The Society for engineering in agricultural, food, and biological systems

Paper Number: 01-8002
An ASAE Meeting Presentation

Sediment and Runoff Losses following Harvesting/Site Prep Operations on a Piedmont Soil in Alabama

J. McFero Grace III, Research Engineer

USDA Forest Service, Southern Research Station, 520 Devall Drive, Auburn, AL 36830, jmgrace@fs.fed.us

Emily A. Carter, Research Soil Scientist

USDA Forest Service, Southern Research Station, 520 Devall Drive, Auburn, AL 36830, eacarter@fs.fed.us

Written for presentation at the
2001 ASAE Annual International Meeting
Sponsored by ASAE
Sacramento Convention Center
Sacramento, California, USA
July 30-August 1, 2001

Abstract. *Impacts of soil erosion on water quality from forest harvesting* and *site preparation have received increased concern in recent years. The study presented here was performed in Lee County, Alabama to investigate the impact of harvesting and site preparation on* a *20-year-old loblolly pine (Pinus taeda L.) plantation on sediment and runoff yield. Sediment and runoff yield responses on treated areas were compared to that of undisturbed areas. Impacts were evaluated by monitoring isolated small plots, 2-m by 5.5-m, over a 2-year period following the harvest prescription. Sediment yield increases of 2-fold and 30-fold were observed from Treatment 1 (harvest/site prep/plant) and Treatment 2 (harvest /plant), respectively. Runoff yield results were similar to those observed with sediment yields from treatments in the investigation. Differences in the two treatments were likely due to the differences in surface roughness, which affects infiltration and surface flow velocity.*

Keywords. Forest operations, Soil Erosion, Surface Runoff, Harvesting

Introduction

Clearly undisturbed forest conditions afford a high level of protection against soil erosion. Vegetative cover intercepts raindrops and therefore reduces the energy for soil detachment. Forest floor cover provides surface roughness and allows for greater infiltration of precipitation, thereby reducing surface runoff that could detach and transport sediment. But even under these undisturbed conditions, some soil erosion is inevitable. Undisturbed forestlands typically have erosion rates less than 0.30 t/ha/yr (Smith and Stamey 1965; Beasley 1979; Yoho 1980).

Disturbed forest conditions, however, can have accelerated erosion losses due to disturbance of the forest floor and removal of vegetative cover. The magnitude of erosion losses in disturbed forest conditions is dependent on the type and extent of disturbance (Nutter 1978). Literature reports that forest operations increase soil erosion and suspended sediments in draining waters in various geographical regions in the United States (Patric 1978; Yoho 1980; Harr and Fredriksen 1988; Blackburn et al 1986; Beasley 1979).

Increased demand for forest products has been meet with intensive forest management activity, which result in some level of disturbance. Forest management activities that scarify the forest floor can increase sediment losses from that of undisturbed conditions. Harvesting, site preparation, and other management activities utilized in intensive forest management systems often involve mechanized equipment and access roads resulting in increased forest floor scarification, compaction, and rutting. Accelerated erosion can be expected following these operations because storm energy has increased potential to detach and transport soil particles. Harvesting and site preparation are necessary elements in forest management to meet the increasing demands, however degrading environmental impacts should not be the consequence The design of environmentally sustainable forest management systems hinges on quantifying the impact of forest operations on the forest ecosystem. Information on the magnitude of erosion losses following harvesting and site preparation is needed to further develop models as planning tools in forest management. The study reported here is an effort to quantify the effect of harvesting and site preparation on sediment and runoff yield from a 20-year-old Loblolly pine (Pinus taeda L.) plantation in the Southern Piedmont in Alabama.

Methods

Study Area

A 25-ha 20-year-old Loblolly pine (Pinus taeda L.) plantation owned by Mead Coated Board, Inc. was selected for study in the Southern Piedmont of central Alabama (Lee County, AL near Auburn, AL). The basal area of loblolly pine was estimated as 27.5 m2/ha. Slopes on the study watershed ranged from 3 to 15 percent. Soils on the study tract were primarily Gwinnett sandy loam soils and classified as clayey, kaolinitic, thermic members of the Rhodic Kanhapludult family (Soil Conservation Service 1981). Long-term mean annual precipitation in the study area is about 1370 mm of which 70 percent occurs from September to March.

Treatments

Both treatments involved a mechanical clear-cut harvest during the spring of 1998. The harvesting system, average production of 181 Mg/day, consisted of two Prentice 270 loaders each equipped with a delimber/slasher, two grapple skidders (Timberjack 450C and 460), and a HydroAx 511 E feller buncher. The following two treatments with different disturbance levels were studied:

1). Treatment 1. Treatment area was clear-cut harvested, sheared, ripped, bedded, and machine planted on contour.

2). Treatment 2. Treatment area was clear-cut harvested and machine planted on contour.

Nine experimental plots with similar topography (10 percent slope), soils, and drainage were installed following harvesting operations during the summer of 1998. Three replications of each treatment and an undisturbed control were used in this experiment. Study plots were monitored for the subsequent fall/winter before removal for site preparation and planting operations. Study plots were reinstalled following planting and monitored through the subsequent fall/winter period.

Plots were bounded to isolate runoff within each plot from the surrounding landscape (Figure 1). Borders, 20-cm high, were installed to bound plots and define treatment areas. Plot area was 11 m2 with dimensions 2 m in width x 5.5 m in length, exactly one-fourth the standard USLE plot. Runoff from each plot was collected in a sediment tank, 210-liter capacity, placed at the bottom of each experimental unit. Sediment movement was quantified for each associated plot by collecting, drying, and weighing sediment deposited in sediment tanks. Total delivered sediment from each associated treatment was determined as the amount of suspended and deposited sediment in collection tanks for each associated treatment. Runoff volume was determined following each event by measuring volume of stormwater collected in sediment tanks. The treatment effect on soil movement and runoff was determined by comparing sediment yields and runoff characteristics from treatment plots to that of the undisturbed controls. Rainfall amount and duration were recorded by a tipping bucket rain gauge located on the study site.

SAS general linear modeling procedures were utilized to analyze response variables for this examination. The hypothesis for this comparison was that treatment means were equal in resulting sediment yield and runoff production. Sediment and runoff yield were dependent variables in this investigation. The independent variable considered in the statistical analysis was treatment method. Duncan's Multiple Range Test was used to test treatment means (a = 0.05), where analysis of variance indicated significant differences.

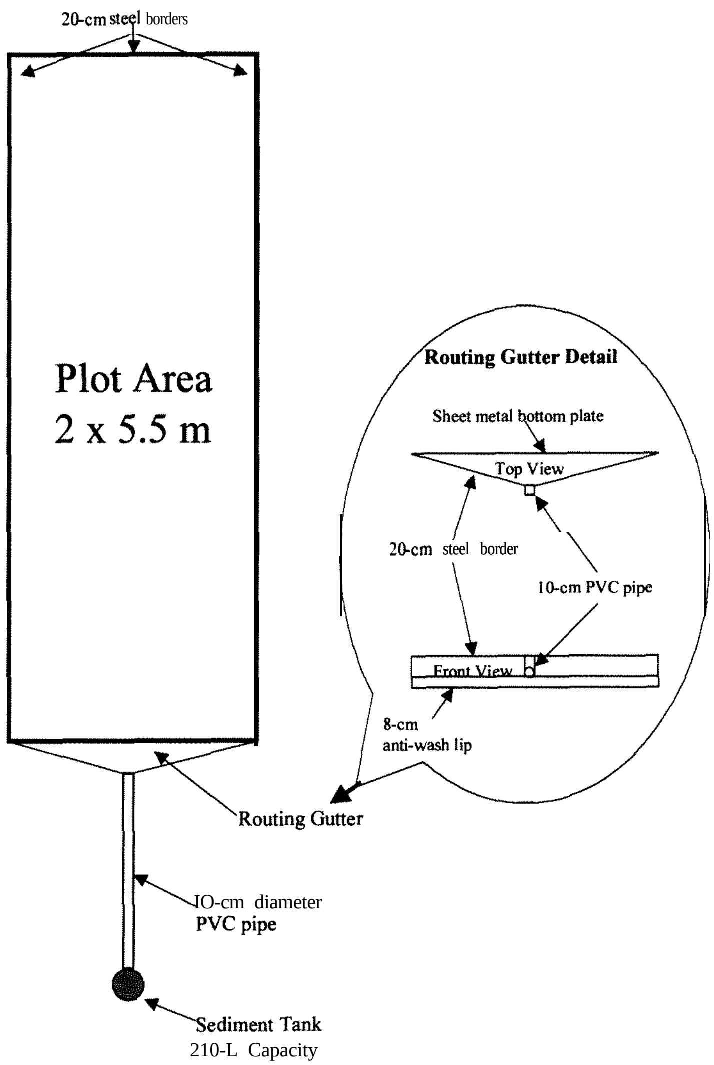

Figure 1. Plot design for the North Auburn study.

Results and Discussion

Thirty-five storm events were recorded during twenty-months of the North Auburn study (Table 1). Installation problems resulted in the exclusion of four of these events due to incomplete data for those events. A total of thirty-one events provided for direct comparisons between the treatments in the analysis of treatment effects. Sampling events, collected within 24 hours of the conclusion of a storm, consisted of single storm events for this investigation. Precipitation, in the form of rain, observed at the study site for individual sampling events ranged from 8.6 to 252.9 mm. The total accumulated precipitation at the site during the 20-month study totaled 1715.2 mm.

Consistent with previous literature, high intensity storms resulted in greater soil erosion than low intensity storms in this investigation. Soil loss was greater for treatments than for the undisturbed control for all but four events (events 11, 15, 19, and 28) (Figure 2). Events 11, 15, and 19 were low intensity storm events, which resulted in little sediment yield from the treatments and the control. Sediment yields for treatments and the control during these events

'Table 1. Precipitation for each sampling event during the North Auburn study.

Sampling Event	Sampling Date	Elapsed Days	Precipitation (mm)
1	12/15/98	3	24.1
2	1/7/99	26	53.3
3	1/27/99	46	41.9
4	2/2/99	52	68.6
5	3/8/99	86	64.5
6	3/19/99	97	54.9
7	3/30/99	108	24.4
6	4/7/99	116	14.7
9	5/11/99	150	47.8
10	5/18/99	157	34.9
11	6/9/99	179	45.8
12	6/21/99	191	66.1
13	6/29/99	199	252.9
14	7/6/99	206	20.3
15	7/8/99	208	18.8
16	7/20/99	220	72
17	8/27/99	258	75.8
16	9/10/99	272	50.1
19	9/30/99	292	46.9
20	10/6/99	299	14.7
21	10/12/99	305	86.9
22	12/29/99	383	26.7
23	1/18/00	403	73.7
24	1/26/00	411	44.5
25	2/29/00	445	18.3
26	3iQi00	454	8.6
27	3/15/00	460	19.8
26	3/23/00	468	60.5
29	4/4/00	480	56.4
30	4/18/00	494	22.9
31	5/22/00	528	74.2
32	6/23/00	560	27.9
33	7/24/00	591	38.6
34	8/4/00	600	43.9
35	8/11/00	607	17.8
	Total Accumulated Precipitation		1715.2

were less than 7 g. The sediment yield differences between the control and treatments during these events were less than 1 g. Event 28 was a high intensity early spring storm, which resulted in the greatest runoff for the control (Figure 3). Event 28 had a greater impact on the control by producing 41 percent of the cumulative sediment yield total for the control. The same event only accounted for 17 and 12 percent of cumulative sediment yield totals for Treatment 1 and 2, respectively.

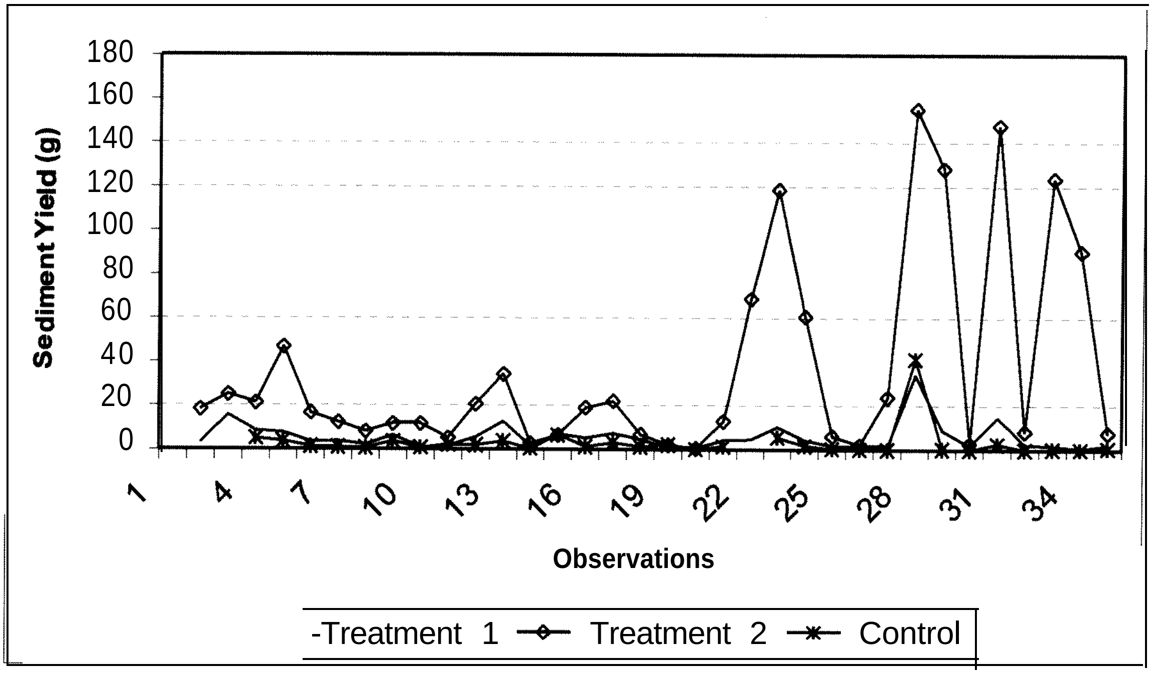

Figure 2. Sediment yield for individual storm events for the North Auburn study.

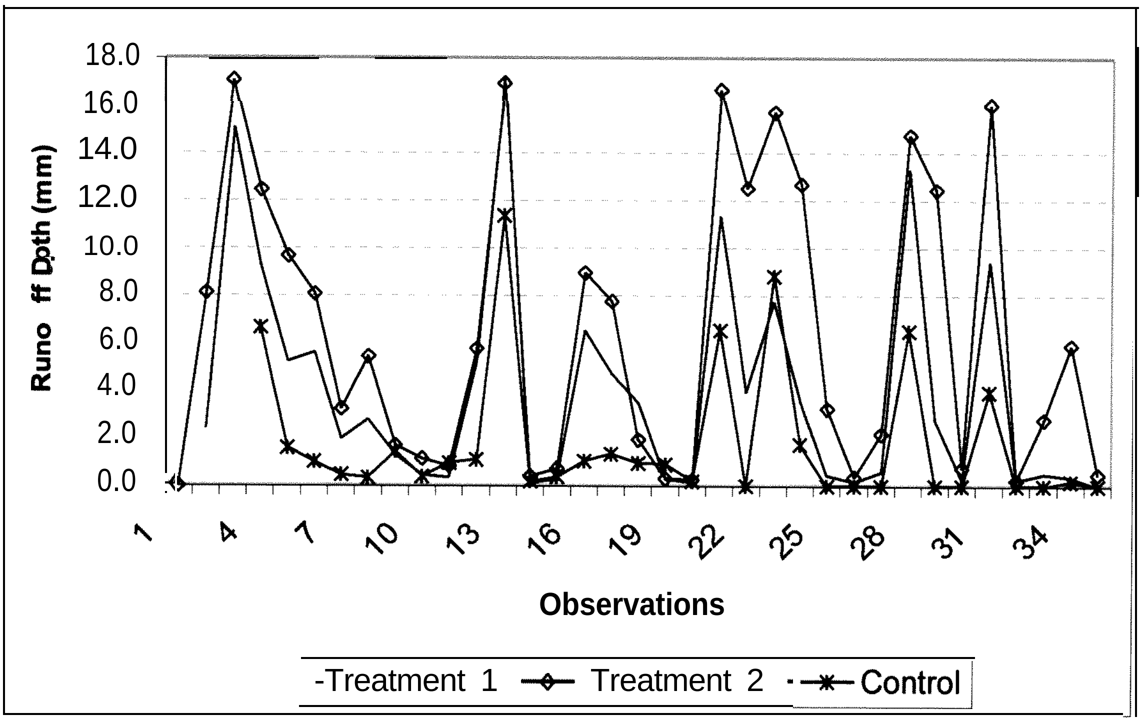

Figure 3. Runoff yield for individual storm events for the North Auburn study.

Over the 20-month period covered by this study, the control produced a total of 100.5 g (representing 0.09 t/ha); nearly half was produced during one storm (Event 28). Excluding event 28, the control produced 59.1 g (representing 0.05 t/ha). Mean sediment yield increases attributed to Treatment 1 and 2 were 220 and 3023 percent increases, respectively, in comparison to the control. Sediment yield increases for Treatment 1 and 2 ranged from 6 to 1350 and 40 to 21250 percent increases in comparison to the control. During the study, Treatment 1 produced a total of 197.3 g (representing 0.18 t/ha) and Treatment 2 produced 1249.6 g (representing 1 .12 t/ha) (Figure 4).

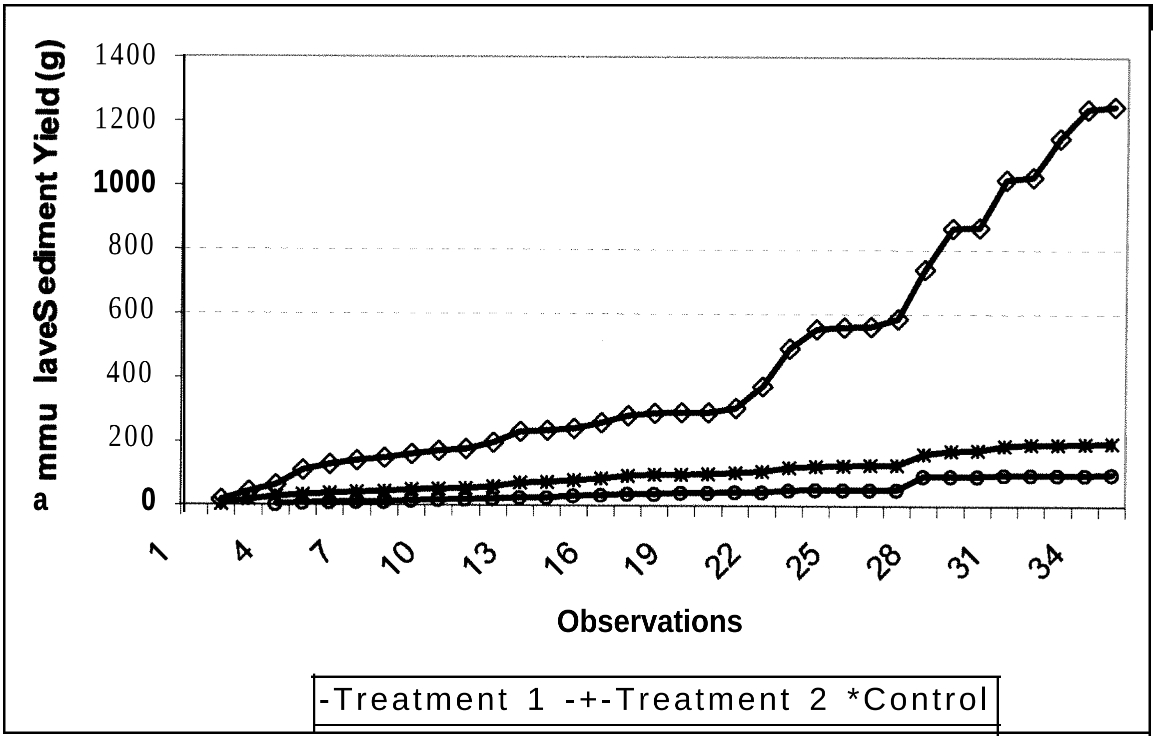

Figure 4. Cumulative sediment yield for treatments during the North Auburn study.

Sediment yield from the control and Treatment 1 was relatively constant during the study period until a moderate increase during event 28. However, Treatment 2 had periods of greatly accelerated sediment yields following large high-energy storms throughout the study period. These patterns are consistent with patterns in erosion losses observed by the investigators in earlier work (Grace et al 1998; Grace 2000). Differences in the sediment yield patterns could be expected due to differences in cover and surface roughness between the treatments and the control. Reduced surface cover and roughness encountered following forest operations often result in less protection from the damaging impacts of high-energy storms.

ANOVA detected significant treatment effects at the 0.05 significance level on sediment yield over the study period ($p<0.0001$) (Table 2). Sediment yields from the treatments were detected as significantly greater than control sediment yields. Treatment 1 sediment yields were significantly less than Treatment 2 based on ANOVA ($p<0.0001$). Differences in sediment yields between treatments can likely be attributed to the differences in the prescriptions. Treatment 1 had a greater surface roughness than Treatment 2 due to the site preparation operation, which resulted in raised beds for seedling establishment. The beds allowed for greater storage of runoff resulting from storms in the investigation. The raised beds likely reduced transport of sediment due to greater infiltration and by providing areas for deposition of detached sediment.

Table 2. Mean sediment and runoff vields for the North Auburn studv.

Parameter	Treatment	N	Mean*	Std. Dev.
Sediment Yield (g)				
	1	80	6.7b	7.5
	2	89	41.4a	72.6
	Control	58	3.0c	10.8
Runoff Yield (mm)				
	1	80	4.9b	5.9
	2	90	7.4a	6.8
	Control	58	2.5c	4.7

*Means with different letters are significantly different at the 5 percent significance level using Duncan's Multiple Range Test (sediment and runoff yield comparisons performed independently).

Runoff yield trends for treatments and the control were similar to those for sediment yield reported above. Total runoff yield from Treatment 1 and Treatment 2 was 137 and 228 mm during the study period. Control runoff yield, totaling 58.1 mm, was significantly less ($p<0.0001$) than runoff yield from treatments based on ANOVA (Table 2). Based on this analysis, Treatment 2 had significantly greater runoff yield than Treatment 1 and the control. Treatment 2 mean runoff yield for individual storm events was 66 and 421 percent greater than Treatment 1 and the control runoff yield, respectively. Treatment 2 had less runoff yield than the control during events with low runoff yield (< 1 .O mm). The greater surface roughness of the site prepared area compensated for the lack of cover resulting in reduced runoff yields in comparison to the control. Raised beds allowed for greater infiltration, which directly reduced the resulting runoff.

Conclusion

Increased demand for timber products has resulted in intensive forest management activities to increase site productivity in the South. In recent years, site preparation has become a common operation utilized to improve seedling survival and establishment. Increased environmental awareness has focused attention on harvesting and site preparation impacts on forest soil and water quality. Scientific data are critical to aid in prediction and mitigation efforts concerning the impacts of forest operations. Research presented here is an effort to assess the impact of harvesting and site preparation on sediment and runoff yield on a Piedmont site in Lee County, Alabama.

Sediment yield increases were observed for both treatments in the investigation. Sediment yield increases as much as 2-fold and 30-fold were observed from Treatment 1 and 2, respectively. ANOVA detected significant treatment effects at the 0.05 significance level on sediment yield. Cumulative sediment yield from the control and Treatment 1 remained relatively constant throughout the study period. However, Treatment 2 was more sensitive to storm energy with dramatic increases in sediment yield following high-energy storms. Runoff yield results were similar to trends observed with sediment yields. The control had significantly less runoff yield than treatments in the investigation. Treatment 2 sediment and runoff yields were likely less than Treatment 1 due to the presence of beds which aided in infiltration and reducing surface runoff.

Acknowledgements

The authors would like to acknowledge Mead Coated Board, Inc. for providing a site to conduct this investigation. A special thanks is due to Mead Coated Board, Inc. personnel for their support efforts and cooperation over the research period.

References

Beasley, R.S. 1979. Intensive site preparation and sediment losses on steep watersheds in the Gulf Coastal Plain. Soil Science Society America Journal 43: 412-417.

Blackburn, W.H., J.C. Wood, and M.G. DeHaven. 1986. Storm flow and sediment losses from site-prepared forestland in East Texas. Water Resources Research 22(5): 776-784.

Grace, J.M. Ill, R. Rummer, B. Stokes and J. Wilhoit. 1998. Evaluation of erosion control techniques on forest road sideslopes. Transactions of ASAE 41(2): 383-391.

Grace, J.M. III. 2000. Forest road sideslopes and conservation techniques. Journal of Soil and Water Conservation 55(1): 96 – 101.

Harr, D.R., and R.L. Fredriksen. 1988. Water quality after logging small watersheds within the Bull Run Watershed, Oregon. Water Resources Bulletin 24(5): 1103-l 111.

Nutter, W.L. and J.E. Douglass. 1978. Consequences of harvesting and site preparation in the Piedmont. In Proc. A Symposium on Principles of Maintaining Productivity on Prepared Sites, 65-72. Mississippi State University, 21-22 March.

Patric, J.H. 1978. Harvesting effects on soil and water in the Eastern hardwood forest. Southern Journal of Applied Forestry 2(3): 66-73.

Smith, R.M. and W.L. Stamey. 1965. Determining the range of tolerable erosion. Soil Science 100(6): 414-424.

Soil Conservation Service. 1981. Soil Survey of Lee County, Alabama. USDA Soil Conservation Service, Washington, D.C. 100 p.

Yoho, N.S. 1980. Forest management and sediment production in the South – A review. Southern Journal of Applied Forestry 4(1): 27-36.