findings are based on Knoepp and Swank, (1993) estimates for average annual inorganic N concentration (0.30 mg L^{-1}) in rainfall. However, nutrient concentration in the sediment was not analyzed and should be considered. Van Lear and Danielovich, (1988) found that burning increased nutrient concentration in accumulated sediment in southern pine forest.

Precipitation and Regrowth

The abnormally dry conditions during this study may have affected the results. Total soil and nutrient losses would likely be greater during a year with normal precipitation. However, it is uncertain if the differences in the measured parameters between control and treatment plots would be affected. The differences between control and treatment plots may have been unusually large compared to a normal year because the lack of precipitation stunted vegetation regrowth, leaving bare soil exposed over longer time periods. Total precipitation recorded during the study was approximately 45 cm less than half the normal annual precipitation of 107 cm Only 36.6 cm of precipitation resulted in erosive events during the 10-month study period.

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