# INFLUENCE OF GRADING INTENSITY ON GROUND COVER ESTABLISHMENT, EROSION, AND TREE ESTABLISHMENT ON STEEP SLOPES [1]

John L. Torbert and James A.Burger [2]

Abstract: In 1991, a 5-year study was established in eastern Kentucky to evaluate the effect of surface grading intensity on ground cover development, erosion, and tree establishment. The study included three grading treatments. The "moderately" graded treatment consisted of backfilling a 40% slope and back-blading with a Caterpillar D-9 bulldozer to create a smooth slope. The "intensively" graded treatment involved additional back-blading passes, followed by "tracking-in" with D-9 bulldozers. The "roughly" graded treatment was created by ripping plots with a 36-in ripping bar pulled directly downslope with a D-9 bulldozer. Each plot (150 by 150 ft) was installed on the slope, with a level area at the base of each plot. Five species of trees were planted in each plot (white pine, loblolly pine, sycamore, sweetgum, and yellow-poplar), and the entire area was hydroseeded with a "tree-compatible" ground cover. Erosion was measured monthly using erosion rods. Ground cover was measured along a transect after the first growing season. Total ground cover averaged 82% after 3 years and was not affected by grading treatment, although there was a significantly higher amount of legume cover on the roughly graded plots. Erosion was highest on intensively graded plots. Tree survival varied by species. Average survival was best for sycamore (83%) and poorest for white pine (11%). Growth of sycamore and loblolly pine was significantly reduced by the intensive grading treatment.

**Additional Key Words:** reclamation, compaction, productivity.

## Introduction

Our reclamation research in the central Appalachian region of Virginia, West Virginia, and Kentucky has caused us to conclude that the single most important factor limiting forestry land use opportunities on mined land is mine soil compaction, specifically, compaction caused by grading the final surface and "tracking-in" with bulldozer treads to create a seedbed. These conclusions are based partially on a compaction study that was maintained for 2 years before the study site was lost to remining (Torbert and Burger 1990). We find this compaction to be particularly disturbing when forest land is the specified post- mining land use. Smooth surfaces (free of boulders, depressions, and gullies) are desirable for hayland or pasture, but are not typical of natural Appalachian forest land, and are not beneficial to forest productivity or forest management activities. We believe coal companies could save money and increase land use productivity by reducing their grading activities on reclaimed forest land. We also believe that creating a productive forest ecosystem is the best way to provide long-term environmental benefits.

The reasons that intense grading practices persist on land reclaimed with trees are understandable. Coal companies usually do not own the land being mined, and consequently, they have no financial interest in the long-term implications of grading impacts on forest productivity. Coal company reclamationists have a

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[2] John L. Torbert, Research Associate, and James A. Burger, Associate Professor of Forest Soils, Virginia Polytechnic Institute and State University, Blacksburg, VA, USA.

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corporate mandate to reclaim the land and achieve bond release as quickly and efficiently as possible. As long as reclamation inspectors expect coal companies to construct smooth surfaces and establish a vigorous ground cover dominated by Kentucky-31 tall fescue, there will be no incentive for coal companies to modify their grading practices, despite pleas from landowners to maximize the productivity of reclaimed forest land. It is also understandable that regulators will have little reason to discourage intensive grading until its adverse effects on tree growth are clearly demonstrated by research. Regulators also need to be convinced that less grading to improve forest productivity will not compromise environmental protection.

To address the issues of grading effects on forest productivity and environmental protection, a 5-year study was established in 1990 to evaluate the effect of reclamation grading practices on ground cover development, erosion, and tree growth. The purpose of this paper is to provide third-year results of the study.

## Methods

### Site Selection and Treatments

The study is located on land mined by Martiki Coal Corp. near Lovely, KY. A slope, approximately 150 ft (upslope) by 1,500 ft (along the contour), had been backfilled and moderately graded to its final contour (40% slope). The site was awaiting final surface grading and hydroseeding when it was selected for study in January 1991. The slope was divided into nine plots (150 by 150 ft) which were used to accommodate three replications of three grading treatments. The three grading treatments, installed on March 26, 1991, were

1. "Moderate" grading. For this treatment, no further grading was applied. Grading already completed when the study site was selected resulted in a fairly smooth surface, although some small boulders and small gullies were present. Since 6 months elapsed between the times these sites were graded and seeded, a hard-crusted surface had developed.

2. "Intensive" grading. This treatment is typical of operational reclamation practices in the region. The purpose of intensive grading is to eliminate small boulders and gullies such as those that existed in the moderately graded treatment, and to break the surface crust and create a better seedbed for ground cover germination. Bulldozers (D-9 Caterpillars) smoothed the slopes by dragging their blades as they backed downhill, after which they tracked-in the surface by running up and down the slope until the entire surface was covered with grouser tracks from the bulldozer treads.

3. "Rough" grading (or "ripped"). The initial study design called for a rough-graded treatment where the slope had been returned to its approximate original contour by backfilling with a minimal amount of grading. Such a site would have an uneven surface with boulders and depressions, and a loose surface soil. Unfortunately, when selected, the study site was already beyond a roughly graded level to the moderately graded treatment. To create a rough surface with loose soil, the mine soil was ripped with a 36-in subsoiler pulled down the slope with a D-9 bulldozer. Rips were created at 10-ft intervals. On the level area at the base of the slope, rips were installed perpendicular to the slope. Ripping created a very rough surface by pulling large boulders to the surface and creating gullies and ridges of loose soil aligned up and down the slope.

### Tree Planting

Trees were planted on April 1 and 2, less than one week after installation of the grading treatments. Five species of trees were planted: white pine (Pinus strobus), loblolly pine (Pinus taeda), yellow-poplar (Liriodendron tulipifera), sweetgum (Liquidambar styraciflua), and sycamore (Platanus occidentalis). Approximately 40 of each of the pines and 20 of each of the hardwood species were planted in each plot. All species were 1-year-old seedlings except white pines, which were 2-year-old seedlings. Trees in the roughly graded treatment were planted in the gullies created by ripping. After the third growing season, tree heights were measured and survival rates were determined.

## Ground Cover Establishment

On April 16, 2 weeks after tree planting, a "tree-compatible" ground cover was established by hydroseeding (table 1). After the first and third growing seasons, three 100-ft transects were established in each plot to measure ground cover. These transects were installed along the contour of each plot, approximately one-fourth, one-half, and three-fourths of the distance from the bottom to top of the slope. At 2-ft intervals along the transect, a 1-in diameter sighting tube was used to assess ground cover. If more than half the area observed through the tube consisted of bare spoil, the point was tallied as such. If more than half the area was covered with vegetation, the existing species were tallied. This was done at 150 points per plot.

Table 1. Ground cover species and seeding rates.

| Species | Application rate lb/acre |
|---|---|
| Winter rye [1/] | 10 |
| Perennial ryegrass | 5 |
| Orchard grass | 5 |
| Kobe lespedeza | 5 |
| Appalow lespedeza | 5 |
| Birdsfoot trefoil | 5 |
| Redtop | 3 |
| Weeping lovegrass | 3 |
| Ladino clover | 3 |
| Crown vetch | 1 |

[1/] Foxtail millet (5 lb/acre) would have been used instead of winter rye, but was unavailable at time of seeding.

## Erosion Measurements

Soil movement from the slope and deposition at the base of the slope were monitored by measuring the changes in the distance between the soil surface and the top of metal rods installed in each plot. Three rows of ten metal rods (spaced 10 ft apart) were installed along the contour of each plot, approximately one-fourth, one-half, and three-fourths of the distance from the bottom to top of the slope. Another row was placed at the base of each slope to measure soil deposition. Rods were measured in October 1991 and 1993, after the first and third growing seasons.

# Results

## Site Description

The study was installed on a steep slope where the likelihood for erosion effects would be greater than on a level or slight slope. The spoil on the site was derived mostly from gray siltstone with a minor component of gray and brown sandstone. The site was not topsoiled. Spoil samples collected from each plot prior to hydroseeding had pH values ranging from 7.7 to 8.8. All plots had a south to southeast aspect, which, combined with dark spoil, resulted in high surface temperatures during the summer. The climate at this site was very dry during 1991. This site received virtually no rainfall from July through September during the first year. Rainfall that did occur in the early summer came as short, intense storms.

## Ground Cover Establishment

The species hydroseeded in this study were mostly acid-tolerant, short- statured species (Vogel 1981) which have provided good cover without overtopping trees in other studies (Torbert et al 1991). Grading treatment had no effect on ground cover during the first 3 years (table 2). Average ground cover after the first year was 44% and increased to 82% after 3 years. Most of the cover in the study resulted from weeping lovegrass, which was virtually the only species surviving on some of the moderately and intensively graded plots after the first year. The average amount of legume cover in the study was 12% after the first year and 34% after 3 years.

For the most part, ground cover on the moderately and intensively graded treatments was uniformly distributed across the plot. On ripped plots, however, values in table 2 are a weighted average of the relatively vigorous cover that existed within the "troughs" of the ripped gullies and the relatively sparse cover that existed between rips.

Table 2. Ground cover (%) after three growing seasons as affected by grading treatment.

| Grading treatment | Total cover,% | | Legume cover,% | |
|---|---|---|---|---|
| | average | range | average | range |
| Rough | 82a | 75-89 | 45a | 28-79 |
| Moderate | 83a | 54-99 | 29a | 5-47 |
| Intensive | 82a | 64-92 | 28a | 15-42 |

Values within a column followed by the same letter are statistically similar according to Duncan's multiple range test ($p<0.10$).

**Mine Soil Erosion**

Compaction on intensively graded plots reduced water infiltration and increased surface runoff. During a heavy storm in the early summer of the first year, surface runoff was observed flowing from the intensively graded plots. On ripped plots, water flowed across the surface of the compacted area between rips, but within the area disturbed by the rips, high infiltration rates prevented any overland flow. At the bottom of the slope, no water flowed from the gullies created by ripping.

Erosion was expressed as the average depth of spoil lost at the 30 erosion rods located on each plot and as the amount of deposition at the base of the slope and 20 ft from the base (table 3). There was a large variation in erosion measurements among treatment replicates that precluded any statistically significant effects. After the first year, the average soil loss from the intensively graded plots was 18 times greater than the loss from the roughly graded plots. Statistically there was a significant increase in soil deposition at the base of the intensively graded plots during the first year.

Erosion measurements after the third year produced some confusing results. Based on the length of metal rod above the soil surface, there would appear to be a net deposition of soil on the rough-graded and moderate-graded treatments. By comparing third year measurements with first year measurements, there appears to be an average net deposition of 0.65 cm of soil in this study. This of course is not realistic, although some deposition may have occurred at the base of some individual rods (especially in the ripped treatment where some rods were located in the trough of a rip). Some soil swelling may have occurred during the winter as a result of freeze thaw, which decreased the length of the rod remaining above the surface.

A comparison of rod measurements at the base of the slope revealed that the intensive treatment had resulted in the most deposition, but again a meaningful comparison with first-year results is not possible because of changes in surface soil density that may have resulted from freezing.

Table 3. Average soil loss from study plots and deposition at bottom of plots after the first and third year as affected by grading treatment.

| Grading treatment | Soil Loss from slope, cm | | Soil Deposition at toe of slope, cm | |
|---|---|---|---|---|
| | Year 1 | Year 3 | Year 1 | Year 3 |
| Rough | 0.04 | -0.38 | 1.51ab | 1.84 |
| Moderate | 0.44 | -0.39 | 0.50b | 0.85 |
| Intensive | 0.72 | 0.0 | 3.48a | 2.21 |

Values within a column followed by the same letter are statistically similar according to Duncan's multiple range test ($p<0.10$).

**Tree Survival and Growth**

The original study design involved only loblolly pine and white pine. These are two commercial species commonly planted on mined land in the region, and they are species that the landowner (Pocahontas Land Corp) intends to manage for sawtimber production. Unfortunately, the average pH of this site was greater than 8, which is much higher than the acidic conditions to which pines are best adapted. Consequently, the hardwood species were added to the study.

As a group, the hardwoods survived better than the pines (table 4). White pine survival was very low. Only 11% of the seedlings survived, and very few surviving trees appeared to be healthy. Loblolly pine did better than white pine, and survival was 51%. Loblolly pine growth was not good, however. Loblolly pine seemed to suffer from a high soil pH and/or high soluble salt concentrations. Most loblolly pines had yellow foliage with orange coloration at the tips. Loblolly pine growth was significantly reduced by the intensive grading treatment.

Survival was highest for sycamore, and survival was significantly reduced by intensive grading. Survival in the intensive-graded treatment was 64%, whereas survival in the moderate and rough treatments was 91% and 94%, respectively. Average height for sycamore and yellow-poplar was signifcantly lower in the intensive-graded treatment.

## Summary

Reclaimed surface mines in the central Appalachians are routinely graded and tracked-in to create smooth surfaces. Some people have argued that intensive grading operations are needed to establish uniform ground covers and reduce erosion. Others have argued that such an approach is short-sighted and that the greatest erosion control in the long term will result from efforts that promote the establishment of a healthy forest. This study was established to provide some information about the short- and longer term impacts of grading on environmental protection and forest productivity. Third-year results show that intensive grading did not result in better ground cover establishment or erosion control. In fact, erosion was highest on the intensively graded plots.

The conditions created by ripping the sites were completely opposite to conditions generally strived for during reclamation. The ripped treatment did not result in an aesthetically desirable smooth surface. There were many rocks and depressions created by ripping. To the surprise of many people, however, the gullies created by ripping did not cause problems with slope stability or erosion. Instead, the loose surface soil created by ripping enhanced water infiltration, facilitated ground cover establishment, and promoted better tree growth.

Table 4. Third year survival and height as affected by species and surface grading treatment.

| | Rough graded | | Moderate graded | | Intensive graded | |
|---|---|---|---|---|---|---|
| Tree species | Survival, % | Height, in | Survival, % | Height, in | Survival, % | Height, in |
| Sycamore | 94a | 88a | 91a | 57b | 64b | 48b |
| Sweetgum | 75 | 35 | 76 | 37 | 75 | 29 |
| Yellow-poplar | 69 | 50a | 64 | 45ab | 67 | 35b |
| Loblolly pine | 58 | 58ab | 40 | 67a | 55 | 46b |
| White pine | 8 | 26 | 17 | 29 | 8 | 26 |

Values for survival or height within a species/treatment combination followed by the same letter are statistically similar according to Duncan's multiple range test ($p<0.10$).

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