SOIL AND NUTRIENT LOSSES FOLLOWING SITE PREPARATION BURNING IN A HARVESTED LOBLOLLY PINE SITE

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ABSTRACT. *Soil 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. Soil 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. Results also indicate a significant increase in sediment concentration and soil loss from plots following the prescribed burning application. The data indicate a gradual decline in soil loss and nutrient concentration over time from treatment plots with respect to control plots. Soil loss following treatment was within the normal range of soil loss for an uncut forest in the south.*

Keywords. *Erosion, Nutrient loss, Prescribed burning, Sediment, Soil loss.*

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 on the effects of site preparation burning on soil and nutrient losses from harvested loblolly pine (*Pinus taeda* L.) stands.

The impact of prescribed burning on soil and nutrient losses are related to several factors including timing, intensity, and frequency of the 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 fire on soil physical properties depends on both the severity (heat penetration into the soil) and intensity (aboveground 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 plant nutrient, 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 losses caused by prescribed burning applications.

Research pertaining to soil and nutrient losses as a result of prescribed fire shows large variations among the findings. For example, Tiedemann et al. (1979) found that high–intensity fires 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 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. Several studies have shown noticeable differences in soil and nutrient losses following prescribed fires. For example, Swift et al. (1993) found that prescribed fires created potential erosion sources of bare soil exposed by smoldering logs. Van Lear and Danielovich (1988) found that nutrient content in sediment increased after burning, but total quantities of nutrient 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) losses 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

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normal annual precipitation and temperature of 107 cm and 19°C, respectively. The dominant soil series is Rosenwall, with slopes ranging from 1% to 5%. Soils are classified as clayey, mixed, thermic Aquic Hapludults with sandy loam A horizons up to 10 cm thick and a clay texture B_t horizon. These soils are moderately well drained, with medium runoff and slight to moderate erosion potential (Dolezel, 1988). Vegetation prior to clear–cut harvesting during the fall of 1998 was loblolly pine. Herbicide 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 bordered erosion plots, 1.8 m wide × 2.4 m long. Each replicated pair consisted of one treatment plot (clear–cut forest followed by prescribed fire) and one control plot (clear–cut forest without prescribed fire). The flumes for each erosion plot were covered to prevent detached soil particles from entering by means other than overland flow. Total runoff volume from each plot was transported downslope into two separate 120 L containers using 4 in. PVC pipes with a two–way splitter attached to the terminal end. 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. In addition, control plots were covered during the burn with saturated blankets to prevent ignition. No evidence of fire 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 preparation area and experienced similar fire characteristics noted throughout the site. The fire was characterized as low intensity and light severity, with maximum aboveground temperatures at 1 m ranging from 200°C to 300°C.

SAMPLE COLLECTION AND ANALYSIS

Total runoff from each storm event was stored in two 120 L collectors in order to determine the runoff volume and collect samples for sediment and nutrient analysis. Sediment that settled in the flumes was collected after each storm event as part of the total soil loss. Representative subsamples of total runoff volume were collected using 1 L plastic bottles. Runoff samples were usually collected within 24 h of each storm event to minimize evaporative water loss and nutrient transformations. Samples for anion (NO_3^-, PO_4^{-3}, and SO_4^{-2}) analysis were stored at 4°C until analyzed, normally within 24 h. 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 soil particles. Sediment collected from runoff samples and the flumes was 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 the Dionex method for analysis of 13 anions with isocratic elution (Dionex, 1996). The method developed for cation analysis was based on the Dionex method for isocratic elution of ammonium (NH_4^+), alkali metals, and alkaline earth metals (Dionex, 1995).

Significant differences among control and treatment plots were determined using 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, 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^{-1}). No significant differences were detected in sediment concentration prior to treatment. Small variations in sediment concentration were observed among individual plots. Total soil loss, including both organic and inorganic fractions, was not significantly different among control (12.2 kg ha^{-1}) and pretreatment burn plots (10.4 kg ha^{-1}). Total soil loss is defined as the quantity of soil lost from the bordered plots, not necessarily the quantity of soil transported off site. Slight variations in soil loss were detected among the three pairs of plots, but not within the individual pairs. Nutrient concentrations in runoff prior to treatment remained constant and fairly uniform among the plots, with the exception of phosphorous (P). Phosphorous concentration in runoff was highly variable among the plots and with each storm event. Total nutrient loss in runoff was small, with no significant differences detected among 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 nine 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)

Table 1. Sediment concentration and soil loss by treatment for 14 storm events (1999–2000) in east Texas. Organic fraction (%) is the percent of organic matter in the total soil loss. Storms with precipitation less than 12.7 mm (0.5 in.) not shown, except July 22.

Storm Event	Pt (mm)	Sediment Concentration (mg L^{-1})		Soil Loss (kg ha^{-1})		Organic Fraction (%)	
		Control	Burn	Control	Burn	Control	Burn
July 13	13	453	462	6.7	5.6	18	22
July 22	9	314	310	5.4	4.8	17	11
Aug. 1	Prescribed Burn Applied						
Sept. 8	17	348	658	8.3	12.5	16	27
Sept. 29	36	272	680[a]	22.3	80.6	22	33
Oct. 8	49	276	893[a]	45.0	133.6[a]	30	33
Oct. 30	31	79	181	10.7	21.9	22	34
Dec. 12	30	73	73	11.9	16.3	16	32
Jan. 10	18	45	65	1.1	2.6	14	23
Jan. 28	19	24	136[a]	0.5	4.1	27	36
Feb. 18	13	183	567[a]	6.2	14.6	27	41
Feb. 23	15	107	313	3.2	8.4	31	26
March 21	21	44	118	4.3	9.8	32	33
March 26	18	27	40	2.3	3.1	24	13
April 3	49	34[a]	25	7.1	8.3	69	47

[a] Significant at the 0.05 level.

occurred during the first storm event following the site preparation burn. Sediment concentration in runoff following treatment 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 treatment and control plots. However, the storm event that occurred on April 4 produced a significantly higher sediment concentration in control plots with respect to burn plots. Variation in sediment concentration was small among the three replicated pairs and within the individual paired plots. Levels of sediment concentration did not correlate to the volume of runoff or amount of precipitation.

Soil Loss

Total soil loss during the first nine months following treatment was 140 kg ha^{-1} and 348 kg ha^{-1} for control and treatment plots, respectively. Soil loss following treatment was significantly greater ($p = 0.0413$) from burn plots than from control plots. The greatest soil loss occurred during the storm event on October 8, accounting for nearly 40% of the total soil loss from treatment plots (table 1). Although cumulative soil loss was significantly greater in treatment plots, only one storm event on October 8 produced a significant difference in soil loss between treatment and control. The organic matter content of the total soil loss remained relatively constant following treatment, except for the first storm event. Analysis of the first storm event after treatment (data not shown) indicated that soil loss from the burn plots was 56% organic matter. On average, organic matter constituted approximately 33% and 28% of the total soil loss from the burn and control plots, respectively (fig. 1). Variation in soil loss from the three replicated burn plots increased after treatment (fig. 2). Soil loss from the burn plot in replicate 3 was approximately 290% and 110% greater than the other two burn plots on September 29 and October 8, respectively. After the first three months, differences in soil loss between control and treatment gradually decreased with respect to time.

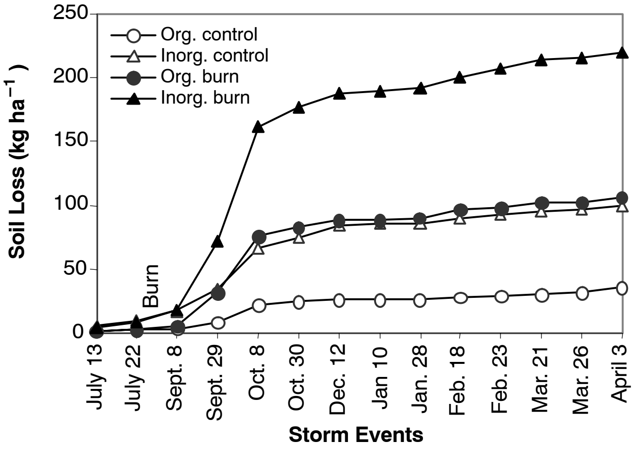

Figure 1. Cumulative soil loss, organic and inorganic fractions, for 14 storm events (1999–2000). Storms with precipitation less than 12.7 mm (0.5 in.) not shown, except July 22.

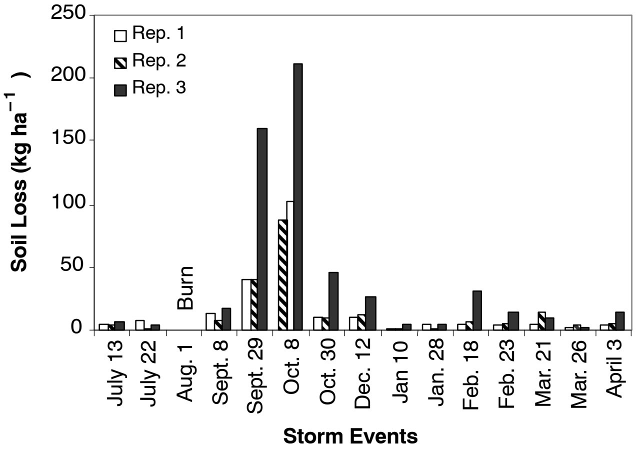

Figure 2. Variation in soil loss among replicated burn plots for 14 storm events (1999–2000). Storms with precipitation less than 12.7 mm (0.5 in.) not shown, except July 22.

Nutrient Losses

Nutrient analysis of runoff indicated that the prescribed fire 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 4.3 kg ha^{-1} for burn. Nitrate–N (NO_3–N) constituted approximately 85% of the total inorganic N loss from treatment and control plots. The remaining 15% of the total inorganic N was composed of NH_4–N. No nitrites were detected in runoff. Nitrate–N and NH_4–N losses greatly increased in the burn plots during the first three months after treatment and then gradually decreased with respect to time (fig. 3). Maximum NO_3–N concentration was greater in burn plots (12.9 mg L^{-1}) than control plots (7.5 mg L^{-1}). Nitrate–N concentration from burn plots increased after treatment and gradually decreased back to the pretreatment levels (fig. 4). Although total inorganic N loss from burn plots increased by 87% with respect to control, no significant statistical differences were detected between burn and control plots. Variation in total inorganic N loss was quite high among the replicated pairs due to the variability in N concentration and the amount of runoff volume. In addition, no significant statistical differences in total inorganic N loss 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.

Nutrient analysis of runoff indicated that site preparation burning caused an increase in P, K, Mg, and Ca losses. Phosphorous (P) loss following treatment was extremely small relative to all other nutrients (fig. 5). Sulfur (S) loss was not affected following the prescribed fire, with a total loss of 5.6 kg ha^{-1} for both control and treatment plots. Burn plots lost more calcium (Ca) than any other nutrient during the first nine months following treatment (table 3). Calcium loss following treatment 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) following treatment, approximately twice the quantity lost from the control plots. However, no significant statistical differences in nutrient losses were detected between control and treatment plots for P, K, Mg, Ca, and S. Variations in nutrient concentrations were large among replicated burn and control plots, with the exception of S. Large variation in nutrient concentrations and the small number of degrees of freedom in this study decreased the probability of finding significant differences between control and treatment plots.

Table 2. Nitrate–N and NH_4–N losses by treatment for 12 storm events (1999–2000) in east Texas. Storms with precipitation less than 12.7 mm (0.5 in.) not shown, except July 22. Nutrient data are not available for storm events occurring on January 10 and April 3.

Storm Event	Pt (mm)	NO_3–N (g ha^{-1})		NH_4–N (g ha^{-1})		Cumulative Inorganic N (g ha^{-1})	
		Control	Burn	Control	Burn	Control	Burn
July 13	13	1	1	3	2	4	2
July 22	9	0	0	2	2	6	4
Aug. 1	Prescribed Burn Applied						
Sept. 8	17	1	2	3	4	4	6
Sept. 29	36	67	163	28	178	99	347
Oct. 8	49	757	905	244	308	1100	1560
Oct. 30	31	604	1758	2	137	1707	3455
Dec. 12	30	546	797	0	0	2252	4252
Jan. 28	19	1	9	0	0	2253	4261
Feb. 18	13	12	14	0	0	2265	4275
Feb. 23	15	2	6	0	0	2268	4281
March 21	21	21	7	0	0	2288	4288
March 26	18	10	4	0	0	2298	4292

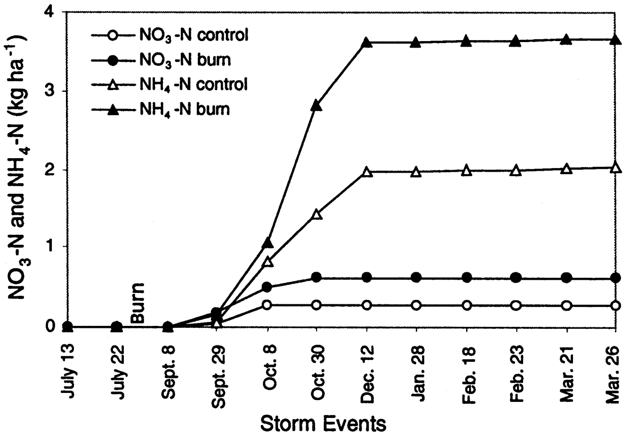

Figure 3. Cumulative NO_3–N and NH_4–N losses in runoff for 12 storm events (1999–2000). Storms with precipitation less than 12.7 mm (0.5 in.) not shown, except July 22. Nutrient data are not available for storm events occurring on January 10 and April 3.

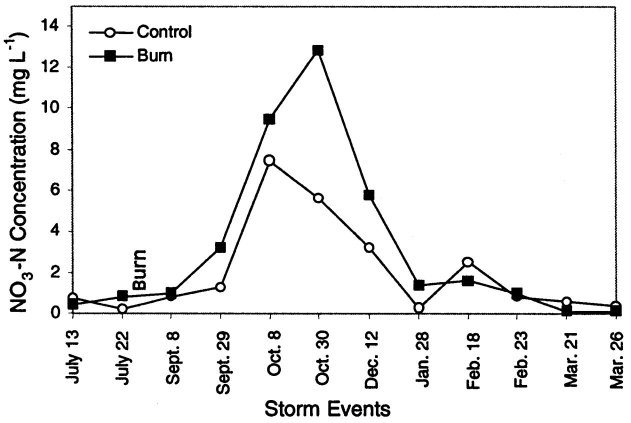

Figure 4. Temporal changes in NO_3–N concentration in runoff following treatment application. Storms with precipitation less than 12.7 mm (0.5 in.) not shown, except July 22. Nutrient data are not available for storm events occurring on January 10 and April 3.

Table 3. Nutrient (P, K, Ca, Mg, and S) losses by treatment for 12 storms events (1999–2000) in east Texas. Storms with precipitation less than 12.7 mm (0.5 in.) not shown, except July 22. Nutrient data are not available for storm events occurring on January 10 and April 3.

Storm Event	Pt (mm)	PO_4^{-3}–P (g ha^{-1}) Control	PO_4^{-3}–P (g ha^{-1}) Burn	K^+ (g ha^{-1}) Control	K^+ (g ha^{-1}) Burn	Ca^{+2} (g ha^{-1}) Control	Ca^{+2} (g ha^{-1}) Burn	Mg^{+2} (g ha^{-1}) Control	Mg^{+2} (g ha^{-1}) Burn	SO_4^{-2}–S (g ha^{-1}) Control	SO_4^{-2}–S (g ha^{-1}) Burn
July 13	13	1	0	35	24	16	9	4	4	2	1
July 22	9	0	0	17	14	3	6	2	2	1	1
Aug. 1	Prescribed Burn Applied										
Sept. 8	17	0	1	16	45	11	35	3	14	2	5
Sept. 29	36	1	40	249	744	151	824	46	203	12	63
Oct. 8	49	27	0	850	997	727	1573	272	385	282	118
Oct. 30	31	0	0	420	1439	774	2451	253	759	50	142
Dec. 12	30	0	0	240	261	252	345	80	105	114	98
Jan. 28	19	0	0	1	8	1	15	0	4	3	9
Feb. 18	13	0	0	31	83	16	31	40	102	12	43
Feb. 23	15	0	0	10	54	3	38	7	25	4	14
March 21	21	1	0	146	98	277	360	47	47	60	49
March 26	18	0	0	58	54	72	65	36	48	43	51

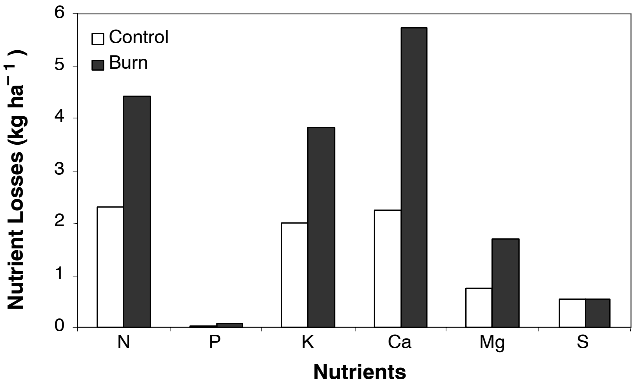

Figure 5. Cumulative nutrient losses following treatment for 16 storm events (1999–2000). Nutrient data are not available for storm events occurring on January 10 and April 3.

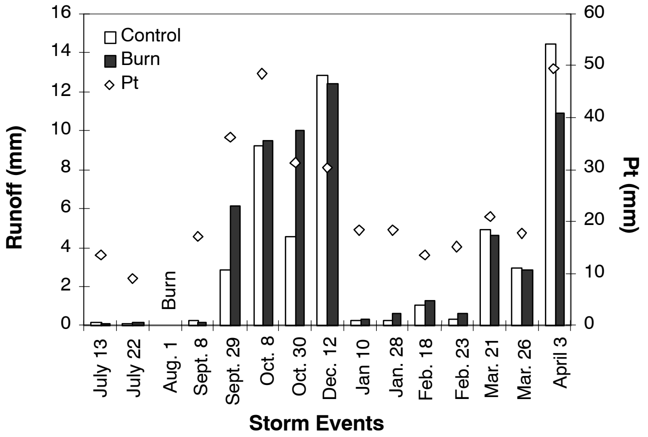

Figure 6. Relationship between precipitation and runoff for 14 storm events (1999–2000). Storms with precipitation less than 12.7 mm (0.5 in.) not shown, except July 22.

Runoff

Total runoff volume for the 18 storm events that occurred after treatment was 12% greater in treatment plots than control plots. The site preparation burn did not significantly affect runoff volume. However, two storm events (September 29 and October 30) produced more than twice the volume of runoff in treatment plots compared to control (fig. 6). Percent runoff for the majority of storm events ranged from 1% to 10%. However, the highest percent runoff was recorded on December 12 during an intense storm event that produced 42% runoff.

Temporal Trends

Results from the storm events evaluated after treatment indicate that site preparation burning had the greatest effect on soil and nutrient losses during the first three months (table 4). Sediment concentration gradually decreased three months following treatment. However, both control and burn plots experienced a similar decrease in sediment concentration, causing the differences among treatments to remain relatively constant. Soil loss from burn plots greatly decreased with respect to control after three months following treatment. Total inorganic N loss from burn plots was 102% and 66% greater than control plots for 0 to 3 months and 3 to 6 months after treatment, respectively. At 6 to 9 months after treatment, control plots lost 28% more inorganic N than burn plots. Similar trends were observed, although not as dramatic, for all nutrients analyzed except sulfur.

Table 4. Pretreatment and post–treatment sediment concentration and soil loss summarized for 18 storm events (1999–2000) in east Texas. Macronutrient losses represent 16 storm events because nutrient data are not available for storm events occurring on January 10 and April 3.

	Average Sediment Concentration (mg L^{-1})		Soil Loss (kg ha^{-1})		Macronutrients					
					Total Inorganic N (g ha^{-1})		PO_4^{-3}–P (g ha^{-1})		K^+ (g ha^{-1})	
Time Period	Control	Burn	Control	Burn	Control	Burn	Control	Burn	Control	Burn
Pretreatment	384	386	12	10	6	4	1	0	52	38
Post–treatment:										
0–3 months	439	766	95	259	1710	3459	28	40	1565	3270
3–6 months	62	221	21	40	552	915	0	5	253	292
6–9 months	84	213	25	50	56	40	1	0	249	312

CONCLUSIONS

SEDIMENT CONCENTRATION

Site preparation burning caused a significant increase in sediment concentration from treatment plots. Extremely dry conditions persisted for one month following the burn treatment and probably affected the maximum sediment concentration (1410 mg L^{-1}) from the first storm event. Windblown sediment might have accumulated in the flumes in both the 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 to 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 (2119 mg L^{-1} to 167 mg L^{-1}) one year following site preparation burning in a harvested shortleaf pine (*Pinus echinata* Mill.) stand in east Texas. By nine months following treatment, sediment concentration was slightly higher in control plots compared to burn plots. This was due to the vigorous vegetation regrowth in the burn plots, which consisted of grasses, forbs, 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 nine months following treatment, sediment concentration returned to normal background levels, which is suggested to be 61 mg L^{-1} for small, undisturbed southern pine watersheds (Ursic, 1979).

SOIL LOSS

Total soil loss was significantly greater from burn plots than control plots. Large variations among replicated treatment plots can be related to the differences in the amount of soil exposed by fire and the slight differences in slopes. The burn plot in replicate 3 accounted for the largest fraction of the soil loss due to a larger area of exposed soil and a slightly steeper slope. Organic matter content in the sediment was high, approximately 30%, for both control and treatment plots. Van Lear and Danielovich (1988) also found high organic matter content in sediment (17% to 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 soil loss for a short period after the burn, the total amount of soil loss was relatively small compared to some site preparation activities. The quantity of soil loss from both the control and treatment plots during this study was within the range of soil loss (trace to 717 kg ha^{-1} $year^{-1}$) for uncut forests in the south (Yoho, 1980).

NUTRIENT LOSS

Burning slightly increased nutrient (N, P, K, Mg, and Ca) concentrations in runoff. Elevated levels of nutrient concentrations persisted for three months following the burn and then gradually decreased with respect to the control. Knoepp and Swank (1993) found elevated levels of NO_3–N and NH_4–N to persist for 1 year and 8 months after prescribed burning, respectively. Levels of NH_4–N in runoff remained elevated for only 3 to 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). Nitrate–N concentration in runoff from the control plots increased slightly after the burn treatment. This increase was probably caused by windblown sediment contamination in control plots, which occurred during the dry period immediately following the burn. Another possibility for the increase of NO_3–N in control plots might have been inflow from the surrounding burn areas. Differences in nutrient losses between control and burn plots were more apparent than the differences in the nutrient concentrations. This resulted from the compounding effect that higher runoff volumes had on the nutrient losses when converting nutrient concentrations to total nutrient losses. 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). As inorganic N loss decreased six months following treatment, inorganic N inputs from rainfall alone may have compensated for the amount lost in runoff. These findings are based on the estimates of Knoepp and Swank (1993) 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

Total precipitation recorded during the study was only 45 cm, less than half of the historic average for the period. 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 among control and treatment plots would be affected. The differences between control and treatment plots may have been unusually large compared to those in a normal year because the lack of precipitation stunted vegetation regrowth, leaving bare soil exposed over longer time periods.

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