# DISTRIBUTION OF SLASH AND LITTER AFTER WET- AND DRY-SITE HARVESTING OF LOBLOLLY PINE PLANTATIONS

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**Abstract**—Displacement of logging slash and forest floor litter in the process of harvesting can interfere with forest nutrient cycling and can modify soil climate in ways that could affect regeneration success and forest productivity. The objective of this study was to assess a visual method for estimating organic matter and slash biomass residues following a typical feller-buncher/grapple-skidder clearcut harvest. A 20 by 20 meter grid was established in six 20-year-old loblolly pine plantations, each of which was 3.2 ha in size. Pre-harvest biomass was estimated using biomass equations developed by Baldwin (1987). Post harvest slash and litter biomass remaining was measured across the grid network by making visual estimates of percent coverage for each of 4 size classes and relating that to biomass using simple linear regression. Harvest slash and litter were collected from 4 $m^2$ plots and weighed to estimated biomass as a function of percent cover for each size class. Heavy slash (> 2.5 cm) on the wet harvest sites had a biomass of 2.49 kg/$m^2$, compared to 1.89 kg/$m^2$ on the dry harvest sites. The amount of light slash (< 2.5 cm) was also significantly greater on the wet harvest sites, 2.47 kg/$m^2$, compared to that on the dry-harvested sites at 1.99 kg/$m^2$. Litter biomass, ~2.4 kg/ $m^2$, and piles, 0.7 kg/$m^2$, were not significantly different between sites. Visual estimation procedures provide a rough but useful estimate of biomass remaining after harvest ($R^2$ = 0.42 to 0.67), an extensive spatial estimate that is difficult to ascertain in any other way. The method reveals a certain amount of homogenization after harvesting. Harvesting sites when dry compared to wet results in a larger amount of displacement from the interior of a logging site. These estimates can be used to judge whether harvesting disturbance on organic residues affects stand productivity.

## INTRODUCTION

The importance of maintaining site quality and productivity on intensively managed forests is important because a higher production per land unit is needed to satisfy increasing population demands for forest products. Understanding how the forest sites resist, respond to, and recover from disturbances associated with forest management practices is essential for sustaining long-term productivity.

The benefits of organic matter in soils for crop production is well known. It helps synchronize the supply and demand of various plant essential nutrients (Walle and Sims, 1999; Gressel and others, 1996), and it has a positive influence on soil water retention, hydraulic conductivity, and infiltration (Prichett and Fisher, 1987). Soil strength, structure, and morphology are also greatly affected by the amount of organic matter in the soil, which helps to bind soil particles together to form soil aggregates (Mankin et.al., 1996).

Forest management can greatly influence the amount of organic materials remaining on a forest site, and, conversely, soil organic matter will influence the response of sites to management disturbances (Sanchez, 2001; Fearnside, 1999; Dick and others, 1991; Nambiar, 1996). Therefore, it is important to understand how forest practices affect the distribution of harvest slash and litter. The purpose of this study is to evaluate a post-harvest visual biomass inventory method based on Terry and Chilingar (1955), and to compare how two harvesting methods, dry-weather and wet-weather harvesting, affects spatial distribution of organic matter.

## MATERIALS AND METHODS

The study site is located near Cottageville, SC, on the Atlantic coastal plain of South Carolina. The topography is flat to gently rolling; soil parent material consists of marine and fluvial sediments deposited during the Oligocene and Pleistocene eras (Stuck, 1982). Soils are poorly to somewhat poorly drained and have an aquic moisture regime. Bt horizons limit permeability and cause perched water tables. These sites are classified by Cowardin system (Cowardin and others, 1979) as Palustrine, forested, needle leaved evergreen wetlands. Regionally, these sites are very productive, and have been managed as loblolly pine plantations for the past 50 years.

In 1992, three 20 ha, loblolly pine plantations were selected based on similar age, soil, and hydrologic conditions. These

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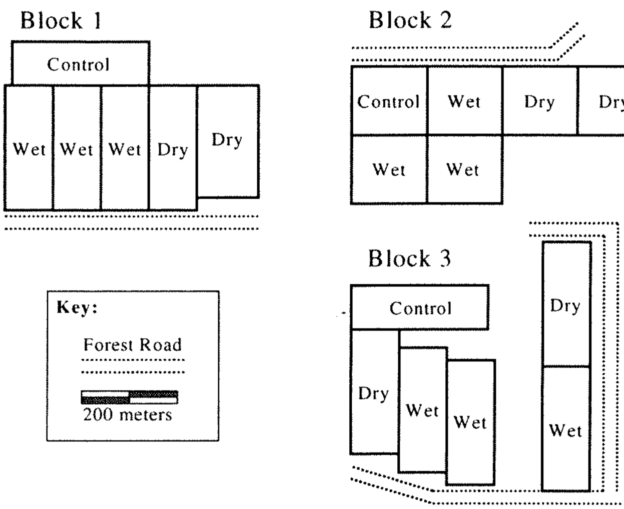


Figure 1—Block design and arrangement of treatments.

plantations (assigned as blocks) were subsequently divided into six 3.2 ha treatment plots (figure 1). Despite being contiguous within each block, each plot was treated as an individual management unit. Harvesting was conducted using conventional commercial logging operations using feller buncher/grapple skidder systems. Each plot was laid out as a separate sale and had separate decks and skid trails. In the fall of 1993, two plots on each block received a dry weather harvesting treatment. In the spring of 1994, the remaining three plots on each block were harvested during wet conditions in order to maximize soil disturbance.

Prior to harvesting, each stand was cruised for height, and diameter. Bole biomass was estimated as a function of height, diameter, and age (Baldwin, 1989). Biomass of crown components (branches and foliage) was estimated as a function of height and diameter. In addition, samples of ground litter were collected and weighed to determine biomass already present on the forest floor.

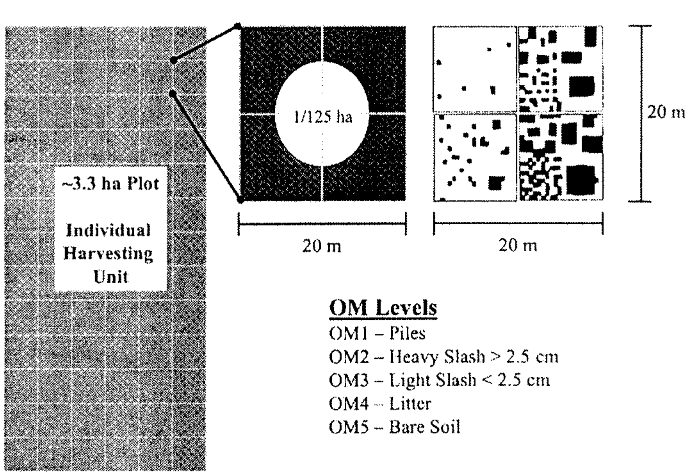


Figure 2— A 20x20 meter grid was established on each 3.3 ha plot. At each gridpoint a 1/235th ha plot was used to inventory aboveground biomass, and visual estimates were made of five classes of logging debris.

After harvesting, each stand was surveyed based on the 20x20 m grid (figure 3). Each grid location was divided into four 10x10 m quadrats in which visual estimates were made of percent cover of harvesting residue and averaged. Harvesting residues were divided into four categories: litter, light slash (<1.5 cm), heavy slash (>1.5 cm), and piles (residue > 0.3 m in depth). Visual estimates were made after a visual calibration to a reference chart (figure 2). In the case of slash piles, the depth of the piles was also measured.

After the visual assessments were completed, a subset of grid points was revisited to relate actual biomass to percent cover. A 2 by 2-m PVC frame was randomly placed in each of the four quadrats and a visual assessment was made for litter, light slash, and heavy slash. The air-dried samples were subsequently collected and weighed *in situ*. Simple linear regression was then used to predict biomass for each category based on percent cover. Regressions and statistical analyses were made at the 5 percent level using SAS procedures (SAS Institute, 1988).

An additional estimate of the biomass in piles was required because we were not able to sample them in a timely way. It was assumed that the maximum biomass of heavy slash was equivalent to the threshold level with a 0.3-m deep pile. The estimate was subsequently multiplied by depth to obtain a biomass estimate for individual slash piles.

## RESULTS AND DISCUSSION

Prior to harvesting, the amount and distribution of biomass of the tree components and the litter layer were similar between the two harvesting treatments (table 1). Approximately 46 to 48 kg/m$^2$ was found aboveground in the form of the stem, branches, and foliage. In addition about 0.55 kg/m$^2$ was found in the pre-harvest litter layer. These materials had normal distributions, meaning they were heterogeneously spread throughout the site (figure 3).

Forty to sixty-five percent of the variation in post-harvest biomass was explained by our visual cover estimates (figure 4). The method tended to under-estimate biomass relative to that predicted by the Baldwin equations (figure 5); the best approximations were made for the dry harvest sites. Standing water and soil disturbances made wet visual assessments of percent cover difficult, which caused the under-estimates of biomass on the sites that were harvested when wet.

**Table 1—Pre-harvest biomass of the wet and dry-harvested plots**

| Treatment | Aboveground Biomass (& carbon) | | | Pre-Harvest |
|---|---|---|---|---|
| | Stem | Branch | Foliage | Litter |
| | ——kg/m (kg-C/ha)—— | | | |
| Dry | 37.63(17.08)a | 4.07(1.85)a | 1.83(0.83)a | 0.53(0.20)a |
| Wet | 42.50(19.30)a | 4.28(1.94)a | 1.86(0.84)a | 0.58(0.21)a |

Note: means separations compare the levels within each biomass class only.

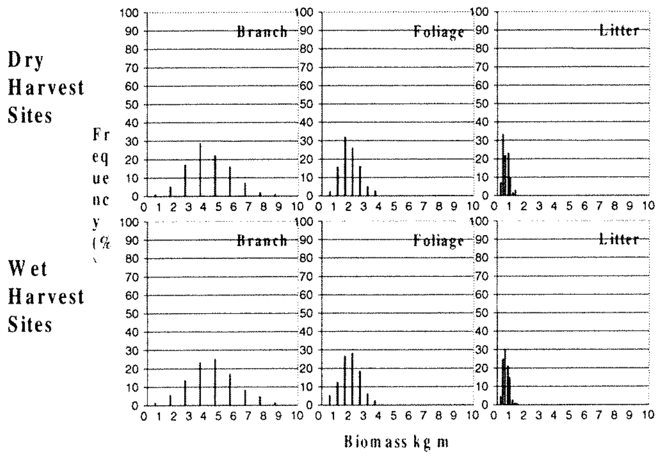


Figure 3—Pre-harvest histograms of coarse organic matter from the standing, live tree (branch and foliage), and on the ground (litter).

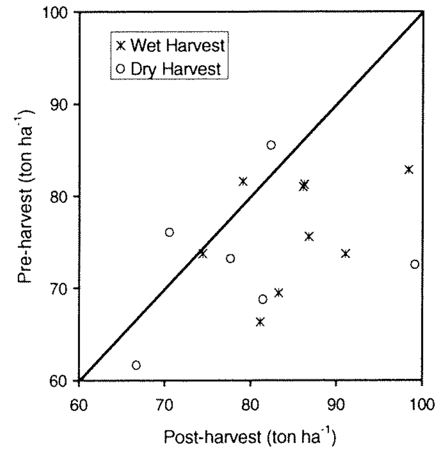


Figure 4—Linear regression plots for the four harvesting debris size classes.

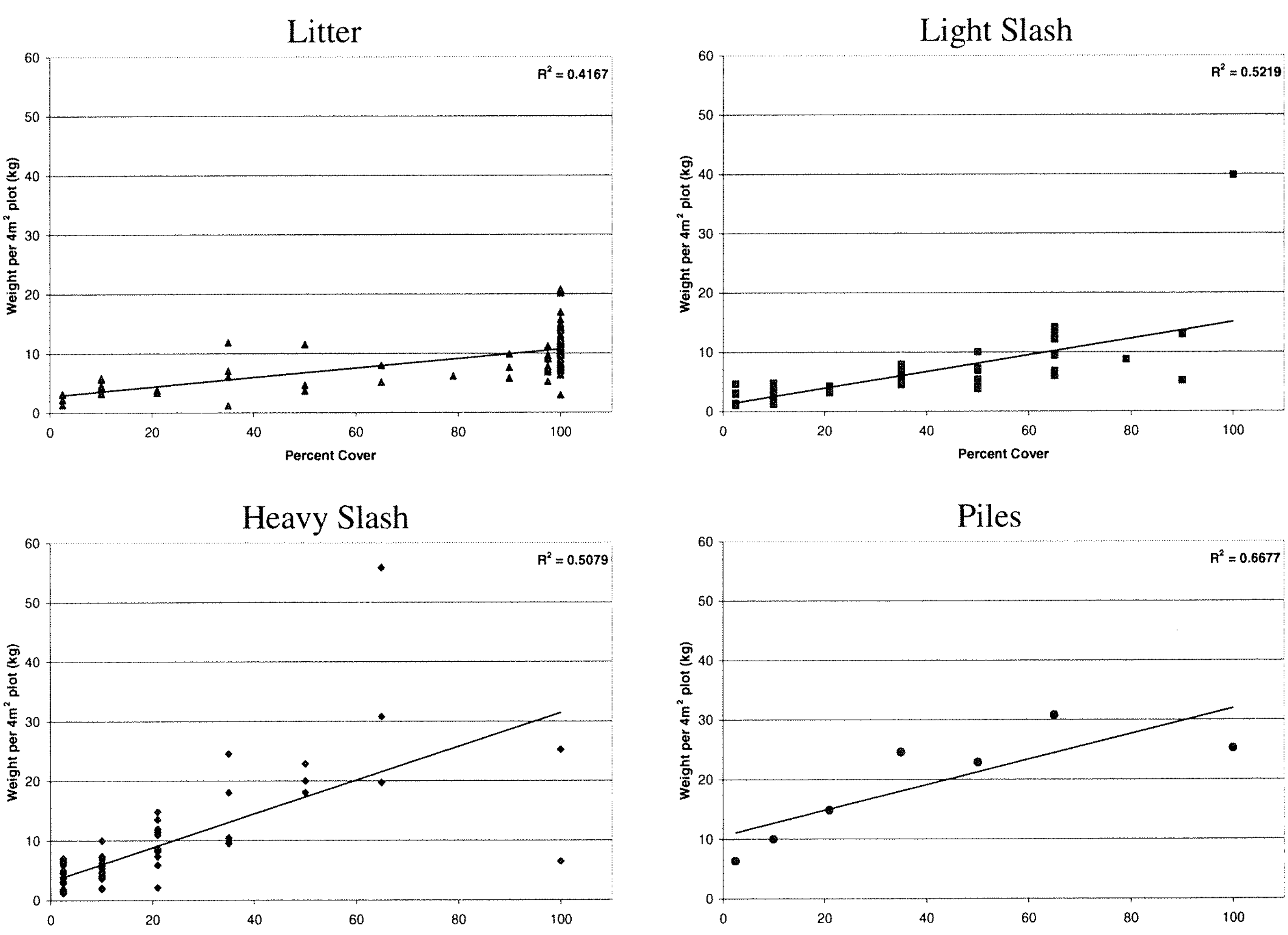


Figure 5—Comparison of pre- and post-harvest total organic matter biomass estimates.

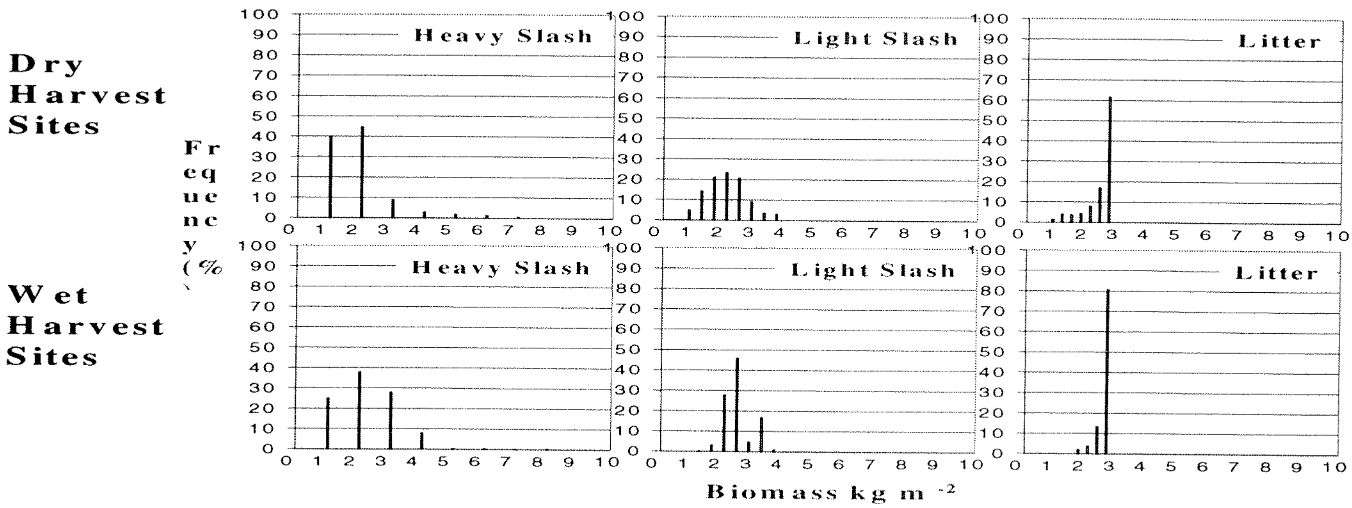


Figure 6—Post-harvest histograms of heavy slash, light slash, and litter.

**Table 2—Post-harvest biomass of the wet and dry-harvested plots**

| Treatment | Heavy Slash > 2.5 cm | Light Slash < 2.5 cm | Piles Slash 1 ft deep | Litter |
|---|---|---|---|---|
| | kg/m (kg-C/ha) | | | |
| Dry | 1.89(0.86)b | 1.99(0.90)b | 1.02(0.46)a | 2.36(0.87)a |
| Wet | 2.49(1.13)a | 2.47(1.12)a | 0.16(0.07)a | 2.50(0.93)a |

Note: means separations compare the levels within each biomass class only.

After harvesting, any biomass that was not removed as product was dispersed as residues across the site. A portion of the ~40 kg m$^{-2}$ of biomass previously contained in the stems along with the 4 kg m$^{-2}$ of biomass from the branches were repartitioned into the post-harvest categories (heavy, light slash, and piles); about 5 kg m$^{-2}$ total for both the wet and dry harvested sites. Foliage biomass from the pre-harvest estimates were combined with the pre-harvest litter layer to form the ~2.5 kg /ha in the post harvest litter layer. Significantly more heavy and light slash was retained within the wet harvested sites (table 2). Dry sites had numerically greater biomass in piles as a result of skidding and delimbing.

Harvesting resulted in a skewed distribution of organic materials compared to pre-harvest conditions (Figure 6).

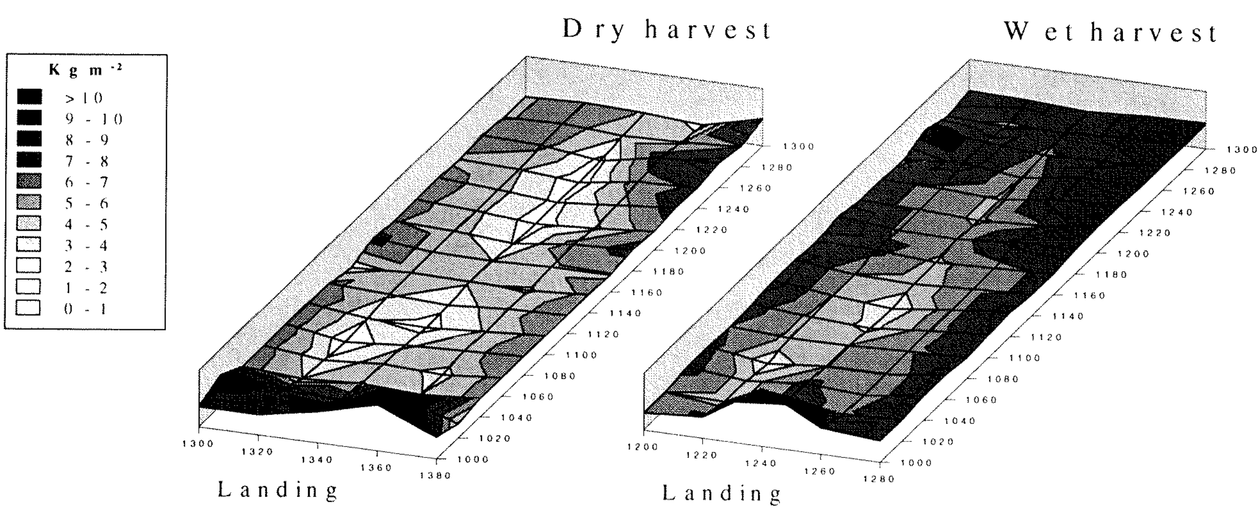


Figure 7—Post-harvest, spatial distribution of organic matter biomass for two treatment plots.

Heavy slash, which would contain components of pre-harvest branch and stem, was left-skewed, indicating that material was being homogenized into many low biomass groupings. Litter on the other hand, which contains components of pre-harvest foliage and litter, was right-skewed, indicating that material was being homogenized into many larger biomass groups.

The displacement of materials by dry-site harvesting is readily apparent in a spatial plot (figure 7). Disturbance of organic materials is minimized around the periphery of a logging site, and it is maximized where traffic is concentrated. In addition, debris are concentrated at the landings of logging sites.

## CONCLUSIONS

The visual approach used in this study for estimating harvest residue biomass tends to underestimate the actual amount of residue biomass, especially on the wet-harvested sites. However, this method may be appropriate for the sites with little surface soil disturbance and standing water. Harvesting in general tended to homogenize heavy slash and litter either by skewing their distributions to the left or to the right. Residue materials were displaced to a greater extent within the interior of the plot where trafficking was the highest. At the periphery of the logging site organic materials were less disturbed.

Wet weather harvesting tended to leave a greater amount of organic debris out on the site. Logging operators topped trees where they were cut, and used those materials to support the equipment on the wet soils. As a result, organic materials were incorporated with the soil and may serve to provide a mitigating effect to soil disturbance as time passes (Kelting, 1999).

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