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SITE PREPARATION TREATMENTS AND NUTRIENT LOSS FOLLOWING COMPLETE HARVEST USING THE NICHOLSON-KOCH MOBILE CHIPPER[1]

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Abstract.--Site disturbance, vegetation control, and nutrient loss were assessed following complete biomass harvesting of a pine plantation by the Nicholson-Koch mobile chipper. Thirty-two percent of the soil area was significantly compacted to a 10 cm depth. Litter zone material showed a two-fold increase due to chips lost during harvest. Herbicide treatments (Tordon 10K and Velpar Gridball) were applied following harvest. Tordon controlled 84 percent of the hardwood resprouts during the first growing season and Velpar 37%. Tension-cup and -plate lysimeters were used to monitor percolation losses from the soil. During the first 5 months, treatments accelerated losses of Ca, Mg, K, Na, PO_4, NO_3, SO_4, and HCO_3. Loss due to Tordon treatment was greater than chipping alone, for all nutrients analyzed.

As current energy sources continue to increase in cost and decrease in availability, attention has turned toward wood as a renewable fuel source for wood processing and other industries. Nationally, the wood processing industry is 40 percent self-sufficient in energy production (Arola 1976) with the Southeast having the greatest potential but the lowest utilization at the present time. Complete biomass harvest for fuel is a'developing reality (Koch and McKenzie 1976) but the concept raises questions regarding impacts on future site productivity. The engineering research work unit of the Southern Forest Experiment Station at Auburn, Alabama, is testing a complete biomass harvest system, the Nicholson-Koch Mobile Chipper (Koch and Savage 1980). A mobile-chipper test site was used in this study to assess site preparation potential, surface disturbance, and nutrient-loss impacts after complete biomass harvest.21

STUDY AREA

A complete biomass harvest was performed during April, 1980 on a l-ha study site in the Forestry Department Woodlot, Auburn University. The soil series was a Blanton loamy sand with well developed litter (8 cm) and humus (5-10 cm) layers. Slope on this site ranged from 5-15% with two old terraces on the steeper slopes. A partially-filled gully runs across the center of the area, resulting from past cultivation.

A plantation of 53-year-old mixed loblolly (*Pinus taeda*) and slash pine (*Pinus elliottii*) averaging 147 metric tons per hectare (m.t./ha) total standing crop comprised the overstory on

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[1] Paper presented at Southern Silvicultural Research Conference, Atlanta, Georgia, November 6-7, 1980.

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[3] All further references to harvesting on this site are made with the assumption that all standing trees, shrubs, and vegetation were removed at or just above the soil surface; no root harvest occurred.

approximately half of the area. A shortleaf pine (Pinus echinata) stand averaging 87 m.t./ha covered the other half of the test site. Prevalent mid-story species were southen red oak (Quercus falcata), water oak (Quercus nigra), sweetgum (Liquidambar styraciflua), persimmon (Diospyros virginiana), dogwood (Cornus florida), red maple (Acer rubra), and high bush blueberry (Vaccinium sp.).

METHODS

A complete block experimental design was used with three blocks and five .05 ha treatment plots per block. Four of the five treatment plots were completely harvested before applying additional treatments to control hardwood resprouting. The fifth treatment plot in each block remained unharvested and untreated.

The following treatments were assigned randomly and initiated on the four harvested plots in each block:

1. Velpar Cridball - hand applied in a grid pattern at 1.3 kg/ha active ingredient (1 cc formulation[1]).
2. Tordon 10K - using commercial fertilizer spreader with a random scatter effect (small pellet[2]), applied at 5.6 kg/ha a.i.
3. Chipped only - no additional vegetation control measures initiated after harvesting (this plot to serve as a baseline for vegetation response to complete harvest).
4. Windrowing - land clearing by crawler-tractor with a straight blade.

Herbicide treatments were applied on June 18, 1980 after resprouting had begun. Windrowing is scheduled to begin in the fall (1980) prior to winter planting of loblolly pine seedlings.

In the following sections, study methods and results will be presented jointly under separate headings.

SURFACE DISTURBANCE

The degree and coverage of surface disturbance was assessed using seven categories, modified from Dyrness (1967).

1. Undisturbed--the humus layer still in place and no evidence of compaction.
2. Slightly disturbed--three conditions fit this class:
    a. Humus removed and mineral soil exposed;
    b. A1-horizon soil, humus layer, and/or chips intimately mixed with about equal proportions;
    c. A1-horizon soil deposited on top of litter.
3. Deeply disturbed--A1-horizon removed and A2-horizon or deeper soil layers exposed.
4. Compacted (depressed)--obvious compaction due to passage or a wheel and/or track.
5. Debris pile--mixture of debris and chips greater than 10 cm deep.
6. Soil deposition--eroded mineral soil deposited on soil surface.
7. Non-soil areas--stumps or logs.

Five 50- to 60-m transects were installed across the test site at regular intervals and the surface condition at 1-m spaced points was categorized into disturbance classes. Soil core samples were extracted in pairs from compacted (depressed) points and from undisturbed points within 30 cm at 0-5 cm and 5-10 cm depths.[3]

Results from the soil-surface survey are tabulated below.

Classes	Covered (%)
Undisturbed	25.3
Slightly disturbed	28.8
Deeply disturbed	1.1
Compacted	32.4
Debris piles	7.1
Soil deposition	2.8
Non-soil	2.5

Compaction is the most prevalent disturbance affecting about one-third of the area. This is less than a theortical maximum calculated from track- and chassis-width measurements in a complete harvest. If the inside track of the mobile chipper and/or wheels of a towed chip wagon followed over the outside track patch of the previous swath then 44 percent of the area would be compacted, while overlapping swaths would result

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[1] A 10% active ingredient pellet of hexazinone manufactured by E.I. Dupont de NeMours and Company.

[2] A 10% active ingredient pellet of picloram manufactured by Dow Chemical Company.

[3] Compaction data furnished by Anthony L. King, formerly with the Southern Forest Experiment Station, presently with Agricultural University, Kenya, Africa.

in 66 percent compaction. Our findings is less than the theoretical compaction potential owing to ground protection afforded mainly by chips from the feller bar operation and also limbs and surface roots. Differences in bulk density between compacted and disturbed soils were compared using paired t-tests and were found significant ($p \geq 0.01$) at both the 0.5 cm and 5-10 cm depths. Mean bulk density at the 0-5 cm depth was 1.54 g/cm^3 for compacted and 1.37 g/cm^3 for undisturbed conditions and at the 10 cm depth 1.58 and 1.42, respectively.

Hatchell (1970) reported that increases in bulk density from 0.17 to 0.20 g/cm^3 in loamy sand and loam soils reduced shoot weights of l-year-old loblolly pine by 33 to 43 percent and root weight by 40 to 55 percent. Such a reduction in growth for seedlings on one-third of the areas harvested by the mobile chipper may not occur due to diminution of compaction effects by continuous-furrow or dibble-planted seedlings. This has not yet been determined. Planting by dibble would be difficult on 7.1% of this area due to deep deposition of chips and twigs.

HUMUS AND LITTER

Humus and litter were sampled prior to mobile chipping and again following harvest. Samples measuring 0.09 m^2 (1 ft^2) were extracted at six systematically located points within each treatment plot before harvest, a total of 90 samples. Sample locations were 4 m from plot corners (45") and mid points on the longest sides (90°), with post-harvest samples taken immediately adjoining pre-harvest sample locations. During pre-harvest sampling the distinct humus and litter layers were separated at the time of collections but post-harvest samples required mechanical separation by nested sieves of chips and twigs from both litter and humus. Ashing will be performed on pre-harvest humus samples and post-harvest humus and litter samples to adjust weights for the mineral soil component. Only humus samples have been ashed at this time.

The chipping operation added 4.5 m.t./ha of chips and twigs to the original litter layer which weighed 2.3 m.t./ha. This 195 percent increase, due principally to chips, is attributed to feller-bar operation and chip-loss during turns when the chip wagon was not aligned with the chip discharge duct on the chipper. Fewer turns on larger areas or better alignment should decrease this loss. The influence of this large influx of material to the forest floor and resulting impacts on the mineralization processes are not known. These low-nutrient, high cellulose chips should decompose slowly releasing nutrients more gradually. Most of the needle and twig component was removed from the site with harvest. Removal from a forest of the leaf, twig and needle components as typifies complete biomass harvest, may diminish the available nutrient supply necessary for future growth. Waide and Swank (1975) in their model of nitrogen cycling in a loblolly pine plantation located in North Carolina have indicated a 100 percent increase in nitrogen removal with complete tree harvesting. Additionally they found that with leaf, twig, and needle removal, a substantial decrease in yield may be expected In the third rotation. Cole et al. (1968) in a study of Douglar-fir (*Pseudotsuga menziesii*) indicated that complete tree removal would more then double nutrient loss from a site following harvest.

NUTRIENT LEACHING

This study has begun to quantify the losses due to leaching following complete biomass chipping and removal, by employing tension lysimeters. Two types of lysimeters were used; tension cup and tension plate.[1] Cups provide soil solution samples with minimum concentration bias due to ceramic adsorption or ion screening. Plates allow calculations of loss on an area basis. Description of these devices and installation procedures can be found in Miller (this same conference). Prior to installation all lysimeters were washed with distilled water to eliminate ceramic contaminants.

Leaching losses are being monitored on the following three treatment plots within each block: (aj unharvested check; (b) chipped only (completely harvested) plot[2]; and (c) complete harvest plus herbicide control (Tordon 10K at 5.6 kg/ha a.i.). Lysimeters were installed below the lateral rooting zone at 60 cm. All installations occurred during the 3-week period following harvest completion. Lysimeters were placed just below the maximum lateral rooting zone to reflect true losses from the system. Lysimeters were systematically grouped into two units, with a central plate, and two cups (three in the check) as satellites at a distance of 3.6 m within monitored plots. A total of 18 plates and 42 cups have been installed on this study site.

All devices are evacuated to 0.2 bars which approximates Field Capacity moisture tensions. Percolating water that is held with less than 0.2 bars of tension may pass through the ceramic elements to be collected. Precipitation inputs are being quantified by 1 recording and 2 non-recording gages on the area.

Calcium (Ca), magnesium (Mg), potassium (K), and sodium (Na) are being analyzed in soil solution and precipitation samples using standard techniques of atomic adsorption spectrophotometry.

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[1] Both lysimeters are modified versions of commercial models manufactured by Soil Moisture Equipment Corp., Santa Barbara, California.

[2] This treatment plot to serve as a baseline for nutrient response following complete harvest, with no additional attempt at vegetation control.

Sulfate (SO_4) determinations are by the barium-chloride gel technique (Tabatabai 1974). Phosphate (PO_4), nitrate (NO_3), bicarbonate (HCO_3), and pH are determined using standard methods (McRand et al. 1976).

A substantial increase in leaching loss has occurred due to complete tree chipping and removal (Table 1). The use of herbicide for resprout control has accelerated this loss for all nutrients studied except phosphorus which has shown only a small increase in loss due to herbicide treatment. Bicarbonate and nitrate are the most concentrated anions responsible for cation leaching in this soil system. This data indicate that ecosystem recovery and on-site nutrient immobilization have not yet begun. The difference between nutrient loss in chipped plots and that incurred with herbicide application is probably attributed to root development and nutrient uptake by the reassurging vegetation.

HERBICIDE CONTROL

First year vegetation control by herbicide treatments was assessed by complete stem counts within three treatments plots; Tordon, Velpar, and Chipped Only. Sprouts were categorized as either uninjured, injured or dead. A tabulation of mean total hardwood stems per hectare reveals further the effectiveness of treatments; Chipped plots averaged 17,200 stems, Velpar plots 14,700 and Tordon 11,700.

Tordon plots demonstrated the most effective early control for hardwood, shrub, and woody-vine regrowth (Table 2), averaging 84 percent of all stems counted as injured or dead. Those plots in which Velpar was applied demonstrated some vegetation control, but suppressed only 37 percent of all stems. The chipped-only plots (no herbicide applied)had the lowest incidence of stem death or injury, averaging only 5 percent. The average per hectare was 14,550 hardwoods, 7850 shrubs, and 5912 vines.

Tordon was most effective against blueberry, sweetgum, red maple and grape controlling over 95 percent of these sprouts. It was least effective against the oaks but controlled an impressive 71 percent.

Velpar has to date been less effective in vegetation control than Tordon. Greatest control by Velpar was found in red maple, while control in excess of 50 percent occurred only in the red oak group. The impact of damage to vegetation by insects, water stress, and disease in the Tordon and Velpar plots may be discounted. The highest per-species injury rate in the chip-only plots, though not attributable to herbicide action, was used to create a baseline for separating true herbicide damage from natural injury of death, in the Tordon and Velpar plots.

Table 1. Areal precipitation inputs and leaching losses for eight nutrients from a completely harvested mixed pine plantation on Blanton loamy sand, collections 5/10 to 10/11/80.

	Inputs[1/]		Losses		
Nutrients	Min.	Max.	Unharvested Check	Chipped	Chipped and Herbicide
	g/ha				
Ca	265	733	58	826	1355
Mg	337	487	46	574	786
K	874	2063	83	732	846
Na	1001	1295	220	1670	2495
NO_3-N	966	1778	60	1161	2363
PO_4-P	59	147	0	15	16
SO_4-S	2185	4972	9	834	2225
HCO_3-C	1297	1812	400	3719	4696

[1/] Minimum inputs calculated using the lowest concentrations of three raingages, presumably minimum additions of bird droppings and insects, and maximum inputs used mean concentrations.

Table 2. Early results of vegetation control from three treatments on a completely harvested mixed pine planatation, Auburn University Woodlot.

Species	Vegetation Control Treatments Chip Only % Damage[1]	Vegetation Control Treatments Chip and Velpar % Damage	Vegetation Control Treatments Chip and Tordon % Damage
Hardwoods			
Red Oak[2]	6a[3]	53b	71b
Sweetgum	8a	40b	100c
Red Maple	8a	89b	100b
Others[4]	2a	37b	93c
Total	2a	47b	76c
Shrubs			
Blueberry	9a	28b	97c
Others[5]	6a	31a	59a
Total	8a	28b	92c
Vines			
Grape	4a	36b	97c
Greenbrier	4a	33b	70c
Total	5a	36b	84c

[1] Includes dead and injured.

[2] Refers to the Red Oak group with several species represented.

[3] Means in a row followed by a different letter are significantly different at the 5% level.

[4] Includes hickory, yellow poplar, persimmon, sassafras, black locust, elm, black cherry, blackgum, beech, magnolia, and American hornbeam.

[5] Includes hawthorn, sumac, and bayberry.

DISCUSSION

Forest managers have a responsibility to understand the balance and regulation of nutrient cycling in a forest ecosystem. Nutrient inputs by precipitation, mineral weathering, dry fallout and fertilization as well as losses by biomass removal, leaching and gaseous losses must be regulated by a modern management approach. Continued site productivity and the renewable nature of the forest resource depends upon this knowledge and regulation. The significance of harvest removal of nutrients may be most critical where complete biomass harvesting occurs and where on-site nutrient capital is low to marginal.

Several studies (Wells and Jorgenson 1975, Weetman and Weber 1972, Pritchett and Smith 1974) have demonstrated the significant increase in nutrient loss when whole tree harvest has occurred. Development of the Nicholson-Koch Mobile Chipper may make possible even greater utilization of the material typically left following harvest, while producing a corresponding increase in nutrient removal.

Future research will quantify major contributing components of the nutrient cycle on this site. Litter, humus, chip and soil nutrient budgets will be determined, while monitoring of leaching loss and precipitation input will continue. It may be important to note that when this or similar harvest systems are used, alteration of the cutting schedule to occur before spring leaf-out may contribute significantly to continued site productivity, especially on typically poor quality sites, Also, the importance of minor essential nutrients that have been removed through harvest may become critical to future site productivity, and therefore an attempt will be made to assess these losses in further efforts.

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