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TUBING vs. BUCKETS: A COST COMPARISON

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Abstract.—Equipment investment for tubing-vacuum systems was significantly less than that for bucket systems. Tubing-vacuum systems required about 22 percent less labor input, the major labor input being completed before sap-flow periods. Annual cost of operation was less for tubing-vacuum than the bucket system. Small tubing-vacuum operations showed more profit potential than small bucket operations. Also, tubing-vacuum operations showed a 28 percent increase in sap volume yield as compared to bucket systems.

Which method of maple sap production costs less—buckets or plastic tubing with vacuum pumping? Our studies show that plastic tubing with vacuum pumping costs less.

For two sap seasons (1972 and 73) we studied the total costs involved in maple sap production in operations of various sizes, for both the bucket system and the tubing system with vacuum pumping. We also compared the two collection systems on a cost-per-tap basis to determine if one system has a cost advantage over the other.

Data Collection

Cost records for sap production were kept on 15 maple syrup operations in Vermont during the 1972 and 73 sap seasons. Of these, 7 were plastic-tubing operations, using either wet or dry vacuum; and 8 were traditional bucket operations. For both collection systems, the size of the operations ranged from approximately 600 taps to 4,200 taps.

Field data were collected in two phases. In phase I, a complete inventory of all equipment used in sap production was made on each sugarbush. In addition, any materials used—paint, fuel, oil, wire, etc.—were recorded and included in the cost.

Phase II of the study consisted of a time study of the labor inputs required. Labor input was classed by specific work activity:

1. *Preparation time.*—Cleaning and repairing equipment, storage tank preparation, etc.

2. *Set-up time.*—Installation of mainlines and small tubing lines, tapping, setting spouts, scattering and hanging buckets, etc.
3. *Sap-gathering time.*—Inspecting buckets, gathering sap, dumping ice or spoiled sap, etc.
4. *Checking time.*—Checking the tubing system for leaks and making necessary repairs.
5. *Take-down time.*—Disassembling the system.
6. *Clean-up and storage time.*—Cleaning and storing all equipment.

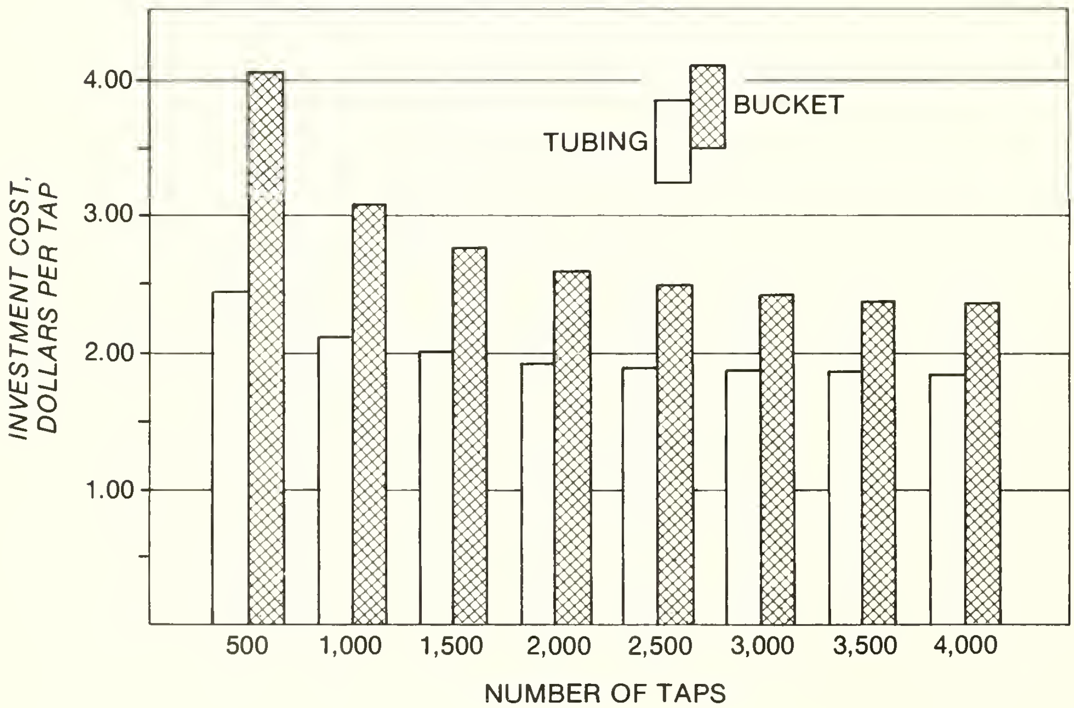
All times were recorded to the nearest ¼ man-hour in each activity.

Cost Development

Four main cost categories were developed for use in analysis of the total cost of sap production:

1. *Equipment cost.*—The equipment costs for the various sizes of operations were developed by averaging up to three prices (1972) as quoted by various sugarbush equipment suppliers. Annual cost charges for equipment were determined by using a 10-year straight-line depreciation schedule for tubing-system equipment and a 30-year straight-line depreciation schedule for bucket equipment. In addition, a 7-percent interest on investment was charged to both collection systems.
2. *Labor cost.*—All labor input to the production of sap was charged a flat rate of $2.25 per hour. This included not only the operator and family labor input, but also any hired labor used during the sap season.
3. *Material cost.*—The materials used in sap production such as paint, wire, coding tags, etc. were charged at actual cost.
4. *Land overhead cost.*—This is generally not considered a cost of production by most sugar producers. However, taxes must be paid on the land, and there is an economic loss in timber value when a maple tree is tapped. To account for taxes and loss in timber value, a flat rate of 11¢ per tap (based on average local prevailing rates in

Figure 1.—Investment cost per tap for bucket and tubing-vacuum sap-collection systems.



Vermont) was charged to the production of sap. The flat-rate charge was used because of the wide variation in local tax rates and differing timber values per acre.

What We Found

Tubing system investment costs less.—All sizes (number of taps) of tubing operations required less investment for equipment than bucket operations (fig. 1). We found that equipment cost per tap for the average size tubing operation (2,400 taps) was $1.91 as compared to $2.54 for the average size bucket operation (2,200 taps).

The investment cost per tap is greatly influenced by the size of the operation or number of taps. The reason is simple: as you increase the number of taps, cost per tap for equipment such as power tappers, vacuum pumps, storage tanks, and hand tools becomes relatively lower as it is averaged over a larger base.

To illustrate: in our study, the smaller tubing operations (2,000 taps and less) had an average investment cost of $2.12 per tap, while the larger operations (2,000 to 4,000 taps) had an average cost of $1.88 per tap. In contrast, the smaller bucket operations (2,000 taps and less) had an average investment cost of $3.12, and the larger bucket operations (2,000 to 4,000 taps) had an average cost of $2.41 per tap.

Requires less labor.—Producers who used plastic tubing averaged 22 percent less labor input than producers who used buckets. This is important because hiring seasonal labor may be a problem. The total labor time per tap for tubing operations ranged from 7.8 to 12.0 minutes, an average of 9.6 minutes per tap. The labor for bucket operations ranged from 9.7 to 13.9 minutes per tap, an average of 12.3 minutes.

In terms of labor cost, at an hourly wage rate of $2.25 per man-hour, the installation of one tubing tap would cost 36¢ compared with 46¢ for one tap with buckets.

Further, the greatest percentage of labor time required with the bucket system is during sap-flow periods, whereas with a tubing system the greatest percentage of labor time is required in the set-up period before sap flow

Figure 2.—Distribution of sap-production work activities for tubing-vacuum and bucket systems.

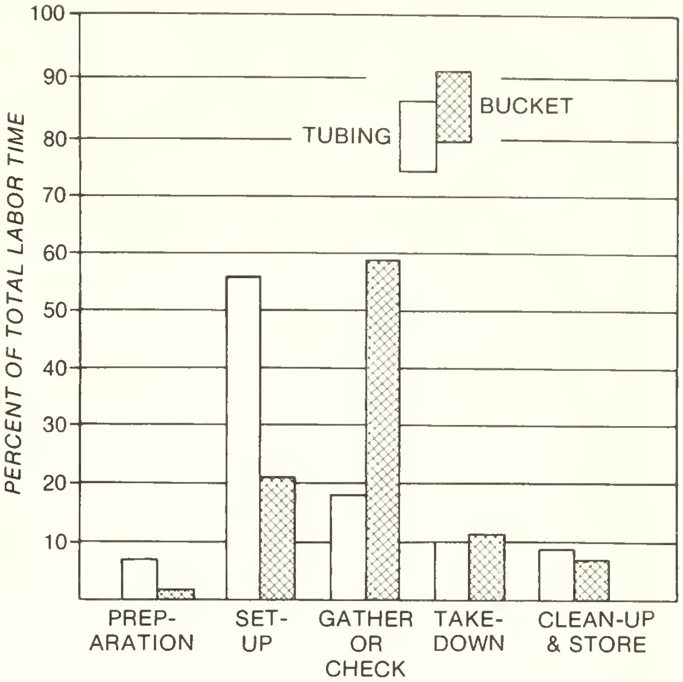


Table 1.—Average labor time[1] for each sap-production work activity

Activity	Tubing-vacuum	Buckets
	Minutes/tap	*Minutes/tap*
Preparation	0.6	0.2
Set-up	5.4	2.6
Gathering	.0	7.3
Checking tubing	1.7	.0
Take-down	1.0	1.3
Clean-up and storage	.9	.9
Total	9.6	12.3

[1] For operations of all sizes.

(fig. 2 and table 1). This indicates that labor for a tubing system is much less time-specific than labor for a bucket system, for which labor must be available when the buckets are ready to empty. Conversely, the set-up time for a tubing system can be spread over a longer time before the sap-flow periods. Thus, when sap-flow periods begin, tubing operators have already completed the major labor requirement and can concentrate on sugarhouse activities.

Long-run operating cost.—The sugar producer who has already invested in his equipment for collecting sap is concerned with his annual operating cost. For the two systems studied, we found that tubing systems had the least annual operating cost. The total annual cost for tubing operations ranged from $1.05 per tap for a 607-tap operation down to 80¢ per tap for a 3,625-tap operation. For the computed average size of a tubing operation (2,393 taps), the total annual cost was 86¢ per tap (table 2).

In contrast, the total annual cost for bucket operations ranged from $1.03 per tap for a 610-tap operation down to 85¢ per tap for a 4,296-tap operation. For the computed average size of bucket operations (2,248 taps), the total annual cost was 93¢ per tap (table 3).

The principal reason why a tubing system has a total annual cost less than a bucket system is because labor costs less (36¢ versus 46¢). This is the area in sap production where better use of labor can have a substantial effect on the total cost of operation.

Minimum size of profitable operation.—For a range of size classes, there is a break-even point at which the income from sugarbushes just covers the costs of operation. For the sugarbushes that we studied, the total annual

Table 2.—Average total costs per tap for tubing-vacuum sap-collection systems

	Size	Annual[1] equipment cost	Labor cost	Material[2] cost	Rental cost	Total annual cost
	Number of taps	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
	607	0.50	0.36	0.08	0.11	1.05
	868	.39	.36	.06	.11	.92
	1,939	.31	.36	.04	.11	.82
	2,435	.31	.36	.04	.11	.82
	3,344	.30	.36	.04	.11	.81
	3,625	.30	.36	.03	.11	.80
	3,936	.33	.36	.03	.11	.83
Average	2,393	0.35	0.36	0.04	0.11	0.86
Percent of total	—	40.00	42.00	5.00	13.00	100.00

[1] Includes cost of snowmobile.
[2] Includes operating costs for gas, oil, and maintenance.

Table 3.—Average total costs per tap for bucket sap-collection systems

	Size	Annual[1] equipment cost	Labor cost	Material[2] cost	Rental cost	Total annual cost
	Number of taps	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
	610	0.35	0.46	0.11	0.11	1.03
	1,022	.34	.46	.08	.11	.98
	1,533	.33	.46	.07	.11	.97
	1,736	.33	.46	.07	.11	.97
	2,003	.26	.46	.07	.11	.90
	2,943	.25	.46	.06	.11	.88
	3,840	.25	.46	.06	.11	.88
	4,296	.23	.46	.05	.11	.85
Average	2,248	0.29	0.46	0.07	0.11	0.93
Percent of total	—	31.00	49.00	8.00	12.00	100.00

[1] Includes cost for tractor and sled.
[2] Includes operating costs for gas, oil, and maintenance.

cost decreased as number of taps increased—up to about 2,900 taps for tubing systems and 3,800 taps for bucket systems. Then the cost remained nearly constant.

We found that an operation of 1,300 taps was the break-even point for tubing systems and 2,200 taps for bucket systems. In both instances we assumed that each tap would yield 10 gallons of sap with a sugar concentration level of 2.5° Brix (Brix value approximates the percentage of sugar solids by weight in maple sap). Thus, operators with more taps should make a profit, and those with fewer taps may be operating at a loss.

The primary reason for the 900-tap spread between the break-even size for tubing systems versus bucket systems is due to savings in labor costs for the tubing systems. This will become the critical factor in sap production as seasonal labor becomes more difficult to find and labor costs increase.

Conclusions

We have examined and compared the costs of the two principal sap-collection systems being used today. Our results indicate the following:

1. The average initial investment cost for sap-collection equipment is less for a tubing system than for a bucket system ($1.91 per tap versus $2.54 per tap). This is an important consideration for producers who are planning to replace old equipment or for people who are considering going into the business.
2. A tubing system requires less labor time than a bucket system (9.6 minutes per tap versus 12.3 minutes per tap). Also, the greatest concentration of labor for a tubing system comes before sap begins to flow, thus enabling the producer to spend more time at the sugarhouse. For a bucket system, most of the labor is required during the sap-flow period.
3. The total annual operating cost for a tubing system is lower than the cost for a bucket system. This is due primarily to the lower labor cost for a tubing system.
4. Small tubing operations show more profit potential than small bucket operations. The break-even point for tubing systems was 1,300 taps as compared with 2,200 taps for bucket systems, assuming a yield of 10 gallons per tap of 2.5° Brix sap. This will change with sap yield and Brix value, and producers who do not consider interest and depreciation as a cost of production and those who do not charge for family help will have a different break-even point.
5. One other important factor is sap-volume yield per tap. For this study, we recorded annual sap yield for both systems and found that average sap-volume yields for tubing systems were 11.4 gallons of sap per tap as compared with 8.9 gallons for bucket systems—about a 28-percent increase in sap yield per tap for the tubing systems.

It is important that each sugarmaker keep accurate cost records so that areas of high cost can be pinpointed and steps can be taken to reduce these costs. The key for a successful maple operation is to increase the overall efficiency of the operation to keep costs of production under control and to maintain an acceptable margin of profit.

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A SUGGESTED GLOSSARY OF TERMS AND STANDARDS FOR MEASURING WOOD AND BARK MILL RESIDUES

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Abstract.——Current information about wood and bark residues lacks the consistency needed to enable complete understanding and comparison from source to source. To make information about wood and bark residues more useful for production and marketing decisions, the Forest Products Marketing Laboratory of the USDA Forest Service and the Tennessee Valley Authority prepared this glossary of terms and standards for measuring wood and bark mill residues. The International System of Units (SI) is recommended as standard practice for workers in this field. Related conversion factors and principles for the use of SI are presented.

The present emphasis on environmental concerns has brought with it an increasing need for information about wood and bark residues. Unused residues can be valuable raw materials for fuel and for the manufacture of pulp, particleboard, fiberboard, charcoal, and agricultural mulches and bedding materials.

Recognizing the value of residues as an energy source and as raw material, timber industries are asking for estimates of types and qualities of residues available. Utilization specialists are seeking to determine how much sawdust, shavings, bark, slabs, and so forth are available for industrial use. Engineers are seeking answers about how much residue a plant produces so they may know what size of incinerators or other disposal apparatus to specify.

Though much data has been published on mill residues, much information of the kind needed is not available, is not suitable in the terms given, or is not comparable from source to source. For example, of seven references recently consulted on the amount of hardwood bark residue produced in debarking, two made no mention of the moisture contents at which weights were taken, three did not fully explain how conversion factors were arrived at, and no two were directly comparable due to differences in definitions, assumptions, methodology, and presentation.

The Forest Products Marketing Laboratory of the USDA Forest Service, in cooperation with the Tennessee Valley Authority, realized that sound production and marketing decisions would require more meaningful and useful reporting on wood and bark residues. As a first step we undertook a project to standardize terms, definitions, and units of measure. The project scope was limited to collecting and publishing standards that would have broad application in measuring residues or byproducts from wood-processing plants. Two objectives were to establish (1) definitions for applicable terminology, and (2) standard units of measurement. In fulfillment of these objectives, a suggested glossary of terminology is presented here, followed by recommendations for use of the International System of Units (SI) as standard practice.

Terms and definitions were obtained from the literature and from consultation with other wood technologists. Twenty-three people in industry, education, and government in the United States and Canada contributed review comments and helpful suggestions; so this glossary represents the thinking and experience of technologists and wood users with a wide range of experience.

Where customary units of measure appear in the glossary, the recommended SI units follow in parentheses.

Glossary

ACTUAL BOARD MEASURE—Lumber measurement according to actual board dimensions.

AIR-DRIED—(adj.) A general term applied to wood or bark seasoned or dried to equilibrium moisture content by exposure to air, usually in a yard and without supplemental heat. It is most useful when stated with the percentage moisture content (ovendry basis) Abbreviated AD.

AIR-DRY—(v.) To dry a material to equilibrium moisture content.

ANGLE OF REPOSE—The angle of maximum slope at which a heap of any aggregate material will stand without sliding. Indicative of the flowability of a bulk material.

BACKING BOARD—In veneer slicing or sawing, that part of the flitch that is used for dogging and remains as a board at the end of the cutting operation.

BAG EQUIVALENT—3 cubic feet (0.084-m^3) of uncompacted material.

BARK—All peripheral tissues of tree stems, branches, and roots outside the vascular cambium, composed of an inner living part (inner bark) and an outer layer of dry, dead tissues (outer bark).

BARK AGE—Length of time that bark has been stored in piles after removal from logs.

BARK, BASE—Any bark used on top of the soil as a mulch that is not primarily decorative. It can contain up to 10 percent wood. It is often used as a base over which a more expensive and decorative mulch is applied.

BARK, INNER—The physiologically active layer of tissues between the cambium and last-formed periderm or protective layer of outer bark. [Syn. phloem.]

BARK, OUTER—The layer of dead tissue, of a dry corky nature, outside the last-formed periderm or protective layer. [Syn. rhytidome.]

BARK, RAW—Bark residues as removed from logs, without further treatment.

BARK, WHOLE—Nontechnical term meaning all the bark tissue, including both inner and outer bark. [Syn. bark.]

BARKING—Syn. debarking.

BLOCK—Log or bolt from which veneer is peeled on a veneer lathe.

BLOCK, END—End trim cut from turnings or shingle bolts.

BOARD FOOT—A unit of lumber-volume measure based on the nominal dimensions of a piece of wood 1 foot long, 1 foot wide, and 1 inch thick, or its cubic equivalent (0.00236-m^3). Abbreviated fbm.

BOARD MEASURE—Lumber measured in board feet. Abbreviated bm.

BONEDRY—(adj.) Syn. Oven-dry. Abbreviated b.d.

BULK DENSITY—Weight per unit volume of an aggregate material at a specific moisture content and compaction ratio.

CHIPS, METALLURGICAL—Wood chips produced to specifications for use in the metallurgical industry.

CHIPPABLE RESIDUE—Wood residue capable of being chipped for some specific use.

CHIPS, PULP—Wood chips produced to specifications for use by pulpmills.

CHIPS, WOOD—Wood particles of various small sizes produced by processing solid wood through chipping machines.

CLIPPING, VENEER—A piece of veneer sheared off in the process of dimensioning dry or green veneers at the clipper.

COMPACTION RATIO—The original volume of a material divided by the volume after being compacted.

COMPOSTED—Converted into compost by piling in a way that encourages decomposition.

CONVERSION FACTOR—A constant used to change a given quantity in a particular unit to an equivalent quantity in another unit.

CORD, LONG—A pile of stacked roundwood (or roughly split pieces) in 5-foot (1.52 m) lengths occupying approximately 160 gross cubic feet (4.48 m^3) of space.

CORD, STANDARD—A pile of stacked roundwood (or roughly split pieces) occupying 128 gross cubic feet (3.58 m^3) of space; generally sticks 4 feet (1.22 m) long, stacked in a pile 4 feet (1.22 m) high and 8 feet (2.44 m) long. Abbreviated cd.

CORE, STAVE BOLT—A solid wood piece left after staves have been sawed from a stave bolt.

CORE, VENEER—The center portion of the veneer log or bolt remaining after veneer has been peeled. [Syn. core block.]

CULL—(1) The deduction from gross volume of a tree or log made to adjust for defect; (2) Any item of production that does not meet specifications.

CUNIT—A unit of volume measure containing 100 cubic feet (2.8 m^3) of solid wood. Used for hogged fuel made from mill waste, pulp chips, wood and bark residues, and as a measure of log volume, especially pulpwood.

DEBARKING—The process of removing bark from logs.

DECORATIVE BARK—Softwood or hardwood bark used as a mulch primarily for its decorative qualities.

DENSITY—The mass of any substance per unit of volume.

EDGE TRIM—See edging.

EDGING—A strip removed from the edge of lumber to square the board and improve the grade. [Syn. edge trim.]

EDGING, STAVE—A strip removed from the edges of rough staves to square edges and eliminate sapwood.

END TRIM—See trimming, lumber.

EQUALIZING BLOCK—The end trim from stave bolts.

EQUILIBRIUM MOISTURE CONTENT—The moisture content at which a material neither gains nor loses water when surrounded by air at a given relative humidity and temperature. Abbreviated EMC.

FINES—General term for particles of wood or bark too small for use in the manufacture of a specific product.

FISHTAIL—A piece of usable veneer, less than 8 feet (2.44 m) long, produced during block roundup on the veneer lathe.

FISHTAIL TRIM—Trim from cutting veneer out of fishtails; it is usually dry.

FLAKE—A small wood particle produced by slicing wood approximately parallel to the grain direction, in overall character resembling a small piece of veneer. Flakes are not usually residue.

GREEN—General term applied to unseasoned wood; above the fiber-saturation point.

GROWING MEDIUM—Material used as a substrate for rooting plants. Sawdust and bark are often used in varying proportions with soil and other materials for growing medium.

HOGGED FUEL—Hogged residue for use as fuel.

HOGGED RESIDUE—Wood and bark residues from manufacturing operations, prepared by processing through an industrial-type hog or hammermill.

INNER BARK—See bark, inner.

INTERNATIONAL LOG RULE, ¼-INCH (6.35 mm) KERF—A method of estimating the board feet of seasoned lumber that can be sawed from logs of a given small-end diameter. It is computed by the formula $V = (0.22D^2 - 0.71D)(0.905)$ in 4-foot (1.22 m) sections, assuming a ½-inch (12.7 mm) taper per section, and a ¼-inch (6.35 mm) kerf, where V = volume in board feet and D = small-end diameter inside bark, in inches.

INTERNATIONAL SYSTEM OF UNITS—Système International d' Unités. A version of the metric system worked out with international cooperation, the use of which is recommended to standardize units of measurement worldwide. It has the following basic units of measurement: meter (m), kilogram (kg), second (s), ampere (A), kelvin (K), and candela (cd) for the base quantities; length, mass, time, electric current, thermodynamic temperature, and luminous intensity. [Abbreviated SI. See metric system.]

KILN-DRIED—(adj.) A general term applied to wood seasoned or dried in a kiln with the use of supplementary heat, moving air, and often humidification. It is most useful when stated with the percentage moisture content. Abbreviated KD.

KILN-DRY—(v.) To dry material in a kiln with the use of supplementary heat, air movement, and humidity.

LILY PAD—An end trimming from a log.

LOG, PEELER—A log suitable for the manufacture of rotary-cut veneer. [Syn. veneer log.]

LOG RULE—A table or formula for estimating the board feet of 4/4 [1 inch (25.4 mm)] lumber that can be sawed from logs of given length and diameter, given a kerf width. Of the many log rules, the International Rule is generally recognized to give the most consistently accurate estimates of the board feet of lumber that can be sawed from a log. In scientific work it is preferred.

LOG, SAW—A log large enough to produce lumber or other products by sawing.

LOG SCALE—The estimated volume of a log or group of logs, based on a specific log rule.

LOOSE FILLED—Syn. uncompacted.

LUMBER TALLY—A record of lumber by number of boards or pieces by size, grade, and species.

MESH—Designation for screen size in terms of the number of openings per linear inch (25.4 mm).

METRIC SYSTEM—A decimal system of weights and measures, using the gram, meter, and liter as basic units of weight, length, and capacity. See International System of Units.

MOISTURE CONTENT—The weight of water contained in a material, generally expressed as a percentage of the material's ovendry weight (ovendry basis). This figure can be greater than 100 percent. It can also be expressed as a percentage of the material's green weight (green basis). The basis for calculation should always accompany the term. Abbreviated MC.

MULCH—Any material spread on top of the soil around plants to conserve soil moisture, insulate plant roots, and reduce weed growth.

NUGGETS, BARK—A commercial term used for 1- to 3-inch (25.4 to 76.2 mm) bark chunks used as a mulch and usually considered as being decorative.

OFFAL—Syn. wood residue.

OUTER BARK—See bark, outer.

OVENDRY—(adj.) Dried to a constant weight in an oven at 105°C (221°F). Abbreviated OD.

OVEN-DRY—(v.) To dry a material to a constant weight in an oven at 105°C (221°F).

OVERSIZE—Residue particles too large to meet their use specifications.

PAD—Partially air dried.

PANEL TRIM—Trim cut from the edges of plywood in the process of squaring and dimensioning a panel; it consists of dry veneer and some glue.

PARTICLE - SIZE CLASSIFICATION — A system to define the distribution of particle sizes in an aggregate material.

RELATIVE HUMIDITY—The ratio of actual vapor pressure to saturated vapor pressure at the same temperature.

RESIDUE, BARK—Bark and wood fragments removed from roundwood forest products as a result of the debarking process.

RESIDUE, COARSE—Solid-wood leftover material produced in the course of timber-processing operations; for example, slabs, edgings, trimmings, log-end trimmings (lilypads), veneer cores, green veneer clippings, culled stave bolts, etc.

RESIDUE, FINE—Small wooden leftovers produced in the course of wood-product manufacturing; for example, sawdust, shavings, chip screenings, spur trim, turnings, rossings, and sander dust; sometimes bark residues are included.

RESIDUE, WOOD—Wood (in all forms) left over from manufacturing operations, not utilized in products.

ROSSING—A splinter-like particle produced by pole- and post-shaving machines in dressing debarked wooden poles and posts. Rossings consist of wood particles and the remains of bark (mainly inner bark).

ROUNDING RESIDUE—All veneer less than 4 feet (1.22 m) long produced in rounding veneer blocks. [Syn. roundup.]

SANDER DUST—Small, dry wooden particles removed in wood sanding operations. It usually contains abrasive particles as well.

SAWDUST—Wood particles resulting from the cutting and breaking action of saw teeth, finer than chips but coarser than wood flour.

SHAVINGS—Small, thin slices of wood, usually curled, that develop from wood-machining operations such as planing, molding, shaping, boring, routing, and turning.

SHINGLE TOW—Shredded wood generated from the shingle saw as residue from the manufacture of shingles.

SHREDDED BARK—Bark reduced to a stringy nature, generally of hardwoods, and used as a mulch, especially in areas such as slopes where wind and rain tend to move other mulches.

SLAB—The exterior portion of a log removed by sawing for lumber.

SOIL AMENDMENT—See soil conditioner.

SOIL CONDITIONER—Material added in varying proportions to soil to improve its physical properties for growing plants.

SPALT—A small piece of excelsior or shingle bolt that cannot be used entirely in excelsior machines or for shingles.

SPECIFIC GRAVITY—The ratio of the ovendry weight of a certain volume of substance to the weight of an equal volume of water at 4°C (39°F). [Abbreviated sp. gr.]

SPLINTS—Edge trim from shingles.

SPUR TRIM—Trim cut from sides of veneer as it comes from a rotary lathe.

SQUARE FOOT OF PLYWOOD—A volume measure of plywood equivalent to 1 square foot of surface measure by some stated thickness, usually 3/8 inch (9.53 mm).

THIN LUMBER—Lumber thinner than the specifications called for in its intended use.

TON, LONG—A weight equal to 2,240 pounds (1017 kg).

TON, METRIC—A weight equal to 1000 kilograms or 2,205 pounds. [Syn. tonne.]

TON, SHORT—A weight equal to 2,000 pounds (908 kg).

TRIMMING, LOG—The end portion of a log removed by sawing for length or to remove defects. [Syn. lily pad.]

TRIMMING, LUMBER—The end portions of boards removed by sawing for length or to remove defects. [Syn. end trim.]

UNCOMPACTED—An indefinite term expressing a low degree of compaction of an aggregate material. The term should be qualified in each instance. For example, gravity-filled from not more than 4 feet (1.22 m) above top of pile.

UNIT—(1) A measure of aggregate material (pulp chips, hogged fuel, bark, or sawdust) having a gross cubic content of 200 cubic feet (5.6 m^3) uncompacted. When used for pulp chips, it has little meaning unless qualified by a factor for solid wood content or ovendry weight [often considered as equivalent to 2,400 pounds (1090 kg)]. It is approximately equivalent to a standard cord (3.58 m^3) of sawmill residues. Abbreviated u. (2) In the South, a 168-gross-cubic-foot (4.70 m^3) [160-gross-cubic-feet (4.48 m^3) trim not included] stack of roundwood with pieces 5 feet 3 inches long piled 4 feet high and 8 feet long.

VENEER CLIPPING—See clipping, veneer.

VENEER CORE—See core, veneer.

WOOD—The lignified water-conducting, strengthening, and storage tissues of branches, stems, and roots of trees, lying between the pith and the cambium. [Syn. xylem.]

WOOD FLOUR—Very fine wood particles ground until they resemble wheat flour, and of such size that the particles usually will pass through a 40-mesh screen.

WOOD LOSS—Wood removed from the log during debarking and not recovered.

WOOD RESIDUE—See residue, wood.

WOOD WASTE—All unusable wood residue that necessitates a net expenditure for disposal.

International System of Units

Inasmuch as a bill is before the Congress for the United States to change to the International System of Units (SI), and many institutions are already in the process of change, we suggest that workers in the field of wood and bark residues become familiar with and use this system as soon as possible. To this end I have included basic information on SI that is appropriate for measuring wood and bark residues. The following tabulation shows some customary and SI units, their symbols, and conversion factors to facilitate changes from one system to the other.

Length	
1 inch (in) = 25.4 millimeters (mm)	1 mm = 0.039 in
1 foot (ft) = 0.3048 meter (m)	1 m = 3.281 ft
1 mile (mi) = 1.609 kilometers (km)	1 km = 0.621 mi
Mass	
1 avoirdupois ounce (oz avdp) = 28.350 grams (g)	1 g = 0.035 oz avdp
1 avoirdupois pound (lb avdp) = 0.454 kilogram (kg)	1 kg = 2.205 lb avdp
Area	
1 square inch (in^2) = 6.452 square centimeters (cm^2)	1 cm^2 = 0.155 in^2
1 square foot (ft^2) = 0.093 square meter (m^2)	1 m^2 = 10.764 ft^2
1 acre (acre) = 0.405 hectare (ha)	1 ha = 2.471 acres
Capacity or Volume	
1 cubic inch (in^3) = 16.387 milliliters (ml)	1 ml = 0.061 in^3
1 cubic foot (ft^3) = 0.028 cubic meters (m^3)	1 m^3 = 35.315 ft^3
1 cubic yard (yd^3) = 0.765 m^3	1 m^3 = 1.308 yd^3
1 board foot (fbm) = 0.00236 m^3	1 m^3 = 423.776 fbm

Decimal multiples and submultiples are formed by using the following factors with SI base units and are labelled by the appropriate prefixes or prefix symbols. The SI base units that concern us here are the meter and kilogram. Since the kilogram already has a prefix, names of decimal multiples and submultiples of the unit of mass are formed by adding prefixes to the word **gram.**

Factor	Prefix	Symbol
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h
10^{1}	deka	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

According to the most recent information from the National Bureau of Standards, the following general principles apply in using SI. These principles were taken from the International System of Units, 1972 edition, Units of Weight and Measure, National Bureau of Standards Miscellaneous Publication 286; and International Organization for Standardization (ISO) Standard 1000, 1973 edition. Several principles were taken verbatim, and others were condensed or expanded.

(1) No period is used with symbols for units except at the end of a sentence.
Example: m, kg

(2) The exponents "2" and "3" are used to signify "square" and "cubic" respectively, instead of the symbols "sq" or "cu".
Example: m^2

(3) The same symbol is used for both singular and plural.
Example: 1 m, 2 m

(4) There should be no spacing between the prefix and the unit that it qualifies, whether names or symbols are used.
Examples: millimeter, mm

(5) An exponent attached to a symbol containing a prefix indicates that the multiple or submultiple of the unit is raised to the power expressed by the exponent.
Examples: $1cm^3 = 10^{-6}m^3$,
$1\ cm^{-1} = 10^2m^{-1}$

(6) Two or more SI prefixes are not to be used together.
Example: 1nm, not 1 mμm

(7) A space is left between numerals and SI names and symbols.
Example: 47.7 kg, not 47.7kg

(8) In numbers, the comma (French practise) or the dot (British and U. S. practise) are used only to separate the integral part of numbers from the decimal part. Numbers may be divided in groups of three by a space in order to facilitate reading; neither dots nor commas are ever inserted in the spaces between groups.
Example: 9 342 770.66

(9) In order to avoid errors in calculations it is essential to use coherent units. Therefore, it is strongly recommended that in calculations only SI units themselves be used, and not their decimal multiples and submultiples.

(10) The use of units with prefixes representing 10 raised to a power which is a multiple of 3 is especially recommended.
Example: refrain from using units with the prefixes hecto, deka, deci, and centi.

(11) It has been found suitable in most applications to choose units that are decimal multiples and submultiples that result in numerical values between 0.1 and 1000.

(12) In tabulated values that extend over a considerable range, it is appropriate to use the same units, even when this means exceeding the preferred value range of 0.1 to 1000.

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FOREST SERVICE, U.S. DEPT. OF AGRICULTURE, 6816 MARKET STREET, UPPER DARBY, PA. 19082

EFFECT OF SEPARATION IN N-PENTANE ON STORABILITY OF SUGAR MAPLE SEEDS

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Abstract.—Seeds in samaras separated in n-pentane have been stored successfully for 5½ years. The seeds in the separated samaras germinated equally as well as the unseparated controls, indicating that there was no detrimental effect from the n-pentane.

It has been known for several years that sugar maple (*Acer saccharum* Marsh.) seeds can be stored successfully up to 54 months without losing viability *(Yawney 1968, Yawney and Carl 1974)*. More recent studies have shown that flotation in n-pentane is an easy method of separating filled and empty sugar maple samaras without reducing the viability of seeds *(Carl and Yawney 1969)*. It was not known, however, if separation in n-pentane affects the viability of seeds stored longer than 70 days. This work was undertaken to determine if pentane has any long-term effects on sugar maple seeds.

Materials and Methods

The study was begun in the fall of 1967 with seed collected from a single tree. It was expanded in 1968 by including seed from four more trees. Seed from four additional trees were added in 1970, for a total of nine collections. The trees were all located in Vermont, in an area between Westford and East Middle-bury. The area was between 44° 35′ 15″ and 44° 58′ 20″ north latitude and 72° 58′ 20″ and 73° 5′ 40″ west longitude.

Regardless of the year, all of the seed were handled in a similar manner. After collection, pre-storage viability tests were performed. Immediately afterward, half of the remaining samaras were put in pentane to separate the filled ones from the empty ones. (The ones filled with seed sink; the empty ones float.) The filled samaras were left in the pentane no longer than 5 minues. They were removed from the pentane and allowed to air-dry for a short period to remove the excess pentane.

All the samaras, both separated and unseparated, were then spread on drying racks in an unheated building to dry to a 10- to 15-percent moisture content. After drying, they were counted out into lots of 50 each for the separated samaras and 100 each for the unseparated samaras. Each lot was sealed in a glass jar and placed in storage at minus 10°C. Periodically thereafter, 10 jars for each tree (five containing samaras separated in pentane and five containing unseparated samaras) were removed from storage and the seeds were germinated.

Germination tests were conducted by stratifying the seeds in the dark for 90 days at 2°C, followed by 2 weeks in subdued light at 16°C *(Carl and Yawney 1966)*. A seed was considered germinated when the radicle appeared through the fruit coat. At the end of each germination test, the samaras that failed to germinate were opened to determine the number of ungerminated seeds. These were added to the number of germinated seeds. This determined the total number of seeds in each sample. Germination percentages were based on that total.

Results

Average germination percentages for each of the years of collection and length of storage are given in table 1. The seeds collected in 1967, which had an initial germination of 98.2 percent, have been stored for up to 5½ years with no decrease in viability of the seeds in the separated samaras. There was some apparent loss of viability of the seeds in the unseparated samaras, but they still had a better than 90 percent of germination. After 66 months in storage the seeds in the separated samaras had 98.4 percent germination, but only 93.1 percent of the seeds in the unseparated samaras germinated.

The 1968 seed collections have been stored for up to 60 months but have not withstood storage as well as the 1967 seeds. Initial germination of the collections averaged 94.9 percent. However, after 60 months of storage, the seeds in the samaras separated in pentane have germinated nearly as well—90.3 percent—as the seeds in the unseparated samaras—91.1 percent—which would imply that any loss of viability was due to some factor other than separation in pentane.

The 1970 seed collections, which had an initial germination of 99.0 percent, have been stored for up to 36 months without loss of viability of seeds in either the separated or unseparated samaras. Germination was 97.7 percent for the seeds in the separated samaras,

Table 1.—Effect of separation in pentane and length of time in storage on the percent germination of sugar maple seeds

Year of collection	Treatment	Months in storage										
		0	6	12	18	24	36	42	48	54	60	66
1967[1]	Pentane	98.2	97.2	—	94.8	—	—	95.6	—	96.8	—	98.4
	Control	98.2	91.5	—	94.4	—	—	87.6	—	93.8	—	93.1
1968[2]	Pentane	94.9	—	92.4	—	90.7	86.2	—	88.2	—	90.3	—
	Control	94.9	—	92.0	—	87.3	86.6	—	90.4	—	91.1	—
1970[2]	Pentane	99.0	—	97.1	—	97.8	97.7	—	—	—	—	—
	Control	99.0	—	96.9	—	97.8	98.6	—	—	—	—	—

[1] Single tree.
[2] Average of 4 trees.

and 98.6 percent for the seeds in the unseparated samaras.

Discussion

Germination of sugar maple seeds stored for extended periods does not seem to be adversely affected when pentane is used to separate the filled samaras from the empty ones. Although in some cases a decline in germination of the separated seeds was observed, there was a corresponding decrease in germination of the unseparated controls, which would seem to indicate that such a decrease was not caused by the pentane. Barnett *(1971)* indicated that pentane is relatively safe for separating longleaf pine (*Pinus palustris* Mill.) seed even when storage is necessary.

It was expected that the control seeds should store as well as those reported by Yawney *(1968)* and Yawney and Carl *(1974)*. But the 1968 collections did not store as well as expected. It may be that the seeds were not as mature as those used in the earlier storage study. Barnett and McLemore *(1970)* reported that longleaf pine seeds collected from a given tree 1 year may store well, while seeds collected from the same tree in another year may store poorly.

This is probably the case with sugar maple seeds too. Another factor that may affect storability might be the drying techniques. Although attempts were made to dry the samaras the same way each year, the rate of drying depends on the relative humidity at the time, and this varied between years. This made a difference in the drying schedule and might account for some of the difference in storability.

The door of the freezer containing the 1968 seeds was inadvertently left ajar over a 3-day weekend in 1971; and although the freezer kept running, it is not known how much warming occurred, or how it affected germinability. Although there was a sharp drop in the germination of the separated seeds between 24 and 36 months of storage, the germination returned to the 24-month level, which may indicate that if there was any effect, it was minor.

From this experiment and from observations of other seed collections, it seems perfectly safe to separate sugar maple samaras in pentane even though it is planned to store them for extended periods. Results of our experiment thus far indicate that seeds in samaras separated in pentane can be stored for periods of up to 66 months without loss in viability greater than that of seeds in unseparated samaras.

CAUTION: Pentane is extremely volatile and should only be used in well ventilated places away from any open flame. Also, breathing the fumes is to be avoided as much as possible.

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FOREST SERVICE, U.S. DEPT. OF AGRICULTURE, 6816 MARKET STREET, UPPER DARBY, PA. 19082

A STUDY OF LOGGING RESIDUE AT WOODS LANDINGS IN APPALACHIA

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Abstract.—A study of residue on five woods landings in West Virginia showed that short lengths, poor quality, and low volumes are obstacles to utilization of this material. Short lengths and dirt accumulation would also pose serious problems for conversion to chips. Some local use for firewood and specialty products is possible.

In most logging operations, the tree stems are hauled to a landing where they can be cut into logs and bolts, stored, and loaded onto trucks for hauling to a mill. These activities create some woody residue—unmerchantable stems or logs, limbs, trimmings, chunks of defective wood, etc. (fig. 1).

This residue is not marketed by the logger or the landowner: it is left in the woods when the landing is abandoned. Some loggers leave it scattered about the landing; others treat the landing site by leveling the residue piles, covering the area with soil, and sowing grass seed (fig. 2). Many loggers in Appalachia treat their landings in this manner even though cleaning up a landing is time-consuming and costly.

This treatment is beneficial in several ways. It hastens the decomposition of the residue, improves the appearance of the landing area, and provides small clearings for use by wildlife.

An alternate, and possibly more beneficial, solution for treatment of this residue at woods landings would be to utilize it for products: chips, mine material, pallet parts, and the like. But before we can consider utilization of this residue, we need to know more about the quantity and quality available.

Figure 1.—Residue left on a landing after logging operations have ceased.

Figure 2.—Some landings, like this one, are cleaned up and sown to grass.

The Study

To find out how much if any of this logging residue is actually usable, our Forest Products Marketing Laboratory in West Virginia conducted an exploratory study of woods landings after all logging activities had ceased. While we knew that most of this material was from long-bucked logs, limbs, defective tree portions, and an occasional overlooked log, we had little knowledge of those characteristics that are the key to potential utilization: size, volume, weight, and amount of defect.

We selected five woods landings in West Virginia for study, each on a separate hardwood logging operation. We determined the boundaries of the landing site and tallied all pieces of wood left on the landing. (Residue from clearing the landing or felling of nearby trees was excluded because this material would normally be classed with logging or road construction residue.) For each piece, we recorded the small- and large-end diameters, length, sweep, amount of defect, and weight.

Results

All pieces.—We measured more than 1,200 pieces (table 1) of wood left on the 5 landings. The pieces ranged in size from short chunks to log lengths, with an occasional whole tree stem. Short lengths predominated on all the landings, 55 percent of all pieces being less than 4.0 feet long. This is below the minimum length required for pulpwood and many other products. Eighty-three percent of all pieces were less than the minimum 8-foot length required for sawlogs. The average length of all pieces was 4.7 feet.

Although lengths were short, diameters were fairly large. Nearly all pieces had small-end diameters equal to or exceeding the minimum diameter requirements for many products. Less than 3 percent of all pieces had diameters of less than 4.0 inches, and 87 percent had diameters of 8.0 inches or more. The average small-end diameter for all pieces was 12.3 inches.

The total gross volume of all pieces was 5,815 cubic feet. More than a third of this volume was in pieces less than 4.0 feet long, and nearly three-fourths of the gross volume was in pieces less than 8.0 feet long. Scalable defects, including sweep, reduced the gross volume (5,815 cubic feet) by 15 percent. Though the amount of defect was relatively small, nearly 65 percent of all pieces were defective in some manner.

Ninety-three percent of all the residue came from the upper portions of tree stems. No information was recorded on surface characteristics other than sweep, but it was obvious that numerous knots, scars, and other degrading features would seriously affect the quality of much of this material. Nearly all of the butt sections contained rot and other interior defects.

The total weight for all pieces amounted to 315,455 pounds, nearly 158 tons of bark and wood fiber. More than one-half of this was in pieces 8 feet or less in length. Accurate weight figures were difficult to obtain because much of the material was covered with dirt or mud from logging activities. Though efforts were made to eliminate as much of this excess weight as possible, our weight figures do reflect some error due to this.

Sawlog-size material.—Of the more than 1,200 pieces measured, only 180 pieces (15 percent) met both the minimum 8-inch small-end diameter and 8-foot length requirement for sawlogs.

Most of the sawlog-size pieces were in lengths of 8 to 16 feet, only 3 percent requiring further bucking (table 2). More than 50 percent of the sawlog-size pieces had diameters greater than 12 inches. This sawlog-size material had an average small-end diameter of 13.2 inches and an average length of 10.9 feet.

Of the 180 pieces considered for sawlogs, 140 were of extremely low quality because of

Table 1.—Characteristics of woods landing residues: all pieces

Dimensions	Pieces		Gross volume		Weight	
Length: (feet)	*No.*	*Pct.*	*Cu. ft.*	*Pct.*	*Lbs.*	*Pct.*
3.9 or less	666	55	2,138	37	121,001	38
4.0 - 7.9	339	28	2,046	35	109,944	35
8.0 or more	212	17	1,631	28	84,510	27
Total	1,217	100	5,815	100	315,455	100
[Average length: 4.7 feet]						
Diameter: (inches)						
3.9 or less	33	3	34	1	2,340	1
4.0 - 7.9	125	10	295	5	17,440	5
8.0 or more	1,059	87	5,486	94	295,675	94
Total	1,217	100	5,815	100	315,455	100
[Average diameter: 12.3 inches]						

Table 2.—Characteristics of woods landing residue: sawlog size only

Dimensions	Pieces		Doyle gross volume		International gross volume		Weight	
Length: (feet)	*No.*	*Pct.*	*Bd. ft.*	*Pct.*	*Bd. ft.*	*Pct.*	*Lbs.*	*Pct.*
8	72	40	4,623	39	5,075	35	43,490	36
10	41	23	1,498	12	2,070	14	20,020	17
12	27	15	2,472	21	2,855	20	22,890	19
14	23	13	1,415	12	1,980	14	17,060	14
16	11	6	1,070	9	1,395	10	9,660	8
16+	6	3	856	7	1,065	7	7,580	6
Total	180	100	11,934	100	14,440	100	120,700	100
			[Average length:		10.9 feet]			
Diameter: (inches)								
7.6 - 10.5	52	29	1,072	9	1,880	13	19,330	16
10.6 - 12.5	39	22	1,312	11	1,835	13	18,090	15
12.6 - 14.5	33	18	2,131	18	2,675	18	22,810	19
14.6 - 16.5	24	13	2,326	19	2,775	19	23,380	19
16.6 - 18.5	18	10	2,128	18	2,310	16	17,200	14
18.6+	14	8	2,965	25	2,965	21	19,890	17
Total	180	100	11,934	100	14,440	100	120,700	100
			[Average diameter:		13.2 inches]			

knots, sweep, interior defect, and other degrading features. However, 40 logs (22 percent of the 180) were good enough to warrant utilization. Apparently these logs had been overlooked or left behind for unknown reasons.

There was a total of nearly 12,000 board feet (Doyle) of sawlog-size pieces with defect amounting to 30 percent. Much of this defect was contained in the butt sections. The 180 pieces of sawlog-size material weighed a total of 120,700 pounds. This accounted for nearly 40 percent of the total weight of all pieces measured.

Conclusions and Discussion

The short length of the residues found on the woods landings precludes its use as a source of raw material for most sawn products. Most present-day sawmill equipment would be unable to handle 83 percent of all the pieces measured.

The low quality of 78 percent of the sawlog-size material would not justify processing as sawlogs. This material might, however, provide a source of pulpwood.

The extremely low quality of most of this material prevents its utilization for many other products. For example, though the mining industry occasionally uses short material, its requirements for soundness and strength qualities are stringent and would reject a large portion of the landing residue. The minimum requirements for pulpwood would reject 55 percent of all the pieces.

Converting the landing residue to chips might be one solution. However, feeding the short lengths into a chipper might be extremely difficult; and dirt accumulation would seriously hamper chipper operations. The volume per landing would not be sufficient to supply a chipper unit for very long. Indeed, the total volume (5,815 cubic feet) from the five landings studied would provide less than 1 day's supply of material for a large chipper.

The immediate prospects for utilization of woods-landing residues are slim. Some of this material is being used for firewood and specialty products, but the markets are local and demand is limited.

If the demand for firewood increases as the Nation's energy crisis continues, the useful residues at woods landings might become important in the development of future firewood markets.

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A PRECIPITATION COLLECTOR AND AUTOMATED pH-MONITORING SYSTEM

by GERALD M. AUBERTIN
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Abstract. A sensitive precipitation collector and automated pH-monitoring system are described. This system provides for continuous monitoring and recording of the pH of precipitation. Discrete or composite rainwater samples are manually obtainable for chemical analyses. The system can easily be adapted to accommodate a flow-through specific conductance probe and monitoring components.

Keywords: Precipitation, rain, pH, precipitation chemistry, acid rain, atmospheric quality, precipitation monitoring.

There is more to rain than water. Rain is generally acidic and contains varying amounts and types of ionic, molecular, and particulate substances. Evidence is accumulating that our rains are becoming more acidic and that their content of nonwater substances is increasing. These changes may influence plant growth.

We need to know the relative quality of the precipitation and how the quality changes with time and storm characteristics. To obtain this information we need to collect and analyze precipitation samples. But collecting precipitation samples is not as simple as one might think. Storms, especially in mountainous regions, are variable in type, timing, duration, intensity, and direction of movement. Limited data indicate that these variables may influence the chemical composition or quality of the precipitation.

Standard or automatic rain gages or simple open containers are adequate for obtaining quantitative and overall qualitative informa-

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tion, but they provide us with no information about changes in precipitation quality with time or storm characteristics.

To overcome this problem, we have developed a sensitive precipitation collector and automated pH-monitoring system that can provide detailed information about precipitation quality throughout a given storm or series of storms. The pH of the precipitation is continuously monitored and recorded on a strip chart. Discrete or composite rainwater samples are obtainable manually for chemical analyses over any period of a storm. The system can easily be adapted to accommodate a flow-through specific-conductance probe, meter, and recorder. With minor modifications, this system could also be connected directly to an autoanalyzer/recording system for complete automation. Rainfall amounts, intensities, and duration are obtained from a companion 24-hour recording rain gage.

The system is composed of (1) a precipitation collector, (2) a conducting system, (3) monitoring equipment, (4) control components, and (5) a companion automatic rain gage.

The Precipitation Collector

The collector consists of (1) a catchment that remains covered except during periods of precipitation, (2) a precipitation detector, (3) electronic and mechanical devices to open and close the catchment lid, and (4) a supporting framework and protective covering (fig. 1).

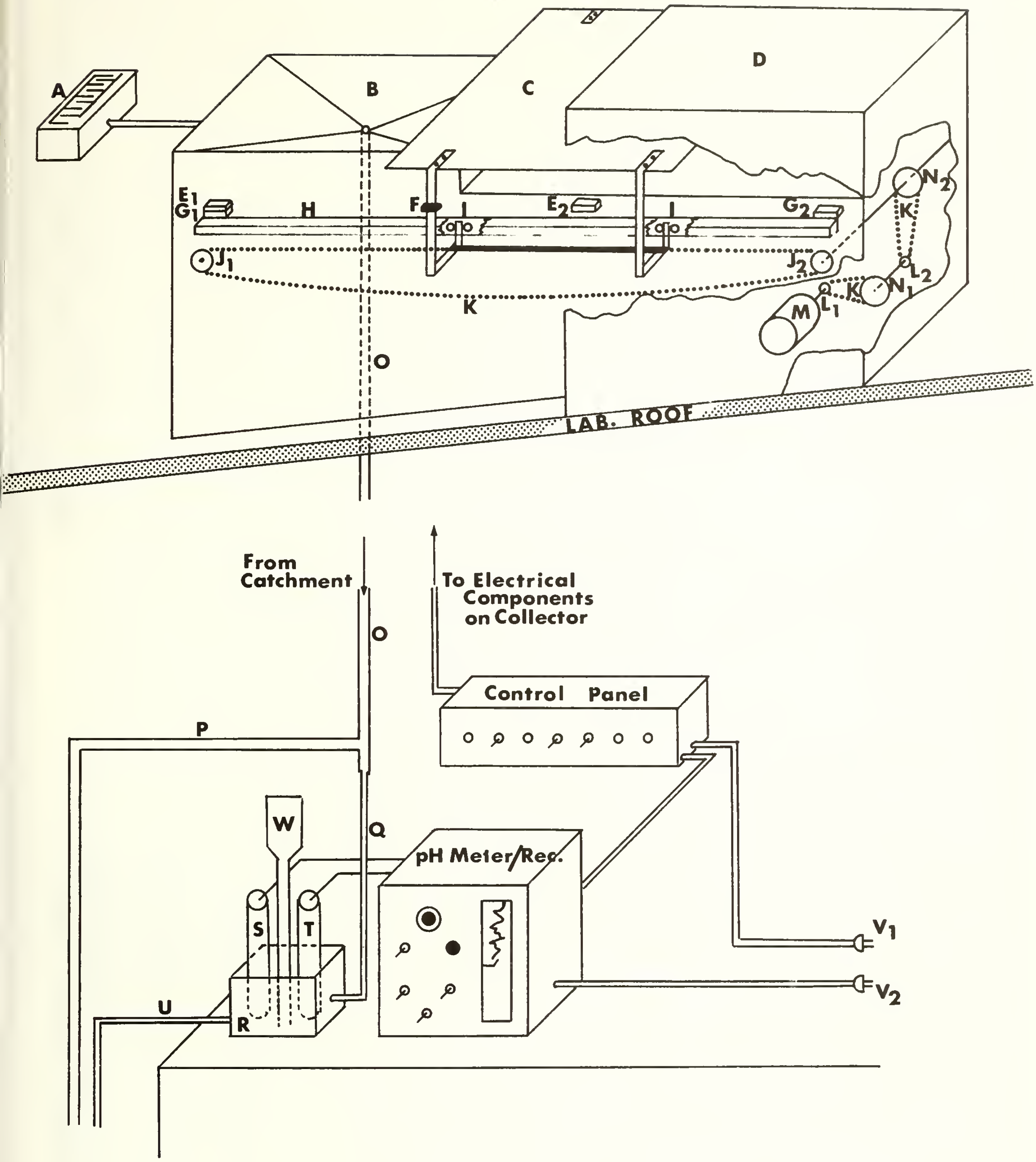
Our catchment is a pyramidal basin 3 feet square and 9 inches deep (fig. 2), providing 9 square feet of open surface. A catchment of this size and shape will collect about ½ pint of rainwater from an 0.01-inch rain or about 5.6 gallons of rainwater from a 1-inch rain. The catchment is made of ½-inch exterior-grade plywood, painted with a noncontaminating, two-component, epoxy sealant that cures to a hard glass-like finish.

During dry periods, the catchment is covered by a sliding lid. When a storm begins, the first few drops of precipitation falling on the sensing element of the detector activate the system, and the catchment is automatically uncovered. After precipitation ceases, the sensing element dries and the relays automatically respond to cover the catchment. The lid can be opened and closed manually with a double throw switch.

The catchment lid is made of a 40 x 40-inch sheet of ¼-inch exterior-grade plywood, fastened to four lightweight garage-door hangers that ride in standard 16-gage trolley tracks. The trolley tracks (one on each side of the collector) were installed with a 1-inch gradient toward the catchment. Thus, with the hanger supports adjusted to keep the lid level throughout its travel on the tracks, the lid settles down on the catchment to form a relatively tight seal. Tightness of seal is enhanced by a 1-inch thick strip of foam rubber attached to the lid.

Figure 1.—Schematic of the precipitation collector (above), which is on the roof of the laboratory; and the pH-recording system in the laboratory below. The parts of the system are:

A	P-566 Rain detector
B	Catchment (9 square feet)
C	Lid
D	Cover
E_1	Lid-closed indicator reed switch
E_2	Lid-open indicator reed switch
F	Permanent magnet
G_1	Lid-closed limit switch
G_2	Lid-open limit switch
H	Trolley tracks (one each side)
I	Trolley tracks (two each side)
J_1	Idler sprockets (one each side) (40 teeth 3.32 inches o.d.)
J_2	Drive sprockets (one each side) (40 teeth 3.32 inches o.d.)
K	Roller chain 0.25
L_1	Drive sprocket (12 teeth 1.08 inches o.d.)
L_2	Drive sprockets (24 teeth 2.05 inches o.d.)
M	Reversible motor
N_1	Sprocket (72 teeth 5.87 inches o.d.)
N_2	Sprockets (60 teeth 4.92 inches o.d.)
O	Conduit, ¾ inch
P	Overflow tube
Q	Delivery tube
R	Measuring chamber
S	pH electrode
T	Automatic temperature compensator probe
U	Discharge tube
V_1	Power supply to control panel, 110 VAC, 60Hz
V_2	Power supply to pH meter/recorder, 110 VAC, 60Hz
W	Constant-head water supply


A
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K
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LAB. ROOF
From Catchment
To Electrical Components on Collector
O
Control Panel
P
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Q
pH Meter/Rec.
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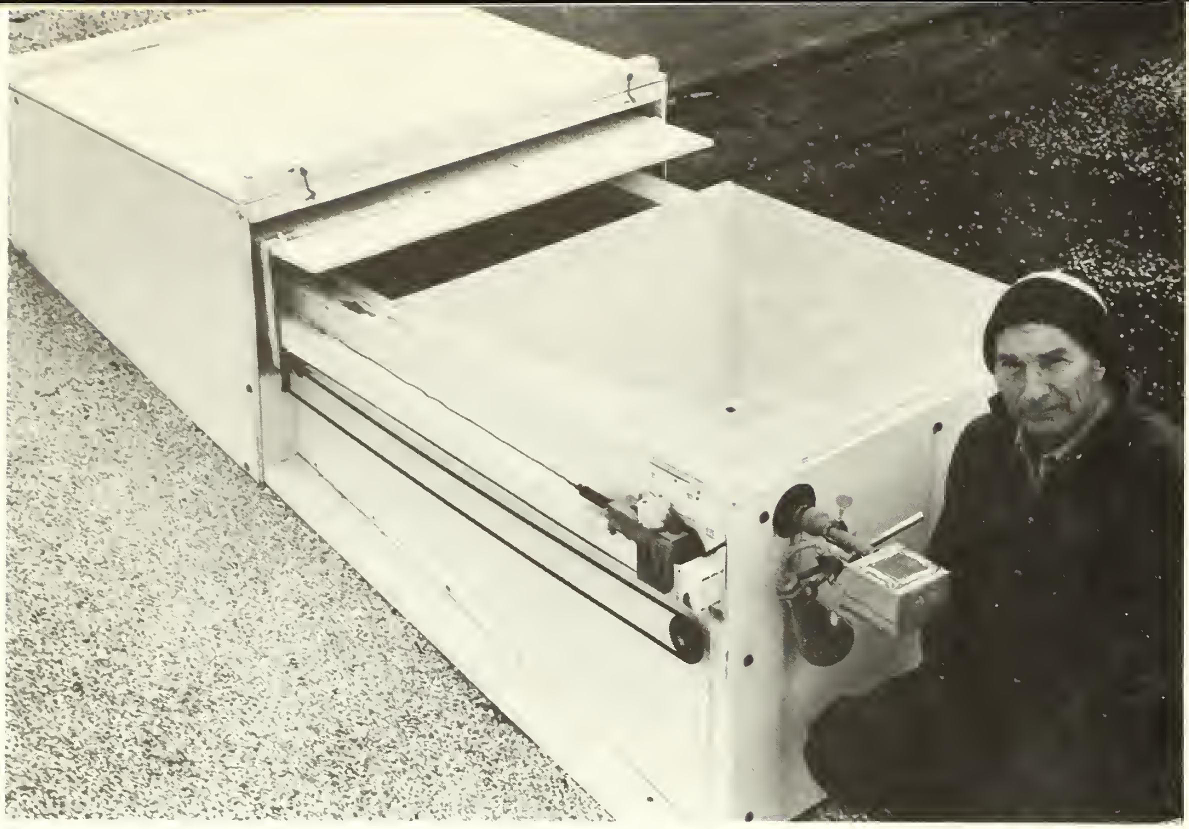
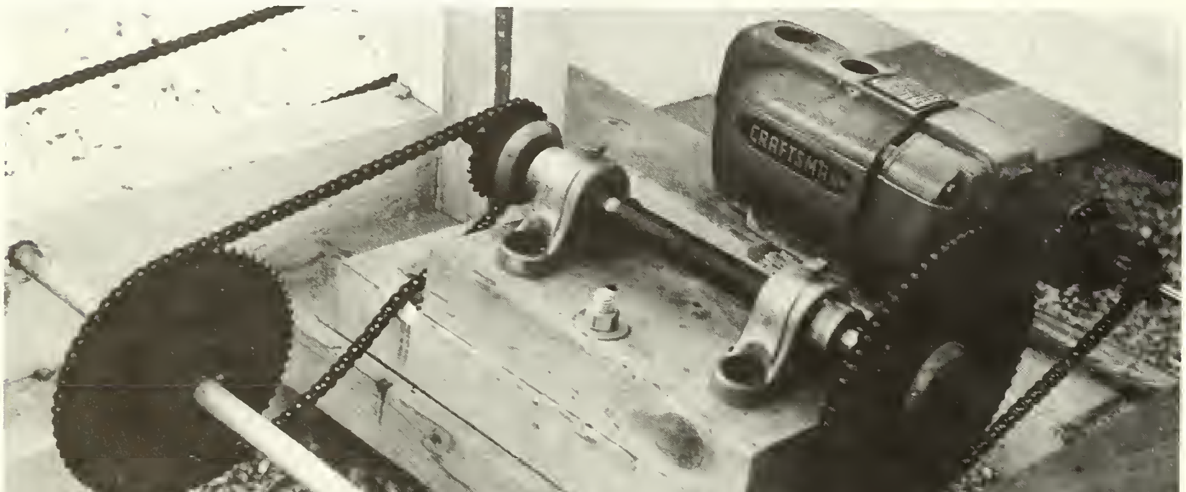


Figure 2.—Precipitation collector on the roof of the Timber and Watershed Laboratory at Parsons, West Virginia. The lid is retracted almost to the full open position.

Figure 3.—Motor and drive train for opening and closing the precipitation collector.



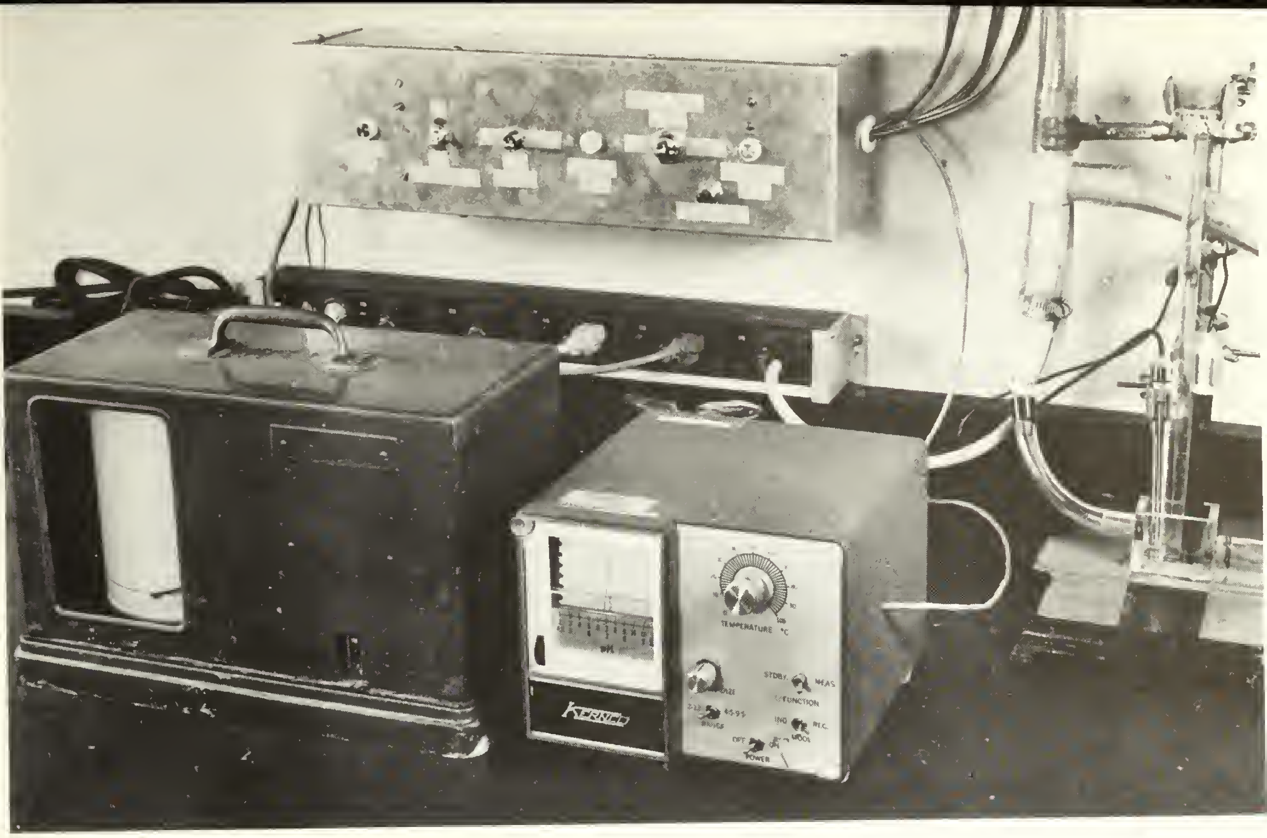


Figure 4.—The control/measuring/recording system located in the Laboratory directly below the collector.

The lid is opened and closed by a system of roller chains and sprockets powered by a ¾-hp. reversible electric motor, activated through relays and switches associated with the precipitation detector (fig. 3).

Lid travel distance is controlled by limit switches in the control wires to the motor. One limit switch (normally closed) opens the lid-opening circuit whenever the lid reaches the fully open position. Another limit switch in the lid-closing circuit opens the lid-closing circuit whenever the lid is fully closed. The limit switches, in effect, over-ride the detector or manual control instructions to the motor; thus the circuits are completed only during actual opening or closing of the lid.

Lid position indicators were incorporated into the system. A permanent magnet attached to one of the hanger supports activates reed switches (normally open) placed at the fully open and fully closed positions. Circuits from these switches lead to indicator lights on the control panel.

The catchment, motor, trolley rails, and drive components were mounted on a wooden framework constructed to fit the slope of the laboratory roof and angled to keep the catchment opening level. The framework was covered with ¼-inch exterior plywood. A housing covers and protects the motor and drive components while keeping snow and freezing rain from building up on the lid. This housing is hinged to allow access to the motor and drive components.

The heart of the automated collector is the precipitation detector. We used a commercially available unit, although costs might be substantially reduced by constructing a precipitation-sensing unit from component parts (see W. W. Bentz, 1968, Inexpensive automatic cover for rain gage, ARS Publ. 41, p. 146).

The principle of the precipitation detector is fairly simple. The sensing element is a grid of gold-plated printed circuit, with contacts spaced about $\frac{1}{16}$ inch apart. Precipitation falling on the grid bridges the contacts and completes the circuit, activating a relay that completes the circuit to the motor. The lid opens and uncovers the catchment and remains open as long as moisture bridges the contacts. A small heater in the detector speeds grid drying after precipitation stops. When moisture ceases to bridge the contacts, the relay opens, and the lid-closing circuit is completed. The lid closes automatically and remains closed until moisture again bridges the contacts.

Conducting System

Rain caught in the collector drains through a ¾-inch tygon tube into the laboratory below and into a small chamber containing the measuring sensors (fig. 4).

This chamber (about 1½ inches wide x 1 inch deep x 1½ inches high), made of plexiglass, is constructed to retain about ½ inch of water at all times, so that the glass membrane of a nonrefillable combination electrode is kept moist. A constant-head reservoir compensates for evaporative losses between storms.

The sensing portion of a pH electrode, an automatic temperature-control probe, and the outlet from the constant-head reservoir are in the chamber. Water in the chamber (about 5 ml) is replaced rapidly by rain coming through the system, and response to differences in pH is rapid.

A bypass built into the system drains off rainwater in excess of the amount desired to pass through the chamber. Outlets from both the bypass and chamber lead to a 2-gallon plastic container. Rainwater samples can be obtained manually from the drain system for any period of the storm desired, or a composite sample can be obtained from the plastic container.

pH Meter/Recorder

The pH of the water in the chamber is constantly monitored by a Kernco Model SR-15 Recording pH Meter. (Mention of a commercial product is for information only and should not be considered as an endorsement by the Department of Agriculture or Forest Service.) However, to conserve recorder chart paper, the mode switch has been electronically tied to the precipitation sensor through a reset relay. This allows the meter to be kept in the indicate mode (monitoring but not recording) during periods of no precipitation. When precipitation begins, the relay is tripped and the recorder becomes operative. It remains operative until it is manually reset, even though the precipitation may have stopped and the catchment lid may have closed. Chart speed is 1 inch per hour, with one stylus strike every 2 seconds. Water-temperature changes in the chamber are compensated for by the automatic temperature-control probe and related internal components of the meter. The system is periodically checked and recalibrated to a pH value of 4.00.

A timing system is electronically tied to the opening circuit of the collector. This system indicates, on 24-hour charts, the periods during which the catchment lid is open. This system is basically made of the clock and pen-arm assembly from an FW-1 water-level recorder. The pen arm is raised on the chart by the activation of an electromagnet connected to the precipitation-detector circuit.

Control Panel

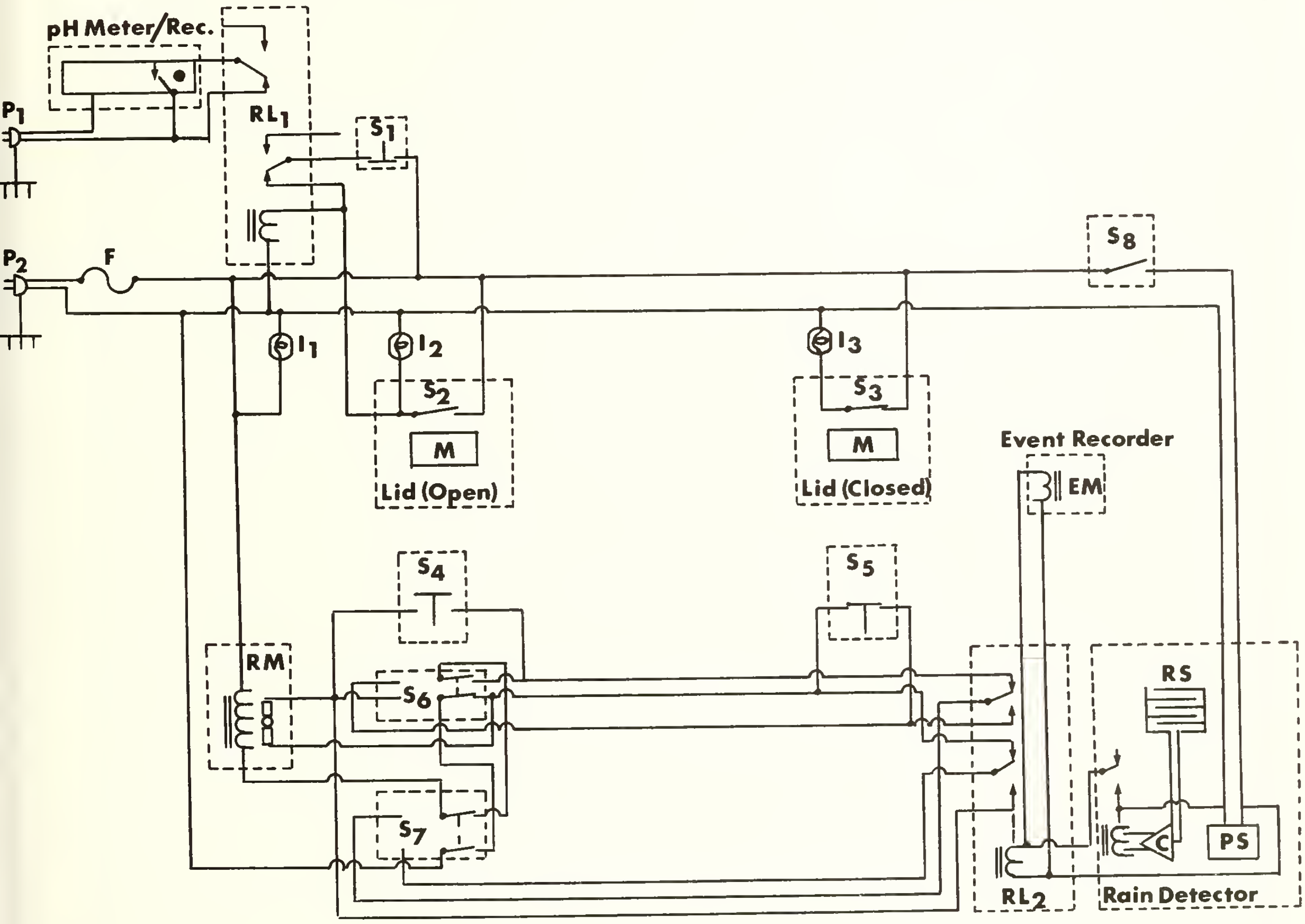
The control panel (fig. 5) consists of an energized circuit indicator, an on-off sensor control switch, a relay reset button, a double-throw switch for automatic or manual operation of the collector, a manual opening-closing control switch, and lid-opening and lid-closing indicator lights. All wiring was brought through the control box, and the switches and components were wired so that everything is powered by a single grounded cord plugged into a standard 110-volt grounded receptacle. A 6.25-amp slow-blow fuse is located in the 110-volt hot line.

Automatic Rain Gage

The timing, amount, and intensity of rainfall is obtained from standard recording rain gages located in a class A climatic station abount 100 feet from the collector. Recording rain gage charts (24-hour) are changed on Monday, Wednesday, and Friday. Rainfall intensities, calculated for each 5-minute inter-

Figure 5.—Schematic of the control system for the pH-monitoring system. The parts are identified as follows:

- P_1 Power supply to pH meter/recorder, 110 VAC, 60Hz
- P_2 Power supply to control panel, 110 VAC, 60Hz
- pH Meter/recorder SR-15 recording pH meter
- F MDX 6.25-amp. fuse and fuse holder
- I_1 110 VAC, 3 ma, 1/3 W indicator lamp energized circuit light
- RL_1 DPDT 0.3 amp, 120 VAC, 60Hz, relay with 8-amp contacts pH meter/recorder control
- S_1 Momentary push-button reset switch SPST, normally closed 1 amp, 110 VAC
- M Permanent reed relay magnet on moving lid
- S_2 0.5-amp 110 VAC reed switch, normally open, lid-open indicator switch
- I_2 110 VAC, 3 ma, 1/3W indicator lamp, lid-open indicator switch
- S_3 0.5-amp 110 VAC reed switch, normally open, lid-closed indicator switch
- I_3 110 VAC, 3 ma, 1/3 W indicator lamp, lid-closed indicator light
- S_4 15-amp limit switch, cut-off switch for lid in fully open position
- S_5 15-amp limit switch, cut-off switch for lid in fully closed position
- RM Reversible motor 3/4 hp, 110 VAC, 60Hz
- S_6 DPDT 10-amp toggle switch, mode switch for manual or automatic lid operation
- S_7 DPDT 10-amp toggle switch, manual lid operation switch
- S_8 SPST 6-amp 110 VAC on-off switch
- Event Recorder Modified FW-1 recorder
- EM 0.3-amp 110 VAC, 60Hz electromagnet
- RL_2 DPDT 0.3-amp 120 VAC 60Hz relay with 8-amp contacts, event recorder control
- Rain detector P-566 rain detector
- C Comparator
- PS Power supply and heater
- RS Rain sensor



val, are expressed as inches of rain per hour. Total 24-hour rainfall is determined daily from standard 8-inch Weather Bureau rain gages.

Comments

We began keeping records 2 May 1974, and the automated system has worked admirably through many major storms. The sensor is very responsive in opening the lid. Numerous observations have shown that the collector is usually open long before exposed surfaces are completely wet (unless subjected to sudden downpour). The time the collector remains open after precipitation is variable, but normally the lid closes within 30 minutes.

The pH meter and electrode are both sensitive and responsive. Observations have shown that the pH reading begins to drop rapidly (assuming an initial reading near pH 6.0) when the first trickle of rain enters the measurement chamber. With our 9-square-foot collector and sensitive pH system, we can measure the pH of rains so light that they are not detected by the recording rain gage.

The precipitation from some of the storms monitored has contained substantial amounts of particulate matter that tend to settle out in the collector and conducting system. What effect this has on the measurements obtained is not clear at this time. However, as a result of the collection of particulate matter in the system, we feel it is desirable to periodically clean the collector and conducting system.

We also have found that the sensor and the precipitation detector require periodic cleaning with laboratory detergent and a brush (a soft toothbrush works very well). Need for cleaning is evidenced by the lid remaining open longer than usual.

This automated system for collecting precipitation samples and monitoring the pH of precipitation has produced reliable and reproducible results under test and use conditions. We are pleased with its performance and feel that it will give us a tremendous amount of useful data that can be utilized in conjunction with weather maps and other related data to provide us with information on how the acidity and chemical composition of precipitation varies with type, timing, duration, intensity, and movement of storms.

The most significant features of this system are its 24-hour-a-day automatic operation, which provides a continuous record of changes in precipitation pH (and conductivity) and its sensitivity, which allows us to monitor the pH of rains so light that they are not recorded on standard rain gages.

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1976

Northeastern Forest Experiment Station

FOREST SERVICE, U.S. DEPT. OF AGRICULTURE, 6816 MARKET STREET, UPPER DARBY, PA. 19082

ACCURACY OF BAND DENDROMETERS

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Abstract.—A study to determine the reliability of first-year growth measurements obtained from aluminum band dendrometers showed that growth was underestimated for black cherry trees growing less than 0.5 inch in diameter or accumulating less than 0.080 square foot of basal area. Prediction equations to correct for these errors are given.

Band dendrometers are often used to monitor changes in diameter growth of trees where accurate measurements of increment are desired. The bands provide an economical, convenient, and accurate method for measuring growth response to cultural treatments over short periods, as well as for making precise measurements over longer periods of one or more growing seasons. Since their introduction by Liming *(1957)*, their use has become common in much forestry research.

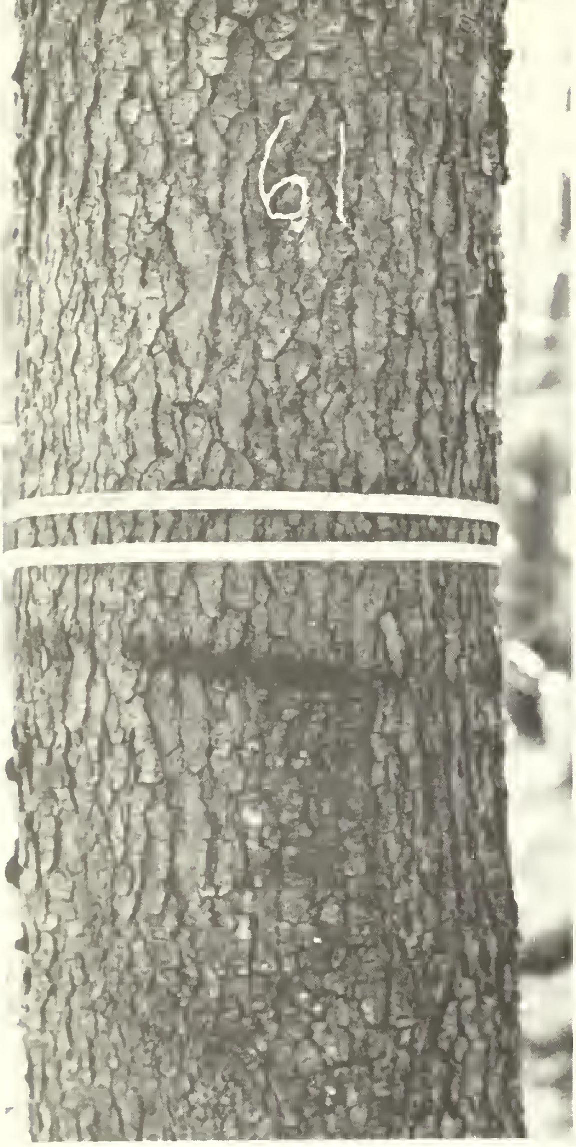
Although band dendrometers are perhaps the most accurate of the common devices for measuring diameter growth rates, newly installed bands tend to underestimate growth during their first season of operation because of slack that cannot be completely eliminated from the band during installation. Correction is needed to provide valid comparisons between growth accumulation in the first year and that of following years.

Because band dendrometers are used extensively in our research, a study was done with black cherry (*Prunus serotina* Ehrh.) to determine the amount of first-year radial growth that was being underestimated, and to see if true growth rates could be predicted by using easily measured variables such as tree size or indicated growth rate. With this information, adjustments to first-year growth data could then be made, allowing more accurate comparisons of growth obtained in the first year with that obtained in future years.

Methods

The study area was located in a fully stocked unthinned stand on the Allegheny Plateau in northwestern Pennsylvania. Thirty-three 60-year-old dominant or codominant black cherry trees were fitted with dendrometer bands at breast height in the spring of

Figure 1.—Paired dendrometers were installed at 4.5 feet above ground on 33 black cherry trees.



1972. The trees were first scraped to remove loose bark, then the bands were fitted over the smoothed bark as tightly as possible. After the fitting, initial diameters were measured with a diameter tape to the closest 0.01 inch. Diameters of the sample trees ranged from 9 to 15 inches; and annual diameter increments at breast height (determined later) ranged between 0.03 and 0.41 inch (basal-area equivalent of 0.003 to 0.080 square foot).

In the spring of 1973, before start of the growing season, each sample tree was equipped with a second dendrometer band. All new bands were installed in exactly the same way as the originals (except that the bark was not re-scraped), by the same person, 1-inch below the existing bands (fig. 1). Diameter-growth readings were obtained from both the original and the new bands following the 1973 and 1974 growing seasons. Readings from the original bands were considered to represent true diameter growth rates for 1973 and 1974. Diameter and basal-area growth adjustment equations were developed, using data from the 1973 growing season. The 1974 growth data were used to verify that band readings obtained after one season of operation were similar for each pair of dendrometers.

Results and Discussion

The degree to which dendrometers underestimated true first-year diameter and basal-area growth varied directly with the growth registered by the dendrometers and with tree size (table 1). Predictions of true growth

Table 1.—*Relationship of true growth rate with initial tree size and first-year growth indicated by band dendrometers*

Dependent variable	Independent variable	r^2	Correlation between independent variables (r^2)
1. True basal-area growth	Initial basal area	0.79	0.76
2. True basal-area growth	Indicated basal-area growth	.99	
3. True diameter growth	Initial diameter	.63	.61
4. True diameter growth	Indicated diameter growth	.99	

rates can be made from either the growth reading indicated by the band or from the initial size of the tree. However, indicated growth provides superior estimates for both diameter and basal-area growth.

Multiple regressions, using indicated growth and initial tree size to predict true diameter and basal-area growth rates, did not improve the amount of explained variation nor the standard error of estimate from equations using only indicated dendrometer growth. For this reason, and also because of the strong correlation between these independent variables (table 1), prediction equations for estimating true growth rates were developed by using only the indicated dendrometer growth.

Figures 2 and 3 show that, to adjust indicated to true growth, larger corrections are necessary for slow-growing trees than for fast-growing trees. Growth on trees indicating accumulation of only 0.001 square foot of basal area was underestimated by 69 percent. Underestimates at the indicated mean growth rate (0.022 square foot) of the sample trees amounted to 11 percent, and no correction was necessary for the faster growers that accumulated 0.080 square foot.

Diameter-growth discrepancies were similar in size to those for basal area. Underestimates amounted to 52 percent for trees indicating only 0.01 inch of diameter, 11 percent at the sample mean (0.15 inches); and no correction was necessary for trees growing 0.50 inch per year. Growth registered by each pair of dendrometers in the second season was identical, indicating that discrepancies are limited to the first season as long as enough growth accumulates to take up the slack in the dendrometer band.

These equations (fig. 2 and 3) may be used to correct first-season growth discrepancies associated with band dendrometers. They can also be used to correct readings from bands that may require replacement throughout the course of a study. However, caution should be used in making adjustments for trees having growth rates and diameters not within the range of our data (0.02 to 0.41 inch and 9 to 15 inches, respectively). Care must also be taken to insure that bands are initially

Figure 2.—Relationship between true diameter growth and first-year growth as indicated by band dendrometers.

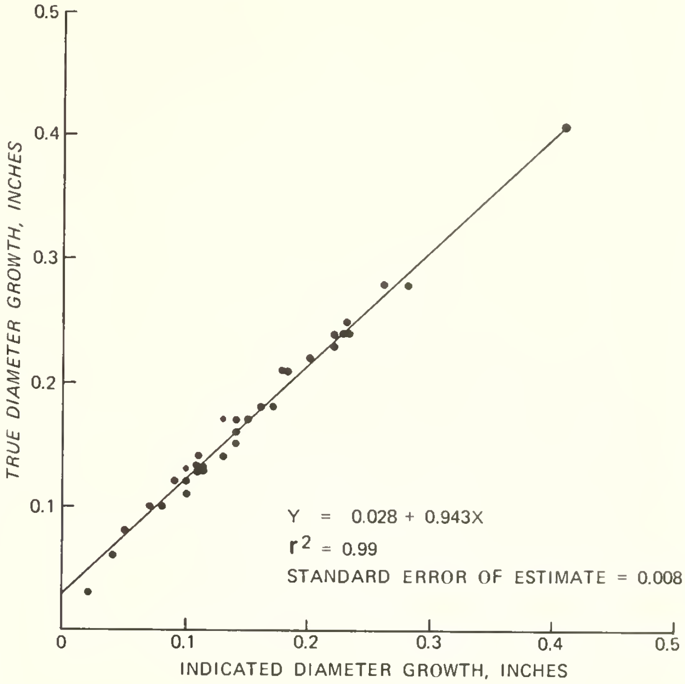
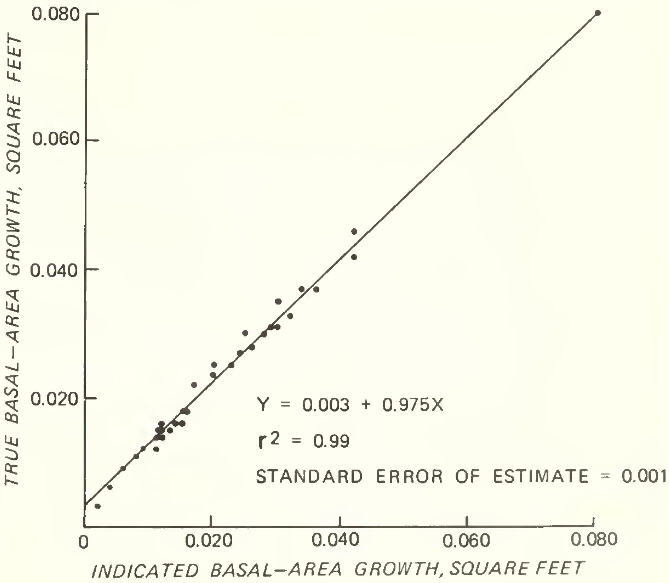


Figure 3.—Relationship between true basal-area growth and first year growth as indicated by band dendrometers.



installed as tightly as possible, or these equations may underestimate the corrections needed.

The equations show that adjustments for trees that have growth rates exceeding 0.5 inch in diameter and 0.080 square foot of basal area are unnecessary. As these growth rates are approached, the amount of band slack becomes negligible relative to the length of band taken up by circumference growth. Also, for very slow-growing trees, adjustment should be made only for those individuals that register a measurable amount of increment. This is essential to avoid overcorrection and the possibility of obtaining negative growth in following seasons.

In an effort to simplify the models, both equations were tested to determine if their slopes were significantly different from one. The regression slope was different from one for the diameter-growth equation, but not for the basal-area equation. This means that the equation (fig. 2) should be used to compute true diameter growth; but in lieu of using the basal-area equation, a constant correction factor of 0.003 square foot may be applied to basal-area computations without introduction of serious errors.

Although black cherry was the only species used in this test, it seems likely that results could be applied to certain other species as well. However, in this we assume that bark characteristics different from those of black cherry would not greatly affect the amount of slack remaining in the band after its installation. Because the bark on all trees in this test was scraped smooth, the equations should be applicable to those species having smooth bark to begin with and also to those that can be scraped to produce a uniform smooth surface.

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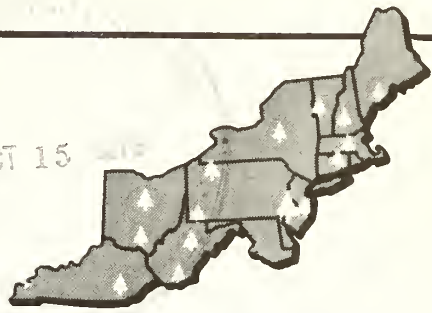

FOREST SERVICE, U.S. DEPT. OF AGRICULTURE, 6816 MARKET STREET, UPPER DARBY, PA. 19082

STUB—A MANUFACTURING SYSTEM FOR PRODUCING ROUGH DIMENSION CUTTINGS FROM LOW-GRADE LUMBER

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Abstract.—A rough mill manufacturing system for producing high-value furniture parts from low-value raw material is described. Called STUB (*S*hort *T*emporarily *U*pgraded *B*oards), the system is designed to convert low-grade hardwood lumber into rough dimension parts. Computer simulation trials showed that more than one-third of the volume of parts produced from No. 2 Common oak lumber is recoverable in 40-inch long or longer cuttings. A pilot line of the STUB system is being established to evaluate operator and equipment efficiency, production rates, and cutting yields from other species of lumber.

The quantity of low-grade hardwood lumber produced by sawmills in the Appalachian Region is increasing, and the trend is expected to continue during the next decade. With improved secondary manufacturing techniques, high-valued furniture parts can be produced from this low-value raw material.

At the Forest Products Marketing Laboratory, we are developing a system we call STUB (*S*hort *T*emporarily *U*pgraded *B*oards). STUB is designed specifically for converting low-grade hardwood lumber into rough dimension parts and will produce as much as one-third of the total yield in the longer (40 inches and longer) and more desirable furniture cuttings.

Low-grade lumber is generally defined by the industry to mean any lumber below No. 1 Common. Of the lower grades, No. 2 Common lumber has the best potential for expanded use in the manufacture of furniture. More than one-fourth of the graded hardwood lumber produced in the sawmills of the Appalachian Region is graded No. 2 Common.

In the manufacture of furniture, No. 2 Common lumber is used primarily for the shorter length clear-one-face (CIF) cuttings and for interior parts. Seldom is No. 2 Common used to produce 40-inch or longer CIF parts. And it is these longer and more valuable cuttings that are needed by the production manager. To get these long cuttings, he has traditionally processed the higher and more expensive grades of lumber.

The production manager strives to produce a given quantity and quality of furniture at the least cost. The first temptation in many industries today is to lower production costs by automating, which is less labor-intensive. The furniture industry cannot afford to indiscriminately go about automating. In doing so, there is a danger that the significance of the bigger costs represented by the raw material itself will be undervalued or lost.

Some furniture rough mills are moving away from evaluating performance of the rough mill on a percent-yield basis and are evaluating performance on a cost-per-part basis. Thus they are concerned with the yield of parts produced from the lumber as well as the costs associated with the lumber and its manufacture into parts.

STUB can make a great contribution toward reducing total costs by concentrating on the bigger cost item—the raw material. The STUB concept is aimed at reducing manufacturing costs by increasing the yield and utility of the lumber processed for furniture.

Conventional Rough Mill

The rough mill in a furniture plant is where lumber is processed into rough dimension parts. Input to the rough mill is standard graded hardwood lumber, usually of random width and random length.

The first step is usually to crosscut the board to specified lengths. The cut-to-length board sections are then rough-planed and sent to a ripsaw where random or specific-width parts are produced. The off-fall from the ripsaw, if the lengths permit, is then sent to a salvage station where it is crosscut back to a shorter length, thus salvaging some of the residue produced at the ripsaw.

The conventional rough mill is too often inefficient because boards are processed on line to completion. For example, if a board comes through the line with a 60-inch clear length and the longest cutting needed at that particular time is 36 inches, then that 60-inch long section is cut to a 36-inch length, and the remainder is cut to a shorter secondary cutting. In effect, a 60-inch long cutting is wasted.

The crosscut operation is the key work station, and the memory and judgment of the crosscut operator are critical. It is not unusual for a cutting order to contain as many as 40 different cutting lengths. A crosscut operator cannot work efficiently with such a large number of lengths. To make such an order manageable, it is divided into operating cutting bills of 4 to 5 lengths, and it is these cutting bills that the crosscut operator uses. Thus the selection of cutting lengths and the skill of the crosscut operator are significant factors in determining yield recovery.

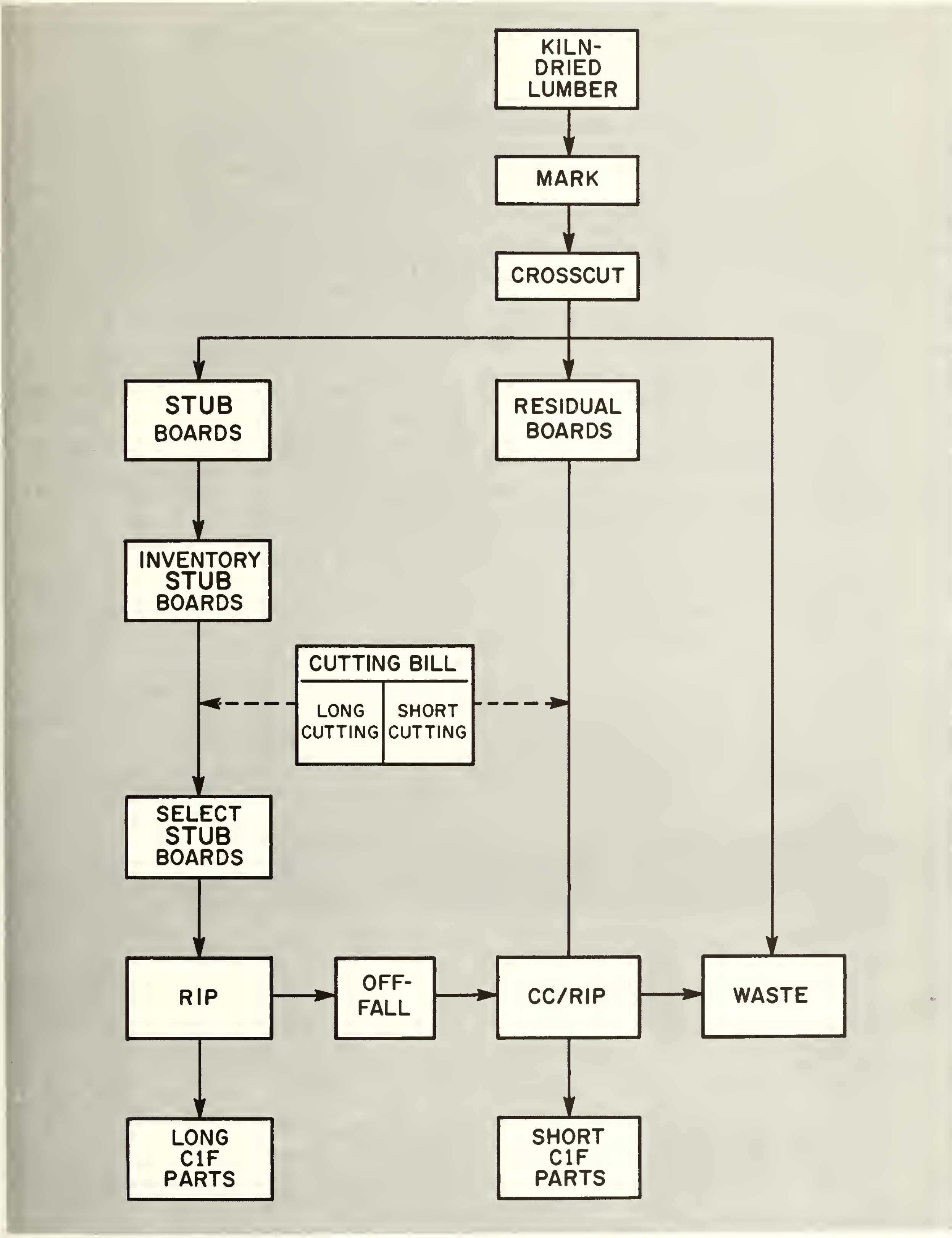
It is not the yield of long cuttings that restricts the use of No. 2 Common lumber. Rather it is the combination of processing a board on line to completion and the physical limitations at the crosscut station that limit the usefulness of No. 2 Common lumber. Our work shows that more than one-third of the volume of No. 2 Common oak lumber can be recovered in cuttings that are 40 inches long and longer *(Lucas 1973)*. To achieve in-plant yields approximating our results requires a different approach to the processing of lumber into furniture parts.

The STUB System Rough Mill

In the STUB system, we start by crosscutting long boards into short boards. But here the similarity between the STUB rough mill and the conventional rough mill ends. Instead of producing cut-to-length dimension, the crosscut operator produces three random length products: STUB boards, residual boards, and waste (fig. 1). STUB boards differ from standard hardwood lumber boards in that each STUB board has at least one CIF cutting of *a specified minimum width* that runs its full length.

Just as the crosscut operator is the key to the yield of parts in a conventional rough mill, the crosscut operator is likewise the key to success in a STUB rough mill. However, the

Figure 1.—Flow diagram of the STUB rough mill line.



STUB crosscut operator's job is not nearly as complex. In the STUB system, instead of giving the crosscut operator a list ot specific cutting lengths, we give him a set of three STUBBING rules:

1. The minimum width of the STUB clear area.
2. The minimum length of the STUB board.
3. The maximum length of the STUB board.

Let's see how a crosscut operator in a STUB rough mill would process a board—in this case a board 12 inches wide and 12 feet long (fig. 2). In this example, the STUBBING rules in effect are:

1. Minimum width of clear area = 3 inches.
2. Minimum length of STUB board = 36 inches.
3. Maximum length of STUB board = 60 inches.

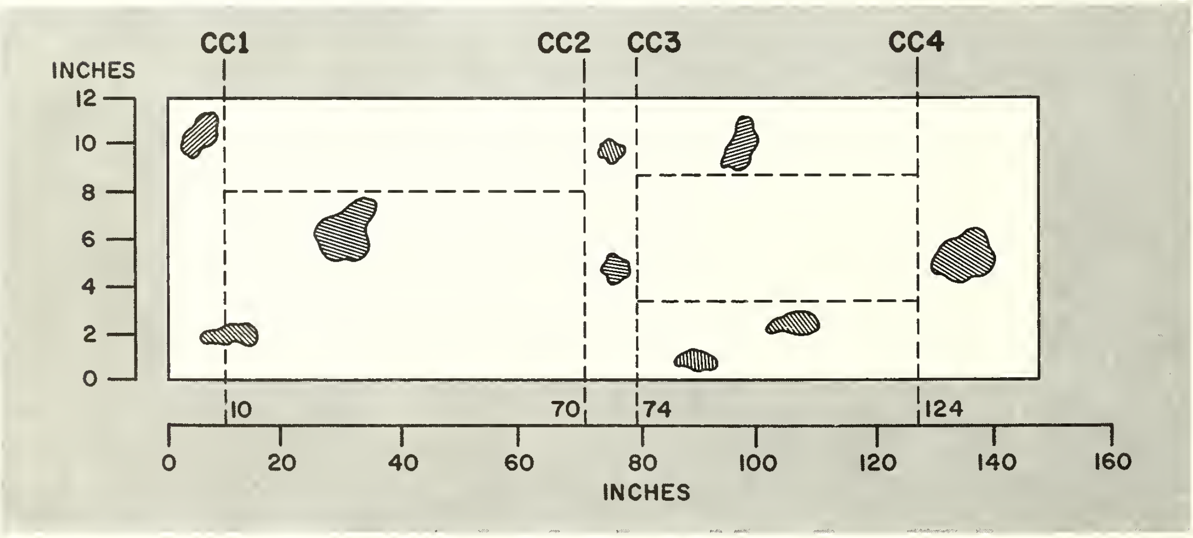
The operator starts scanning the board from left to right, looking for the first section of the board that meets the minimum requirements. When the first area that meets the minimum requirements is found, the operator marks the beginning of this area (cc 1, fig. 2) and continues to scan down the length of the board until he finds a defect or until he reaches the maximum STUB board length requirement, where he will again mark the board for crosscutting (cc 2, fig. 2).

The operator, having marked out one STUB board, now treats the remaining portion of the board as if it were a new board and again repeats the process of looking for another section of the board that meets the minimum requirements. Starting at the end of the STUB board (cc 2, fig. 2), he continues to scan along the remaining portion of the board and marks the board at the points where the next crosscuts are to be made (cc 3 and 4, fig. 2). The operator continues this scanning and marking process until the entire board has been viewed.

Since the crosscut operator has no specific cutting lengths to be concerned about, he need only develop a mental image of the width and length of the minimum clear area. Our trial runs of the STUB system show that the operator can quickly develop this mental image and consistently and quickly apply it for marking actual boards.

The crosscut operation in a STUB system consists of a marking station and an automatic mark-sensing crosscut saw. The crosscut operator is positioned at the marking station, where he scans the board and marks the board

Figure 2.—Marking a board for processing in a STUB rough mill. The board is scanned from left to right, and marks for crosscutting are made at points CC1, CC2, CC3, and CC4. From left to right, this produces 10 inches of waste, a 60-inch STUB board, 9 inches of waste, a 45-inch STUB board, and a 20-inch residual board.



with a conducting type of electrolytic solution at the places where he wants the board to be crosscut.

At the marking station, screens are used so that the operator sees only a portion of the board—not the entire length. The distance between screens corresponds to the maximum allowable length of the STUB board. These screens allow the operator to give his full attention to only that portion of the board he is currently inspecting.

Once a board has been marked, it moves past the marking station to a mark-sensing saw where it is automatically cut to length.

Application of the STUB System

We envision a STUB rough mill operating with standard graded hardwood lumber as input. The lumber will pass through the marking station and to a mark-sensing saw where it will be crosscut, producing random-length STUB boards and residual boards.

The STUB boards will then be inventoried by length classes—perhaps 2- to 4-inch classes. The rough mill foreman will draw from the STUB board inventory to satisfy his long-length cutting requirements, matching the STUB boards with the specific cutting lengths.

The selected STUB boards will then be sent to the ripsaw, where the full length cuttings will be ripped out. Since the ripsaw operator is concerned only about recovering the full-length cuttings (he knows there is at least one full-length cutting in each STUB board), he should be able to perform more efficiently and consistently.

The processing of the residual boards—a salvage operation—will be one line and will operate much the same as in existing rough mills; that is, specific part lengths will be cut directly.

We have developed a computer program (program STUB) to match the scanning and marking logic described. From the board-defect data bank developed at the Forest Products Marketing Laboratory *(Lucas and Catron 1973)*, the data for 100 randomly selected boards were processed through the program to determine the yield of CIF parts obtainable by using 10 different sets of STUBBING rules. The total yield of parts for the 10 different rules ranged between 56 and 65 percent, and the yield of long CIF parts (40 inches and longer) averaged 36 percent of the total yield.

These preliminary tests of the system have also shown that, by changing the STUBBING rules, you can change the size distribution of the CIF parts produced. This allows individual furniture plants to select the STUBBING rules that best fit their part size requirements.

We are now establishing a pilot STUB line at our Methods Testing Plant. We will use the pilot line to:

1. Evaluate operator and equipment efficiency and layout.
2. Develop yield data on other lumber species and grades.
3. Determine size and methods of controlling the STUB board inventory.

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A TECHNIQUE FOR MARKING FIRST-STAGE LARVAE OF THE GYPSY MOTH FOR DISPERSAL STUDIES

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Abstract.—Zinc cadmium sulfide fluorescent particles can be used to mark first stage larvae of the gypsy moth, *Porthetria dispar* (L.), without effecting changes in their development and behavior. Marked larvae dispersed readily; so the technique could be used to correlate dispersed larvae with any particular source point.

Wind dispersal of newly-hatched larvae of the gypsy moth, *Porthetria dispar* (L.), is a major factor in the geographical spread of this pest. Although this means of distribution was noted in the early 1900s, only recently have studies been initiated to identify the morphological and meteorological characteristics associated with airborne distribution of the tiny first-stage larva *(McManus 1973)*.

One of the problems associated with identifying the characteristics of the aerobiological pathways of dispersal was the lack of an adequate technique for correlating dispersed larvae with any particular point source. Development of such a technique requires an appropriate tagging or tracing element that will not adversely affect the relatively fragile insect and can be detected easily in the field.

Various physical, chemical, and radioactive techniques have been used to mark insects for use in release-recapture studies. Each requires a certain amount of handling of the study insect; most can be conveniently used with large sturdy species. Because fluorescent powders have been used successfully with a variety of insects *(Turner and Gerhardt 1965, Vail and others 1966, Medley and Ahrens 1968, Bennett and Smith 1968, Holbrooks and others 1970)* and are readily available, they were tested for tagging gypsy moth larvae.

Zinc cadmium sulfide fluorescent particles (FP) are readily distinguishable from almost all naturally-occurring particulates by their color, size, and intensity *(Himel and Moore 1967)*. The fluorescent properties of FP are physically stable under exposure to sunlight, and the particles are insoluble in water. Also, FP characteristically clings to hairs and setae, a definite advantage for this particular problem.

In the spring of 1973, studies were begun to determine: (1) the effect of FP on the development and behavior of the first-stage larvae; (2) if the marked insects would readily disperse; and (3) if identification of the marked larvae could be made at subsequent recapture intervals.

Methods and Materials

Samples of yellow and green fluorescent particle tracer material, each with a mean particle size of 3.5 microns, were obtained from Metronics Associates, Inc., Palo Alto CA. (Mention of brand-name materials should not be construed as endorsement by the U.S. Department of Agriculture or the Forest Service.)

Gypsy moth egg masses were collected near Easton CT in November 1972 and held at 2 to 3°C until April 1973. The eggs were then cleaned of hair and placed in Saran screen packets. Eggs and larvae were maintained in a Sherer-Gillett Mobile Greenhouse at 26°-27°C and 16:8 LD photoperiod. All laboratory bioassays were conducted under the same conditions. Larvae were reared on a diet described by ODell and Rollinson *(1967)*.

To determine FP effect on egg hatch, three packets of eggs were brushed with FP and three packets were left untreated. Recently emerged first-stage larvae were individually marked by flicking a small amount of fluorescent powder on the dorsal surface of the abdomen. All larvae were checked with a short-wave ultra-violet lamp to ensure that they were satisfactorily marked. In some cases FP was easily identified without the lamp.

Twenty-five marked larvae were placed in each of ten 15 x 100-mm plastic petri dishes, and diet was provided. The dishes were sealed with masking tape and placed in the environmental chamber. Similarly, 226 unmarked larvae were set up in nine plastic petri dishes. Larvae were inspected every 48 hours for the next 8 days.

On 30 May 1973, as part of an investigation of the meteorological parameters affecting dispersal of the gypsy moth, field tests were held at the Saltonstall Experimental Area in Branford CT. A mass of about 180,000 newly emerged gypsy moth larvae were dusted with yellow FP and allowed to disperse from a box attached about 20 feet up in the lower crown of an American elm *(vonLindern 1973)*. Butcher's paper streaked with Tac-Trap was laid on the ground, starting at the crown drop line and running downwind for 350 feet. The trap paper was inspected every 2 hours for larvae stuck in the Tac-Trap. Larvae crawling free on the paper, between the sticky streaked areas, were collected on masking tape. Counts and collections were made five times on each of 2 days. The larvae collected on masking tape were examined under the ultra-violet lamp for FP.

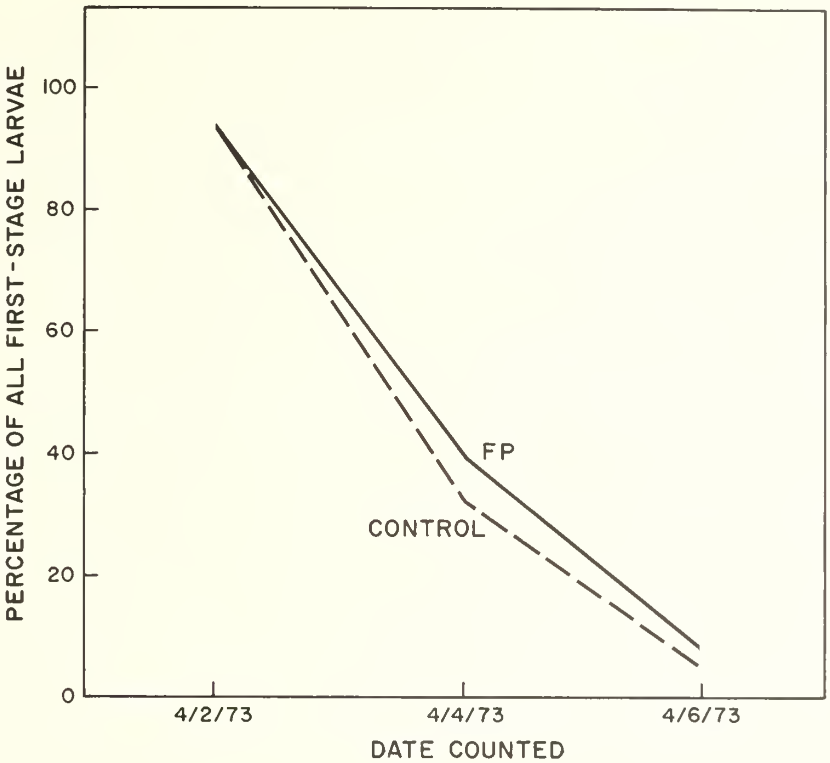
Results

Egg hatch, development and, behavior. — The first hatch of larvae was observed on the sixth day after treatment on both treated and control replicates. Daily emergence counts and total emergence were similar for all packets. Development (molting) and

Table 1.—The effect of treatment with fluorescent particles on the development and survival of gypsy moth larvae

Date	Number of larvae in instar—						Mortality	
	I		II		III			
	FP	C	FP	C	FP	C	FP	C
3/29/73	250	226	0	0	0	0	0	0
3/31/73	250	226	0	0	0	0	0	0
4/2/73	238	215	3	5	0	0	9	6
4/4/73	93	72	146	147	0	0	2	1
4/6/73	17	10	165	160	31	25	26	24

Figure 1.—First-stage larvae counted in each 48-hour period, expressed as a percentage of the total number of larvae.



mortality were recorded and summarized (table 1 and fig. 1). There was no observable difference in molting time or behavior. Survival of FP-treated larvae was 85.2 percent compared to 86.3 percent survival of controls. FP was picked up easily on cast skins with the black light. This may be useful for monitoring dispersal after first-stage larvae have settled and molted.

Field test. — We were interested only in whether or not marked larvae could be picked up at all distances monitored in the test; that is, if dispersal was affected by the marking procedure, and if the marked larvae could be identified easily. Approximately 30 percent of all larvae collected were marked. The ratio of marked to unmarked larvae was about the same in each 100-foot section of the paper.

The ratio of marked to unmarked larvae was influenced by several factors, which may be important in future use of fluorescent particles: (1) the collected larvae were not examined under the microscope, and to see the smaller FP, magnification is required; (2) many larvae in the middle and at the bottom of the large dispersing mass were probably not marked; (3) the resident gypsy moth population was dispersing on both release days.

Table 2.—Number of larvae collected on masking tape during 48-hour dispersal period and examined for presence of FP

Collection	Day 1		Day 2	
	FP	No FP	FP	No FP
1	11	20	0	24
2	18	48	0	17
3	24	45	8	32
4	33	64	28	48
5	27	53	61	142
Total	113	230	97	263
Percent	33	67	27	73

Conclusion

The results indicate that fluorescent particles can be used to mark first-stage gypsy moth larvae without effecting changes in development and dispersal behavior and thus could be used for identifying point sources of dispersing gypsy moth populations.

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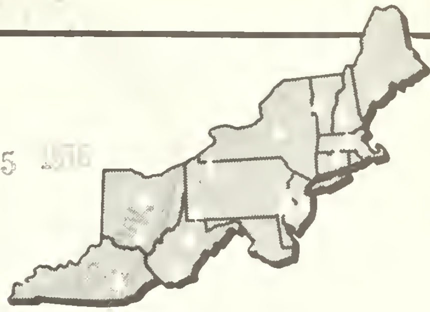

FOREST SERVICE, U.S. DEPT. OF AGRICULTURE, 6816 MARKET STREET, UPPER DARBY, PA. 19082

SIX-YEAR RESULTS OF A WHITE PINE SEED-SOURCE TEST IN WEST VIRGINIA

by G. W. WENDEL and FRANKLIN CECH*

Abstract:—The best white pine growth during a 6-year period in a West Virginia outplanting was obtained with seedlings grown from seed collected in Tennessee, Georgia, and North Carolina. These seed sources are recommended for plantings in West Virginia.

Early results of the USDA Forest Service rangewide white pine provenance study showed that trees from southern Appalachian seed sources grew extremely well as far north as southern Pennsylvania and lower Michigan and throughout the Ohio Valley in Indiana, Illinois, and Ohio *(King and Nienstadt 1968; Funk 1971; Garrett and others 1973; Funk and others 1975)*.

To determine which areas in the southern Appalachians produced white pine *(Pinus strobus* L.*)* seed best adapted to Michigan, Jonathan Wright of Michigan State University obtained seed from 200 southern Appalachian white pine stands in 1965. Seeds from 63 of these stands were made available to the Northeastern Forest Experiment Station and to West Virginia University for an outplanting in West Virginia. In addition, seeds from 35 other West Virginia sources were included in the study. In most cases cones were collected from individual trees in the stands, and the mother-tree identity was maintained in the nursery and field outplanting.

This is a report on the 6-year performance of seedlings grown from the 98 seedlots that were outplanted in West Virginia.

The Study

The study area is an 11-acre, steep, cutover, south-facing slope on the Fernow Experimental Forest near Parsons, West Virginia. Oak site index for the area is 65.

Preplanting site preparation consisted of basal spraying all hardwood trees with 2,4,5-T before felling, to reduce stump sprouting. The sawlogs and pulpwood were removed from the

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area, and all the trees smaller than 5 inches dbh were felled.

The area was divided into seven 1-acre square blocks. By careful layout, the variation in site conditions within a block was kept small. Blocks were separated by unplanted areas 30 to 65 feet wide.

Seedlings, grown in the Clements State Tree Nursery near Point Pleasant, West Virginia, were 2 years old when outplanted in the spring of 1968.

In each block a seedlot was represented by four trees planted 8 feet apart in a row perpendicular to the contour. Rows were also spaced 8 feet apart. The identities of the seedlots by parent trees were maintained in the nursery except for a few seedlots that were represented by composite samples of seed from several trees. Seedlot identity was also maintained in the outplanting.

A two-tree-wide border of undesignated seedlings was planted around the outside of each block.

In the second summer after outplanting (1969), each block was mistblown with 2,4,5-T at a concentration of 2.4 pounds acid per acre in a water-oil emulsion applied at a rate of 7 gallons per acre to reduce the dense cover of blackberries, greenbrier, and hardwood sprouts. A follow-up treatment was made in the summer of 1970 to cover areas missed or only lightly treated in 1969.

Survival was measured annually. Height measurements to the nearest 0.1-foot were recorded at the end of the second growing season and then annually through the sixth growing season. Data were analyzed by an analysis of variance.

Results

6-year survival.—Average survival for all blocks after six growing seasons was 84.2 percent. Eleven percent of the mortality was due to transplanting shock and 3 percent was due to the 2,4,5-T spray *(Wendel and Cech 1975)*. About 1 percent mortality was attributed to frost-heaving, browsing, "buck rub", and white pine root decline *(Verticicladiella procera)*.

6-year total height.—An analysis of variance over all blocks and seedlots showed a highly significant difference (1-percent level) among blocks and sources.

The data were grouped by stands, and an analysis of variance was computed for each stand that was represented by seedlings from more than one parent tree. In about half of the stands there was a significant difference in 6-year height between seedlings originating from different parents within a stand (table 1).

When the heights of seedlings from a given stand were combined, we found that the tallest trees originated from seed collected in Anderson County, Tennessee (table 1). These trees averaged 7.9 feet and were 22 percent taller than the mean height for all stands. However, the within-stand height difference was significant, which indicates that certain parents yielded better-growing progeny than others—a factor that must be considered when making seed collections from this stand.

In general, the seedlings grown from Georgia, North Carolina, and Tennessee seeds have performed better in our outplanting than those from collections in West Virginia.

An exception was that one bulked seedlot from Raleigh County, West Virginia (No. 64), averaged 6 percent taller than the mean of all progeny. Even so, it should be pointed out that there were progenies from some parent trees in these poor stands that were considerably taller than the average tree for all stands. In effect, grouping of the progenies from all parent trees within a stand has tended to mask the performance of progeny of individual parent trees in that stand.

Discussion

After 6 years, survival was good; and there were no differences in survival due to seed origin. Significant differences in survival among blocks can be attributed mostly to planting difficulties. Three percent of the mortality was due to herbicide damage. Mistblowing release treatments were very effective, and most of the trees were in a free-to-grow position at the end of 6 years.

In general, the overall vigor of the plantation is good. The seedlots from the southern

Table 1.—Mean 6-year total height of seedlings from southern Appalachian white pine seedlots

MSFG number[a]	County	Stand location Lat.	Stand location Long.	Average 6-year total height	Percent of mean height	Within stand Variance[b]
		° ′	° ′	*Feet*	*Pct.*	
3534-3541	Anderson TN	36 00 N	84 10 W	7.9	122	* (6)[c]
3487	Burke NC	35 52 N	81 46 W	7.7	119	—
3513-3521	Fannin GA	34 35 N	84 10 W	7.5	115	NS (8)
3545	Union GA	34 43 N	84 06 W	7.5	114	—
3495-3502	Polk TN	35 00 N	84 25 W	7.3	112	NS (6)
3551	Madison NC	35 50 N	82 40 W	7.3	111	—
3544	Fannin GA	34 44 N	84 09 W	7.1	110	—
3452	Graham NC	35 20 N	83 52 W	7.1	110	—
3503-3512	Monroe TN	35 20 N	84 10 W	7.1	108	** (10)
64	Raleigh WV	— — N	— — W	6.8	106	—
3439-3443	Henderson NC	35 00 N	82 50 W	6.9	106	NS (5)
3423	Caldwell NC	31 30 N	81 30 W	6.7	103	—
3449	Whitley KY	36 55 N	84 15 W	6.6	101	—
3420	Carter TN	36 20 N	82 04 W	6.4	98	—
3416-3417	Buncombe NC	35 30 N	82 30 W	6.4	98	NS (2)
3548	Rabun GA	34 54 N	83 30 W	6.3	97	—
67	Raleigh WV	— — N	— — W	6.3	97	—
3422	Burke NC	35 51 N	81 51 W	6.2	95	—
3552	Burke NC	35 51 N	81 30 W	6.1	95	—
3407	Montgomery VA	37 14 N	80 27 W	6.1	95	—
94-98	Braxton WV	38 45 N	80 30 W	6.1	95	** (5)
3570, 68-76	Wetzel WV	39 30 N	80 45 W	6.1	95	** (9)
81-86	Pocahontas WV	38 20 N	79 30 W	6.1	95	NS (6)
3554, 87-93	Pleasants WV	39 25 N	81 07 W	6.0	94	NS (8)
77-80	Greenbrier WV	38 00 N	80 14 W	5.8	91	NS (4)
3522-3531	Cherokee NC	35 10 N	84 10 W	5.8	91	** (6)
65	Greenbrier WV	— — N	— — W	5.6	88	—
66	Greenbrier WV	— — N	— — W	5.0	78	—
3470	Botetourt VA	37 31 N	79 37 W	4.9	75	—
3590	Pocahontas WV	38 20 N	79 53 W	4.7	73	—
3460, 3462, 3463	Greenbrier WV	37 58 N	80 08 W	4.6	72	* (3)
3453	Greenbrier WV	38 28 N	79 48 W	2.8	44	—

[a] Michigan State University Numbers. Seedlots 64 to 98 are West Virginia collections and do not have MSFG numbers.
[b] * = significant at 5-percent level; ** = significant at 1-percent level; NS = not significant.
[c] Numbers in parentheses indicate number of parent trees in the stand.

Appalachians—those from Tennessee, Georgia, and North Carolina—are growing at a much faster rate than the best of the local West Virginia sources after 6 years. The better growth of trees from these seedlots was evident after the first year and is still evident after 6 years.

The data from this trial and earlier trials *(Garrett and others 1973; Funk and others 1975)* showed that seedlings from Tennessee, Georgia, and North Carolina sources were the best performers in Iowa, Illinois, Indiana, Kentucky, and West Virginia. However, generalizations can be risky, and it would be best to specify stand and parent tree to obtain the best seed because in some cases the progenies from one parent tree in a stand might grow better than the progenies from other trees. For example, in 6 of the 13 stands represented in this study, there was a significant difference in 6-year seedling height among parent trees within a stand.

The plantation in this study is located on a fair site (site index 65 for oak) whereas the West Virginia plantation in the study reported on by Garrett and others *(1973)* is on a good river bottom site; yet the more southern Appalachian sources rank high in both situations.

As a general rule we recommend that seedlings grown from Tennessee, Georgia, and North Carolina seedlots be used for plantings in West Virginia. The generally better juvenile growth of progenies from these areas would be advantageous in competing with other vegetation, particularly on cutover sites where rapidly growing hardwood sprouts often are a problem.

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COMPATIBILITY OF OHIO TRAIL USERS

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Abstract.—Compatibility indexes show how Ohio trail users feel about meeting each other on the trail. All four of the major types of trail users—hikers, horseback riders, bicycle riders, and motorcycle riders—enjoy meeting their own kind. But they also feel antagonism toward the faster, more mechanized trail users; e.g., everyone likes hikers, but few like motorcycle riders. Separating the average indexes into their components gives important information for trail planners, builders, and managers attempting to optimize the enjoyment of trails.

KEYWORDS: Recreation, hiking, horseback riding, bicycle riding, motorcycle riding.

Introduction

The trails in Ohio traverse all sections of the state. They extend from urban areas through open farmland, rolling hills, and strip mines, and into the foothills of the Appalachian Mountains. Some of these trails are routed along canals and abandoned railroads. Others lead to pockets of geological formations. Trails in and near metropolitan areas get heavy use from spring through fall. More remote trails are used heavily only during a few peak times—holiday weekends and the fall foliage change. Ohio's trails are highly accessible—few go for more than 3 miles without crossing a road.

People use these trails for many reasons—to go somewhere, to experience nature without being disturbed, to do things with their friends, to be alone. Many times the trails suit the individual user's objectives. But not always. To some trail users, part of the enjoyment of being on a trail is seeing and meeting other people, but to others the very thought of meeting other trail users is revolting. Consequently there can be conflict between trail users.

The conflict between trail users is of major concern to trail planners, builders, and managers. Just what are the needs of trail users? Are these needs compatible? If we are to optimize users' enjoyment of trails with limited land and dollar resources, we must know more about trail-user compatibility.

We developed compatibility indexes to measure how the four major types of trail users—hikers, horseback riders, bicycle riders, and motorcycle riders—feel about encountering each other on a trail. This information may help trail planners, builders, and managers to provide trails for everyone.

Approach

The 3,350 miles of trails mapped by the Ohio Departmet of Natural Resources were separated into categories based on their primary use: 50 miles of motorcycle trails; 500 miles of bicycle trails; 800 miles of horseback riding trails; and 2,000 miles of hiking trails. Trails in each category were divided into 5-mile segments. A stratified random sample of trail segments were selected for study. This insured a broad geographic representation of trails and trail users. All motorcycle trail segments were sampled, as were 15 percent of the bicycle trail segments, 10 percent of the horseback riding trail segments, and 6 percent of the hiking trail segments. In total, trail users were interviewed on 10 percent of the 3,350 miles of trails.

One interviewer conducted all the interviews in 56 days—40 weekdays, 6 weekend days, and 10 holiday weekend days—between June 1, 1974 and November 1, 1974. Most of the interviews were conducted between 10:00 A.M. and 5:00 P.M., but 15 percent of the time the interviewer stayed until dark. Only two bicycle riders refused to be interviewed.

The interviewer chose a convenient sampling location within each 5-mile trail segment, following, when possible, two guidelines: (1) locate at trail crossings, and (2) locate between trailheads and a natural or scenic attraction. All trail users 10 years old or older who passed the sampling location were interviewed.

The interviewer gave a brief explanation of the purpose of the study and a self-administered questionnaire that was returned on the spot.

Trail travel preference was determined by asking respondents how they preferred to travel on trails. Four categories of travel were listed: hiking, horseback, bicycle, and motorcycle. When more than one activity was checked, we assumed an equal preference for those checked:

Expressed trail use preference	*Number of respondents*
Hiking	252
Horseback riding	110
Bicycle riding	108
Motorcycle riding	29

Respondents were asked how desirable it would be for them to encounter other types of trail users on the trail. Five degrees of compatibility were suggested:

Expressed feelings about encounters	*Index value*
Very desirable	5
Desirable	4
Neutral	3
Undesirable	2
Very undesirable	1

Thus an average compatibility index (ACI) of 5.0 would indicate perfect compatibility; conversely an ACI of 1.0 would indicate absolute incompatibility.

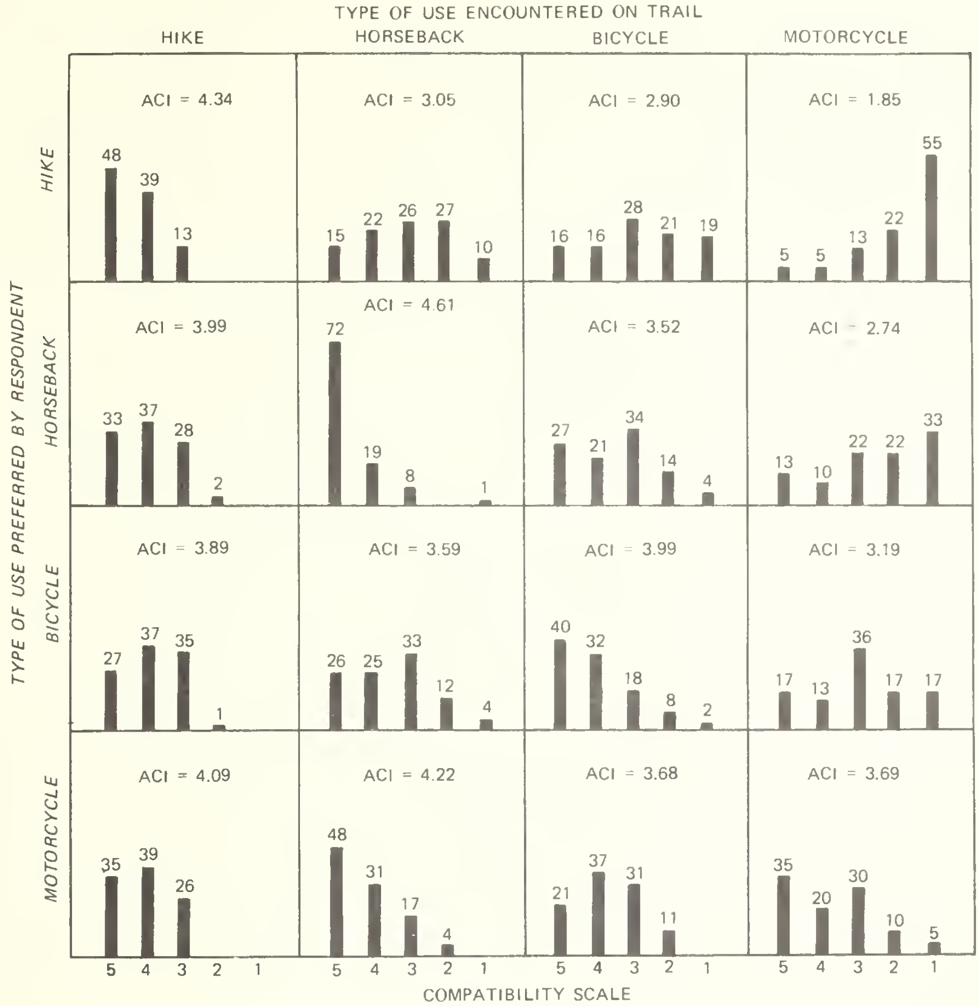
Results

Average compatibility indexes show how each type of user feels about meeting others (figure 1). For example, hikers do not like meeting motorcycle riders—ACI = 1.86, but motorcycle riders enjoy meeting hikers—ACI = 4.09.

The highest ACI's for three of the four trail-using groups were for encountering their own kind. That is, hikers like to meet hikers, horseback riders like to meet horseback riders, and bicycle riders like to meet bicycle riders.

When the ACI's are divided into their components, we get an even sharper picture of compatibility. For example, examine hikers' feelings about meeting bicycle riders. The ACI of 2.90 (figure 1) indicates that hikers,

Figure 1.—Attitudes of trail users toward meeting other trail users. Bars show percentage of respondents who chose each of five attitude descriptions, ranging from 5 (very desirable) to 1 (very undesirable), on the compatibility scale. ACI = Average Compatibility Index.



on the average, feel neutral about meeting bicycle riders. But the components of this ACI indicate that 40 percent of the hikers find them undesirable or very undesirable. However, 32 percent of the hikers enjoy meeting bicycle riders; they rate them desirable or very desirable. Only 28 percent of the hikers really feel neutral about bikers.

Generally speaking, hikers enjoy meeting other hikers; are about equally divided on meeting horseback riders and bicycle riders; and do not enjoy meeting motorcycle riders.

Horseback riders tend to enjoy meeting all other users except motorcycle riders. Some horseback riders indicated that strange or loud noises startle their horses; therefore, the riders dislike meeting motorcycles on the trail.

Bicycle riders seem to be tolerant of all other types of users. Most of the interviews with them were conducted along hard-surfaced roads because most of the designated bike trails in Ohio are on such roads. Many cyclists feel that if other trail users would use these same routes, car and truck traffic could be limited so that bicycle riding would be safer.

Motorcycle riders are the most tolerant of all trail users; 74 percent enjoy meeting hikers, 80 percent enjoy meeting horseback riders, 58 percent enjoy meeting bicycle riders, and 55 percent enjoy meeting other motorcycle riders.

Implications

Developing successful trails is a challenge, because no users are completely compatible and the compatibility is different between different types of users.

Three general conclusions of this research deserve mention:

(1) Most trail users enjoy meeting their own kind. This is shown by high average compatibility indexes—none was less than 3.69.

(2) The pattern of ACI's reflects antagonism among trail users toward faster and more mechanized types. Every group enjoys meeting hikers—ACI's range from 3.89 to 4.34. But hikers, in general, are not overjoyed about meeting any of the other types. Furthermore, horseback riders and bicyclists are not particularly fond of motorcycle riders. As a matter of fact, only other motorcyclists really enjoy meeting motorcyclists on the trail.

(3) Not all the members of one user group dislike any other user group. For example, a small percentage of hikers enjoy meeting motorcycle riders. The percentage of users who enjoy and do not enjoy meeting other types of users on the trail is revealed by separating the average compatibility indexes into their components.

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ODC [232.322.4+232.323.1+232.325.3] : 892.4

HYDROMULCH: A POTENTIAL USE FOR HARDWOOD BARK RESIDUE

by DAVID M. EMANUAL

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Abstract.—Hardwood bark fines and two hardwood bark fibers were compared with wood-cellulose fiber and paper fiber mulch to determine their effectiveness as hydromulches in revegetating disturbed soil. The results showed that either bark fines or bark fibers can be utilized as a hydromulch to aid in the revegetation of strip mines, highway construction sites, and similar earth-moving operations.

KEYWORDS: mulching, hardwood bark, revegetation.

In the Appalachians, most land disturbed by surface mining, highway construction, and similar earth-moving projects is mulched with hydroseeders. These machines apply a water-borne mixture of mulch, seed, and fertilizer in a single operation. The mulches used most often in hydroseeding (hydromulches) are either wood or paper fiber. Wood fiber is the most commonly used.

Research has shown that coarse hardwood bark residues perform effectively as mulch for revegetating severely disturbed soils. But commercial use of bark mulch has been limited by the lack of efficient application equipment. The machines commonly used for applying coarse mulches are incapable of spreading bark mulch over the long slopes common in the region. Consequently, we investigated the potential for using hardwood bark fibers as hydromulches.

The Study

Our objective was to compare three types of bark fibers—bark fines and two processed bark fibers—with other commercial hydromulches for establishing vegetation on severely disturbed soils.

Bark fines result from screening shredded hardwood bark to produce decorative bark mulches. The fines make up about 20 percent

Figure 1.—Hydroseeder applying seed, fertilizer, and bark fines.

of the total bark residue volume, and have limited commercial markets.

The two bark-fiber products were produced from raw bark from a sawmill debarker: Bark fiber A—raw bark was hammermilled and processed through a pressurized refining system. Bark fiber B—raw bark was hammermilled and processed through an attrition mill. Except for color, both bark-fiber products were physically similar to wood-fiber hydromulch.

Preliminary tests revealed that bark fines small enough to pass through a screen with 1/10-inch openings, and all bark fiber A and bark fiber B could be applied with a hydroseeder.

Procedure

In the spring of 1973, eighteen 1/20-acre plots were established on a regraded strip mine. All plots had a southeasterly aspect and the same percent of slope. Five mulch treatments were used: bark fines, bark fiber A, bark fiber B, wood fiber, and paper fiber. All mulches were applied at a rate equivalent to 1,500 pounds per acre at 20 percent moisture content. The treatments were replicated twice and applied randomly to the test plots. Three plots were left unmulched for controls.

All plots were fertilized with 100 pounds of ammonium nitrate and 100 pounds of 18-46-0 fertilizer per acre and seeded with 15 pounds of Kentucky 31 fescue (*Festuca*

Table 1.—Vegetative coverage of sample plots

Treatment	Vegetative coverage[1]		
	27 June 1973	26 October 1973	13 June 1974
Control	63 b	75 a	87 a
Wood fiber	58 b	83 a	92 a
Paper fiber	83 a	88 a	92 a
Hardwood bark fines	86 a	93 a	95 a
Hardwood bark fiber A	76 ab	89 a	89 a
Hardwood bark fiber B	67 ab	85 a	88 a
		(n.s.)	(n.s.)

[1]Any two means with different letters are significantly different at the 5-percent level; n.s. appears at the bottom of columns when means are not significantly different.

arundinacea), 6 pounds of redtop (*Agrostis alba*), 3 pounds of lovegrass (*Eragrostio curvula*), 13 pounds of perennial rye (*Lolium perenne*), 20 pounds of sericea lespedeza (*Lespedeza cuneata*), and 10 pounds of Japanese millet (*Echinochloa frumentacea*) per acre. Fertilizer, seed, and mulch were applied with a hydroseeder (fig. 1).

Ocular estimates of the percentage of vegetative cover on the plots were made 2 months after hydroseeding, at the end of the first growing season, and 14 months after hydroseeding (table 1). All estimates were made independently by three observers. For each inspection, the mean values of percentage of cover for the five treatments and the controls were analyzed by analysis of variance to determine differences among the treatments. Percentage-of-cover data for the treatments were then analyzed by Duncan's new multiple-range test to determine differences between the individual treatments.

Results

Two months after hydroseeding, the plots mulched with hardwood bark fines and paper fiber had significantly more vegetation than (1) plots mulched with wood fiber and (2) the unmulched control plots (table 1). There were no significant differences in percentage of vegetative cover among the plots mulched with hardwood bark fines, bark fiber A, bark fiber B, and paper fiber.

By the second and third inspections, the percentage of vegetative cover had increased on all plots, but there were no significant differences either among treatments or between treatments (table 1). All plots contained adequate vegetative cover.

Conclusions and Recommendations

Both bark fines and fiberized bark are as effective as commercial hydromulches for establishing and maintaining vegetation on severely disturbed soils. Either hardwood bark fines or fiberized bark can be applied successfully with a hydroseeder.

Bark fines should be screened to remove materials larger than 1/10-inch in diameter to prevent clogging the hydroseeder. Raw bark can be processed through a hammermill and attrition mill or fiberizer and used without screening. Bark fines are the cheapest form of bark hydromulch because they are the byproduct of hammermilling and require only screening before use.

Acknowledgments.—I thank the Plumly Lumber Company of Winchester, Va., Lester Lumber Company of Martinsville, Va., Hammer Lumber Company of Ronceverte, W. Va., and Bauer Brothers Company of Springfield, Ohio, for supplying the hardwood bark mulches used in this study. Our thanks go also to Ranger Fuel Corporation of Beckley W. Va., and Willco Reclamation Company of Summersville, W. Va., for supplying manpower, materials, and hydroseeders for the field tests. Mention of a commercial product does not imply endorsement by the Forest Service or the U. S. Department of Agriculture.

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A LOGGING RESIDUE "YIELD" TABLE FOR APPALACHIAN HARDWOODS

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Abstract.—An equation for predicting logging-residue volume per acre for Appalachian hardwoods was developed from data collected on 20 timber sales in national forests in West Virginia and Virginia. The independent variables of type-of-cut, products removed, basal area per acre, and stand age explained 95 percent of the variation in residue volume per acre. A "yield" table was then prepared to show probable residue volumes for four cutting practices, and various levels of basal area and stand age.

Keywords: Logging residue, slash, tables (data)

Today's forester manages forest land for a variety of multiple-use benefits. He is, therefore, concerned with many aspects of resource production that have only recently become public issues. Because of this new awareness, pressures have developed that now affect nearly every decision the forester makes.

One aspect now receiving greater attention is management to minimize logging residues. In the past, residue was called slash. When accumulations were judged excessive in streams, along roads, for regeneration, or as fire hazards, the slash was usually disposed of by mechanical or other means. Recently, however, the esthetic impact of slash has gained importance; disposal practices now considered wasteful or as sources of air pollution by many people have been sharply curtailed. Consequently, the forester must now consider alternatives that so far are rather poorly defined.

If the forester is to design timber-production activities that will minimize logging residues, he must be able to forecast the results of his actions before they are taken. He needs a reliable method for predicting the amount of logging residue for various cutting practices and under different stand conditions. The method should be simple and, if possible, based on information that is usually known before a harvest cut is made.

Such a method is now available for Appalachian hardwoods. Data collected for a recent study of logging residue in the Monongahela National Forest in West Virginia and the Jefferson National Forest in Virginia were used to develop a very simple prediction equation. The equation was then used to prepare a "yield" table that permits the forester to readily estimate logging-residue volumes for several harvesting alternatives and a range of stand conditions.

Methods and Procedures

Data were obtained from 20 harvest sites, 11 on the Monongahela National Forest and 9 on the Jefferson National Forest. On 4 of the sites improvement cuts were made; selection cuts were made on 4 sites; 5 were clearcut for removal of sawlogs only; and 7 were clearcut for removal of other products such as pulpwood and mine props, or sawlogs and other products. All of the sampled areas were logged in 1974 or earlier, and in the conventional manner—ground-skidding and hauling of roundwood to the mill. Logging-residue volumes in gross cubic feet per acre (with and without bark) were estimated by using the line-intersect technique for each area *(Bailey 1970, Martin 1975, 1976)*.

Only those residue pieces with a small-end diameter outside bark (dob) of 4.0 inches or more *and* a length of 4.0 feet or more were included in the sample. Our residue estimates include all down material from the current logging operation, plus all trees felled during postharvest timber-stand improvement (sale-area betterment with K-V funds). Standing trees (alive or dead) were not considered logging residue and were excluded. Although defect was not directly estimated, only pieces that were at least 50 percent sound were measured. Sweep, crook, or other defects that did not reduce the content of solid wood fiber were ignored in estimating soundness.

Additional information for each site was obtained from sale records maintained at the appropriate ranger district offices. The records included a description of the type of cut, the products and volumes removed, basal area per acre before harvest, stand age, and site index. These items were then used as independent variables in a multiple-regression analysis to determine their usefulness as predictors of logging-residue volume per acre (the dependent variable).

Predicting Residue Volumes

After a variety of models were examined, the following equation was selected as the best for predicting residue volumes because of its simplicity and good statistical qualities:

$$V = -302.36011 - 20.14233UA + 242.82202UB + 1781.67993UC + 3.02592BA + 3.40529A$$

$$(R^2 = .953;\ S_{y.x} = 212.2 \text{ cubic feet})$$

Where:

V = Gross logging-residue volume (including bark) in pieces 4.0 inches or more in diameter at the small end, and 4.0 feet or more in length (in cubic feet per acre)

UA-UC = Dummy variables that represent four types of harvest cut - utilization options:

	UA=	UB=	UC=
(1) Improvement cuts	1	0	0
(2) Selection cuts	0	1	0
(3) Clearcuts where only sawlogs are removed	0	0	1
(4) Clearcuts where other products or sawlogs and other products are removed	0	0	0

BA = Total stand basal area (square feet per acre)

A = Stand age (years)

This equation was then used to prepare the guidelines shown in table 1. To convert these figures to volume of wood only, simply deduct 18 percent (the average bark volume found in my study). Also, an approximate weight estimate can be obtained by multiplying the values by average weight per cubic foot. Conversion to board feet would not be too reliable since logging residues contain many small diameter pieces.

Thus, to forecast residue accumulations before logging activities begin, all that the forester needs is an estimate of basal area per acre and stand age, and a knowledge of how the harvest will be conducted. With this information he can consult table 1 and quickly estimate the probable residue volume when the harvest has been completed.

Discussion

The logging residue "yield" table should be considered only as a first step. Even though the statistical quality was high, the sample size was rather small. Therefore additional sampling

Table 1.—*Gross volume of logging residue (including bark)*[a] *expected for Appalachian hardwoods for various stand densities, ages, and harvesting practices*

Stand age (years)	Basal area per acre (sq. ft.)									
	50	60	70	80	90	100	110	120	130	140
	Cubic feet per acre									
	IMPROVEMENT CUT									
60	33	63	94	124	154	184	215	245	275	305
80	101	131	162	192	222	253	283	313	343	374
100	169	200	230	260	290	321	351	381	411	442
120	237	268	298	328	358	389	419	449	480	510
	SELECTION CUT									
60	296	326	357	387	417	447	478	508	538	568
80	364	394	425	455	485	515	546	576	606	637
100	432	463	493	523	553	584	614	644	674	705
120	500	531	561	591	621	652	682	712	742	773
	CLEARCUT (SAWLOGS ONLY)									
60	1,835	1,865	1,895	1,926	1,956	1,986	2,016	2,047	2,077	2,107
80	1,903	1,933	1,964	1,994	2,024	2,054	2,085	2,115	2,145	2,175
100	1,971	2,001	2,032	2,062	2,092	2,122	2,153	2,183	2,213	2,243
120	2,039	2,070	2,100	2,130	2,160	2,191	2,221	2,251	2,281	2,312
	CLEARCUT (OTHER)									
60	53	84	114	144	174	205	235	265	295	326
80	121	152	182	212	242	273	303	333	363	394
100	189	220	250	280	311	341	371	401	432	462
120	258	288	318	348	379	409	439	469	500	530

[a] Pieces 4.0 inches or more at small-end diameter, and 4.0 feet or more in length; at least 50 percent sound.

might improve precision and also detect real differences that the present sample has not shown.

For example, we may find a significant difference between cover types; with additional data from a greater range of sites, we may find that site index or volume removed per acre or both are useful predictors. Also, we may be able to expand the breakdown of cutting practices to include, for example, subdivisions of selection and improvement cuts by products removed.

Of course, being able to predict logging-residue volumes does not solve the problem of what to do with the material. However, these forecasts can be valuable in solving this problem when they are complemented with professional judgment and other information.

Since logging residues affect esthetics, regeneration, wildlife habitat, erosion, and on some sites, soil nutrients and fire fuel buildup, it is important to know the impact of different management systems and harvesting methods on residue accumulations. For example, if the forester can predict differences in residue volumes for even-age versus uneven-age management, or for sawlog removal versus whole- tree utilization, he will be in a better position to decide which system or harvesting method to use.

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FOREST SERVICE, U.S. DEPT. OF AGRICULTURE, 6816 MARKET STREET, UPPER DARBY, PA. 19082

OHIO TRAIL USERS

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Abstract.—Hikers, horseback riders, bicycle riders, and motorcycle riders were interviewed on randomly selected trails in Ohio to better understand who they are and why they use trails. Bicycle riders were found to be the most active trail users; bicycle and motorcycle riders were younger than hikers and horseback riders. The majority of hikers and horseback riders preferred single-use trails. People used trails for the enjoyment of nature.

Keywords: Recreation, trails, hiking, horseback riding, bicycle riding, motorcycle riding.

There is something about traveling along a forest trail that most people find relaxing. Maybe that is one reason why more people are visiting the woods—some for a few minutes and others for several weeks. The concern of land managers about understanding and satisfying this growing urge prompted me to survey Ohio trail users. The findings presented here will help trail planners, builders, and managers gain a better understanding of who trail users are and why they use trails.

Data for the study were collected by a single interviewer on randomly selected trails all over Ohio. All trail users 10 years of age or older who traveled past the interviewer from June 1, 1974, to November 1, 1974 were interviewed. A detailed description of the study method is in a report on the compatibility of trail users in Ohio (*McCay and Moeller 1976*).

Each respondent was asked how he preferred to travel on trails. Four categories of travel were listed: hiking, horseback, bicycle, and motorcycle. When more than one trail use was checked, we assumed an equal preference for those checked.

Expressed trail use preference	*Number of respondents*
Hiking	252
Horseback riding	110
Bicycle riding	108
Motorcycle riding	29

Results

The enjoyment one derives from using a trail depends on many factors. One is the people he travels with. Few trail users travel alone; some travel only with their families. The majority of horseback riders and bicycle riders interviewed traveled with friends in groups that averaged nine and three people, respectively.

Trail companions	*Hikers*	*Horseback riders*	*Bicycle riders*	*Motorcycle riders*
	.... (*percent*)			
None	10	6	18	10
Friends	45	73	58	45
Family	45	21	24	45
	100	100	100	100

The majority of hikers and horseback riders preferred single-use trails. Most bicycle and motorcycle riders preferred trails that are intended for more than one type of trail user.

Trail uses (no.)	*Hikers*	*Horseback riders*	*Bicycle riders*	*Motorcycle riders*
	.... (*percent*)			
One	69	54	36	17
Two	22	25	47	31
Three	8	18	14	42
Four	1	3	3	10
	100	100	100	100

Frequency of participation indicates the interest an individual or group has in using a trail. Bicycle riders were the most active trail users.

Use per year (days)	*Hikers*	*Horseback riders*	*Bicycle riders*	*Motorcycle riders*
	.... (*percent*)			
Less than 10	70	38	40	48
10 - 49	20	32	21	31
50 - 99	5	15	12	4
100 or more	5	15	27	17
	100	100	100	100

Four-fifths of the bicycle and motorcycle riders were under 30 years of age. Hikers and horseback riders were represented in all age classes.

Age (years)	*Hikers*	*Horseback riders*	*Bicycle riders*	*Motorcycle riders*
	.... (*percent*)			
17 or less	21	35	60	35
18 - 29	35	23	22	44
30 - 49	27	30	12	18
50 or more	17	12	6	3
	100	100	100	100

Disagreement between trail users and land managers over what type of users should use the trails may cause problems. My results indicate that hikers, more than any other group, agreed with managers.

Agree with managers	*Hikers*	*Horseback riders*	*Bicycle riders*	*Motorcycle riders*
	.... (*percent*)			
Yes	74	46	64	51
No	26	54	36	49
	100	100	100	100

Most of the trail users interviewed did not belong to a trail club. Horseback riders had the largest percentage of membership, but less than two-fifths of them were members of a trail club.

Trail club membership	*Hikers*	*Horseback riders*	*Bicycle riders*	*Motorcycle riders*
	.... (*percent*)			
Yes	10	36	13	21
No	90	64	87	79
	100	100	100	100

The more that trail planners, builders, and managers know about why people use trails, the more effectively they can satisfy the desires of trail users. The reasons that people gave for being on the trail did not differ significantly among the four types of trail users. The responses can be summarized by saying that people used trails for the enjoyment of nature. One fourth of the respondents were "just looking at the scenery". "Pleasure and enjoyment" was the reason given by another one-eighth of the people interviewed. Other notable reasons given were that trails were "convenient or close to home"; that users were "exploring or trying to learn more about nature"; the trail "was well signed"; and "the people we are with wanted to go on it".

Conclusions

The following findings about trail users in Ohio can be recommended for use by trail developers.

- Horseback riders travel in larger groups than other types of trail users.
- Hikers and horseback riders prefer single- use trails.
- Bicycle riders are the most active participants.
- Bicycle and motorcycle riders are younger than hikers and horseback riders.
- Hikers are more in agreement with managers concerning what type of users should use the trails.
- Most trail users do not belong to trail clubs.
- The main reason why people use trails is for the enjoyment of nature.

These findings, combined with other information on the requirements of trail users, terrain, and land-management objectives, will help planners and managers provide trails that are more meaningful to the people who use them.

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APPALACHIAN HARDWOOD STUMP SPROUTS ARE POTENTIAL SAWLOG CROP TREES

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Abstract.—A survey of 8- and 12-year-old hardwood stump sprouts was made in north-central West Virginia. Species surveyed were yellow-poplar, black cherry, red oak, red maple, and basswood. Of the stumps cut 12 years ago, 66 percent produced at least one dominant or codominant sprout that originated at groundline and was free from forks in the lower 25 feet of the bole. The abundance and quality of these stump sprouts indicated that many of them can be considered as potential sawlog crop trees.

Many foresters feel that hardwood stump sprouts do not produce good sawlog crop trees. Because little is known about the possibility of selecting young sprouts as crop trees, a survey was made to determine the relative quality of 8- and 12-year-old Appalachian hardwood stump sprouts in north-central West Virginia. Five hardwood species were sampled: yellow-poplar (*Liriodendron tulipifera* L.), black cherry (*Prunus serotina* Ehrh.), northern red oak (*Quercus rubra* L.), red maple (*Acer rubrum* L.), and basswood (*Tilia americana* L.).

Methods

Only sprouts originating from stumps at least 12 inches in diameter were sampled. A potential sawlog crop tree was defined as a dominant or codominant sprout attached to the stump not more than 6 inches above groundline. It is generally recognized that stem form—sweep and crook—is an important factor in determining stem quality. However, stem form was not considered in this study because it could not be measured accurately on 8- and 12-year-old sprouts; and many crooked young trees have the ability to outgrow poor stem form.

The following measurements were taken on each potential sawlog crop tree: dbh, total height, and clear length—that is, height to the first live branch, and height to any fork below 25 feet. A fork was defined as the branching of the main stem into two or more stems of approximately the same diameter. Also, number of live sprouts was recorded for each stump.

Stumps were examined on 8 areas; 6 of the areas had been clearcut 8 years ago and 2 had been clearcut 12 years ago. The average age of the stands before cutting was between 50 and 60 years. Site indexes for the study areas ranged from red oak indexes 70 to 80. A total of 736 stumps with live sprouts were examined: 164 yellow-poplar, 206 basswood, 186 red oak, 134 red maple, and 46 black cherry. The number of potential sawlog crop trees measured for each species was: yellow-poplar 250, basswood 520, red oak 294, red maple 244, and black cherry 111, a total of 1,419 sprouts.

Results

The survey data were summarized as follows: characteristics of stump sprouting (table 1) and characteristics of sprouts classified as potential sawlog crop trees (tables 2 and 3). The data were grouped by age of sprouts—8-year and 12-year. No attempt was made to compare the two age groups. Data were compared separately for each species.

8-year-old stumps.—Basswood had the greatest number of live stems per stump—16.8—and yellow-poplar the least—5.0 (table 1). Basswood also had the greatest number of potential crop trees per stump, averaging 2.5 stems. Red maple had an average of 1.9 potential crop trees per stump; yellow-poplar had 1.4, and red oak had 1.2. For all species, 86 percent of the stumps cut 8 years ago had at least one potential crop tree.

12-year-old stumps.—Red oak had the greatest number of live sprouts per stump—6.5 (table 1). All species were similar in this respect, having between 3.9 and 6.5 stems per stump. Black cherry had the greatest number of potential crop trees per stump—2.4. The other species had between 1.5 and 1.8. The average numbers of potential crop trees per stump were similar at 8 and 12 years.

Every black cherry stump examined had at least one potential crop tree; at least 88 percent of the stumps of each of the other species had at least one potential crop tree. The major cause for the lack of potential crop trees on some stumps was overtopping of sprouts by adjacent stems. A few stumps did not have any low-origin sprout stems.

Characteristics of potential crop trees.—About 89 percent of all stumps had at least one potential crop tree that originated at groundline (table 1).

Potential-crop-tree data were summarized separately for 8- and 12-year-old stems. Average dbh, clear length, and total height data are summarized in table 2; origin and forking characteristics are presented in table 3. Thirty-six percent of the yellow-poplar, 20 percent of the red oak and red maple, 15 percent of the basswood, and 46 percent of the black cherry sprouts were classified as potential sawlog crop trees.

About 66 percent of all 12-year-old stumps had

Table 1.—*Characteristics of stump sprouting*

Age class and species	Stumps surveyed	Live sprouts per stump	Potential crop trees per stump	Stumps without potential crop trees
	No.	*No.*	*No.*	*No.*
8-year-old:				
Yellow-poplar	119	5.0	1.4	14
Basswood	206	16.8	2.5	31
Red oak	51	7.9	1.2	9
Red maple	78	11.1	1.9	6
12-year-old:				
Yellow-poplar	45	3.9	1.8	2
Red oak	135	6.5	1.7	13
Red maple	56	5.5	1.5	7
Black cherry	46	5.2	2.4	0

Table 2.—*Average dbh, height, and clear length of sprout-origin potential sawlog crop trees*

Age class and species	Dbh	Clear length	Total height
	Inches	*Feet*	*Feet*
8-year-old:			
Yellow-poplar	3.1	7.2	28.9
Basswood	2.6	9.5	25.7
Red maple	2.1	5.7	22.0
Red oak	1.9	6.3	21.4
12-year-old:			
Yellow-poplar	4.7	19.0	40.0
Red maple	3.2	10.7	31.5
Red oak	3.0	11.9	30.8
Black cherry	4.4	14.4	42.8

Table 3.—*Origin and forking characteristics of sprout-origin potential sawlog crop trees*

Age class and species	Crop trees surveyed	Crop trees originating at groundline	Crop trees with no forks below 25 feet
	No.	*Pct.*	*Pct.*
8-year-old:			
Yellow-poplar	167	81	93
Basswood	520	88	77
Red maple	156	94	84
Red oak	61	95	85
12-year-old:			
Yellow-poplar	83	84	93
Red maple	88	89	69
Red oak	233	78	62
Black cherry	111	74	70

at least one stem of groundline origin with no forks below 25 feet. By species, yellow-poplar had 84 percent, red oak 59 percent, red maple 73 percent, and black cherry 65 percent of the stumps in this class.

Low forking was found to be much more of a problem with black cherry, red maple, and red oak than with yellow-poplar and basswood (table 3). No apparent reason for this difference in branching characteristic was observed.

Discussion

Stump sprouts traditionally have been associated with butt rot resulting from decay of the parent stem. However, several points about stump sprouts must be considered.

First, much of the butt rot observed in the past may have been initiated by fire at a time when fire protection was not nearly as good as it is today.

Second, sprouts originating high on the stump are more susceptible to butt rot (*Roth and Hepting 1943*). Improved timber-harvesting practices have led to lower stump heights, which means fewer high-origin sprouts. Also, increased intensity of forest management includes thinning sprouts at an early age, and this eliminates many high-origin sprouts.

Third, single sprouts originating from small stumps may be mistaken for seedling-origin stems (*Roth and Sleeth 1939*). In past comparisons of sprouts versus seedlings, the best sprouts may often have been considered seedlings.

Research results indicate that, at an early age, sprouts generally grow faster than seedlings. Dbh and total height data for 12-year-old sprouts were compared to similar data for seedlings (table 4). Total heights of the sprouts averaged about 1.4 times that of the seedlings, and dbh for the sprouts averaged 1.6 times that of the seedlings. Faster early growth must be considered as an advantage of sprouts.

Table 4.—*Comparisons of 12-year-old seedling-origin[a] and stump-sprout-origin potential sawlog crop trees*

Species	Dbh		Height	
	Seedlings	Sprouts	Seedlings	Sprouts
	Inches		*Feet*	
Yellow-poplar	2.5	4.7	24	40
Black cherry	2.7	4.4	26	43
Red oak	1.8	3.0	23	31

[a]Seedling-origin data from Trimble (*1973, 1974*) for red oak site index 75 or greater.

Conclusions

Eighty-nine percent (655) of the 8- and 12-year-old stumps produced at least one potential crop tree, that is, a dominant or codominant sprout that originated on the stump less than 6 inches above groundline. About 66 percent (186) of the 12-year-old stumps had at least one dominant or

Figure 1.—Twelve-year-old black cherry stump sprouts before thinning.

Figure 2.—Twelve-year-old black cherry stump sprouts after thinning.

codominant sprout of groundline origin that did not fork in the lower 25 feet of the bole.

Although the future quality of stump sprouts cannot be predicted with certainty, a high proportion of stumps will produce some stems of crop-tree quality (fig. 1 and fig. 2).

The results of the study indicate that many stump sprouts have a high potential for producing quality stems.

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UTILIZING HARDWOOD LOGGING RESIDUE: A CASE STUDY IN THE APPALACHIANS

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Abstract.—An Appalachian hardwood timber stand that contained 6,700 board feet per acre of sawtimber was harvested by clearcutting. After the merchantable sawlogs were removed, this stand contained 69.3 tons per acre of green wood residue. Thirty-three and one-third tons of residue were from tops of merchantable sawtimber; 36 tons were from residual trees. Treetop residue yielded 1,800 board feet of marketable sawed products and 26 tons of chippable wood. The residual trees yielded 3,000 board feet of sawed products and 25.6 tons of chippable wood. The overall weight of residue was about 1.8 times greater than the weight of sawtimber removed.

Keywords: Utilization, logging residues, clearcuts, Appalachian hardwoods, treetops, residual trees, sawed products, chips.

Researchers at the Forest Products Marketing Laboratory are evaluating opportunities for commercial use of hardwood logging residues in the Appalachians. The initial phase of this research includes determining the amounts and characteristics of residues, after harvesting, for a variety of timber-stand conditions, logging methods, and product objectives. As a part of this phase, we are investigating the amount and types of marketable products that could be manufactured from residue that results from clearcutting sawtimber stands in the oak-hickory type. This report provides a summary of residue weights and sawed-product volumes for the initial sample area.

The Study

My objective was to determine (a) the total weight of residue that was on the study area after commercial harvest of merchantable sawlogs; and (b) the amount of residue that was suitable for sawing into cants, blocking, and other marketable sawed products.

A merchantable tree was defined as a sound tree of an acceptable species that was at least 12 inches in diameter at breast height (dbh). A merchantable log was defined as a log from a merchantable tree with a minimum scaling diameter of 10 inches and a minimum length of 8 feet. Merchantable species included yellow-poplar, hickory, chestnut oak, black oak, white oak, red oak, sugar maple, red maple, and beech.

Logging residue was defined as all unused parts above the stumps of the harvested trees (topwood residue); and all parts above the stumps of live standing or down trees (residual trees) that were on the site after logging.

All residue except decayed wood was considered chippable. All sound residue pieces at least 6 inches in diameter inside bark (dib) on the small end and at least 4 feet long were considered sawable, provided they were straight enough to yield at least a 4-inch by 4-inch by 4-foot cant.

The Site

In cooperation with the forest supervisor and staff, I selected an 18-acre unit of a commercial timber sale on the Monongahela National Forest near Richwood in Nicholas County, West Virginia. The stand contained 6,144 board feet per acre (International ¼-inch tree scale) of merchantable sawtimber 12 inches dbh or larger. Average tree dbh was 16 inches. Seventy-two percent of the sawtimber volume was oak, 14 percent was yellow-poplar, 8 percent was beech, 3 percent was hickory, and 2 percent was maple. The average slope was about 25 percent and had a generally southern exposure; the site index is 80 for red oak.

The stand was harvested by clearcutting. The logging contractor felled all merchantable trees 12 inches dbh or larger and removed all logs to a 10-inch top scaling diameter. Actual yield of sawlogs was 6,667 board feet per acre, International ¼-inch log scale. Skidding was done with a rubber-tired skidder; all logs were skidded uphill over grades of 15 to 35 percent.

Since there were no local commercial markets for round pulpwood, mine props, or similar products, the remaining trees that were 2 inches dbh or larger were felled and left on the site to assist regeneration.

Procedure

After the merchantable timber was felled and removed, a typical acre within the 18-acre unit was selected for study (fig. 1). The first treatment was the removal of all topwood residue (fig. 2). All sound material that would yield a straight or nearly straight piece at least 6 inches in diameter by 4 feet 3 inches long or longer was decked for sawing into cants and lumber. The remaining material was stored for chipping. A 5-ton crane with a dial scale in line with the lifting cable was used to weigh both groups of residue (fig. 3).

The second treatment was the felling and skidding of all residual trees that were 6 inches dbh or larger. These trees were bucked, weighed, and separated into the same two categories that were used for topwood residue. Final treatment of the plot was the felling and skidding of all trees below 6 inches dbh (fig. 4). This residue was weighed and piled for chipping.

Sample disks were taken from each category of residue for determining moisture contents. Because several months elapsed between logging and the study, there was some drying of logging residue. Therefore all residue weights were adjusted to the equivalent of 61 percent moisture content, the actual average moisture content of standing unmerchantable trees.

A three-man crew used one chain saw and a 35-horsepower farm tractor with a rear-mounted winch to recover the residue. The average bunching distance to the tractor was about 60 feet. Average skidding distance to the landing was 300 yards. All material was moved up a 30- to 35-percent grade over a logging skidroad to the landing (fig. 5).

Sawable material was bucked so that each piece would yield the largest cant possible. Because of the small diameters, sweep and crook had a strong influence on the maximum size for cants. Bucking out

Figure 1.—One-acre plot after commercial logging.

Figure 2.—One-acre plot after all topwood residue was removed.

Figure 3.—Weighing and decking sawable bolts from residual trees.

Figure 4.—One-acre plot after all residue was removed.

Figure 5.—Farm tractor with rear winch used for skidding residue.

sweep and crook resulted in a 9-foot maximum length for sawable bolts.

Sawable bolts were then processed into cants and lumber on a mobile sawmill and a trailer-mounted edger. The manually-operated mill is equipped with a 50-inch diameter, 7- to 8-gauge saw with forty-four 17/64-inch kerf bits; it is powered by a 68-horsepower diesel engine. The engine is mounted on a 2-ton short-wheel-base truck that also serves as the towing unit for the mill (fig. 3).

Results

Residue weight.—The total weight of all residues recovered from the 1-acre plot was 69.3 tons: 33.3 tons from topwood residue, and 36 tons from the residual trees. The topwood residue yielded 11.0 tons (1,363 board feet, International ¼-inch log scale) of sawable bolts; residual trees yielded 14.9 tons (2,312 board feet, International ¼-inch log scale) of sawable bolts (fig. 6). Assuming an average weight of 6.0 tons per M board foot, the weight of merchantable logs harvested from the 18-acre unit was about 40 tons per

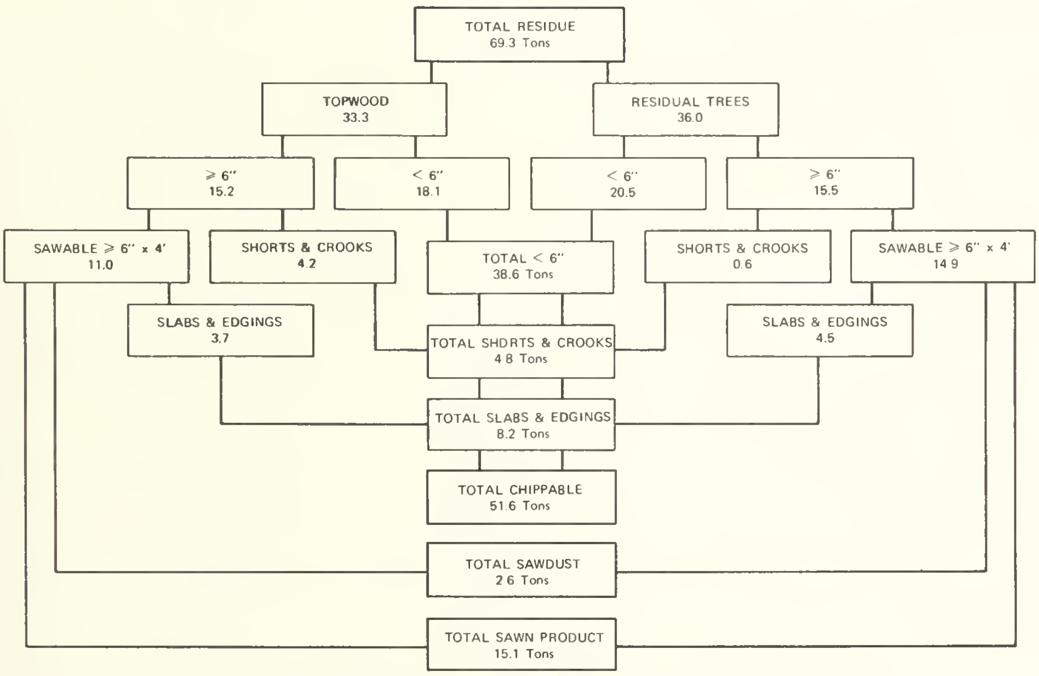

Figure 6.—Residue weights from 1-acre sample plot, (green weights at 61 percent moisture content, ovendry basis).

Table 1.—Distribution of sawable pieces, by diameter class and length, in percent

Diameter small end (inches)	Type of residue [a, b]	Length (feet)						Total	
		4	5	6	7	8	9	T	R
6	T	22	5	3	3	7	3	43	—
	R	20	5	8	3	4	8	—	48
7	T	12	3	3	1	3	—	22	—
	R	12	1	6	1	2	4	—	26
8	T	7	3	1	—	2	—	13	—
	R	5	1	3	—	3	4	—	16
9	T	5	1	—	—	1	—	7	—
	R	2	—	2	—	1	4	—	9
10	T	1	3	1	—	1	—	6	—
	R	—	—	—	—	1	—	—	1
11	T	1	—	1	—	1	—	3	—
	R	—	—	—	—	—	—	—	—
12	T	—	—	1	—	—	—	1	—
	R	—	—	—	—	—	—	—	—
13	T	1	—	1	1	—	—	3	—
	R	—	—	—	—	—	—	—	—
14	T	1	—	1	—	—	—	2	—
	R	—	—	—	—	—	—	—	—
Total	T	50	15	12	5	15	3	100	—
	R	39	7	19	4	11	20	—	100

[a] T = Topwood.
[b] R = Residual trees.

Table 2.—Distribution of sawable volume (International ¼-inch rule), by diameter class and length, in percent

Diameter small end (inches)	Type of residue [a, b]	Length (feet)						Total	
		4	5	6	7	8	9	T	R
6	T	7	2	2	2	7	2	22	—
	R	7	2	5	2	4	8	—	28
7	T	7	2	2	1	3	—	15	—
	R	6	1	5	1	3	6	—	22
8	T	7	2	2	—	3	—	14	—
	R	5	4	4	—	4	9	—	26
9	T	6	2	—	—	3	—	11	—
	R	3	1	3	—	3	10	—	20
10	T	1	5	3	—	2	4	15	—
	R	1	—	—	—	—	3	—	4
11	T	1	—	2	—	3	—	6	—
	R	—	—	—	—	—	—	—	—
12	T	—	—	2	—	—	—	2	—
	R	—	—	—	—	—	—	—	—
13	T	4	—	3	3	—	—	10	—
	R	—	—	—	—	—	—	—	—
14	T	2	—	3	—	—	—	5	—
	R	—	—	—	—	—	—	—	—
Total	T	35	13	19	6	21	6	100	—
	R	22	8	17	3	14	36	—	100

[a] T = Topwood.
[b] R = Residual trees.

Figure 7.—Some of the products sawed from residue bolts.

acre. Thus for every ton of merchantable logs harvested, about 1.8 tons of residue remained.

Sawable bolts.—Sawable bolts from topwood residue ranged from 6 to 14 inches in diameter and 4 to 9 feet in length. Sawable bolts from the residual trees ranged from 6 to 10 inches in diameter and 4 to 9 feet in length. The average bolt size was 7 inches in diameter by 6 feet in length for both groups. All bolts and logs were cut to the nearest foot length, with a 3-inch trim allowance. Complete bolt size distribution is shown in tables 1 and 2.

Thirty-eight percent of the sawable volume was yellow-poplar, 34 percent was oak, and the remaining 28 percent was distributed among six other hardwood species.

Saw products.—Total yield of sawed products from the 1-acre plot was 4,719 board feet of which 3,057 were in cant products, and 1,662 board feet were in 4/4 and 8/4 lumber (fig. 7). Total sawed volume overran the International ¼-inch log scale by 28 percent. Ninety-five percent of the cants ranged from 4-inch by 4-inch pieces to 8-inch by 8-inch pieces. Five percent of the cant pieces were less than 4-inch by 4-inch size because of errors in estimating sweep in some of the small diameter bolts. The sawing operation produced 8.2 tons of chippable slabs and edgings and 2.6 tons of sawdust (fig. 6).

All the cants met National Hardwood Lumber Association standards for sound, square-edge quality and were suitable for use as pallet material, blocking, mine timbers, and other marketable sawed products. The sawed material was used for maintenance and construction of recreation structures on the Monongahela National Forest, and for lumber package separators at the Forest Products Marketing Laboratory.

Further Research

We plan similar research on at least two other clearcut areas in the oak-hickory type. This will be followed by research for developing economical systems for harvesting and processing residue.

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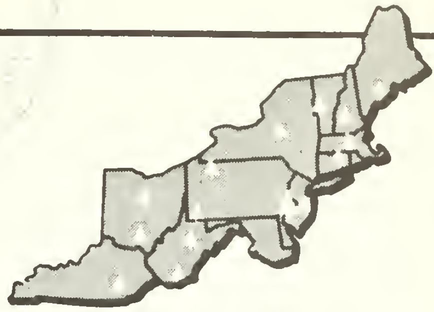

FOREST SERVICE, U.S. DEPT. OF AGRICULTURE, 6816 MARKET STREET, UPPER DARBY, PA. 19082

ANIMAL DAMAGE TO YOUNG SPRUCE AND FIR IN MAINE

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Abstract.—The loss of terminal buds on small balsam fir (*Abies balsamea* (L.) Mill.) and spruce (*Picea* spp.) trees because of nipping by mammals or birds has increased on the Penobscot Experimental Forest in recent years. The cut stem is smooth and slightly angled; there is no sign of tearing. Unnipped trees grew about 13 percent more than the nipped trees; the nipped trees showed less vigor in the lateral bud that took over as leader.

KEY WORDS: Animal damage, balsam fir, spruce, bud injury.

Balsam fir (*Abies balsamea* (L.) Mill.) is damaged by many agents, from butt rots to budworms. One form of damage that seems to have increased in recent years is the nipping or cutting of terminal buds in late winter or early spring. This damage is most noticeable on young growth up to a height of about 15 feet. Although lateral buds are also cut, the cut terminals probably have the greatest adverse effect on growth. Large areas of young growth often look "mowed".

The agent responsible for this damage is not known, but red squirrels (*Tamiasciurus hudsonicus*) have often been observed nipping cones, lateral twigs, and flower buds (*Bakuzis and Hansen 1965*). Damage to Norway spruce (*Picea abies* (L.) Karst.) described by Viidik *(1973)* seems to be similar. However, damage of the type that I studied is so extensive and occurs during such a short time that I suspect flocks of migrating birds such as grosbeaks or crossbills (*Fringilladae* spp.). The lack of pronounced tooth marks on the damaged stems adds to this suspicion. All of the cut or nipped stems are similar in appearance: slightly angled and smooth, with no evidence of tearing (fig. 1).

Damage by nipping has become increasingly widespread in young, even-aged stands of softwood on the Penobscot Experimental Forest in central Maine. The buds apparently are nipped during a short period in late February or early March. Although balsam fir sustains most of the damage, the spruce (*Picea* spp.) also is nipped occasionally. Although the extent of such damage in other areas of the state is unknown, nipping is often cited as a source of damage to

Figure 1.—Size comparison for nipped and unnipped terminal buds. Nipping also is evident on lateral buds.

balsam fir Christmas trees. (Personal communication from Lewis P. Bissell, Extension Forestry Specialist, now retired, U.S. Department of Agriculture, Cooperative Extension Service, Orono, Maine.)

In the spring of 1974 the damage was so prevalent in a young even-age stand of spruce and fir that I decided to determine the amount of damage to the trees, by species and relative crown class. Forty-five permanent milacre regeneration plots were used, 3 each at 15 points on a systematic grid throughout a 33-acre compartment. In 1970, regeneration on the compartment was estimated at 18,160 stems at least 6.0 inches high; 48 percent of these stems were spruce and fir. At the time this study was initiated, the bulk of the regeneration was under 18 years of age *(Blum 1973).*

From the plot tallies, I found that approximately 25 percent of all balsam fir, red spruce *(Picea rubens* Sarg.), and white spruce (*Picea glauca* (Moench) Voss), had lost their terminal buds. Nipped lateral buds, though observed, were not tallied.

Analysis of the damage indicated that balsam fir had the greatest percentage of terminal buds nipped, followed by red spruce and white spruce (table 1). It is not known whether this indicated a preference for balsam fir by the agent or was the result of the greater number of balsam fir in the stand.

Nearly 44 percent of the dominant and codominant trees were affected. The amount of damage seems quite severe because these trees were nearly half of the potential spruce-fir crop, and because nipping of both new and previously nipped trees has been observed for several consecutive years. Nipping of the terminal bud can cause a loss in height growth and malformation of the leader, and creates the potential for pathogens to enter the cut leaders. Also, damage seems to have increased during the 1975 and 1976 growing seasons; I estimated that 75 percent of the firs were nipped in the spring of 1976.

Since the potential for growth loss is of immediate concern, I compared the growth of leaders on nipped and unnipped trees for the 1974 season. I tagged 50 trees that had been nipped during the late winter of 1974, and 50 undamaged trees. Though these trees were not actually paired, I avoided gross bias by choosing nipped and undamaged trees that were fairly close to each other and alike in height and diameter at breast height (dbh).

When a tree is nipped, the uppermost lateral bud on the terminal usually assumes dominance

Table 1.—Percentage of trees nipped

Species	Crown class				All classes	Number of trees
	Dominant	Codominant	Intermediate	Suppressed		
Balsam fir	57	45	30	4	28	449
Red Spruce	7	12	50	0	10	41
White Spruce	0	20	0	0	3	39
All species	48	42	28	3	25	
Number of trees	88	147	76	218		529

Figure 2.—Lateral buds assumed dominance on this tree after it was nipped in late winter of 1972 and 1973.

and takes over as leader (fig. 2). Of the 50 nipped trees in my sample, however, 15 either developed multiple leaders or, in most cases, the uppermost bud failed to develop and a lower bud assumed dominance. The average distance from the "nip" to the first lateral bud in the sample was 5.1 cm (range: 1.9 to 9.2 cm). This can be considered an immediate loss in height since the stem above the bud that assumes dominance dies back to this point (fig. 3). However this loss was not subtracted from the subsequent growth reported here.

Leader growth on the undamaged trees for the 1974 growing season was measured from the center of the old terminal whorl to the top of the newly set terminal bud. For the undamaged trees, the average growth in 1974 was 35.6 cm (14.0 inches); growth ranged from 16.0 to 68.0 cm. On the nipped trees, the growth of the new leader was measured from the center of where it joins the stem to the top of the newly set terminal bud. The average growth in 1974 for the nipped trees was 22.9 cm (9.0 inches); growth ranged from 8.0 to 40.6 cm. This difference in average growth between damaged and undamaged trees was highly significant.

Besides the immediate loss in height when the nipped stem dies back to the first viable bud, an additional loss of growth is inherent in the creation of a new leader.

I tried to remeasure the sample trees in 1975, but of the 40 previously undamaged trees that were found again, 43 percent had been nipped during the winter of 1974-75. Forty-six percent of the nipped trees remaining from the 1974 season had been nipped again. I observed some trees that seemed to have been nipped for 3 or 4 consecutive years.

Damage to the terminal bud by any agent results in an immediate loss in height, a subse-

Figure 3.—Dead stub of a previously nipped leader, and point where lateral bud assumed dominance.

quent loss in height growth, some stem malformation and, occasionally, the creation of multiple leaders. I found that balsam fir receives most, but not all, of the damage. Height growth may be seriously impaired if the damage is repeated for several years, and losses in height growth may be substantial over large acreages. The possibility that nipping provides entrance courts for pathogens could be of major concern.

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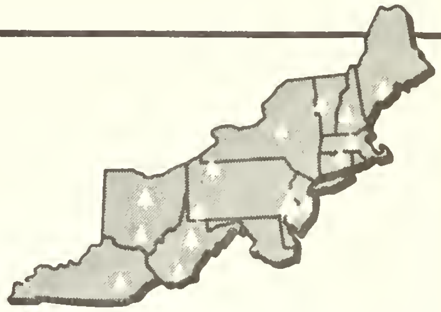

FOREST SERVICE, U.S. DEPT. OF AGRICULTURE, 6816 MARKET STREET, UPPER DARBY, PA. 19082

ATTEMPT AT CONCENTRATING RED OAK BORER EGGS BY PROVIDING ARTIFICIAL OVIPOSITION SITES

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Abstract.—Thirty-eight scarlet and 14 black oaks were spirally wrapped to a height of about 2 m with black or white cotton tape 2.5 cm wide in an attempt to increase oviposition of the red oak borer, *Enaphalodes rufulus* (Haldeman), on selected trap trees. However only 57 eggs were laid under tape on 17 of the trees, all scarlet oaks. Attacks but no eggs were found on some of the wrapped black oaks.

Key words: *Enaphalodes rufulus*, cerambycidae, oviposition, control

The red oak borer, *Enaphalodes rufulus* (Haldeman), is a primary borer in living oak trees. Its boring causes permanent defects which show up in milled products as degrade; the losses amount to millions of dollars annually *(Donley 1974)*.

Red oak borers will mate readily when confined in jars; in the laboratory, they also will lay eggs under cotton textile tape wrapped around bolts of freshly cut red, black, scarlet, white, or pin oak. The tape is a substitute for bark scales, lichen patches, and other natural sites that the beetles usually select for oviposition *(Hay 1969)*. Since the beetles readily lay eggs under tape in the laboratory, I thought they also might oviposit under tape wrapped around selected oak trees. Borer populations could be reduced if the beetles were enticed to concentrate their eggs on a few selected trees where the eggs or larvae could more easily be destroyed.

Materials and Methods

During June, 1975, 38 scarlet and 14 black oaks were selected for this study. They ranged from 4.8 cm to 17.5 cm in diameter at breast height (dbh); the mean dbh was 10.2 cm. The trees ranged from vigorous dominant trees to suppressed trees with dead tops and likely to die within 2 or 3 years. About two-thirds of the trees were overtopped by larger trees and these were most likely to be attacked.

Half of the scarlet and black oaks were spirally wrapped to a height of about 2 m with white cotton textile tape 2.5 cm wide. The tape spirals were spaced about 8 cm apart. The remaining trees were wrapped the same way, but with black tape. The tape was held in place with thumbtacks.

The trees were checked weekly during July; I unwrapped the tape, counted and destroyed any cerambycid eggs, and rewrapped the trees.

Results and Discussion

A total of 57 red oak borer eggs were laid under tape on 17 scarlet oaks. The greatest number of eggs on a single tree (9) were laid under black tape on a scarlet oak 4.8 cm dbh. The largest tree with eggs (7) was 15.5 cm dbh and was wrapped with white tape. Apparently tape color was not a factor in oviposition—31 eggs were laid under black and 26 under white tape. No eggs were laid by red oak borers under tape wrapped around trees with dead tops; all eggs were deposited under tape wrapped around trees with very smooth bark. No eggs were found under tape wrapped around black oaks, but attacks were found on some of these trees. This indicated that borers had been on black oaks but failed to oviposit under the tape. One black oak wrapped with tape had 12 red oak borer attacks, but the female beetles used the natural rather than the artificial oviposition sites.

A total of 121 eggs of an unknown cerambycid species were laid under black and white tape wrapped around some of the trees with dead tops. No eggs of the unknown species were laid under tape on trees that seemed healthy.

The results suggest that the physical—and perhaps physiological—requirements for oviposition are more critical for red oak borers in the forest than they are for borers in the laboratory. Borers in the forest are more selective about where they lay eggs; natural egg sites, when available, are used before artificial sites are used. This explains why no eggs were laid under tape on black oaks, which usually have many oviposition sites, and why eggs were laid under tape on scarlet oaks, which usually have few sites.

In conclusion, not enough eggs were laid under cotton tape to be useful in reducing red oak borer populations. However a material other than cotton tape, or another technique, might successfully induce and increase oviposition on selected trees.

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FOREST SERVICE, U.S. DEPT. OF AGRICULTURE, 6816 MARKET STREET, UPPER DARBY, PA. 19082

EFFECTS OF PRUNING HEIGHT ON THE DIAMETER GROWTH OF YELLOW BIRCH

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Abstract.—The diameter growth rate of pruned trees increased the second year after pruning, whereas the diameter growth of unpruned trees was not as fast during the second year. Diameter growth rate was positively correlated with the height to which all branches were pruned. After the pruning shock of the first year, trees pruned to 50 percent of their height showed the greatest cumulative growth in diameter.

One cultural method used to meet the increased need for quality hardwoods, especially birch (*Betula alleghaniensis* Britton), is to prune young trees as early as possible to insure maximum growth of clear wood in the shortest period without reducing diameter growth. The removal of branches while they are small eliminates branch stubs and reduces the surface area available for the entrance of organisms that can cause discoloration. Rapid diameter growth also reduces the time a wound remains open. The objective of this study was to determine the effect of various degrees of pruning on growth in diameter.

In 1963, twenty 13-year-old dominant and codominant yellow birch trees on the Bartlett Experimental Forest in Bartlett, New Hampshire, were divided into four groups, five trees per group. The mean height and diameter of the trees were 7.62 m and 4.42 cm, respectively. Of the four groups, one was unpruned; the other three were pruned of all branches up to 50, 65, or 75 percent of total tree height.

Radial growth was measured weekly to the nearest 0.025 mm with a dial-gage dendrometer at 1.37 m above ground. The use and accuracy of the dial-gage dendrometer have been described previously (*Blum 1966; Blum and Solomon 1966*).

Growth Differences

An analysis of variance of the cumulative growth in diameter was used to test for differences between treatments. The data were transformed to the logarithm of final diameter divided by initial diameter in order to make amounts of growth comparable, regardless of tree size. When data for two growing seasons were averaged, there were no differences between groups in diameter growth significant at the 5 percent level. However, when the cumulative diameter growth was plotted on an annual basis, there were differences in diameter growth between unpruned trees and trees pruned to 75 percent for the first growing season, and between unpruned trees and trees pruned to 50 percent of their total height for the second growing season (fig. 1 and 2).

Figure 1.—Cumulative diameter growth of pruned and control trees during the first growing season.

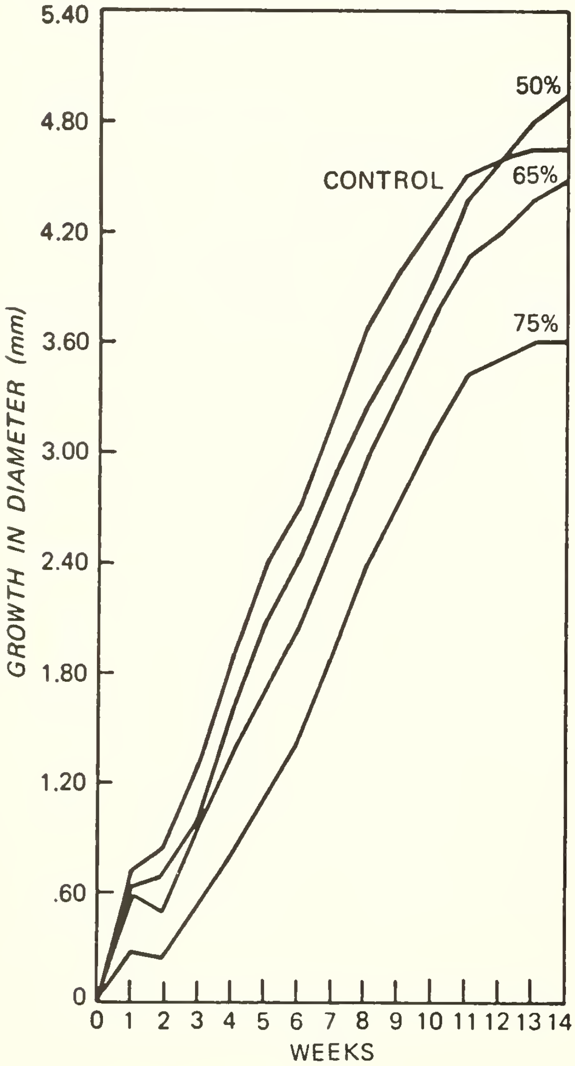
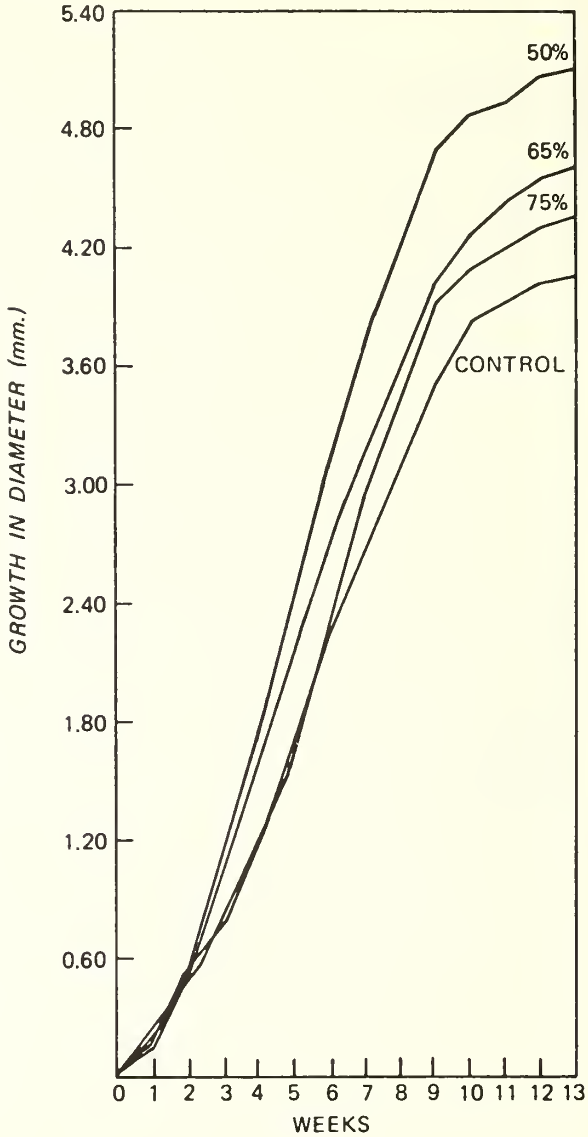


Figure 2.—Cumulative diameter growth of pruned and control trees during the second growing season.



In the first growing season after pruning, unpruned trees showed the fastest diameter growth. The growth rates of the treated groups of trees were lower where the intensity of pruning was higher. Trees pruned to 65 and 75 percent of their height showed a definite decline in growth for the first growing season, compared with control trees, indicating that some of the crown needed for growth had been removed. This detrimental effect on growth at the end of the first growing season had been overcome by the end of the second growing season.

In the second growing season, unpruned trees showed a very small reduction in growth rate, with a lower growth peak than in the first growing season. Pruned trees had faster growth rates and greater cumulative growth in the second growing season than in the first growing season. Trees pruned to 75 percent showed the greatest reduction in growth rate during the first growing season after pruning, perhaps because more of the crown was removed. During the second growing season, these trees showed the greatest increase in growth rate, but did not attain the overall cumulative growth of trees pruned to 50 and 65 percent.

The increased cumulative growth of trees pruned to 50 percent of their height is similar to the response of pruned black walnut *(Clark 1955)*. Although a faster growth rate was found for yellow birch trees pruned to 75 percent, the greatest increase in diameter over 2 years was found in trees that had been pruned to 50 percent. The results indicate that the diameter growth of pruned trees is better than that of unpruned trees after the first year. Such a result can be accomplished by keeping the crown length slightly greater than 50 percent of the total tree height. Pruning yellow birch once may not have an appreciable influence on subsequent tree growth *(Skilling 1959)*.

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A PREVIEW OF KENTUCKY'S FOREST RESOURCE

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Abstract.—Forty-eight percent of the total land area of Kentucky is forest. Sixty-three percent of this forest land is the oak-hickory forest type and 47 percent of the forest area supports sawtimber stands. There has been a 23-percent increase in the volume of growing stock and a 24-percent increase in the volume of sawtimber since the 1963 inventory. Total volume of growing stock is 11.4 billion cubic feet, and the sawtimber component is 27.6 billion board feet.

KEYWORDS: Forest surveys (Kentucky), forest area, resources (timber), statistics (forestry).

Forest is a major land use in Kentucky. Inventories of this resource have been made by the U.S. Forest Service three times in the past quarter century. Each survey was designed to provide a reliable estimate of the extent and condition of the forest resource and to indicate what changes were occurring. A detailed statistical and analytical report of the most recent inventory is being prepared for publication. It will give a comprehensive analysis of the current situation and trends in the forest resource. This is a preview of that report.

Forest Land Area Increases Slightly

Forests now occupy 12.2 of the 25.5 million acres of land in Kentucky. The state is essentially rural, and the area of forest has changed very little during the past quarter century. In 1949, forest accounted for 45 percent of the total land area. This increased to 47 percent in 1963 and to 48 percent in 1975.

The distribution of forest land in the state is not uniform. Eastern Kentucky is 81 percent forested and has one-half of the total forest land. This is the mountainous part of the state, from the Daniel Boone National Forest east to West Virginia and from Tennessee north to the Ohio River. Urban-industrial development has been slight in this region, and mining activity is the principal cause of land-use change. Since 1963, the net effect of all forms of land-use change in the region has been a 1-percent increase in forest area. In the remainder of the state, forest varies from less than 25 percent of the land area in the Bluegrass Region to 46 percent in the Pennyroyal Region. Western Kentucky had a small decline in forest acreage since 1963 and is now 34 percent forested.

Nearly all of the 12.2 million acres of forest land is classified as commercial. Only 1 percent of the total land area—259 thousand acres—is classified as noncommercial forest. This category includes two land classes: (1) unproductive—forest land that is not capable of producing industrial roundwood products; (2) productive-reserved—publicly-owned forest lands, such as parks, where timber production is prohibited by law or regulation.

Since 1963 the area of productive-reserved forest lands has more than doubled. Though increases in this category of land use have occurred throughout the state, the largest increases were noted in eastern Kentucky and the Pennyroyal Region. Here the changes resulted from special land-use designations on the Daniel Boone National Forest and from recreational development of public lands in the Land Between the Lakes.

The distribution of forest types on commercial forest land in 1975 shows the oak-hickory type predominating, with 63 percent of the total. In addition, there are another 1 million acres of the oak-pine type. The oaks and hickory also predominate in this type, but a significant component of the stand is softwoods. Other important types are loblolly-shortleaf, maple-beech-birch, and elm-ash-red maple. These three types occupy nearly all the remaining forest area.

Nearly half—47 percent—of the commercial forest area now supports sawtimber stands. These are stands in which trees 5.0 inches dbh and larger constitute more than 50 percent of the total basal-area stocking and in which sawtimber-size trees are the majority. Poletimber stands occupy 25 percent of the area; seedling/sapling stands occupy the remaining 28 percent. This indicates only minor shifts in the area of sawtimber and poletimber stands since 1963.

A study of forest-land owners was conducted in conjunction with this inventory. Two objectives of this study were to define the pattern of forest-land ownership more clearly and to seek an understanding of the motives and intentions of forest-land owners. An estimated 455,600 individuals, groups, or corporations each own 1 acre or more of the 11 million acres of private commercial forest land. In the past, 30 percent of these owners have harvested timber from their lands. The forest land owned by those who have harvested timber makes up 54 percent of the total private commercial forest area.

Volume Change

Data from the remeasurement of a portion of the ground sample plots established for the 1963 inventory provide estimates of growth, mortality, and removals during the period between inventories. During the 12-year period, average annual net growth of growing stock was 27 cubic feet per acre; sawtimber growth was 75 board feet per acre. In 1974 the annual net growth of growing stock was 33 cubic feet per acre, and of sawtimber was 80 board feet per acre. The ratio of growth to removals was more than 2 to 1 during the entire period.

Analysis of the current volume and growth includes a procedure to determine whether past volume and growth estimates are directly comparable with the present estimate. This procedure helps to locate inconsistencies in the data and to evaluate differences that may be the result of procedural or definitional differences between inventory occasions. The analysis for Kentucky pinpointed average tree volume by 2-inch diameter class as the major area of discrepancy between the 1963 and 1975 inventories. The volume table used in 1963 was found to be very conservative in comparison to all others tested. When the 1963 stand-table data were used with average tree volumes from the 1975 inventory, the adjusted 1963 estimates of volume reflected the standards, procedures, and definitions used in the 1975 inventory.

Here are the 1963 figures, adjusted as described above, to be used in making comparisons of trends:

	Growing stock (million cubic feet)	*Sawtimber (million board feet)*
Softwoods	613.0	1,413
Hardwoods	8,673.4	20,841

Growing Stock and Sawtimber Volume Increases

There has been a 23-percent increase in the volume of growing stock and a 24-percent increase in the volume of sawtimber since 1963. The total volume of growing stock in Kentucky is 11.4 billion cubic feet. This is an average of 962 cubic feet per acre of commercial forest land. The sawtimber portion of growing stock totals 27.5 billion board feet, equivalent to 2,315 board feet per acre.

The distribution of growing-stock volume by species has changed very little since 1963. Hardwoods continue to predominate. Softwoods make up only 7.5 percent of the total volume. The white oak group is now the most prevalent hardwood group, with 22.7 percent of total volume. The maples have increased from 5.6 to 7.4 percent of total volume. Both red maple and sugar maple contributed about equally to this increase.

The following tables describe the forest resource of Kentucky.

Table 1.—Land area in Kentucky, by land classes, counties, and geographic units, 1975

County	Total land area [a]	Nonforest land area	Forest land		
			Non-commercial [b]	Commercial	
	Thousand acres				*Percent*
Floyd	255.5	39.0	5.3	211.2	83
Harlan	300.0	23.5	8.3	268.2	89
Knott	227.9	19.5	4.7	203.7	89
Leslie	263.7	12.7	4.3	246.7	94
Letcher	217.0	19.3	3.2	194.5	90
Martin	147.8	16.0	1.9	129.9	88
Perry	219.6	18.6	8.8	192.2	88
Pike	503.0	54.9	6.4	441.7	88
Eastern Unit	2,134.5	203.5	42.9	1,888.1	88
Boyd	102.1	41.3	.1	60.7	59
Carter	257.4	69.5	6.7	181.2	70
Elliott	153.6	38.7	3.3	111.6	73
Greenup	224.3	66.3	3.6	154.4	69
Johnson	169.0	33.4	—	135.6	80
Lawrence	272.0	54.1	—	217.9	80
Lewis	311.3	79.8	—	231.5	74
Magoffin	193.9	30.6	—	163.3	84
Menifee	134.4	28.0	9.0	97.4	72
Morgan	236.2	63.8	—	172.4	73
Powell	110.7	26.3	5.1	79.3	72
Rowan	185.6	43.7	—	141.9	76
Wolfe	145.4	31.2	13.0	101.2	70
Northern Cumberland Unit	2,495.9	606.7	40.8	1,848.4	74
Bell	236.7	34.9	13.4	188.4	80
Breathitt	316.2	38.8	—	277.4	88
Clay	303.4	52.2	—	251.2	83
Estill	166.4	51.2	—	115.2	69
Jackson	215.7	62.0	—	153.7	71
Knox	238.7	54.2	—	184.5	77
Laurel	285.2	104.0	1.1	180.1	63
Lee	134.4	24.5	—	109.9	82
McCreary	267.4	30.5	10.4	226.5	85
Owsley	126.1	20.8	—	105.3	84
Rockcastle	199.0	63.7	—	135.3	68
Whitley	293.4	63.7	.5	229.2	78
Southern Cumberland Unit	2,782.6	600.5	25.4	2,156.7	78

CONTINUED

Table 1.— (Cont'd)

County	Total land area [a]	Nonforest land area	Forest land: Non-commercial [b]	Forest land: Commercial	
	Thousand acres				*Percent*
Anderson	131.8	86.7	0.2	44.9	34
Bath	183.7	125.4	—	58.3	32
Boone	159.6	110.2	.2	49.2	31
Bourbon	192.0	181.7	—	10.3	5
Boyle	117.3	96.3	—	21.0	18
Bracken	130.4	84.3	—	46.1	35
Campbell	95.4	66.9	.2	28.3	30
Carroll	83.5	45.8	.6	37.1	44
Clark	165.8	143.7	—	22.1	13
Fayette	179.3	170.1	.3	8.9	5
Fleming	224.0	151.1	—	72.9	33
Franklin	135.0	95.4	—	39.6	29
Gallatin	63.8	36.2	—	27.6	43
Garrard	151.3	124.4	—	26.9	18
Grant	159.2	104.7	.3	54.2	34
Harrison	197.1	158.8	—	38.3	19
Henry	185.0	138.5	.4	46.1	25
Jefferson	239.8	203.3	3.1	33.4	14
Jessamine	113.4	98.1	—	15.3	13
Kenton	105.7	73.6	.4	31.7	30
Lincoln	217.6	168.2	—	49.4	23
Madison	285.2	210.3	.7	74.2	26
Mason	152.1	125.5	—	26.6	17
Mercer	163.6	143.3	—	20.3	12
Montgomery	130.6	102.9	—	27.7	21
Nicholas	130.6	103.6	—	27.0	21
Oldham	117.4	91.5	—	25.9	22
Owen	224.6	131.2	—	93.4	42
Pendleton	178.6	118.8	.7	59.1	33
Robertson	64.6	43.9	.1	20.6	32
Scott	181.8	150.7	—	31.1	17
Shelby	245.1	200.2	.2	44.7	18
Spencer	123.5	95.3	—	28.2	23
Trimble	93.5	51.3	—	42.2	45
Washington	196.4	161.8	—	34.6	18
Woodford	123.5	110.6	—	12.9	10
Bluegrass Unit	5,641.8	4,304.3	7.4	1,330.1	24
Adair	251.5	128.6	13.1	109.8	44
Breckenridge	361.2	203.8	4.9	152.5	42
Bullitt	192.0	87.6	.6	103.8	54
Casey	278.5	127.4	.8	150.3	54
Clinton	121.3	55.0	2.5	63.8	53
Cumberland	198.2	67.0	2.0	129.2	65
Grayson	327.5	177.3	4.7	145.5	44
Green	180.5	119.4	.2	60.9	34
Hancock	119.7	55.6	.5	63.6	53
Hardin	394.3	251.9	.7	141.7	36
Hart	272.0	154.9	6.4	110.7	41
Larue	166.4	105.7	.4	60.3	36
Marion	219.5	146.7	.5	72.3	33
Meade	195.3	112.3	2.4	80.6	41
Metcalfe	189.4	105.0	.4	84.0	44
Nelson	279.6	181.1	.7	97.8	35
Pulaski	418.2	217.4	8.6	192.2	46
Russell	152.5	75.5	13.4	63.6	42
Taylor	181.4	108.5	13.0	59.9	33
Wayne	281.7	89.3	5.8	186.6	66
Pennyroyal Unit	4,780.7	2,570.0	81.6	2,129.1	45

CONTINUED

Table 1.— (Cont'd)

County	Total land area [a]	Nonforest land area	Forest land: Noncommercial [b]	Forest land: Commercial	
	Thousand acres				*Percent*
Allen	232.9	139.5	0.7	92.7	40
Barren	311.0	241.5	2.1	67.4	22
Butler	283.4	135.8	—	147.6	52
Caldwell	228.4	140.1	—	88.3	39
Christian	464.1	293.9	.6	169.6	37
Crittenden	233.3	140.7	—	92.6	40
Daviess	295.6	239.6	.6	55.4	19
Edmonson	194.6	79.2	44.8	70.6	36
Henderson	277.1	222.8	1.6	52.7	19
Hopkins	353.8	200.1	2.1	151.6	43
Logan	360.1	244.5	.1	115.5	32
McLean	164.5	123.1	—	41.4	25
Monroe	213.7	120.8	.1	92.8	43
Muhlenberg	307.5	172.4	1.0	134.1	44
Ohio	381.2	186.2	—	195.0	51
Simpson	152.9	129.8	—	23.1	15
Todd	240.3	165.8	—	74.5	31
Union	217.9	183.9	—	34.0	16
Warren	349.4	261.6	.2	87.6	25
Webster	216.8	157.9	—	58.9	27
Western Coalfield Unit	5,478.5	3,579.2	53.9	1,845.4	34
Ballard	165.9	121.4	1.4	43.1	26
Calloway	245.8	166.2	—	79.6	32
Carlisle	125.1	93.2	1.1	30.8	25
Fulton	129.9	103.6	—	26.3	20
Graves	358.3	276.0	—	82.3	23
Hickman	157.5	122.1	.3	35.1	22
Livingston	199.5	120.4	—	79.1	40
Lyon	161.8	80.9	—	80.9	50
McCracken	159.7	121.0	.2	38.5	24
Marshall	193.7	125.2	2.4	66.1	34
Trigg	293.6	149.8	1.5	142.3	48
Western Unit	2,190.8	1,479.8	6.9	704.1	32
State total	25,504.8	13,344.0	258.9	11,901.9	47

[a] Source: Bureau of the Census, Area Measurement Report, Areas of Kentucky, 1960 (July 1964).

[b] Includes unproductive and productive-reserved forest land.

Table 2.—Area of commercial forest land in Kentucky, by ownership classes and geographic units, 1975

[In thousands of acres]

Ownership class	Eastern	Northern Cumberland	Southern Cumberland	Bluegrass	Pennyroyal	Western Coalfield	Western	Tota
National Forest	47.6	103.5	394.5	16.2	27.0	—	—	588
Other federal	24.6	—	.2	1.8	72.6	5.1	125.6	229
State	15.4	.8	24.5	3.1	4.1	21.2	6.9	76
County and municipal	—	—	—	.1	.1	.1	.3	
Total public	87.6	104.3	419.2	21.2	103.8	26.4	132.8	895
Forest industry	53.0	81.6	26.6	—	26.4	20.2	47.3	255
Farmer-owned	266.8	880.4	682.2	905.6	1,228.3	1,157.2	368.5	5,489
Miscellaneous private:								
Individual	1,051.1	725.8	958.5	372.1	746.4	422.4	155.5	4,431
Corporate	429.6	56.3	70.2	31.2	24.2	219.2	—	830
Total miscellaneous private	1,480.7	782.1	1,028.7	403.3	770.6	641.6	155.5	5,262
All ownerships	1,888.1	1,848.4	2,156.7	1,330.1	2,129.1	1,845.4	704.1	11,901

Table 3.—Area of commercial forest land, by forest types and standsize classes, Kentucky, 1975

[In thousands of acres]

Forest type	All stands	Sawtimber stands	Poletimber stands	Sapling-seedling stands [a]
White and red pine	38.2	38.2	—	—
Loblolly and shortleaf pine	942.8	281.4	157.6	503.8
Oak-pine	1,040.6	335.8	215.6	489.2
Oak-hickory	7,488.5	3,622.6	2,183.3	1,682.6
Oak-gum	101.6	57.6	19.2	24.8
Elm-ash-red maple	936.0	288.0	212.9	435.1
Maple-beech-birch	1,354.2	920.7	217.5	216.0
All types	11,901.9	5,544.3	3,006.1	3,351.5

[a] Includes 46,200 acres of nonstocked areas in the oak-hickory type.

Table 4.—Area of commercial forest land in Kentucky, by forest types and geographic units, 1975

[In thousands of acres]

Geographic units	White and red pine	Loblolly-shortleaf pine	Oak-pine	Oak-hickory	Oak-gum	Elm-ash-red maple	Maple-beech-birch	All types
Eastern	14.3	29.6	56.6	1,215.5	13.4	89.0	469.7	1,888
Northern Cumberland	12.0	119.4	157.9	1,286.3	—	142.9	129.9	1,848
Southern Cumberland	11.9	261.9	299.0	1,239.1	—	107.5	237.3	2,156
Bluegrass	—	207.3	250.5	677.1	—	121.7	73.5	1,330
Pennyroyal	—	236.1	161.4	1,232.0	49.7	125.2	324.7	2,129
Western Coalfield	—	74.9	88.4	1,357.3	24.9	201.0	98.9	1,845
Western	—	13.6	26.8	481.2	13.6	148.7	20.2	704
Total	38.2	942.8	1,040.6	7,488.5	101.6	936.0	1,354.2	11,901

Table 5.—Estimated number of private owners of commercial forest land in Kentucky, and acres owned, by form of ownership, 1975

Form of ownership	Number of owners	Thousand acres owned	Percent of owners who have harvested	Percent of acres owned by harvesters
Individual	427,200	9,200.0	28	43
Corporation	2,600	1,023.9	(*)	8
Partnership	8,400	243.9	1	1
Undivided estate	16,300	478.6	1	2
Other	1,100	60.2	(*)	(*)
Total	455,600	11,006.6	30	54

*Less than 0.5 percent.

Table 6.—Area of commercial forest land in Kentucky, by stand-size classes and geographic units, 1975

[In thousands of acres]

Geographic units	Sawtimber stands	Poletimber stands	Sapling-seedling stands	Nonstocked areas	All classes
Eastern	1,081.2	383.3	423.6	—	1,888.1
Northern Cumberland	794.4	550.0	492.1	11.9	1,848.4
Southern Cumberland	1,153.4	555.0	426.5	21.8	2,156.7
Bluegrass	381.5	308.6	640.0	—	1,330.1
Pennyroyal	1,097.6	547.8	471.2	12.5	2,129.1
Western Coalfield	757.4	465.1	622.9	—	1,845.4
Western	278.8	196.3	229.0	—	704.1
Total	5,544.3	3,006.1	3,305.3	46.2	11,901.9

Table 7.—Net volume of growing-stock trees[a] on commercial forest land in Kentucky, by species and tree size, 1975

Species	All trees	Poletimber trees	Sawtimber trees	
	----------*Million cubic feet*		----------	*Million board feet*[b]
Redcedar	116.1	82.9	33.2	116.2
Hard pines	661.2	216.5	444.7	1,577.9
Other softwoods	85.2	13.9	71.3	272.9
Total softwoods	862.5	313.3	549.2	1,967.0
Select white oaks	1,519.0	548.9	970.1	3,807.0
Select red oaks	652.5	150.8	501.7	2,055.4
Other white oaks	1,081.3	377.8	703.5	2,775.4
Other red oaks	1,744.6	533.1	1,211.5	4,832.2
Red maple	409.8	213.0	196.8	768.5
Sugar maple	441.4	222.1	219.3	848.6
Hickory	1,496.0	725.0	771.0	2,991.3
Beech	486.2	92.6	393.6	1,677.9
Ash	335.9	162.5	173.4	660.6
Black Walnut	124.9	60.9	64.0	237.7
Sweetgum	130.0	60.4	69.6	265.0
Yellow-poplar	1,007.9	402.5	605.4	2,389.9
Blackgum	221.1	86.2	134.9	515.9
Basswood	107.4	43.2	64.2	254.7
Other hardwoods	823.2	438.4	384.8	1,504.8
Total hardwoods	10,581.2	4,117.4	6,463.8	25,584.9
All species	11,443.7	4,430.7	7,013.0	27,551.9

[a] Growing-stock trees are trees that satisfy national specifications for form and allowable cull. Net volumes are given for all such trees 5.0 inches dbh and larger.

[b] International 1/4-inch rule.

Table 8.—Net volume of growing stock and sawtimber on commercial forest land in Kentucky, by counties and geographic units, 1975

County and unit	Growing stock	Sawtimber
	Million cubic feet	*Million board feet* [a]
Floyd	204.2	558.3
Harlan	272.5	758.4
Knott	197.8	543.0
Leslie	246.3	679.9
Letcher	192.6	529.9
Martin	129.4	356.4
Perry	189.8	520.7
Pike	427.7	1,167.0
Eastern Unit	1,860.3	5,113.6
Boyd	54.6	111.5
Carter	184.4	391.9
Elliott	126.4	279.3
Greenup	164.3	349.8
Johnson	134.9	276.6
Lawrence	212.9	433.3
Lewis	273.1	624.1
Magoffin	166.1	340.9
Menifee	108.4	236.1
Morgan	171.4	349.1
Powell	92.5	206.5
Rowan	167.4	378.6
Wolfe	115.5	254.8
Northern Cumberland Unit	1,971.9	4,232.5
Bell	168.4	380.2
Breathitt	259.6	598.0
Clay	241.3	566.0
Estill	114.7	265.4
Jackson	157.5	375.1
Knox	169.4	385.9
Laurel	193.0	455.8
Lee	116.4	271.7
McCreary	231.0	544.1
Owsley	101.0	237.4
Rockcastle	130.6	298.9
Whitley	218.7	505.0
Southern Cumberland Unit	2,101.6	4,883.5
Anderson	17.7	37.0
Bath	28.6	65.7
Boone	20.4	42.9
Bourbon	4.1	8.9
Boyle	10.9	25.7
Bracken	16.8	34.6
Campbell	12.0	26.2
Carroll	18.6	43.2
Clark	9.1	20.2
Fayette	3.9	9.3
Fleming	43.3	106.7
Franklin	14.8	29.6
Gallatin	12.5	27.2
Garrard	13.3	30.9
Grant	15.9	29.1
Harrison	13.4	26.2
Henry	18.1	37.3
Jefferson	14.1	30.8
Jessamine	7.4	17.1
Kenton	13.3	28.3
Lincoln	25.7	60.4
Madison	32.4	72.3
Mason	12.5	28.3

CONTINUED

Table 8.—(Cont'd)

County and unit	Growing stock	Sawtimber
	Million cubic feet	*Million board feet* [a]
Mercer	7.7	15.8
Montgomery	13.7	32.0
Nicholas	10.7	22.3
Oldham	11.2	24.8
Owen	48.5	114.1
Pendleton	19.7	37.6
Robertson	7.0	13.7
Scott	13.5	29.3
Shelby	18.1	38.0
Spencer	10.7	21.8
Trimble	18.8	41.0
Washington	17.1	39.8
Woodford	5.6	12.1
Bluegrass	581.1	1,280.2
Adair	112.6	280.7
Breckenridge	149.0	370.7
Bullitt	106.1	266.0
Casey	167.4	426.6
Clinton	66.5	166.3
Cumberland	138.1	346.7
Grayson	142.0	351.1
Green	63.3	161.0
Hancock	64.5	159.2
Hardin	133.2	331.1
Hart	107.5	264.7
Larue	63.9	161.5
Marion	70.7	173.6
Meade	79.0	194.6
Metcalfe	91.1	232.6
Nelson	97.6	242.2
Pulaski	190.0	465.9
Russell	68.7	172.9
Taylor	63.4	160.1
Wayne	195.7	485.7
Pennyroyal Unit	2,170.3	5,413.2
Allen	107.1	266.7
Barren	71.5	175.1
Butler	162.5	390.8
Caldwell	87.6	203.6
Christian	188.3	455.1
Crittenden	92.2	216.9
Daviess	48.4	114.3
Edmonson	73.2	177.7
Henderson	50.1	116.1
Hopkins	153.2	368.0
Logan	134.6	332.3
McLean	38.1	90.4
Monroe	102.1	246.7
Muhlenberg	131.1	308.4
Ohio	204.4	487.9
Simpson	25.8	63.8
Todd	81.2	192.9
Union	35.1	84.0
Warren	93.3	224.5
Webster	57.8	138.1
Western Coalfield Unit	1,937.6	4,653.3

CONTINUED

Table 8.— (Cont'd)

County and unit	Growing stock	Sawtimber
	Million cubic feet	*Million board feet* [a]
Ballard	46.5	109.8
Calloway	95.1	230.6
Carlisle	34.9	81.4
Fulton	31.1	78.4
Graves	78.6	180.4
Hickman	43.7	111.2
Livingston	99.5	243.0
Lyon	103.5	246.9
McCracken	38.3	92.5
Marshall	71.3	168.2
Trigg	178.4	433.2
Western Unit	820.9	1,975.6
State total	11,443.7	27,551.9

[a] International 1/4-inch rule.

Table 9.—Average annual net growth and removals of growing stock and sawtimber on commercial forest land in Kentucky, by geographic units, 1962-74

Geographic units	Growing stock		Sawtimber	
	Average annual net growth	Average annual removals	Average annual net growth	Average annual removals
	Thousand cubic feet		*Thousand board feet* [a]	
Eastern Unit	47,501	14,450	127,310	43,761
Northern Cumberland Unit	50,055	23,426	119,551	70,557
Southern Cumberland Unit	49,675	21,189	115,905	62,998
Bluegrass Unit	21,911	4,781	58,403	15,181
Pennyroyal Unit	65,359	30,341	208,331	95,347
Western Coalfield Unit	62,554	31,612	191,247	99,942
Western Unit	22,295	13,776	73,670	38,715
State total	319,350	139,575	894,417	426,501

[a] International 1/4-inch rule.

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CHANGE IN SOMATIC GROWTH RATES OF *MICROTUS PENNSYLVANICUS* AS A RESULT OF CROSS-FOSTERING WITH *PEROMYSCUS LEUCOPUS*

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Abstract.—A litter of five meadow voles (*Microtus pennsylvanicus*) was cross-fostered on a white-footed mouse (*Peromyscus leucopus*). All *Microtus* pups survived through weaning. Daily weight gain was 0.30 gm before weaning and 0.96 gm after weaning. When weaned, the *Microtus* pups were approximately 1/3 normal size for that stage of development. The timing of post-natal physiological events was not affected by cross-fostering.

KEYWORDS: *Microtus, Peromyscus,* cross-fostering, somatic growth, physiological growth.

This note documents the effects of cross-fostering five *Microtus pennsylvanicus* pups on a *Peromyscus leucopus* adult.

Cross-fostering is a technique commonly used to explore the imprinting effect of early experience on later behavior *(Lagerspetz and Wuorinen 1965; Denenberg et al. 1966; Southwick 1968; Hudgens et al. 1968)*, but the technique has not been used to explore the physiological effects of such cross-fostering. Merchant and Sharman *(1966)*, however, suggested that growth rates may be altered in a species cross-fostered on another.

With the exception of that study and another by Quadagno and Banks *(1970)*, successful cross-fostering has been reported only among highly inbred strains of rats and mice. Blus and Johnson *(1969)* reported a *Blarina brevicauda* adult suckling a *Mus musculus;* however, the mouse died within 1 week.

The Study

The haying of a small field in Branford, Connecticut, on 7 July 1972 exposed a nest containing five newborn meadow voles, *Microtus pennsylvanicus.* The biological dam was not seen and did not return to the nest during the next 2 hours. When found, the *Microtus* pups were resting. Two hours later they were noticeably restless.

Meanwhile, moments before the *Microtus* nest was found, a white-footed mouse *(Peromyscus leucopus)* had completed parturition in

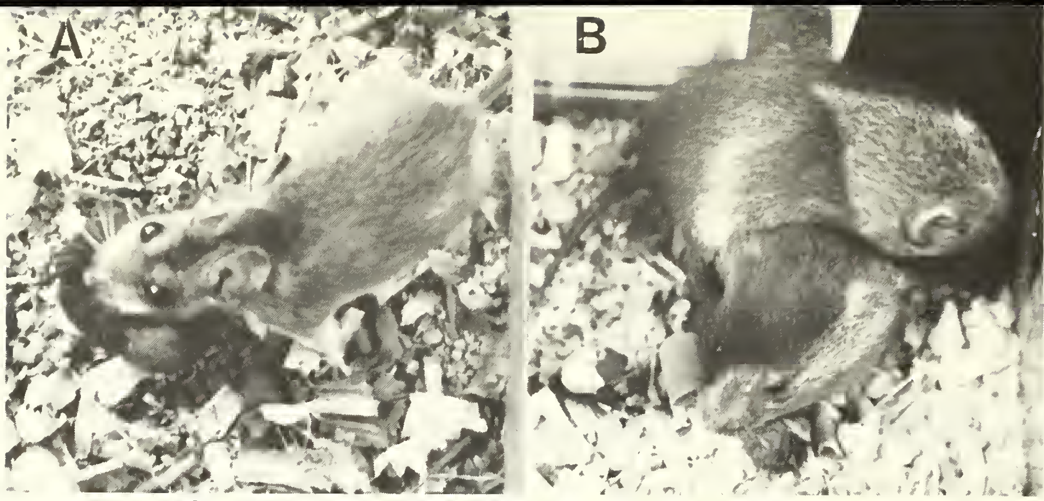


Figure 1.—*A,* (left), foster dam carrying young *Microtus* pup to nest. This photograph was taken about 4 days after the nest had been found. The *Microtus* pups were removed from the nest for photographing and were then returned to the nest by the *P. leucopus* dam. *B,* (right), two of the *Microtus* pups after weaning.

our field laboratory. This *P. leucopus*, born in captivity on 22 February 1972 to wild field-collected parents, presented an opportunity to cross-foster the *Microtus* pups with a different wild species. The *P. leucopus* litter of two was transferred to a second lactating female of the same species.

Until this occasion, all our attempts to cross-foster young came as a result of dam mortality and involved only intraspecies transfers. Our success at intraspecies cross-fostering (all attempts) has been about 50 percent. "Success" is defined as the number of young that survive through weaning and continue to show a steady increase in body weight.

In this interspecific experiment, a clean 10-gallon aquarium (floor space 180 square inches) was prepared by covering the floor to a depth of 2 inches with kitty litter, which was then covered with 2 inches of cedar shavings. A single 100-milliliter water bottle with a glass sipper tube was suspended in one corner, and the aquarium was covered with a 1/8-inch mesh hardware cloth lid.

The *Microtus* nest had been taken carefully from the field, and the young were removed bxfore the nest was placed in the cage. The *Microtus* pups were transferred with forceps into a small cotton nest where they were held temporarily until the adult *P. leucopus* foster dam had been placed in the cage.

As soon as the white-footed mouse dam was placed in the cage, she examined the *Microtus* nest by thoroughly sniffing and exploring in and around it. In the hope that the foster dam would rear the *Microtus* pups, I placed them singly on the floor of the cage at about 2-minute intervals. Without hesitation, the foster dam picked up each pup in her mouth (fig. 1) and carried it to the nest, remaining with it and examining it until another was placed on the floor of the cage. Shortly after the fifth and final *Microtus* pup was carried to the nest, the foster dam made herself available so that the young could nurse.

Weights were not taken before the pups were placed in the aquarium. However, judging from my previous experience in weighing several litters of that size, I estimated that they weighed about 2.5 to 3 grams each.

Results

The only difficulty encountered in cross-fostering this *Microtus* litter was the initial attachment of the young to the teats. The foster dam assumed a dorsum-up position, and the young burrowed beneath her to attach themselves to the teats. Because the foster dam had just given birth, her teats were not enlarged from suckling, and it appeared that the *Microtus* pups did not at first associate them with the larger teats of their biological dam.

Three hours later, the pups were all nursing, but would easily fall off the teats when the female mouse was disturbed. My first thought was that the tendency of the young to cling to the teats might vary between these species. However, by the following morning, the young voles had obviously improved their grip because they were able to remain attached when the foster dam changed her position within the nest. I noticed that the foster dam had consumed a normal amount of water and solid mouse chow during the night, indicating that she had left the voles at least once and had returned to them.

Seven days after the nest had been found, the weights of the *Microtus* pups were individually recorded on a top-loading analytical balance. The initial weights ranged from 4.83 to 5.96 grams. Weights taken on five other occasions are shown in table 1, along with standard deviations that demonstrate the small range of variation between individuals.

The physiological development of each individual in the litter was checked daily. On 17 July (sixth day in captivity), the first pup opened its eyes. On the following day, all the pups had their eyes open and were wandering from the nest, sometimes stopping to nibble on solid food (mouse chow). On 21 July, the pups demonstrated their independence of the foster dam and could be classified as weaned *(King et al. 1963; Layne 1968)*. This observation agrees with the 11- to 12-day weaning time reported by Hamilton *(1937)*; however, the mean weight I recorded at weaning was 6.35 grams, which is considerably less than the 14-gram weight recorded by Hamilton.

The pups remained with the foster dam for an additional 3 days. During this period, she permitted them to nurse occasionally, which provided a valuable nutritional supplement to their diet, as evidenced by their rapid rate of weight gain (fig. 2). The voles gained an average of 1.5 grams per 24 hours.

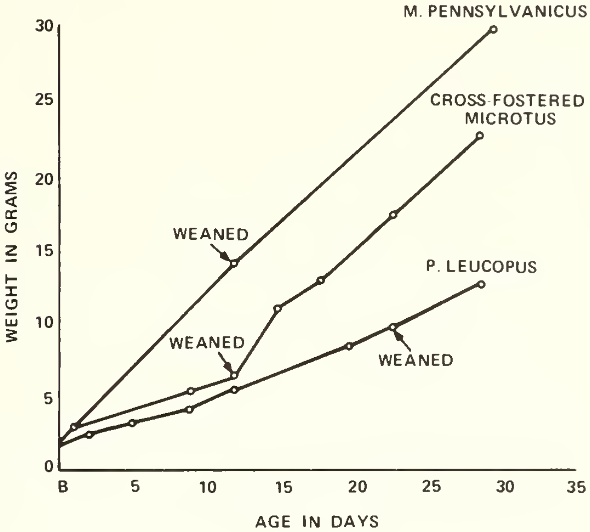
Table 1.—*Mean weight of cross-fostered* M. pennsylvanicus litter during period of observation.

Date	Age	Mean weight	S.D.
	Days	*Gm.*	
11 July	2 [a]	3.00 [b]	--
18 July	9	5.35	0.45
21 July	12	6.36	.49
24 July	15	10.87	.74
27 July	18	12.77	1.40
1 August	23	17.73	2.33
7 August	29	22.69	3.34

[a] Assumed age when found.

[b] Visual estimate.

Figure 2.—Growth rate of the cross-fostered *Microtus* litter compared to the growth rate of a litter of *P. leucopus* and a growth rate for *M. pennsylvanicus* as indicated by Hamilton *(1937)*.



The average rate of growth through weaning was 0.30 gram per 24 hours or about one-third of that recorded by Hamilton *(1937)* for the species. However, this is nearly identical to the 0.31-gram-per-24-hour growth rate demonstrated by the *P. leucopus* litter at 12 days of age (fig. 2).

Discussion

I can only speculate as to whether quantity or quality of the foster dam's milk was responsible for the low mean weight at weaning. It seems reasonable to assume, because of the size differential between the adult females of the two species, that quantity was the primary cause for the low daily weight gain. Hamilton *(1937)* reported an average weight of about 39 grams for a sample of 58 sexually mature *M. pennsylvanicus* females captured in July, which is 1.77 times heavier than the average adult *P. leucopus* female caught near our field station in July 1972. Because all the *Microtus* pups survived, the foster dam obviously provided milk in excess of their minimal requirements for subsistence, but simply did not have the capability of producing the necessary volume for the *Microtus* pups to reach normal weights at these ages. Furthermore, there is no apparent numerical difference in the mean litter size between these species.

Aside from the altered growth rate, three points are noteworthy:

First, the *P. leucopus* dam accepted all the *Microtus* pups, and each survived through weaning. Quadagno and Banks *(1970)* were the only researchers to report success percentages of cross-fostering among small mammal species. They reported that *Mus* dams accepted foster *Baiomys* pups 36.2 percent of the time, whereas *Baiomys* dams accepted *Mus* pups only 24.6 percent of the time; survival through weaning was 83 percent and 96 percent, respectively.

Second, within certain species (in this case, *M. pennsylvanicus)* the regulatory controls over physiological growth and somatic growth (size and weight) seem to function independently. Merchant and Sharman's *(1966)* work demonstrating the separateness of the two kinds of growth in marsupials is easily understandable because of the small body size and yet high degree of physiological competence of newborn marsupials and early pouch young. Moreover, in that instance a young of a smaller species was fostered on the female of a larger species, and this situation would not be expected to present a less-than-adequate environment for the young's survival.

My results, on the other hand, document the reverse case in placental animals: that is, the young of a large species were fostered on a female of a smaller species. One might expect that this would result in the death of the young due to an inadequate supply of milk, and indeed the weight gain before weaning was reduced to about one-third of normal groth. However, the post-natal physiological events of the cross-fostered *Microtus* pups agreed with the schedule indicated for that species by Hamilton *(1937)*.

Clearly, the genetic programs for physiological progress and somatic growth can be separated and followed independently in these placental mammals. There are in the literature other examples of this decoupling that are not concerned with fostering and so support my contention from a different point of view *(Weir and Rowlands 1973)*.

Third, it is also interesting to note the apparent difference in quantity between the amount of dam milk required for subsistence and that normally provided by *Microtus* mothers. It would at first seem reasonable to expect that natural selection would have brought this range in milk quantities closer together. However, there would also be a clear adaptive value to a situation in which young are able to withstand long and even continuous periods of deprivation of resources, such as when the dam is absent or is unable to provide (for nutritional or other reasons) the usual quantity of milk.

Somatic growth, on the other hand, can generally be recouped at a later time. Indeed, once weaned, the *Microtus* pups in this experiment equalled the recorded daily weight gain for the species, including the 3-day period when solid food was supplemented with *P. leucopus* milk. The average weight gain was 0.96 gram per 24 hours. The alteration in their somatic growth was therefore only a temporary interruption.

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RIDGE: A COMPUTER PROGRAM FOR CALCULATING RIDGE REGRESSION ESTIMATES

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Abstract:—Least-squares coefficients for multiple-regression models may be unstable when the independent variables are highly correlated. Ridge regression is a biased estimation procedure that produces stable estimates of the coefficients. Ridge regression is discussed, and a computer program for calculating the ridge coefficients is presented.

KEYWORDS: Regression, computer program, correlated variables.

Multiple-regression models are widely used in forestry. In some studies, the independent variables are highly correlated. In this case the least-squares coefficients may be too large in absolute value, and the signs may reverse with small changes in the data. With highly correlated data, one should consider estimation methods that reduce the effects of the correlation and produce stable regression coefficients *(Marquardt and Snee 1975).*

The purpose of this note is to discuss ridge-regression methods and present a computer program for ridge regression. A list of references is also given.

Ridge Regression

The observational equations for a multiple-regression model can be written as

$$\underset{\sim}{Y}=\underset{\sim}{X}\underset{\sim}{\beta}+\underset{\sim}{\epsilon}$$

in which $\underset{\sim}{Y}$ is the nxl vector of observations, $\underset{\sim}{X}$ is the nxp matrix of independent variables, $\underset{\sim}{\beta}$ is a pxl vector of parameters unknown, and $\underset{\sim}{\epsilon}$ is the nxl vector of errors. It is assumed that $E(\underset{\sim}{\epsilon})=\underset{\sim}{0}$ and $E(\underset{\sim}{\epsilon}'\underset{\sim}{\epsilon})=\delta^2\underset{\sim}{I}$.

The least-squares estimate of $\underset{\sim}{\beta}$ is

$$\hat{\underset{\sim}{\beta}}=(\underset{\sim}{X}'\underset{\sim}{X})^{-1}\underset{\sim}{X}'\underset{\sim}{Y}. \qquad [1]$$

For convenience, we assume that $\underset{\sim}{X}'\underset{\sim}{X}$ and $\underset{\sim}{X}'\underset{\sim}{Y}$ are in the correlation form. Methods of scaling $\underset{\sim}{X}'\underset{\sim}{X}$ and $\underset{\sim}{X}'\underset{\sim}{Y}$ to the correlation form are discussed by Draper and Smith *(1966, p. 147)*. It is well known that $\hat{\beta}$ is the best linear unbiased estimate of $\underset{\sim}{\beta}$. However, when the predictor variables are highly correlated, the average distance of $\hat{\underset{\sim}{\beta}}$ to $\underset{\sim}{\beta}$ is large. In particular, $E[(\hat{\underset{\sim}{\beta}}-\underset{\sim}{\beta})'(\hat{\underset{\sim}{\beta}}-\underset{\sim}{\beta})]$ is large.

Hoerl and Kennard *(1970a)* suggested that the estimator

$$\hat{\underset{\sim}{\beta}}^* = (\underset{\sim}{X}'\underset{\sim}{X}+k\underset{\sim}{I})^{-1}\underset{\sim}{X}'\underset{\sim}{Y};\ k \geq 0 \qquad [2]$$

be used when the independent variables are highly correlated. The estimate $\hat{\underset{\sim}{\beta}}^*$ is called the ridge estimator. If $\underset{\sim}{\beta}'\underset{\sim}{\beta}$ is bounded, there exists a value of $k>0$ such that $E[(\hat{\underset{\sim}{\beta}}^*-\underset{\sim}{\beta})'(\hat{\underset{\sim}{\beta}}^*-\underset{\sim}{\beta})] < E[(\hat{\underset{\sim}{\beta}}-\underset{\sim}{\beta})'(\hat{\underset{\sim}{\beta}}-\underset{\sim}{\beta})]$. The ridge estimator has the property that, as k increases, the variance of $\hat{\underset{\sim}{\beta}}^*$ decreases, but the bias increases. The best regression estimates of $\hat{\underset{\sim}{\beta}}^*$ are those that are stable and have a small mean-square error.

To calculate the ridge estimator $\hat{\underset{\sim}{\beta}}^*$ from equation [2], one would have to invert the pxp matrix, $(\underset{\sim}{X}'\underset{\sim}{X}+k\underset{\sim}{I})$, for each value of k. This sequence of matrix inversions could be time-consuming even with a high-speed computer. The ridge estimator can be expressed in a form that may be better for computing purposes.

We know from matrix theory that, because $\underset{\sim}{X}'\underset{\sim}{X}$ is symmetric, there exists an orthogonal matrix $\underset{\sim}{A}$ and a diagonal matrix $\underset{\sim}{D}$ such that $\underset{\sim}{A}'\underset{\sim}{X}'\underset{\sim}{X}\underset{\sim}{A}=\underset{\sim}{D}$ and $\underset{\sim}{A}'\underset{\sim}{A}=\underset{\sim}{I}$. The matrix $\underset{\sim}{A}$ is the matrix of eigenvectors of $\underset{\sim}{X}'\underset{\sim}{X}$, and the matrix $\underset{\sim}{D}$ is the diagonal matrix of eigenvalues of $\underset{\sim}{X}'\underset{\sim}{X}$. Adding $k\underset{\sim}{I}$ to both sides of $\underset{\sim}{A}'\underset{\sim}{X}'\underset{\sim}{X}\underset{\sim}{A}=\underset{\sim}{D}$ gives

$$\underset{\sim}{A}'\underset{\sim}{X}'\underset{\sim}{X}\underset{\sim}{A}+k\underset{\sim}{I}=\underset{\sim}{D}+k\underset{\sim}{I}. \qquad [3]$$

Multiplying the second term on the left-hand side of equation [3] by $\underset{\sim}{A}'\underset{\sim}{A}$, gives

$$\underset{\sim}{A}'\underset{\sim}{X}'\underset{\sim}{X}\underset{\sim}{A}+k\underset{\sim}{A}'\underset{\sim}{I}\underset{\sim}{A}=\underset{\sim}{D}+k\underset{\sim}{I}, \qquad [4]$$

which can be written as

$$\underset{\sim}{A}'(\underset{\sim}{X}'\underset{\sim}{X}+k\underset{\sim}{I})\underset{\sim}{A}=\underset{\sim}{D}+k\underset{\sim}{I}. \qquad [5]$$

Premultiplying both sides of equation [5] by $(A')^{-1}$ and postmultiplying by A^{-1} gives

$$\underset{\sim}{X}'\underset{\sim}{X}+k\underset{\sim}{I}=(\underset{\sim}{A}')^{-1}(\underset{\sim}{D}+k\underset{\sim}{I})\underset{\sim}{A}^{-1}. \qquad [6]$$

Taking the inverse of both sides yields

$$(\underset{\sim}{X}'\underset{\sim}{X}+k\underset{\sim}{I})^{-1}=\underset{\sim}{A}(\underset{\sim}{D}+k\underset{\sim}{I})^{-1}\underset{\sim}{A}'. \qquad [7]$$

Substituting the results of equation [7] in equation [2], we find that the ridge estimator can be written

$$\hat{\underset{\sim}{\beta}}^*=\underset{\sim}{A}(\underset{\sim}{D}+k\underset{\sim}{I})^{-1}\underset{\sim}{A}'\underset{\sim}{X}'\underset{\sim}{Y}. \qquad [8]$$

This form of the ridge estimator may be efficient for computing in problems with a large number of independent variables. The matrix $(\underset{\sim}{D}+k\underset{\sim}{I})$ is diagonal, and the elements of the inverse are the reciprocals of the diagonal elements. The matrix of eigenvectors $\underset{\sim}{A}$ and the matrix of eigenvalues $\underset{\sim}{D}$ need to be calculated only once. However, the algorithm for computing the eigenvalues is iterative, and the solution may occasionally take more time than calculating the inverses of $(\underset{\sim}{X}'\underset{\sim}{X}+k\underset{\sim}{I})$.

The estimates of the ridge coefficients at $k=0$ are the least squares estimates. If the least squares regression is significant, then different values of k should be explored.

The ridge trace, which is a plot of the ridge coefficients for different values of k, is an important part of ridge regression. The sums of squares of residuals should also be plotted. The ridge trace is examined for trends of the ridge coefficients as k is changed. The best estimates of the ridge coefficients are those where the trace shows that the coefficients have stabilized and the sums of squares of residuals is still small *(Marquardt and Snee 1975)*.

Hoerl and Kennard *(1970b)* discuss the use of the ridge trace to eliminate variables with the least predicting power. Thus, ridge regression can be used as a guide for selecting the best subset of variables; that is, ridge regression is an alternative for stepwise regression.

Program Ridge

Program RIDGE is written in ASA Fortran IV for the IBM 370/168 computer. Information needed for the control cards is listed in the appendix. A variable format statement is used to input the data. The dependent variable is positioned by the program, hence special arrangement of the data is not necessary. A maximum of 19 independent variables is allowed for program RIDGE. This capacity may be increased by changing the dimension statements. Nineteen values of k from 0 to 1.0 are automatically supplied by the program. Other values of k may be designated by the user.

The means and variances of the variables are printed by program RIDGE. The $\underset{\sim}{X}'\underset{\sim}{X}$ and $\underset{\sim}{X}'\underset{\sim}{Y}$ matrices are transformed into the correlation form and printed.

The eigenvalues and corresponding matrix of eigenvectors for the $\underset{\sim}{X}'\underset{\sim}{X}$ matrix are calculated. The presence of one or more zero eigenvalues indicates linear dependencies between the independent variables. If this condition exists, $\underset{\sim}{X}'\underset{\sim}{X}$ is singular for $k=0$, and the program terminates with an error message. If no linear dependencies are present, an analysis of variance table is printed.

Standardized and actual regression coefficients are printed for the different values of k. The ridge trace can be plotted by the user from the standardized coefficients. However, we found that in most cases the tabled values of standardized coefficients provide sufficient information for selecting the appropriate ridge solution.

The computer program is available from the Biometrics Group, Northeastern Forest Experiment Station.

An Example of Ridge Regression

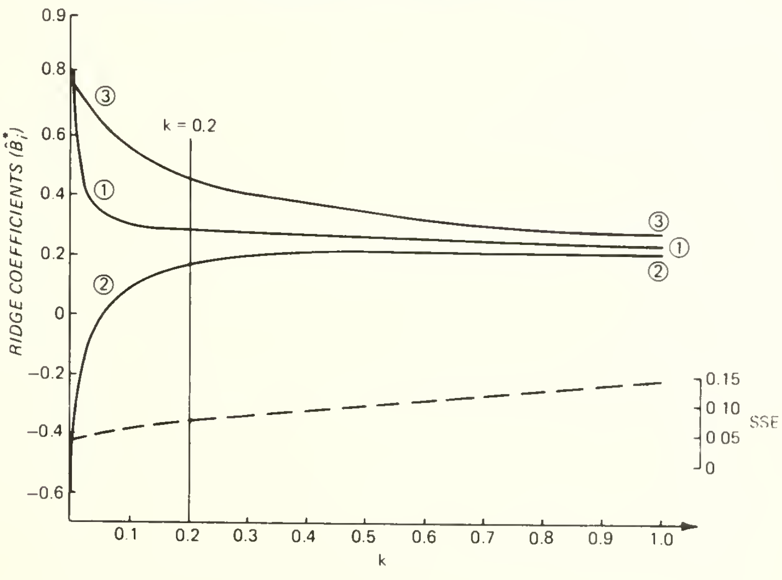
Suppose we have 10 sample observations for 3 independent variables and 1 dependent variable (table 1). Computer output from program RIDGE for this example is given in the appendix. Investigation of the correlation matrix reveals high correlations between the predictor variables; and one of the eigenvalues, 0.0138, is small. These conditions suggest that ridge regression be used to estimate the regression coefficients. Since the F ratio for the least-squares solution is highly significant, ridge-regression coefficients and the residual sums of squares were calculated for 19 values of k.

The ridge trace was constructed by plotting

Table 1.—*Data for sample problem*

Y	X_1	X_2	X_3
223	11	11	11
223	14	15	11
292	17	18	20
270	17	17	18
285	18	19	18
304	18	18	19
311	19	18	20
314	20	21	21
328	23	24	25
340	25	25	24

Figure 1.—Ridge trace for 19 values of k.



the standardized regression coefficients against values of k (fig. 1). The trace suggests that the least-squares coefficients are too large in absolute value, $\hat{\beta}_2$ even having the wrong sign. At k=0.2 the coefficients have stabilized, and the residual sums of squares (SSE) has not substantially increased.

The ridge regression

$$\hat{Y}^* = 132.5 + 2.870(X1) + 1.650(X2) + 3.934(X3)$$

should be a better predicting equation than the least-squares equation even though the coefficients are biased.

Summary

Ridge regression is a statistical technique that foresters should find useful. It is used to estimate coefficients for multiple-regression models when the independent variables are highly correlated.

Considerable research has been done on ridge regression. The paper by Hoerl and Kennard *(1970a)* introduced ridge-regression theory. Although there is considerable matrix algebra in this paper, it provides a sound background for the understanding and application of ridge regression. The subsequent paper by Hoerl and Kennard *(1970b)* illustrates the applications of ridge regression, including its use as a guide to variable selection. The article by Marquardt and Snee *(1975)* is perhaps the most readable paper on ridge regression. All aspects of ridge regression are discussed at length, and many examples are included. Some of the other articles listed are more mathematically sophisticated.

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Manuscript Received For Publication 6 October 1976

APPENDIX

```
      PROGRAM RIDGE REGRESSION


CXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXC
C                                                                              C
C                                                                              C
C     PROGRAM CONTROL INFORMATION:                                             C
C                                                                              C
C     PROGRAM CONTROL CARDS MUST BE THE FIRST CARDS IN THE DATA DECK.          C
C                                                                              C
C          CARD 1 (REQUIRED): PROBLEM TITLE,UP TO 80 CHARACTERS LONG.          C
C                             A BLANK CARD MAY BE SUBMITTED IF NO              C
C                             PROBLEM TITLE IS DESIRED.                        C
C                                                                              C
C          CARD 2 (REQUIRED): SPECIFY N,M,PY,D,AND V. FORMAT IS 5I5,           C
C                             RIGHT JUSTIFIED.                                 C
C                                                                              C
C                             N = NUMBER OF OBSERVATIONS.                      C
C                             M = NUMBER OF VARIABLES,INCLUDING Y.             C
C                                 MAXIMUM OF 19 INDEPENDENT VARIABLES.         C
C                             PY = POSITION OF THE DEPENDENT VARIABLE          C
C                                  IN THE DATA. THE PROGRAM WILL MAKE          C
C                                  THE DEPENDENT VARIABLE THE LAST             C
C                                  VARIABLE.                                   C
C                             D = NUMBER OF INCREMENTS (K'S) FOR THE           C
C                                 X-PRIME-X MATRIX, IF INCREMENTS ARE          C
C                                 TO BE USER-SUPPLIED. MAXIMUM OF 18           C
C                                 K'S MAY BE SPECIFIED. INCREMENTS             C
C                                 WILL BE PROGRAM-SUPPLIED IF LEFT             C
C                                 BLANK. K = 0.0 IS ALWAYS SUPPLIED            C
C                                 BY THE PROGRAM, AND SHOULD NOT BE            C
C                                 SPECIFIED BY THE USER. CARD 5                C
C                                 REQUIRED IF D IS NOT BLANK.                  C
C                             V = 1 IF VARIABLE NAMES ARE TO BE                C
C                                 SPECIFIED BY THE USER. LEAVE BLANK           C
C                                 OTHERWISE. CARD 4 REQUIRED IF V IS           C
C                                 NOT BLANK.                                   C
C                                                                              C
C          CARD 3 (REQUIRED): VARIABLE FORMAT FOR DATA, ENCLOSED IN            C
C                             PARENTHESES.                                     C
C                                                                              C
C          CARD 4 (OPTIONAL): VARIABLE NAMES. FORMAT IS MA8, LEFT              C
C                             JUSTIFIED. BLANKS MUST BE LEFT FOR THOSE         C
C                             VARIABLES WITH NO NAMES IF THIS OPTION           C
C                             IS IN EFFECT. MORE THAN ONE CARD IF              C
C                             NECESSARY.                                       C
C                                                                              C
C          CARD 5 (OPTIONAL): VALUES OF INCREMENTS,K,TO BE ADDED TO            C
C                             THE X-PRIME-X MATRIX. FORMAT IS DF5.0.           C
C                             VALUES SHOULD HAVE DECIMAL POINTS.               C
C                             MORE THAN ONE CARD IF NECESSARY.                 C
C                                                                              C
C                                                                              C
CXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXC
```

RIDGE REGRESSION
NORTHEASTERN FOREST EXPERIMENT STATION
UPPER DARBY, PA.
JUNE 4, 1976

VARIABLE NO.	NAME	MEAN	VARIANCE
1	X1	0.18200E+02	0.16178E+02
2	X2	0.18600E+02	0.16711E+02
3	X3	0.18700E+02	0.21789E+02
4	Y	0.28900E+03	0.16171E+04

CORRELATION MATRIX R

VARIABLE NO.	NAME				
1	X1	1.0000			
2	X2	0.9853	1.0000		
3	X3	0.9386	0.9247	1.0000	
4	Y	0.9384	0.9064	0.9725	1.0000

EIGENVALUES OF X-PRIME-X

VARIABLE NO.	NAME	
1	X1	2.8993
2	X2	0.0869
3	X3	0.0138

MATRIX OF EIGENVECTORS OF X-PRIME-X

0.5824	-0.3219	-0.7465
0.5796	-0.4795	0.6589
0.5700	0.8164	0.0927

ANALYSIS OF VARIANCE TABLE FOR
LEAST SQUARES SOLUTION (K=0.0)

SOURCE	DF	SUMS OF SQUARES	MSE	F
TOTAL	9	0.14554E+05		
REGRESSION	3	0.14008E+05	0.46694E+04	0.51332E+02
RESIDUAL	6	0.54579E+03	0.90965E+02	

RIDGE TRACE FOR STANDARDIZED REGRESSION COEFFICIENTS

VARIABLE NAME	VALUE OF K 0.0 0.250 0.800	0.020 0.300 0.900	0.040 0.350 1.000	0.060 0.400	0.080 0.450	0.100 0.500	0.150 0.600	0.200 0.700
B 1 X1	0.82425E+00 0.28309E+00 0.24724E+00	0.44130E+00 0.27955E+00 0.24129E+00	0.35900E+00 0.27616E+00 0.23556E+00	0.32723E+00 0.27283E+00	0.31181E+00 0.26952E+00	0.30315E+00 0.26623E+00	0.29252E+00 0.25974E+00	0.28709E+00 0.25340E+00
B 2 X2	-.61820E+00 0.18481E+00 0.21313E+00	-.19054E+00 0.19591E+00 0.21074E+00	-.57015E-01 0.20331E+00 0.20787E+00	0.13927E-01 0.20826E+00	0.59237E-01 0.21151E+00	0.90985E-01 0.21355E+00	0.14012E+00 0.21520E+00	0.16773E+00 0.21478E+00
B 3 X3	0.77053E+00 0.42875E+00 0.30189E+00	0.71965E+00 0.40692E+00 0.29011E+00	0.66185E+00 0.38914E+00 0.27961E+00	0.61559E+00 0.37421E+00	0.57879E+00 0.36137E+00	0.54897E+00 0.35013E+00	0.49428E+00 0.33110E+00	0.45665E+00 0.31535E+00
SSE	0.038 0.075 0.123	0.043 0.080 0.132	0.048 0.084 0.142	0.052 0.088	0.056 0.092	0.059 0.097	0.065 0.105	0.071 0.114

ACTUAL BETAS CORRESPONDING TO STANDARDIZED COEFFICIENTS

VARIABLE NAME	VALUE OF K 0.0 0.250 0.800	0.020 0.300 0.900	0.040 0.350 1.000	0.060 0.400	0.080 0.450	0.100 0.500	0.150 0.600	0.200 0.700
B 0	0.12800E+03 0.13460E+03 0.15638E+03	0.12754E+03 0.13673E+03 0.15980E+03	0.12749E+03 0.13886E+03 0.16306E+03	0.12774E+03 0.14097E+03	0.12818E+03 0.14304E+03	0.12875E+03 0.14508E+03	0.13051E+03 0.14902E+03	0.13250E+03 0.15279E+03
B 1 X1	0.82408E+01 0.28303E+01 0.24719E+01	0.44171E+01 0.27949E+01 0.24124E+01	0.35892E+01 0.27610E+01 0.23551E+01	0.32717E+01 0.27277E+01	0.31175E+01 0.26946E+01	0.30309E+01 0.26617E+01	0.29246E+01 0.25968E+01	0.28703E+01 0.25334E+01
B 2 X2	-.60813E+01 0.18180E+01 0.20966E+01	-.18743E+01 0.19272E+01 0.20730E+01	-.56086E+00 0.20000E+01 0.20449E+01	0.13700E+00 0.20486E+01	0.58272E+00 0.20806E+01	0.89502E+00 0.21007E+01	0.13784E+01 0.21169E+01	0.16500E+01 0.21128E+01
B 3 X3	0.66381E+01 0.36937E+01 0.26008E+01	0.61998E+01 0.35056E+01 0.24992E+01	0.57016E+01 0.33524E+01 0.24088E+01	0.53032E+01 0.32238E+01	0.49863E+01 0.31132E+01	0.47293E+01 0.30163E+01	0.42582E+01 0.28524E+01	0.39340E+01 0.27167E+01

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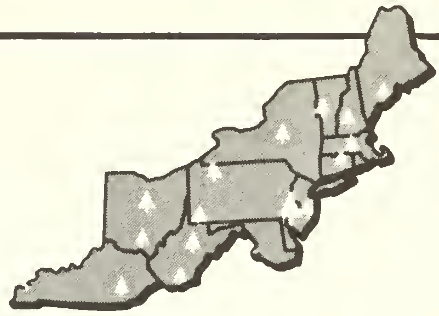
Northeastern Forest Experiment Station



FOREST SERVICE, U.S. DEPT. OF AGRICULTURE, 6816 MARKET STREET, UPPER DARBY, PA. 19082

WAGE DIFFERENTIALS AMONG APPALACHIAN SAWMILLS

by **CHARLES H. WOLF**
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Princeton, W. Va.

Abstract.—Wage differences among Appalachian sawmills were investigated, using multiple-regression analysis. Wages and fringe benefits were found to vary with type of product sawed, education of the work force, distance to urban areas, general wage levels, and use of collective-bargaining agreements between management and labor.

KEYWORDS: wages, wage differentials, fringe benefits, sawmill labor.

Different plants in the same industry and region often pay strikingly different wage rates. In the Appalachian sawmill industry, I found that the average wage for production workers in high-wage sawmills was a dollar per hour more than the average in low-wage mills. The number of paid holidays and vacation days provided by employers varied even more. Two-fifths of the mills in my survey did not grant any holidays or vacation time. In contrast, some employers provided as many as 14 days off with pay.

Recent studies by the Bureau of Labor Statistics showed that variation in plant wage levels is associated with several factors *(Schwenk 1974, Schwenk and Personick 1974)*. These include unionization, plant and city size, value added per man-hour, product type, and geographic location. An investigation of interregional wage differentials in the wood industries suggests that labor quality and the concentration of timber resources may also be important *(Kaiser 1973)*.

The objective of my study was to document and explain differences in wages and fringe benefits among Appalachian hardwood sawmills. The analysis was based upon data from 54 hardwood sawmills. These mills, selected through stratified cluster sampling, were located in Pennsylvania, Ohio, West Virginia, Kentucky, North Carolina, and Tennessee. All cut more than 1 million board feet of lumber annually and employed at least five nonsupervisory production workers.

Grade lumber was the primary product of half the sample mills. The others produced mine timbers, railroad ties, pallet lumber, and other low-value products. The number of production workers ranged from 5 to 80, with an average of 20 men per mill *(Wolf 1975)*.

Definition of Variables

Dependent variables.—Multiple-regression analysis was used to estimate three equations for predicting a sawmill's average wage, starting wage, and number of paid holidays and vacation days (days off). These variables were defined as follows:

- Average wage: The average straight-time hourly wage paid to full-time nonsupervisory production and maintenance workers.
- Starting wage: The straight-time hourly wage paid to new employees without prior training or work experience in the lumber industry.
- Days off: The total number of employer-paid holidays and vacation days provided to employees with 1 year of company service.

All wage and fringe-benefit data are based on the first payroll in July 1972. During this period, the lowest wage rate that could be paid to any employee was the federal minimum wage of a $1.60 per hour. The sample mills had average wages ranging from $1.71 to $2.81 per hour (table 1). The mean starting wage for all mills was $1.86 per hour—26 cents above the federal minimum.

Independent variables.—Eight independent variables were included in the regression equations. The first variable indicated the major product produced by the sample mill. The next two variables—headsaw type and average employment—were included to represent potential differences in technical efficiency that could affect the wage-paying ability of the plants. The education and timber-resource variables represented the quality of the labor force and the concentration of sawtimber stumpage. The last two variables pertained to the location of the plant and the general wage level in the local labor market.

The independent variables were defined as follows:

- Grade lumber: A dummy variable indicating that a majority of the mill's production was sold as grade lumber to the furniture industry.
- Headsaw type: A dummy variable indicating that the mill had a band headsaw.
- Average employment: Average quarterly employment of nonsupervisory production and maintenance workers measured in units of 10 employees.
- Union: A dummy variable indicating that a majority of the mill's production workers were covered by a labor-management contract.
- Education: The proportion of the mill's production employees who had completed high school.
- MBF per acre: The volume of sawtimber per acre of commercial forest land in the county where the mill was located.
- Distance to city: The distance from the mill to nearest city of 5,000 or larger, measured in units of 10 miles. This particular city size was chosen after examining the correlation coefficients between distance and wages for cities of 5,000, 10,000, and 25,000 population and over. Although all coefficients were statistically significant, the negative relationship between distance and wages was strongest for cities of 5,000 and greater population.
- County wage: Average hourly earnings of all workers employed in the county where the mill was located.

Data on the above variables were obtained from both primary and secondary sources. Sawmill wages and employment were tabulated

Table 1.—Mean, standard deviation, and range in wages and days off for mills in the study sample, July 1972 (N = 54)

Dependent variables	Mean	Standard deviation	High	Low
Average wage	$2.19	$0.26	$2.81	$1.71
Starting wage	$1.86	$0.23	$2.50	$1.60
Days off	4.37	4.61	14	0

from company payroll records. County wage data were obtained from state employment security agencies. The sawtimber volume per acre was taken from forest-resource bulletins compiled for each state by the U.S. Forest Service. Distances from the mills to cities were determined from highway road maps. Data on the remaining variables were obtained in interviews with mill supervisors.

Results and Discussion

The most important explanatory variables in the regression equations were: (1) the major product sawed, (2) the education of the mill's labor force, (3) the distance from the mill to an urban area, and (4) the county wage (table 2). A fifth variable, unionization, was important in determining starting wages and the number of days off, but did not have a significant effect upon the average wage.

As expected, mills oriented toward sawing grade lumber paid better wages and granted more holidays and vacation time than those that cut mostly mine timbers, pallet lumber, and other low-value products. There are at least two possible explanations for this finding. First, it requires more skill and attentiveness to manufacture grade lumber than it does other wood products for which the proper thickness, length, and maximum clear surface are less critical. The higher wages and fringe benefits are likely to reflect these greater demands upon the workers.

A second possible explanation is that higher profit margins exist in the market for grade lumber than in the markets for other sawn products. Therefore, mills cutting grade lumber would be in a better position to compensate their employees.

The proportion of a sawmill's work force that completed high school indicates formal education levels and possibly the motivation and innate abilities of its workers. All other things being equal, sawmills with the greater proportion of high school graduates paid higher wages and were more liberal in granting paid holidays and vacations.

However, labor costs per thousand board feet would not necessarily be higher in mills that paid premium wages and granted extra days off in order to attract and retain a well-educated work force. If education improves labor productivity, unit labor costs in high-wage mills could be equal to or even less than unit labor costs in low-wage mills.

Table 2.—Regression equations for predicting the average wage, starting wage, and number of days off in Appalachian hardwood sawmills

Dependent variables	Constant	Independent variables								Sample size	Adjusted R square
		Grade lumber	Headsaw type	Average employment	Union	Education	MBF/acre	Distance to city	County wage		
Average wage	1.591	0.198** (.058)	−0.016 (.116)	0.008 (.029)	0.056 (.127)	0.719** (.117)	0.013 (.036)	−0.058** (.015)	0.121** (.040)	54	0.519
Starting wage	1.402	.148* (.064)	.096 (.126)	−.051 (.031)	.300* (.137)	.246* (.127)	.016 (.039)	−.039* (.017)	.137** (.043)	54	.281
Days off	4.863	2.897** (1.090)	−1.727 (2.239)	.040 (.556)	9.236** (2.457)	7.905** (2.284)	−1.069 (.686)	−.860** (.298)	—	54	.405

**Significant at the 1-percent level.

*Significant at the 5-percent level. Estimated errors of the estimated regression coefficients are in parentheses.

Wages and fringe benefits in sawmills were also influenced by their proximity to urban areas. As the distance from cities of 5,000 or more people increased, wages and the number of days off declined. The partial regression coefficients showed that the average wage and starting wage declined by 6 and 4 cents per hour respectively for each 10 miles beyond urban areas.

The typical sawmill was 25 miles from the nearest urban area. A few mills were as far away as 70 miles. The lower wage scales in rural mills could reflect a greater supply of labor relative to capital and a willingness of rural people to accept lower wages to avoid commuting long distances to work.

Union mills had starting wages that were 30 cents per hour more than nonunion mills when all variables in the regression equation were considered. They also provided nine more paid holidays than nonunion mills. However, the union effect on the average wage, while positive, was not large enough to be statistically significant.

Why should unionization result in significantly higher starting wages and number of days off but have little effect on average wages? A possible explanation is that employers of union labor are less resistant to union demands for increases in starting wages and days off because these concessions are less costly than general wage increases, and they benefit the firm by making it easier to recruit new employees. Furthermore, because all mills sell in the same product markets, competitive forces would operate against the creation of large differences in overall labor costs between unionized and nonunionized mills.

The final variable that influenced sawmill wages was the general level of wages in the counties where the mills were located. This variable showed that, to attract and retain a sufficient number of workers, sawmills must adjust their pay scales to the prevailing wage level in their local area. Mills in low-wage labor markets have an advantage so far as labor costs are concerned.

Differences in technical efficiency resulting from the type of headsaw and economies of scale, as indicated by the average number of employees, had no appreciable effect on wages or number of days off. There was also no evidence to suggest that the timber resource influenced wages in the Appalachian sawmill industry.

Overall, the predictor variables explained about half of the variation in average wages ($\overline{R}^2 = 0.52$) and somewhat less for starting wages and days off. Log-linear functional forms of the regression equations were estimated but failed to improve the results.

The unexplained variation may be attributed to several factors that were beyond the scope of this study. First, many sawmills are vertically integrated with furniture plants, dimension plants, and pallet manufacturing facilities. Integrated plants may have paid better wages than those that were operated independently. Second, some plants were expanding their employment while others were laying off workers. And third, there were also differences in managerial abilities, capital/labor ratios, and the degree and combination of skills employed.

Related Findings

It has been argued by some mill managers that total weekly earnings are more important to sawmill workers than hourly wage rates. Therefore, wage differences could occur because some workers maximize their weekly paychecks by accepting employment at less than the prevailing wage if given an opportunity to work overtime. An inverse association between wages and overtime would support this argument.

For the sawmills in the sample, overtime per employee had a positive correlation with the average wage ($r = 0.383$). The starting wage and the number of days off also showed statistically significant positive correlations with overtime. Thus the opposite appears to be true. High-wage mills generally provide more overtime work than low-wage mills.

Hourly wage rates are not necessarily true indicators of the relative levels of employee compensation among plants. A low-wage mill may compensate its employees to the same degree as a high-wage mill by offering a greater number of paid holidays and better working conditions. However, this was not the situation in the sample mills. The average hourly wage showed significant positive correlations with days off ($r = 0.389$) and working conditions ($r = 0.223$).

Conclusion

There clearly seems to be a range in the types of plants in the Appalachian sawmill industry. High wages, good working conditions, and liberal fringe benefits characterize some sawmills whereas the opposite extreme is represented by others.

Several key factors associated with this variation were identified. These included: (1) product type, (2) education of the work force, (3) distance to urban areas, (4) local wage levels, and (5) the use of collective-bargaining agreements between management and labor. Wages and fringe benefits for sawmills in other regions of the United States are likely to be influenced by these same factors.

There was no evidence of a relationship between the forest resource (sawtimber volume per acre) and the wages of sawmill workers. This finding differed from that obtained in a study of interregional wage differentials *(Kaiser 1973).* Because of its importance, the association between these two variables should receive further study.

Both the interregional analysis and this study were in agreement about the importance of education as a factor in wage determination in the sawmill industry. A greater investment in education, training, and possibly other forms of human capital should lead to higher earnings for sawmill workers.

Data limitations precluded the use of labor productivity as an explanatory variable and the estimation of wages by occupation. Wage equations by occupation would have permitted a more comprehensive analysis and would have helped to control variation caused by differences in skill mix. It also would have been desirable to have had a single measure of compensation per man-hour that included wage and nonwage benefits such as hospitalization and life insurance, holiday and vacation pay, and employer contributions to pension plans. These considerations should be taken into account in future studies.

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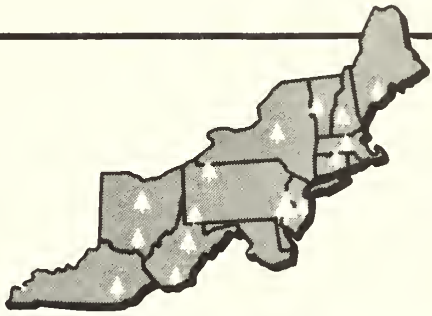

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PERMIT COMPLIANCE IN EASTERN WILDERNESS: PRELIMINARY RESULTS

—VICTOR GODIN and RAYMOND LEONARD*

Abstract.—Sixty-eight percent of the visitors to a wilderness area in the White Mountain National Forest obtained the required travel permits during the summer of 1975. These data appear to follow patterns found in other such studies.

INTRODUCTION

Commencing in June 1975, visitors to the Great Gulf Wilderness and the Dry River Wilderness of the White Mountain National Forest in New Hampshire and Maine were required to obtain and carry with them wilderness travel permits.

The need to institute permit systems such as this arises from the now familiar problems of managing wilderness areas under increasing public use. It is important to the backcountry recreation manager to know how many people are using the areas under his control, in order to manage appropriately the maintenance of and access to these areas.

Self-registration systems have been of some assistance in the estimation of actual wilderness use, but the percent of people registering at unmanned trail registers has been found to be as low as 28 percent *(Lucas 1975)*. As Hendee and Lucas *(1973)* point out: "Although the self-registration systems employed on the national forests provide the best data available on wilderness visitation, many of the estimates of use do not meet even. . .very lenient standards." Hence, the trend has been to introduce mandatory permit systems for wilderness travel.

As might be expected, some backcountry recreationists ignore even the mandatory registration. In order for backcountry managers to estimate *actual* usage of backcountry areas, it is necessary to know the proportion of users complying with the permit system.

THE STUDY

A study was carried out in the summer of 1975 to determine what proportion of backcountry trail users had the required permits. This was the first year of mandatory permits in the

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White Mountain National Forest wilderness areas and, since no fines were imposed on those who did not get their permits before entering the wilderness areas, we did not expect the 90 percent compliance ratios cited by Hendee and Lucas *(1973)* and Lime and Lorence *(1974)*.

The study was carried out in the Dry River Wilderness Region of the White Mountain National Forest. Permits for the use of this area are readily available at several locations.

Throughout the summer of 1975, a trail patrolman (called a ridgerunner) spent a total of 63 days walking the three major trails of the Dry River Wilderness. He spent 56 percent of his time on the Dry River Trail, 29 percent on the Rocky Branch Trail and 16 percent on Davis Path. The first two of these trails are on low-lying, wet terrain; the Davis Path is higher and dryer.

In general, the reaction of the parties to the ridgerunner was favorable. They seemed glad that someone was "caring" for the wilderness.

RESULTS AND DISCUSSION

Table 1 presents the data on compliance gathered by the ridgerunner on each of the three major Dry River Wilderness trails.

Approximately 68 ± 3 percent of all the people using the Dry River Wilderness in the summer of 1975 obtained the required wilderness permits. The ridgerunner stopped and interviewed every group he met along the trail. If a party did not have a permit, one was issued on the trail, and the group was instructed on the proper procedure for getting one in the future and on the potential fine for noncompliance.

Length of Stay

Table 2 shows the expected length of stay of the 48 groups found without permits in the wilderness during July. Of these parties, 83 percent were planning to camp for at least one night. This finding is especially troublesome, because an attempt is being made to regulate overnight use much more carefully than day use because of its potential impact on the area.

Table 2.—Intended length of stay of parties found without permits in the Dry River Wilderness during July 1975.

Length of stay	Percentage
Daytime only	17
1 night	35
2 nights	29
3 nights	15
4 nights	2
5 nights	0
6 nights	2
More than 6 nights	0

Conclusions

Additional studies should be made to determine whether there are any noncompliance patterns among the trail users. The Dry River

Table 1.—Compliance with permit requirements in the Dry River Wilderness, June through October 1975

Item	Trail			Total
	Davis Path	Dry River	Rocky Branch	
Number of people in parties with permits	65	477	163	705
Number of people in all parties	119	655	267	1,041
Percentage with permits	55	73	61	68
Confidence limits at $p < .05$	46-54	70-76	55-67	65-71

Wilderness and the Great Gulf Wilderness areas are rather different with respect to a number of variables (popularity, distance from White Mountain National Forest campgrounds, etc.). There is no reason to believe that their compliance ratios are the same. In future summers, we plan to gather data in the Great Gulf Wilderness.

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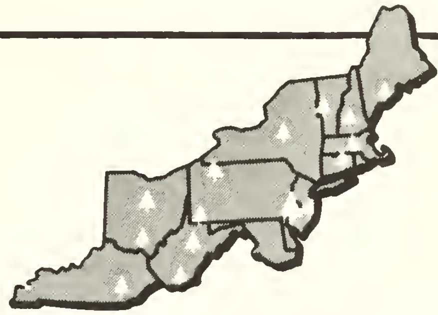

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CHANGES IN TREE DENSITY DO NOT INFLUENCE EPICORMIC BRANCHING OF YELLOW-POPLAR

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Abstract.—Epicormic branching was studied in a West Virginia yellow-poplar stand thinned to various tree density levels. Study trees in the 55- to 60-year-old second-growth stand were primarily codominant in crown class with 32 to 48 feet of log height. Eight-year study results indicated that yellow-poplar trees in this age class and locale could be thinned without serious loss of log quality from epicormic branching.

Epicormic branches often develop on the main boles of many Appalachian hardwood trees. As these epicormic branches develop, knots form and the wood is discolored. Log quality is reduced.

The origin and development of the epicormic branches are well documented *(Kormanik and Brown 1969)*. Several factors are known to stimulate epicormic branching; exposure of the tree bole to light being cited most frequently. Species differ in their production of epicormic branches; the oaks (*Quercus* sp.) and black cherry (*Prunus serotina* Ehrh.) characteristically produce more branches than do white ash (*Fraxinus americana* L.) or yellow-poplar (*Liriodendron tulipifera* L.) *(Smith 1966)*.

Certain hardwood species can be thinned to a residual basal area of about 80 square feet per acre without stimulating epicormic branching *(Hedlund 1964, Huppuch 1961)*. Della-Bianca *(1972)* thinned 30- to 76-year-old yellow-poplars in the southern Appalachians to about 40 square feet of residual basal area per acre with no significant increase in the number of epicormic branches.

This paper reports the results of an 8-year West Virginia study in which yellow-poplar trees were thinned to various density levels.

METHODS

This study was made in a second-growth yellow-poplar stand on the Fernow Experimental Forest near Parsons, West Virginia, growing on an excellent site. The stand was between 55 and 60 years old when thinned.

Data from 631 study trees having 32 to 48 feet of bole height were used in the analyses. The trees ranged in size from 6 to 20 inches in diameter at breast height (dbh), averaging 13 inches dbh, and the sampling was confined largely to codominant trees. Densities were measured around each sample tree with a Spiegel relascope,[1] using 10 and 40 factors. The stand was thinned so that residual basal areas around the study trees ranged from 0 to 160 square feet per acre. We used the density around each tree as the treatment effect because density is correlated with the amount of light that reaches the tree bole.

The following measurements were recorded for each sample tree before or immediately after thinning: dbh; crown dominance class; and density around the tree. The number of epicormic branches was recorded before cutting and at each remeasurement period. Trees were reexamined 2, 5, and 8 years after treatment. Epicormic branches were recorded by 8-foot sections, numbered 1 to 6, with section No. 1 located at the base of the tree and section No. 6 as the half-log between 40 and 48 feet.

Analyses.—The data were analyzed by multivariant regression with 60 dependent variables and 17 independent variables, a technique chosen because the various measurements of the number of epicormic branches on each tree are likely to be correlated. The independent variables were measures of dbh, crown class, and density around the tree. Data were analyzed for 4-section (32-foot), 5-section (40-foot), and 6-section (48-foot) trees.

[1] The use of trade names is for the information and convenience of the reader and does not imply endorsement or approval by the Department of Agriculture or the Forest Service of any product to the exclusion of others that may be suitable.

RESULTS

Number of Epicormic Branches

Effect of thinning (density).—The analysis revealed no relationship between the number of epicormic branches and the degree of thinning. Results for the 2-, 5-, and 8-year periods showed that thinning of any intensity did not increase epicormic branching. A trend toward more epicormic branches at greater heights had been apparent before thinning and was evident after thinning.

The average number of branches for the 40-factor density class is presented in table 1. The increase in number of branches was small, averaging one branch per tree or less, regardless of density class.

Effect of crown class.—Data on epicormic branches are summarized by crown class for each tree in table 1. The average increase in number of epicormic branches was small, 1.0 or

Table 1.—*Average number of epicormic branches per tree before and 2, 5, and 8 years after thinning (40 factor)*

Time period	Thinning density class				Crown class			
	0-40	41-80	81-120	120+	Dominant	Codominant	Intermediate	Overtopped
				4-SECTION TREES				
Before	0.9	0.8	0.7	0.7	0	0.6	0.8	0.9
2-year	1.5	1.1	1.0	.9	0	.3	.1	.1
5-year	1.4	1.0	.8	.7	1.0	.9	1.1	1.3
8-year	.9	.7	.7	.5	1.0	.6	1.0	1.0
				5-SECTION TREES				
Before	0.8	0.5	0.7	0.8	0.9	0.7	0.7	1.7
2-year	1.3	.8	1.0	1.0	.2	.4	.3	.2
5-year	1.3	.7	.9	1.0	.9	1.0	.9	1.2
8-year	1.0	.6	.8	.8	.7	.9	.9	1.1
				6-SECTION TREES				
Before	0.4	0.3	0.4	0.4	0.3	0.3	0.6	0.9
2-year	.8	.7	.7	.7	.5	.7	1.0	1.1
5-year	.7	.9	.7	.7	.5	.7	1.1	.8
8-year	.6	.7	.6	.5	.4	.6	.9	.8

less, regardless of crown class. There was a significant increase in epicormic branching for the top section of all six-section trees. However, this significant increase in the number of branches averaged 0.5 branch or less per tree and was not important in reducing upper log quality. No differences were found when the data were combined on a per-tree basis (table 1).

CONCLUSIONS

Thinning 55- to 60-year-old second-growth yellow-poplar in the central Appalachians to various densities did not produce significant increases in epicormic branching. These results agree with those of Huppuch *(1961)* and Della-Bianca *(1972)*.

Sawlog size yellow-poplar stands can be thinned without serious risk of reducing log quality by encouraging epicormic branching.

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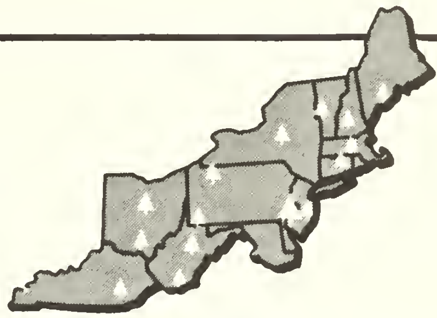

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EVIDENCE FOR A PHEROMONE IN THE LOCUST BORER

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Abstract.—Laboratory studies have suggested the existence of a pheromone in the locust borer. Male beetles spent more time on bolts of wood exposed to virgin females than on control bolts. The females apparently deposited the pheromone on the bolts of wood and filter paper.

KEYWORDS: *Megacyllene robiniae*, Cerambycidae, wood borers, pheromone

Little is known about the manner by which most cerambycid adults locate each other for mating. Pheromones that function over long distances could be involved in some species *(Duffy 1953)*. Direct contact by the sexes on the host plant, on flowers, or at other aggregation points may be the means by which some species succeed in mating.

During the summer of 1975, attempts were made in the field to attract the red oak borer, *Enaphalodes rufulus* (Haldeman) to various combinations of caged virgin females, males, and mating pairs. No beetles were caught, even by accident, indicating that they were not attracted over long distances by a volatile pheromone. An attempt was then made to attract another cerambycid, the locust borer, *Megacyllene robiniae* (Forster), with virgin females, but the results were again negative.

However, field observations of locust borer adults indicated that they did aggregate; it was not unusual to find several adults on one tree, while neighboring trees had none. Laboratory studies were thus begun to determine if this aggregation was pheromone-related.

This paper reports a female-produced pheromone that causes males to search intensively the substrate on which it is deposited.

Materials and Methods

The beetles in this study were reared artificially by the methods used by Galford (1974) to rear the red oak borer, except that the artificial medium was as follows: alphacel: 105 g; agar: 12 g; wheat germ: 45 g; vitamin diet fortification mixture: 2 g; riboflavin: 15 mg; folic acid: 10 mg; lysine: 400 mg; tryptophane: 200

mg; sorbic acid: 600 mg; methylparaben: 400 mg; chloramphenicol: 150 mg; and water: 345 ml.

Ten-gallon aquariums with five 3/16" bolts fastened through the bottom were used as test chambers. A bolt was placed near each corner and one in the middle. Holes were drilled in the bottoms of freshly cut sticks of black locust, *Robinia pseudoacacia* L., and the sticks were placed on the bolts. Five sticks of wood were cut from the same tree for each test. Four sticks unexposed to any adult beetles were used as controls; one stick was exposed for 24 hours to five virgin females 7 to 10 days old. A test consisted of releasing five virgin males into the aquarium, then recording the amount of time spent on each stick during 1 hour.

The position of the test stick was changed each time to allow for any possible effect of the laboratory ceiling lights on the adults' behavior. A total of six tests was conducted.

Three more tests were conducted with four sticks of American elm, *Ulmus americana* L., as controls and one stick of elm exposed for 24 hours to five virgin females 7 to 10 days old.

A tenth test used four strips of filter paper about 50 mm wide and 200 mm long, taped to the underside of the glass plate used to cover each aquarium. One of the four strips was cut from filter paper exposed for 72 hours to five virgin females 7 to 10 days old. The other three strips were controls.

An eleventh test used one stick of black locust exposed to five virgin females for 24 hours and, as controls, four sticks of unexposed American elm. In this test, five males with excised antennae were tested for 1 hour, then five males with intact antennae were added and observed for a second hour.

Results

In all tests, initial visits to any piece of wood or paper appeared to be entirely random. The beetles crawled up the sides of the aquarium and onto the glass covers. When two males encountered each other, one often fell to the bottom of the aquarium and then usually crawled up the nearest object. Sometimes, by chance, one or two sticks of wood would be visited more often than others.

The average amount of time males spent per visit on each stick of female-exposed black locust wood was 2 to 25 times longer than that spent on control sticks (table 1). In five of the six black locust wood tests, the female-exposed stick was occupied continuously by at least 1 male from the time of the first visit. When another male came to a female-exposed stick already occupied by a male, a fight always resulted and only one male occupied the stick for extended periods. Sometimes all five males climbed onto the treated stick, but the largest usually expelled the others. In only one test was the treatment stick not occupied continuously,

Table 1.—Results of bioassays using sticks of black locust, *R. pseudoacacia*, or of American elm, *U. americana*

Replicate	Average time per visit (seconds) on control sticks				Average time per visit (seconds) on female-exposed stick
	Stick No. 1	Stick No. 2	Stick No. 3	Stick No. 4	Stick No. 5
			BLACK LOCUST		
1	30	50	10	20	725
2	50	60	10	180	910
3	120	30	30	40	1200
4	300	30	40	20	600
5	60	0	10	0	1205
6	5	10	30	30	1020
			AMERICAN ELM		
1	10	20	20	30	2400
2	15	10	0	10	630
3	20	5	10	10	425

and that occurred when two fighting males fell from the bolt, which was not revisited during the remainder of the test. Long visits to treated sticks were of a "search-rest-search" type, in which the beetle made many trips up and down the stick for several minutes, rested, then made several more trips up and down the stick. Long visits to untreated sticks were of a "resting" type, in which the beetle did not move but just sat on the stick.

Table 1 also shows that the males could detect elm sticks exposed to females and spent more time on those sticks than on control sticks.

In the test with filter paper, the average stay on female-exposed filter paper was about 60 seconds and on control paper, about 10 seconds. Males usually walked across the untreated paper, whereas males approaching the treated paper usually turned right or left and followed the treated paper to the end. Males on treated paper were able to "track" the paper, constantly returning to the paper if they walked off it.

When a black locust stick exposed to virgin females was used with four American elm control sticks, for males without antennae the average stay was 80 seconds on the locust stick and 30 seconds on elm control sticks; for males with intact antennae, the average stay was 600 seconds on the locust stick and 20 seconds on elm control sticks. Removal of the males' antennae had apparently reduced their ability to detect the female-exposed stick.

The locust borer has a chemical means of communication that causes males to search extensively a substrate on which a female has been active. Further laboratory and field tests are needed to determine if males as well as females of this species produce a pheromone.

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1977

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INTRODUCTION OF BLACK WALNUT AND NORTHERN RED OAK SEEDLINGS IN AN UPLAND HARDWOOD FOREST IN SOUTHEASTERN OHIO

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Abstract.—Black walnut and northern red oak seedlings were planted on a clearcut area in 1964. Three cultural treatments were applied to seedlings to control competing trees. Average height and survival were analyzed 13 growing seasons after planting. Results indicated that black walnut seedlings can be effectively established on good sites if cultural treatments are applied. Red oak seedlings are difficult to establish, regardless of treatment or site.

Keywords: black walnut, red oak, planting, height growth.

The upland timber stands on many of southeastern Ohio's good sites contain few, if any, black walnut (*Juglans nigra* L.) or northern red oak (*Quercus rubra* L.) trees. Yet such sites are capable of growing high-quality timber at a rapid rate and could possibly be stocked with these high-value species. The most obvious way to introduce high-value species is to plant them after removing residual trees in a regeneration cutting.

The dense sprout and brush cover that develops on these sites after a regeneration cutting creates fierce competition for any seedlings planted there. Therefore the seedlings should be selected from superior stock, planted with great care, and helped along by release cuttings or other cultural measures as necessary. The high value of the species and the potential for rapid growth on these good sites may very well justify the costs of these intensive methods.

The purpose of this study was to evaluate several methods of establishing black walnut and northern red oak seedlings after clearcutting a hardwood stand on a good site where these species were scarce or absent.

The Study

Planting site.—A timber sale in an upland mixed oak stand on the Vinton Furnace Experimental Forest[1] in southeastern Ohio during the winter of 1963-64 created a convenient and suitable test area for this study. The 8-acre sale

[1]The Vinton Furnace Experimental Forest, located in southeastern Ohio, is managed cooperatively by the Northeastern Forest Experiment Station and the Mead Corporation.

area, located in a north-facing cove, was regenerated by a complete clearcutting. All trees and brush larger than 1.5 inches (3.8 cm) dbh were cut. The original stand contained a few northern red oak trees but no black walnut.

Northern red oak and black walnut seedlings were planted in the spring of 1964. The field layout consisted of four square blocks, 105.6 feet (32.19 m) on a side. Two of the blocks were on a noticeably better site. Each block contained 32 red oak seedlings and 32 black walnut seedlings, planted alternately in a checkerboard fashion, 13.2 feet (4.02 m) apart. The average height of all 256 seedlings at the time of planting was 1.2 feet (0.37 m) ± 1.6 percent.

Planting stock.—Red oak seedlings were selected from 1-year nursery-run stock. The black walnut seedlings were 1+0 surplus stock[2] from a walnut progeny study. The black walnut seedlings planted on the two blocks with lower site were from a selected parent tree located in Indiana, and the walnut seedlings on the two blocks with higher site came from a selected parent tree in Ohio. Results of other outplantings using these seed sources *(Funk 1972)* indicated that the progeny from the Indiana tree grew better than the progeny from the Ohio parent tree; the 9-year height growth averaged 13.5 feet (4.11 m) and 9.5 (2.90 m), respectively.

Cultural treatment.—Each seedling received one of three treatments:

Mulch: brush was cut from a 3-foot (0.91-m) radius around the seedlings, and a mulch of building paper was applied.

Rake: brush was cut from a 3-foot radius around the seedling, the soil was cultivated in an 18-inch (45.7-cm) radius, and herbicide spray was applied from 18 inches out to a 3-foot radius.

Spray: brush was cut from a 3-foot radius around the seedling and stubs were sprayed with herbicide.

On check seedlings, no cultural treatments were applied.

Treatments were assigned randomly to seedlings within the limits of a Latin square design. The rake and spray treatments were repeated four successive springs from 1964 to 1967. The mulch treatment was made in the spring of 1964 and repeated in 1966, using black polyethelene plastic instead of the paper mulch. Total heights were recorded for each tree in the summers after treatment. Both total height and dbh were recorded in August 1976, thirteen growing seasons after planting.

Natural reproduction competing with the planted seedlings included fast-growing species such as yellow-poplar, aspen, and cherry. Shrubs such as hazelnut, dogwood, sassafras, and serviceberry were prevalent. Other species, some of which were fast-growing sprouts with established root systems, included chestnut oak, red maple, and black oak.

Natural Disturbances

A drought in 1964 and a periodical cicada attack in 1965 were the two major natural disturbances during the experiment. The drought caused some damage, but the cicada attack caused damage to 60 percent of the red oak seedlings and 25 percent of the black walnut seedlings.

Since many of the leaders had been damaged by cicadas or had died back and sprouted, it was decided in the spring of 1966 to try cutting back some of the stems to the ground line and letting the new sprouts take over (coppicing). Forty-five damaged red oak seedlings, 10 uninjured red oak seedlings, and 24 uninjured black walnut seedlings were cut back. None of the damaged walnut seedlings were cut back. Those seedlings selected for coppicing had the least height growth. It was hoped that the new sprouts would grow faster and straighter than the original stems.

Results

The most recent height and dbh measurements recorded in 1976 were used in the analysis. Results indicated that site quality was a major factor affecting the establishment of the black walnut seedlings. Survival and average height were therefore determined for each species x site x treatment category (table 1). Planned statistical analyses were not performed because there were not enough surviving trees in some of the categories.

Suppression was the major cause of mortality. The drought and cicada attack undoubtedly increased the number of suppressed seedlings.

[2]Some of the walnut seedlings planted on the two blocks with lower site may have been 1+1 stock. Records are not clear on this point.

Damage by small mammals and local erosion accounted for the deaths of several seedlings.

Natural sprouting of planted seedlings occurred following dieback. Twenty-two percent of all live trees measured in 1976 originated from natural sprouts following dieback. Ninety percent of all seedlings coppiced in 1966 sprouted successfully. Although their average height had almost caught up to that of the uncut seedlings after only two growing seasons, they were still the shorter trees. Their competitive status relative to surrounding trees was not improved. Therefore, the primary effect of coppicing was to delay mortality due to suppression over the short run only. It did not significantly reduce mortality or increase height growth during the length of the experiment. Because of the amount of natural sprouting that occurred, inclusion of the coppiced seedlings in table 1 does not distort the results to any major degree.

Red oak.—Site apparently did not have much effect on the survival or height growth of the red oak seedlings (tables 1 and 2). Growth, mortality, and crown class of the seedlings were similar on all four blocks.

Forty-nine percent of the red oak seedlings on all four blocks survived the 13 growing seasons. However, the average height was only 16.0 feet (4.88 m), and the average diameter[3] was only 1.2 inches (3.0 cm). Most of the remaining red oaks are now well below the main crown canopy and

[3]Quadratic mean, breast height. The diameter of a tree of average basal area.

Table 1.—Survival and average height of trees, in feet, 13 growing seasons after planting, by treatment, species, and site

Site class	Check		Mulch		Rake		Spray		Average	
	Survival [a]	Average height [b]	Survival	Average height	Survival	Average height	Survival	Average height	Survival	Average height
	Pct.	*Ft.*	*Pct.*	*Ft.*	*Pct.*	*Ft.*	*Pct.*	*Ft.*	*Pct.*	*Ft.*
					NORTHERN RED OAK					
Good	38	13.1	63	17.9	50	15.6	63	15.5	53	15.8
Medium	44	16.7	56	16.8	50	16.5	31	14.6	45	16.3
					BLACK WALNUT					
Good	38	16.0	56	26.3	75	25.1	75	23.7	61	23.5
Medium	13	13.1	13	15.9	6	12.3	13	13.9	11	14.0

[a] There were 16 original seedlings planted in each species x site x treatment category.
[b] Height in meters = 0.3048 x height in feet.

Table 2.—Crown class distribution of surviving trees, 13 growing seasons after planting, by species and site, all treatments combined

Site class	Original number of seedlings	Dominant/ codominant		Intermediate		Suppressed		Total, all crown classes	
		Survival	Average height [a]	Survival	Average height	Survival	Average height	Survival	Average height
	No.	*No.*	*Ft.*	*No.*	*Ft.*	*No.*	*Ft.*	*No.*	*Ft.*
				NORTHERN RED OAK					
Good	64	2	27.9	8	21.8	24	12.8	34	15.8
Medium	64	9	21.5	8	16.5	12	12.4	29	16.3
				BLACK WALNUT					
Good	64	25	29.3	3	20.2	11	11.4	39	23.5
Medium	64	1	20.6	1	11.1	5	13.2	7	14.0

[a] Average height in meters = 0.3048 x height in feet.

do not look vigorous enough to last until rotation age. Only 11 of the original 128 seedlings are in the dominant-codominant crown class (table 2). Competing trees in the dominant-codominant crown class in 1976 included yellow-poplar, chestnut oak, cherry, aspen, and red maple.

None of the cultural treatments resulted in a dramatic increase in height growth compared to that of the check trees. Only the mulch treatment was consistently better than no treatment (table 1).

Black walnut.—Site apparently was a major factor influencing establishment of the black walnut seedlings (tables 1 and 2). Even though the sources of the planting stock were slightly different for the good and medium sites, the results indicated that the large differences between sites should probably be attributed mainly to site effects.

Only 11 percent of the original seedlings on the two blocks on the medium site survived. Only one of these remaining trees was in the dominant-codominant crown class (table 2). Intermediate and suppressed trees probably will not make it to rotation age. Average height of all surviving walnut trees on the lower site areas was 14.0 feet (4.2 m), and the average diameter was 1.1 inches (2.7 cm).

Sixty-one percent of the original seedlings on the two blocks on the good site survived. Twenty-five of these remaining trees were in the dominant-codominant crown class (table 2), and 17 were more than 25 feet tall. Average height of all trees on the good site areas was 23.5 feet (7.16 m), and average diameter was 3.1 inches (7.8 cm). The tallest walnut tree was 43.2 feet (13.17 m), and had a dbh of 4.7 inches (11.9 cm). Another of the larger walnut trees was already bearing fruit (fig. 1).

All cultural treatments showed a distinct advantage over the check trees on the good site areas, the mulch treatment having the best average height (table 1). Only 2 of the 25 trees in the dominant-codominant crown class were check trees (table 2). Differences were not as distinct on the medium site areas. Again though, there were too few surviving trees to make sound conclusions regarding treatment effects.

Figure 1.—Black walnut tree 35.5 feet (10.8 m) tall and 5.7 inches (14.5 cm) dbh, 13 growing seasons after planting. Original seedling received mulch treatment on good site area.

Discussion

Seedlings planted in a recently clearcut area must compete with fast-growing trees, shrubs, and sprouts that have established root systems. To establish valuable species such as red oak and black walnut, the planted seedlings must be kept free of competition through cultural treatments that are usually expensive to apply.

Krajicek *(1975)* found that, after seven growing seasons, survival of black walnut seedlings planted in cleared forest openings in Illinois did not differ by competition-control treatments. He also found that the trees grew somewhat larger where all competing vegetation was controlled, but almost as large when only herbaceous competition was controlled.

Although our study did not provide conclusive evidence, the results do warrant some general observations. Northern red oak seems to be difficult to establish regardless of site quality or cultural treatment. However, the poor performance of red oak may be due to the severe cicada attack and the large number of seedlings that were coppiced. Black walnut also performed poorly on medium sites, regardless of cultural treatment; but on good sites walnut can be effectively established with cultural treatments. The fact that 39 percent of the original walnut seedlings planted on the good site are now in the dominant-codominant crown class and average 29.3 feet in height after only 13 growing seasons is very promising. I believe that survival and development of walnut would be even better if the treatment area were larger than a 3-foot (0.91-m) radius and if the treatments had been continued at 3- or 4-year intervals.

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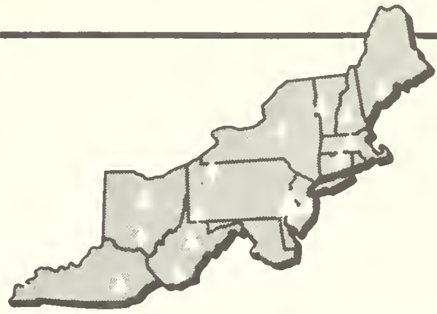

FOREST SERVICE, U.S. DEPT. OF AGRICULTURE, 6816 MARKET STREET, UPPER DARBY, PA. 19082

DECAY IN YELLOW-POPLAR, MAPLE, BLACK GUM, AND ASH IN THE CENTRAL HARDWOOD REGION

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Abstract.—In a study of decay in yellow-poplar (*Liriodendron tulipifera* L.), red maple (*Acer rubrum* L.), sugar maple (*Acer saccharum* Marsh.), black gum (*Nyssa sylvatica* Marsh.), and ash (*Fraxinus* spp.) in the central hardwood region, decay was found in 57 of 148 study trees. Extent of decay, causal fungi, and method of entry are discussed. The relationship between tree age and diameter and decay is also examined.

Several years ago, we investigated the extent of decay in oak stands of the central hardwood region. One hundred fifty sample plots, 1/5-acre in size, were established in well-stocked, undisturbed (except for fire), even-aged oak or oak-hickory stands in Kentucky, Ohio, Indiana, Illinois, and Missouri. Trees 3.6 inches dbh (diameter breast high) and larger were felled and dissected, and decay data were collected. Papers on the extent of decay in oak and hickory, the fungi associated with decay, and the relation of decay to external indicators, tree age, and diameter in these species have been published (*1, 2, 3, 4, 5*).

When hardwood tree species other than oak and hickory were encountered on our plots, these species were also felled and examined for decay. This paper deals with decay in these other hardwood species, namely yellow-poplar (*Liriodendron tulipifera* L.), red maple (*Acer rubrum* L.), sugar maple (*Acer saccharum* Marsh.), black gum (*Nyssa sylvatica* Marsh.), and ash (*Fraxinus* spp.).

Infections and Decay Volumes

Fifty-seven of the 148 study trees had decay (table 1). Sugar maple had the least incidence and amount of decay. Almost half of the red maple trees were infected. Although root and butt infections (41) only slightly exceeded trunk infections (36), 76 percent of the decay volume was in the butts.

The Fungi that Caused Decay

Cultures were prepared from decay samples to determine the fungus species that caused decay. Only about one-fifth of the fungi respon-

Table 1.—*Number of infections and percent of decay volume, by tree bole location, for several hardwood species in the central hardwood region*

Host species	Trees	Trees infected	Infections			Decay volume		
			In butt[1]	In trunk	Total	In butt[1]	In trunk	Total
	No.	*No.*	*No.*	*No.*	*No.*	*Pct.*	*Pct.*	*Cu. ft.*
Yellow-poplar	47	19	12	10	22	82.2	17.8	33.7
Red maple	35	17	15	14	29	78.8	21.2	34.4
Sugar maple	32	7	4	4	8	12.0	88.0	2.5
Black gum	25	10	7	7	14	89.9	10.1	33.8
Ash	9	4	3	1	4	16.3	83.7	10.4
All species	148	57	41	36	77	76.0	24.0	114.8

[1] Decay originating at stump height or below was considered as butt rot.

sible for infections could be identified. Thus we were unable to draw conclusions about the relative importance of the various fungus species. The species of *Coprinus* isolated from a white rot in sugar maple is an undescribed new species near *C. exstinctorius* Fr. *(6)*. Identified fungi associated with decay were as follows, by host species:

Ash:
- None identified.

Black gum:
- **Spongipellis delectans* (Pk.) Murr.

Red maple:
- *Hericium erinaceus* (Bull. ex Fr.) Pers.
- *Pholiota adiposa* (Fr.) Kumm.
- **Pleurotus cystidiosus* O. K. Miller
- *Spongipellis delectans* (Pk.) Murr.
- **Spongipellis fissilis* (Berk. & Curt.) Murr.
- **Inonotus andersonii* (Ell. & Ev.) Černý
- *Hypoxylon deustum* (Hoff. ex Fr.) Grev.

Sugar maple:
- **Coprinus* sp.
- **Inonotus andersonii* (Ell. & Ev.) Černý

Yellow-poplar:
- **Pholiota adiposa* (Fr.) Kumm.
- **Spongipellis fissilis* (Berk. & Curt.) Murr.

How Fungi Gained Entry

As trees were felled and dissected, we attempted to trace established heart-rot infections to the various entry points. Infection courts were characterized by type and frequency of occurrence (table 2).

Fire scars were the most important entry court for decay fungi, accounting for approximately one-third of all infections and 63 percent of the total decay volume. As protection from wild fires in forested areas becomes more efficient, butt rots should be reduced. Mechanical wounds—for example, felling and skidding injuries during partial cutting—were second in importance as entry courts, followed by top damage, unsound branch stubs, and parent stumps. Four of the six infections through unsound branch stubs and all six of the infections through parent stumps were in red maple.

Decay vs. Tree Age and Diameter

The amount of decay in trees of different ages is shown in table 3. In trees up to 70 years old, decay losses were relatively minor in the five hardwood species. Beyond this age, decay volume increased rapidly in red maple and ash. In black gum, decay losses rose rapidly after trees reached 90 years of age. In yellow-poplar and sugar maple, decay losses were minimal for all age classes.

Tree diameter is, of course, a function of age. Hence the percentage of decay volume should increase with diameter as well as age. Generally, this held true (table 4). Indications are that larger yellow-poplar and sugar maple trees are relatively free of decay. It should be pointed out, however, that parts of this analysis are based on a small number of samples.

*These species have not previously been reported on these hosts.

Table 2.—*Infection incidence and percent of decay volume by type of infection court and species*

Host species	Infection courts															
	Fire scars		Mechanical injuries		Damaged tops		Unsound branch stubs		Parent stumps		Miscellaneous		Unknown		Totals	
	Infect.	Decay	Infect.	Decay	Infect.	Decay	Infect.	Decay	Infect.	Decay	Infect.	Decay	Infect.	Decay	Infect.	Decay
	No.	*Pct.*	*No.*	*Pct.*	*No.*	*Pct.*	*No.*	*Pct.*	*No.*	*Pct.*	*No.*	*Pct.*	*No.*	*Pct.*	*No.*	*Pct.*
Yellow-poplar	10	23.4	4	3.5	4	0.8	—	—	—	—	3	0.9	1	0.7	22	29.3
Red maple	5	11.5	4	1.7	1	.4	4	2.7	6	11.2	7	1.6	2	.9	29	30.0
Sugar maple	2	.2	2	.2	2	.6	1	1.2	—	—	—	—	1	(*)	8	2.2
Black gum	6	26.2	—	—	—	—	1	.3	—	—	4	1.9	3	1.0	14	29.4
Ash	3	1.5	—	—	1	7.6	—	—	—	—	—	—	—	—	4	9.1
All species	26	62.8	10	5.4	8	9.4	6	4.2	6	11.2	14	4.4	7	2.6	77	100.0

*Less than 0.1 pct.

ble 3.—*Relationship between age and percent of decay volume in several hardwood species in the central hardwood region*

Age class (years)	Yellow-poplar		Red maple		Sugar maple		Black gum		Ash	
	Trees	Decay volume	Trees	Decay volume	Trees	Decay volume	Trees	Decay volume	Trees	Decay volume
	No.	*Pct.*	*No.*	*Pct.*	*No.*	*Pct.*	*No.*	*Pct.*	*No.*	*Pct.*
31 to 50	15	2.3	17	0.6	6	1.4	5	0.0	—	—
51 to 70	12	1.9	6	1.6	22	.8	7	.0	6	1.2
71 to 90	18	2.3	8	18.3	4	(*)	4	2.2	2	14.7
90+	2	.0	4	15.2	—	—	9	13.7	1	8.3
Total	47	2.0	35	10.7	32	0.6	25	11.2	9	10.8

*Less than 0.1 pct.

able 4.—*Relationship between diameter and percent of decay volume in several hardwood species in the central hardwood region*

Dbh class (inches)	Yellow-poplar		Red maple		Sugar maple		Black gum		Ash	
	Trees	Decay volume	Trees	Decay volume	Trees	Decay volume	Trees	Decay volume	Trees	Decay volume
	No.	*Pct.*	*No.*	*Pct.*	*No.*	*Pct.*	*No.*	*Pct.*	*No.*	*Pct.*
3.6 to 7.5	5	0.2	22	2.8	18	0.6	14	(*)	5	1.6
7.6 to 11.5	15	.9	7	6.9	5	.6	1	.0	2	1.6
11.6+	27	2.2	6	14.0	9	.5	10	12.6	2	15.2
Total	47	2.0	35	10.7	32	0.6	25	11.2	9	10.8

*Less than 0.1 pct.

Conclusions

Although no direct control of heart rots is known, losses can be minimized by fire control and silvicultural practices.

It was pointed out earlier that fire scars serve as entry courts for a large number of heart rot fungi. With more effective fire protection, occurrence of decay in the butt log should decrease.

In red maple, more than half of the infections took place through parent stumps. By removing unwanted sprouts before heartwood is formed, butt rot can be reduced in tree species that originate from stump sprouts. In thinning operations, sprouts low on the parent stump are less likely to decay and should be favored over others at higher levels.

Since decay loss increases with tree age, rotation age should be adjusted depending on species so that trees are cut before decay losses become significant. For example, the rotation age of red maple should not exceed 70 years, while the rotation age of yellow-poplar and sugar maple could be considerably longer.

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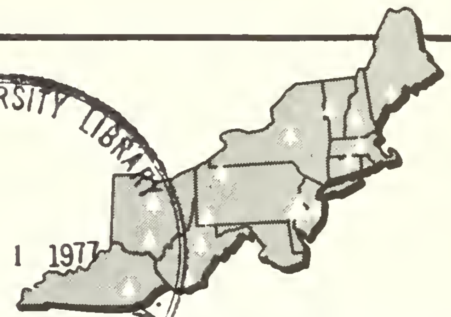

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DEVICES TO PROTECT SEEDLINGS FROM DEER BROWSING

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Abstract.—Studies on the Allegheny Plateau of Pennsylvania have shown that several types of wire or plastic tubes can be erected around tree seedlings to protect them from deer browsing. The two most promising devices are a 4- to 6-inch diameter plastic tube with small mesh and a 12-inch diameter tube constructed of chicken wire. Both types need to be at least 5 feet tall to provide adequate protection in areas of heavy browsing pressure. The plastic protectors are more expensive than those made of wire, but are somewhat quicker to fabricate, and they offer the added advantage of protection against rodents.

Severe browsing of tree seedlings by white-tailed deer has resulted in complete regeneration failures in many sections of Pennsylvania, and planting of areas that fail to regenerate naturally is futile unless the planted seedlings are protected against browsing. One promising way to protect both natural and planted seedlings is to place plastic or wire-mesh tubes around the seedlings to protect their terminal leaders until they grow above the reach of deer.

Trials of various types of individual protection devices conducted over the past 5 years have shown that cost and effectiveness vary greatly. This report describes the results obtained with various devices and makes recommendations on their use.

Study Methods

In May 1972, two recently clearcut areas on the Allegheny National Forest in northwestern Pennsylvania were selected for an experiment to compare seven different types of protective devices. Both areas contained natural seedlings that were being browsed.

The seven devices studied were as follows:

1. A cattle-wire mesh tube, 3 feet in diameter and 5 feet tall, held in place around the seedling by three wooden stakes. The openings in this wire varied from 2 by 6 inches at the bottom to 4 by 6 inches at the top.

2. Same as 1 above but 1 foot in diameter and supported with two rather than three wooden stakes.
3. Same as 2 above, but made of 2-inch chicken-wire mesh rather than cattle-wire.
4. A large mesh white plastic tube 1 foot in diameter, 5 feet tall, and supported by two wooden stakes. The mesh in this device was diamond-shaped, with openings about 1 inch high by 1/2 inch wide.
5. A green plastic tube with mesh similar to item 4 above, but only 2 inches in diamter.
6. A 3-inch diameter yellow plastic tube with small (3/8-inch square) mesh, 5 feet tall.
7. A single wooden stake, erected without any sort of plastic or wire tube. The stake was 5 feet tall, and the terminal shoot of the seedling was tied to the stake with a piece of string.

Sixteen groups of seedlings were selected in each of the two clearcut areas. All seedlings within each group were similar in height, and the individual devices were assigned at random within each group. In addition to the seven different protective devices, each group contained a control or unprotected seedling.

Thermocouples were attached to a few sample seedlings in treatments 5, 6, and 7 so that temperature measurements could be taken. Measurements of light quantity and spectral distribution inside each of the tubes were made with an ISCO spectralradiometer.

Seedling height, incidence of deer browsing, and condition of the protective device were observed each spring and fall in 1972 and 1973, then again in the spring of 1976. Analyses of variance were run to test differences among treatments in height growth and percent of browsing.

Beginning in 1974, seedlings in additional clearcuts on the Allegheny National Forest were protected, using yellow plastic tubes similar to those described for treatment 6 above, but 6 inches in diameter. Both 4-foot and 5-foot-tall tubes were used, and a variety of supporting stakes were tried. These included steel reinforcing rods, fiberglas rods, and reject wooden tool handles from a local ash handle factory. In some cases, two stakes were applied to each tube, and the tube was attached with soft wire or hog rings. In other cases, a single stake was used, with several wood pieces attached to the stake to keep the tube spread open.

The tubes applied since 1974 have not been part of a formal experiment, but represent administrative trials of the devices. Observations of seedling growth and device condition were made in August 1976, but no attempt was made to tally all devices in use.

In the spring of 1975, additional chicken-wire protectors identical to those for treatment 3 above were erected as part of a planting experiment on the Tuscarora State Forest near Mifflintown, Pa. In that experiment, seedlings of several species were planted in rows under various stand conditions. Seedlings in half of the rows were fitted with protectors, and half were unprotected. Measurements of seedling growth, incidence of browsing, and condition of the devices were made three times during each of the 1975 and 1976 growing seasons.

Results

Effectiveness against browsing.—The effectiveness of the tube-like protective devices was a function of both the diameter and the mesh of the plastic or wire material (table 1). Deer were able to reach through the very large mesh of the cattle-wire protectors to browse on the seedlings inside. As a result, these protectors were not effective unless they were of such large diameter (3 feet) that deer could not reach the seedling in the center. Almost all seedlings in the 1-foot-diameter cattle-wire protectors were browsed during the first year of the study. However, the smaller mesh of the chicken wire or plastic protectors was fully effective when used in the 1-foot diameter.

Table 1.—Proportion of terminals browsed during first two growing seasons

Protective device	Terminals browsed
	Percent [a]
1-foot chicken wire	0a
1-foot white plastic	0a
3-foot cattle wire	6a
3-inch yellow plastic	6a
2-inch green plastic	50b
Wooden stake	81c
1-foot cattle wire	94c
Control	94c

[a] Values with same subscript are not significantly different at 0.05 level.

In the smaller diameters, even the medium-size mesh of the green plastic protectors was too open to afford protection. The terminals of many seedlings simply grew out through the side of these 2-inch tubes (fig. 1). Of the small-diameter tubes, only the extremely small mesh of the yellow plastic tubes proved small enough to keep the seedlings inside where they could not be reached by deer.

The wooden stake alone offered very little protection from browsing. Although the terminals had been tied close to the stake initially, they quickly grew out away from the stake to where they could be nipped.

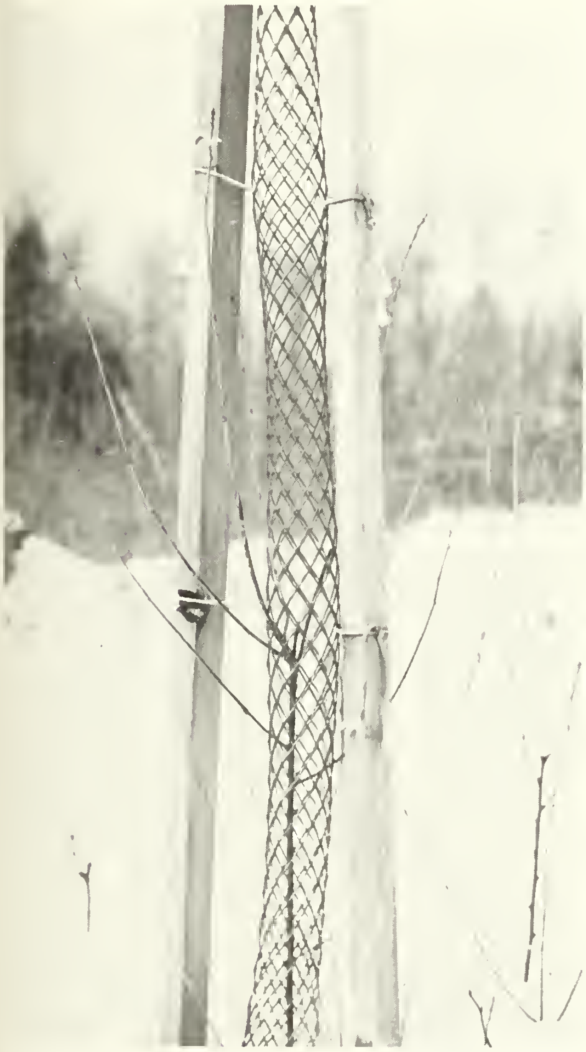
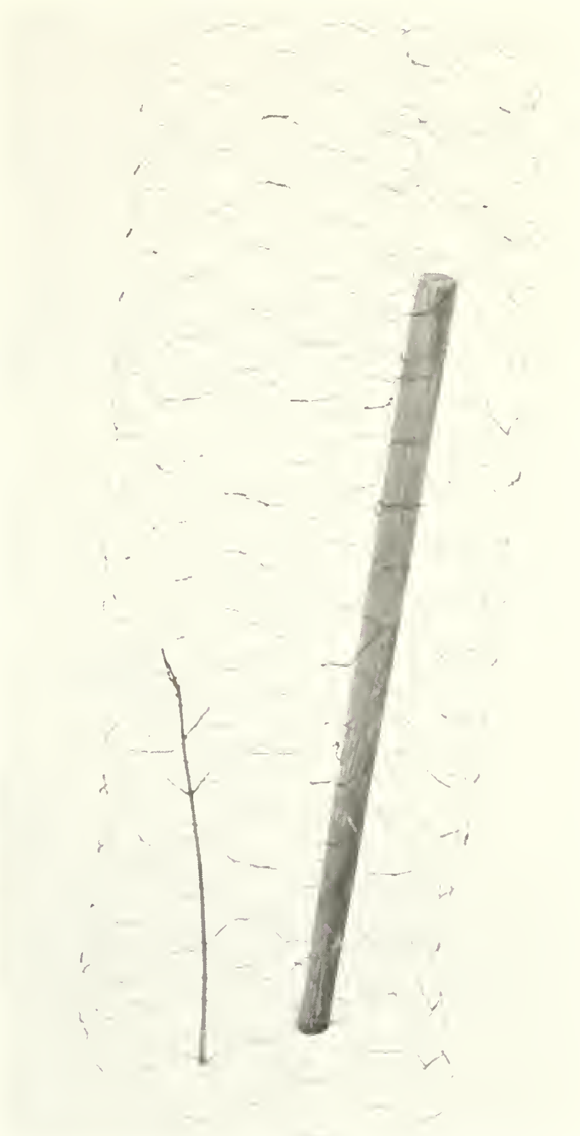


Figure 1.—A seedling growing out through the sides of a large-mesh, small tube is vulnerable to deer browsing.

Figure 2.—A chicken-wire tube used to protect planted seedlings.



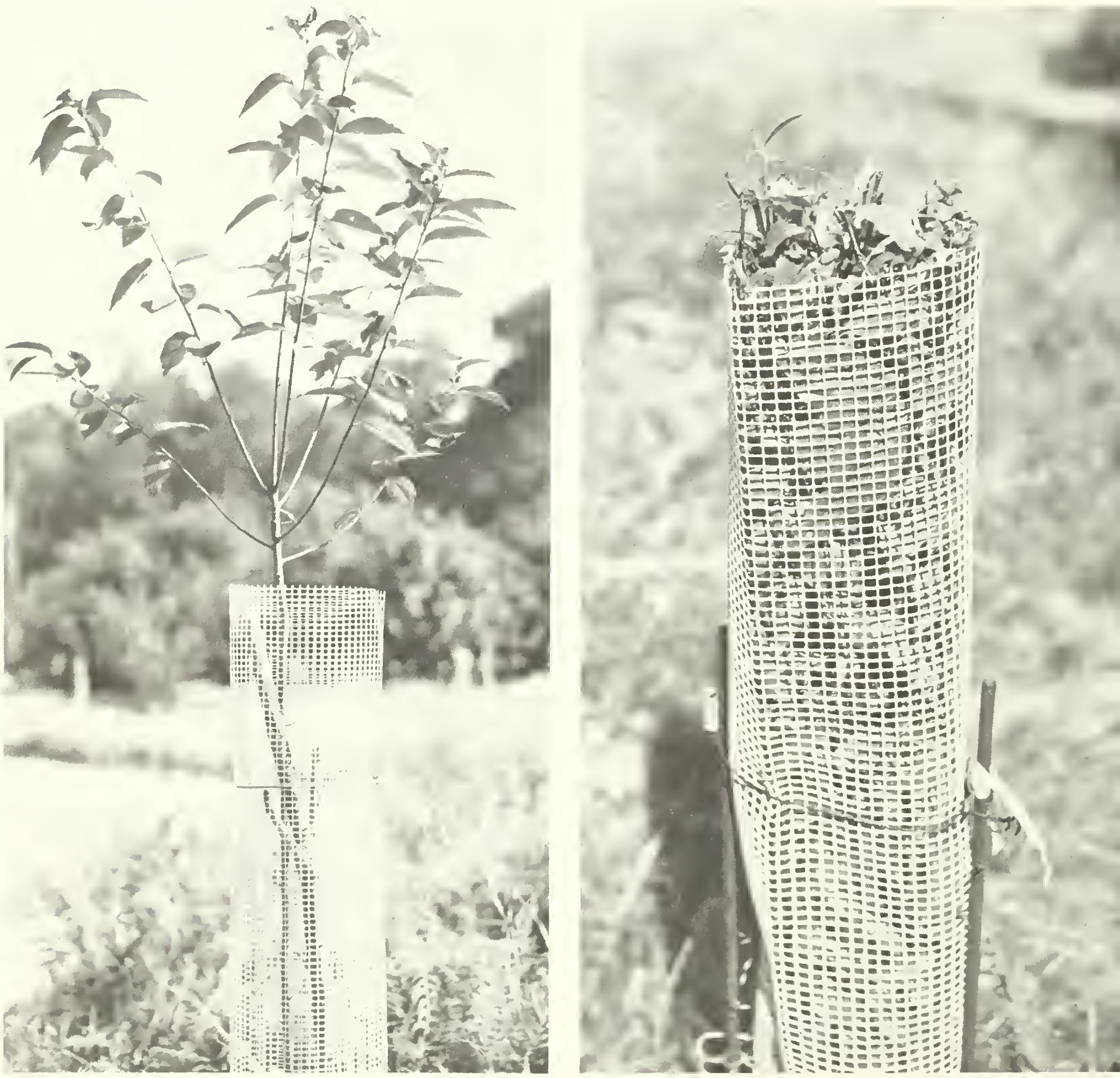
The chicken wire and yellow plastic devices used in later trials have been more than 90 percent effective, and only an occasional terminal was nipped when it grew out the side of the protector (fig. 2). When this occurred, a new shoot invariably formed inside the device to replace the one lost, so that a protected seedling remains in spite of the one browsing incident.

Physical condition and durability of devices.—The wire-mesh protectors suffered little damage during the 5-year study period, although a few fell over because the wooden support stakes had rotted at the ground level. But the wire itself remained effective as long as the stakes were in place.

The first plastic protectors used were not nearly as durable as the wire; they were constructed of different plastic materials. The white plastic became very brittle and shattered easily when cold. This material had completely disintegrated by the start of the third growing season. The yellow plastic began disintegrating after the third growing season, and was nearly all gone after the fourth year. The green plastic remained intact after 5 years.

After consultation with the manufacturers of

Figure 3.—Small-mesh yellow plastic tubes protecting black cherry seedlings from deer browsing. The seedling on the left has grown out the top of the 5-foot tall protector and is now beyond the reach of deer. The seedling in the shorter 4-foot tube on the right has been browsed repeatedly. To be effective, tubes at least 5 feet tall are recommended.



the plastic, it was learned that durability could be altered readily by the quantity of ultra-violet inhibitors included in the plastic during manufacture. The yellow plastic materials used in more recent trials included these inhibitors, and they show little sign of deterioration after three growing seasons.

Problems with stakes rotting at the ground level were common to all devices in which wooden stakes were used. Without adequate support, protectors were quickly flattened by snow, usually resulting in complete loss of the seedling inside. Both ash handles and 1-inch-square pine stakes began to break off after the second year, although 65 to 70 percent were still standing after 5 years.

Another difficulty experienced with some of the plastic devices was drooping of the upper portion if the supporting stakes were not long enough. This problem was overcome by using longer stakes, but it emphasized the need for care in providing adequate support.

In some of the more recent trials with 4- and 5-foot tall plastic devices, it has become apparent that the shorter protectors are inadequate. Because these trials were not set up as an experiment, there are no data to use for comparisons, but many of the seedlings in the 4-foot tubes were browsed back repeatedly as the terminal grew out the top. Some seedlings in these short tubes may eventually escape, but this has not occurred to date. A few seedlings have also been browsed at the top of the 5-foot tubes, but most of these have grown well out of the reach of deer (fig. 3).

A supplementary benefit of the small-mesh plastic tubes is that they provide protection from girdling by mice, rabbits, and porcupines as well as protection against deer browsing. This is likely to be most important in grassy areas where small-mammal populations are high. Damage by small mammals has been observed on up to 50 percent of the seedlings on one Allegheny National Forest area.

A few seedlings have had cambium damage as a result of wind action that has caused the top of the tube to rub against the stem. This is a problem only after the seedling has grown out the top of the tube and the protector is no longer needed. The ideal situation would be to have the tube disintegrate at an appropriate time (possible with the plastic tubes); or, it may be necessary to remove the tubes after they have served their purpose. There are not enough data available yet to evaluate the extent of this damage.

Growth.—Seedling growth has not varied significantly among devices, with one exception: seedlings in the yellow plastic tubes grew slightly (and significantly) taller during the first growing season than seedlings in the other treatments. Heights were not significantly different after 5 years, although the seedlings in the yellow tubes were still slightly taller than those in the other devices (table 2).

Measurements of light quality inside the yellow tubes revealed that the proportion of far-red to red energy inside the tube was nearly three times higher than in full sunlight, as a result of filtering by the yellow plastic material. There were only minor shifts in other wavelengths.

Light that is high in far-red is known to stimulate stem elongation, and this may explain the slightly greater growth in the yellow tubes during the first year. The proportion of far-red was not significantly different from that in full sunlight in the other tubes, nor was it significantly different from full sunlight in the yellow tubes during the second growing season after the yellow color had faded from the plastic.

Air temperatures inside the plastic tubes were not significantly different from air temperatures adjacent to seedlings without tubes.

Table 2.—Height growth in the various protectors

Protective device	Total height	
	After 1 year	After 5 years [a]
	Feet	*Feet*
3-foot cattle wire	1.0	5.4
1-foot cattle wire	.8	3.7
1-foot chicken wire	.8	5.2
1-foot white plastic	1.1	—
3-inch yellow plastic	1.6 [b]	5.5
2-inch green plastic	1.1	5.1
Wooden stake	1.0	4.6
Control	.8	—

[a] Includes only seedlings on which devices were still effective.

[b] This treatment was significantly different from other treatments at 0.05 level.

Cost.—Material costs for these types of protective devices were as follows, based on 1975 prices:

- Yellow plastic tube (6-inch diameter):)$0.16 per foot.
- 2-inch mesh chicken wire (5 feet tall): $20.00 per 150-foot roll.
- Cattle wire (5 feet tall): $32.00 per 165-foot roll.
- Wooden stakes: $0.20 each.

Labor required to erect the tubes was as follows:

Fabricate & erect wire tubes: 15 per hour (2-man crew)

Erect plastic tubes: 25 per hour (2-man crew)

Cost per man: $4.00 per hour

These costs would vary depending upon sources of supply, quantities ordered, and availability of manpower. They do not include any planting costs. For the values above, the cost per protective device would be as follows:

	Tube material	*Stakes*	*Labor*	*Total*
3-foot cattle wire	$1.80	$0.40	$0.55	$2.75
6-inch plastic	.80	.20	.30	1.30
1-foot chicken wire	.40	.20	.55	1.15

Conclusions and Recommendations

These studies and trials have shown that several types of wire or plastic tubes can be erected around tree seedlings to protect them from deer browsing. In terms of cost and effectiveness, the two most promising devices are a 4- to 6-inch diameter plastic tube with small mesh and a 12-inch diameter tube constructed of chicken wire. Both types need to be at least 5 feet tall to provide adequate protection in areas of heavy browsing pressure, such as exist throughout Pennsylvania. The plastic protectors are more expensive than those made of wire, but are somewhat quicker to fabricate, and they offer the added advantage of protection against rodents.

Efforts are now under way by the U.S. Forest Service and the plastic manufacturers to develop a plastic protector that would be more easily supported and would be less expensive than present tube-stake combinations.

The minimum number of seedlings that must be grown above deer browsing height is probably somewhere between 100 and 200 per acre. If an entire regeneration area were to receive protective devices, the total cost would run between $115 and $230 per acre for chicken-wire protectors plus planting costs if natural

Figure 4.—Plastic tubes used to protect natural seedlings in those portions of a regeneration area that are being browsed severely.

seedlings were not present. This cost is high; but until some cheaper method is found, the use of protective devices seems necessary on some areas if they are to remain in forest production. The use of individual protective devices is usually cheaper than protecting the entire area with a deer-proof fence.

Use of currently available natural regeneration guidelines *(Marquis and others 1975)* could reduce the number of regeneration failures to a minimum. But even in areas classified as successfully regenerated, heavy deer browsing frequently creates pockets where stocking is inadequate. These nonstocked areas can reduce yields by important amounts, and the selective use of seedling protectors in such areas could bring the entire area to full stocking (fig. 4). Protectors also provide an opportunity to improve species composition by ensuring protection of species that are preferentially browsed (such as red maple and yellow-poplar), or —if combined with planting— of introducing genetically-improved stock or species now absent from that site.

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DISTRIBUTION OF TREE SPECIES IN AN UNDISTURBED NORTHERN HARDWOOD-SPRUCE-FIR FOREST, THE BOWL, N. H.

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ABSTRACT.—Knowledge acquired from forests that have never been logged can provide clues to the long-term effects of resource utilization. In 1974, a survey was made of the vegetation of the Bowl Research Natural Area in central New Hampshire, known to be undisturbed by humans; and an adjacent watershed known to have been logged in the late 1880's. There were no significant differences in the mean basal areas and aboveground biomass of trees between the two watersheds, indicating that 90 years after logging this forest has nearly recovered. The major species in the Bowl are yellow birch, beech, sugar maple, red spruce, and balsam fir. The forest has a mean basal area of 28 m^2/ha and contains about 260 metric tons of aboveground dry biomass. A nearby 60-year-old second growth forest contains about 23 m^2/ha basal area and only about 140 t/ha.

Knowledge acquired from forests that have never been logged can provide clues to the long-term effects of resource utilization. Very few virgin forests remain in the northeastern United States. The Bowl Research Natural Area (Area I, fig. 2) near Wonalancet, N. H., administered by the White Mountain National Forest, is one of the few left.

In 1973, a study of the flux of chemical elements through this undisturbed watershed was begun (Martin 1975). Several nutrients essential to plant growth were measured in precipitation. These same nutrients were also measured as they left the forest dissolved in streamwater. An analysis of the vegetation on the watersheds was necessary to evaluate the differences between these inputs and outputs. The results of the vegetation survey are presented here.

The objectives of the study were: (1) to describe generally the forest vegetation of the valley as a whole; (2) to determine the relationship between tree distribution and elevation; (3) to determine the logging and wind damage history; (4) to compare the vegetation between the reserved natural area of the Bowl and the rest of the valley; (5) to compare the forest vegetation of the Bowl with other forests nearby.

The Study Area

The study area is a 607-hectare (ha) valley on the southern flank of the White Mountains near Wonalancet, N.H. (Fig. 1). The valley is bordered on the north by Mt. Passaconaway 1,238 m), on the east by Mt. Wonalancet (854 m), and on the west by Mt. Whiteface (1,215 m). It is bisected by a central ridge running from north to south that rises to an elevation of about 1,000 m (Fig. 2), and divides the valley into two major watersheds, East and West.

The 206-ha area west of the West Branch Stream (Area I, Fig. 2) up to the ridge top from Mt. Whiteface nearly to Mt. Passaconaway has been reserved for research by the U. S. Forest Service (Lyon and Bormann 1962). Several surveys of the vegetation in the reserved area (Leak 1974, 1973; Oosting and Billings 1951) indicated that this part of the forest developed naturally; there was no evidence of past logging. No data were available for Area II.

Some of the East Branch watershed has been logged. A temporary portable steam-powered lumber mill operated there in 1888 (Harkness 1958). There is no record of the duration of the operation, the amount of lumber sawed, or the amount of firewood cut.

Methods

In 1974, the Bowl was divided into four areas conforming to the four major slopes (Fig. 2). A systematic sample of circular 100-square-meter plots (Cain and Castro 1971) on a 100-meter grid was selected for areas I, II, and III. A 100- x200-meter grid was used in area IV. The survey was confined to elevations below 915 meters. Spruce-fir dominates the forest above this elevation, and it has been windthrown to the point of masking even recent human disturbances. To avoid duplications of effort, some data on basal areas per hectare by species that had been collected by D. G. Mott of the Forest Service were used to supplement my data in Area I.

Analysis of variance was used to test the hypothesis that there were no significant

Figure 1.—A view of the Bowl, looking due North into the West and East watersheds.

re 2.—Map of the Bowl near Wonalancet, N. H.

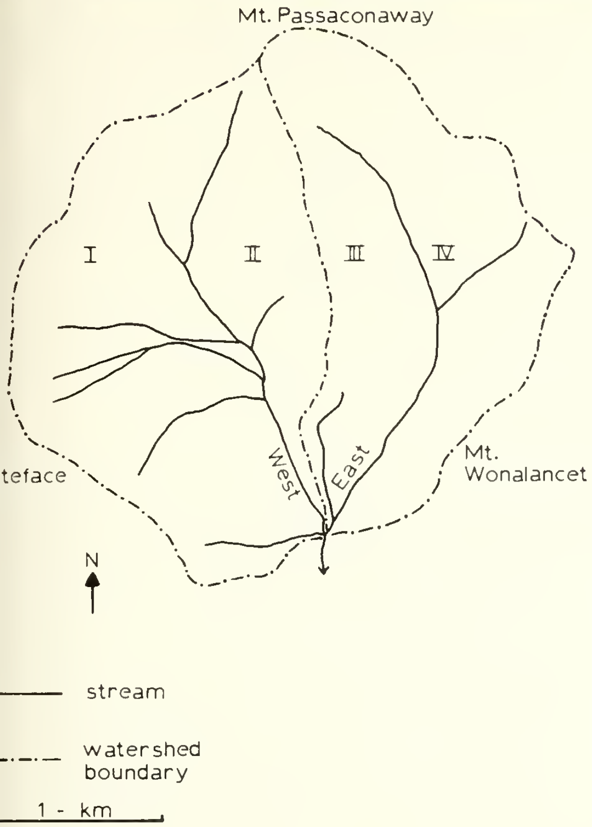

Table 1.—*Summary of statistical analysis of vegetation survey data*

Statistic	Area I	II	III	IV
Number of plots	28	56	83	51
Mean basal area (m²/ha)	29.1	29.9	27.2	27.0
Standard deviation	15.7	10.1	10.6	13.2

Analysis of variance showed no significant differences among areas.

differences between the mean basal areas of the trees in the four areas (Table 1).

Above ground dry-weight biomass of trees and shrubs was calculated from diameter measurements alone, using the following equations selected from Whittaker, et al. (1974):

$\text{Log}_{10}\ y$ *(Acer saccharum)* $= 2.2151 + 2.4209 \log_{10} x$

$\text{Log}_{10}\ y$ *(Betula alleghaniensis)* $= 2.2264 + 2.4150 \log_{10} x$

$\text{Log}_{10}\ y$ *(Fagus grandifolia)* $= 2.2916 + 2.3916 \log_{10} x$

$\text{Log}_{10}\ y$ *(Acer spicatum)* $= 2.3096 + 2.2524 \log_{10} x$

$\text{Log}_{10}\ y$ *(Picea rubens)* $= 2.3151 + 2.1830 \log_{10} x$

y = aboveground dry weight in grams.
x = dbh in cm.
Abies balsamea was combined with *P. rubens*.
Betula papyrifera was combined with *B. alleghaniensis*.

Results

Yellow birch (*Betula alleghaniensis* Britt.) was the dominant tree in the 607-ha valley, with 27 percent of the basal area. Beech. (*Fagus grandifolia* Ehrh.), red spruce (*Picea rubens* Sarg.), sugar maple (*Acer saccharum* Marsh.), balsam fir (*Abies balsamea* L. Mill.), paper birch (*Betula papyrifera* Marsh.), and striped maple (*Acer pensylvanicum* L.) followed in importance (Table 2).

The smallest diameter class (0-12 cm) accounted for 16 percent of the basal area; red spruce and balsam fir made up nearly half of it. The major hardwoods accounted for 55 percent of the next size class (12-28 cm), with yellow birch predominant. Beech accounted for a high proportion of the 28-40 cm class, while sugar maple made up 40 percent of the largest size class (Table 2).

Yellow birch accounted for more than 23 percent of the total basal area at each elevation (Table 3). At the lower elevations (575-650 m) the northern hardwoods (birch-beech-maple) accounted for 88 percent. In the middle slopes (650-850 m) these species still accounted for more than 50 percent, but red spruce began to make a considerable contribution, with 17 to 20 percent of the basal area. At the higher elevations (850-915 m) beech and sugar maple dropped out, balsam fir and yellow birch accounted for 50 percent of the basal area, with paper birch and mountain maple ("other" in Table 3) adding 24 percent, and red spruce alone contributing 18 percent of the population.

Yellow birch may be found in all stages of succession, but it regenerates and survives

Table 2.—*Estimated basal area of trees in the Bowl by species and diameter class*

Dbh	Beech	Yellow birch	Sugar maple	Red spruce	Balsam fir	Paper birch	Striped maple	Others [a]	Total	Percent
cm				m²/ha						
0-12	0.6	0.7	0.3	1.0	0.9	0.2	0.5	0.3	4.5	16
12-28	1.5	3.3	0.8	1.9	0.9	1.3	0.2	0.3	10.2	36
28-40	2.8	2.1	1.1	.9	0	0.3	0	0.1	7.3	26
40+	1.0	1.6	2.5	1.0	0	0	0	0.1	6.2	22
Total	5.9	7.7	4.7	4.8	1.8	1.8	0.7	0.8	28.2	
Percent	21	27	17	17	6	6	3	3		

[a] Other species included pin cherry (*Prunus pensylvanica* L.), mountain maple (*Acer spicatum* Lam.), mountain ash (*Sorbus americana* Marsh.), red maple (*Acer rubrum* L.), and hemlock (*Tsuga canadensis* L. Carr.). Hobblebush (*Viburnum alnifolium* Marsh.) was prolific, but was not inventoried.

Table 3.—*Stand composition in percent of basal area by species and elevation*

Elevation (m)	Beech	Yellow birch	Sugar maple	Red spruce	Balsam fir	Paper birch	Striped maple	Others
575-650	30	42	16	7	1	1	1	2
650-750	28	29	18	17	2	3	2	1
750-850	18	24	13	20	7	10	4	4
850-915	0	23	2	18	27	13	5	12

Of the 190 plots inventoried:
Pin cherry occurred on 22 plots; 16 of these plots were in windthrow in Area III.
Mountain maple occurred on 25 plots at all elevations.
Mountain ash occurred on 7 plots, all above 850m.
Red maple occurred on 5 plots, all below 750m.
Hemlock occurred on 4 plots, all below 750m.
One Canadian yew (*Taxus canadensis* Marsh.) and one white ash (*Fraxinus americana* L.) were noted.

readily only after some type of disturbance (Leak 1974). This might be the death of a single tree providing an opening. But the apparent dominance of yellow birch in the Bowl indicates a major disturbance some time in the past (Forcier 1975). Paper birch was almost exclusively associated with the spruce-fir type at the higher elevations. Pin cherry was included in this analysis as an indicator of recent disturbance. It was found at the site of windthrow disturbances, usually limited to a very few hectares widely scattered throughout the forest. In Area III approximately 24 ha have been disturbed twice rather recently. The current vegetation contains a high percentage of pin cherry in decadence. Borings indicated that the stand ranges in age from 35 to 55 years. Therefore, it may or may not have been the result of the 1938 hurricane. Observations of fallen stems indicated that the previous stand was predominately red spruce and paper birch with an average dbh of 30cm. Many old paper birch logs remain with all of the wood rotten but the bark largely intact. These stems all lie oriented from NW to SE.

Discussion

One of the objectives of the study was to compare the vegetation of the reserved area (I) of the Bowl, known to be a virgin forest, with the rest of the valley. There were no statistically significant differences in basal areas per hectare among the four areas of the Bowl (Table 1). The mean basal area for the Bowl as a whole was

28.2m^2/ha. Data from the nearby Bartlett Experimental Forest indicate that 29m^2/ha is about the maximum that can be maintained in an old-growth northern hardwood stand (Filip et al. 1960).

The solutions to the dry weight aboveground biomass regression equations (Whittaker et al. 1974) were:

Area	*Aboveground dry biomass/(metric tons/ha)*
I	262
II	254
III	230
IV	217

These data also indicated very little difference between the areas of the Bowl.

Within the Bowl, however, there were individual stands that were quite different from the average. One stand of sugar maple and beech averaged 35m^2/ha of basal area and 350t/ha of dry biomass, while another stand of beech averaged only 2m^2/ha and 8t/ha. Leak (1974, 1973) discussed one 18-ha stand in the southeast corner of the Bowl in depth.

A 13-ha northern hardwood stand at the Hubbard Brook Experimental Forest, heavily logged before 1920, averaged only about 23m^2/ha of basal area (Bormann et al. 1970) and about 140t/ha of dry aboveground biomass (Whittaker et al 1974). In spite of these differences, there were several similarities between the stands at Hubbard Brook and the Bowl. Sugar maple was the major species at both locations at lower elevations, but began to drop out at 700m. In both forests, yellow birch was quite evenly distributed throughout the elevational range. In the 60-year-old stand, beech seemed to be evenly distributed over the forest as a whole and was a major component above 732m. At the Bowl, however, basal area in beech decreased with elevation and beech essentially dropped out above 850m (Table 3). Red spruce, balsam fir, and paper birch were found at all elevations in both forests and increased in importance rapidly with increases in elevation.

There seemed to be major differences in the sapling populations between the 60-year-old forest at Hubbard Brook and the mature forest at the Bowl, but these differences may be edaphic. At Hubbard Brook, beech saplings are dominant, while red spruce and balsam fir saplings are minor constituents. In the Bowl, conditions were reversed, with 42 percent of the saplings in spruce and fir, while beech make up only 13 percent of the basal area in stems 0 to 12 cm (Table 2). Again, these are area-wide data; individual stands in the Bowl differ from the average.

Conclusions

The Bowl Research Natural Area is one of the few remaining examples of forests that have never been logged in the eastern United States. It is a mixed forest, stocked mainly with yellow birch, beech, and sugar maple at the lower elevations; red spruce and balsam fir at higher elevations. Contrary to popular opinion this "virgin" forest is not homogeneous; wind and disease have created a mosiac of stands. Some have as little as 2 m^2/ha of basal area and 8 t/ha of above-ground dry biomass; others have as much as 35 m^2/ha and 334 t/ha.

Accumulated biomass, basal area per hectare and species composition do not differ significantly between the slopes of the West Branch watershed. Therefore, I feel it is reasonable to conclude that none of the western watershed has been logged.

We know that the eastern watershed was logged to some degree 90 years ago. The forest there now has 27 m^2/ha of basal area, which is not statistically different from that of the undisturbed forest. The eastern watershed has accumulated about 220 t/ha of biomass, less than the 262 found in the undisturbed forest but much more than the 140 t/ha reported from a nearby 60-year-old northern hardwood forest. Thus, it seems that the eastern watershed has recovered from the logging of 90 years ago.

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FOREST SERVICE, U.S. DEPT. OF AGRICULTURE, 6816 MARKET STREET, UPPER DARBY, PA. 19082

ALTERNATE HOSTS OF *BLEPHARIPA PRATENSIS* (MEIGEN)

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Abstract.—A current tactic for biological control of the gypsy moth, *Lymantria dispar* Linnaeus, is to release its parasites in forests susceptible to gypsy moth damage before the gypsy moth arrives. The basic assumption in these anticipatory releases is that the parasites can find and utilize native insects as hosts in the interim. *Blepharipa pratensis* is being used in this way.

The efficacy of such releases has not been demonstrated. The present state of our knowledge about the niche requirements of gypsy moth parasites in general, and *B. pratensis* in particular, does not permit an evaluation now. However, we do have sufficient information to determine the crucial point of whether *B. pratensis* can live and develop in particular native lepidopteran species that are potential hosts.

We report here on the survival of *B. pratensis* in eight potential North American hosts.

Background

B. pratensis females lay their eggs on the surfaces of vegetation. Upon ingestion by a gypsy moth larva, the egg hatches in the gut and the maggot bores through the gut wall into the hemocoel. Within 24 hours most maggots bore into a longitudinal intersegmental muscle. The maggot remains there as instar I until the gypsy moth larva pupates. After this event, the maggot quickly completes its development and leaves the pupa to pupariate, about 7 days later *(Shields 1976)*. Infection of host, then, requires that the egg be ingested.

In Europe, *B. pratensis* is an oligophagous parasite *(Mesnil 1950; Herting 1960)*. In North America it has been recovered from field-collected larvae of the tent caterpillars *Malacosoma americanum* (Fabricius) and *M. disstria* Hubner *(Schaffner and Griswold 1934; Bess 1936)*. Schaffner and Griswold reported it from *Datana integerrima* Grote and Robinson; *Symmerista albifrons* (J. E. Smith); *Graptolitha* sp.; *Catocala* sp.; and an unidentified noctuid. The number of *B. pratensis* recovered from these naturally infected species was extremely low. The incidence was highest (1:46) for the *Catocala* species, and lowest for *Datana in-*

tegerrima. It has also been recovered from *Stilpnotia salicis* (Linnaeus) *(Schaffner 1950)*.

Thompson *(1913)* fed *B. pratensis* eggs to a number of forest lepidoptera in the laboratory. The parasite successfully developed in *M. americanum* and *M. disstria*, but none survived in *Nymphalis antiopa* Linnaeus, *Orgyia leucostigma* (J. E. Smith), or *O. antiqua* Linnaeus.

Except for the tent caterpillars, the record is too fragmentary to tell whether *B. pratensis* survives only rarely in the species observed—in some special set of circumstances—or whether *B. pratensis* can develop normally, but is out of phase either in time or place, or both, with other potential hosts.

For our purposes, we have simply bypassed the time and place aspects of infection and fed eggs directly to larvae in the laboratory.

Methods

The species studied were collected in the field, brought to the laboratory, and reared in environmental chambers at 25°C and 60% RH with 16 hours of light (6:00 am to 10:00 pm). Penultimate and last instar larvae were fed *B. pratensis* eggs by placing two eggs on an edge of a 1-cm^2 piece of leaf in a 100 x 15-mm petri dish. If the eggs were not eaten within 12 hours, the eggs were removed and replaced with a new leaf fragment and eggs. The larvae were then reared to the pupal stage to await the emergence of the maggot, if any.

For each species, a number of larvae equal to the number tested was reared to check for the incidence of natural infection. After pupation, the puparia were weighed; and 14 days later they were radiographed to determine whether pupation had taken place *(ODell et al. 1974)*.

Results

B. pratensis was not recovered from any of the larvae reared to check for natural infection.

No *B. pratensis* maggots emerged from the following species: *Heterocampa guttivitta* (Walker), *Dasychira basiflava* (Packard), *Nymphalis antiopa*, or *Acronicta* spp. The data are summarized in Table 1.

B. pratensis maggots did emerge from *Malacosoma americanum*, *M. disstria*, *Hemiluca maia* Drury, and *Anisota senatoria* (J. E. Smith).

Only in *M. disstria* did *B. pratensis* survive as well as it did in *L. dispar*. Survival in all other species was significantly lower. However, the insects that developed in *M. disstria* were significantly lighter. The mean weight of 3-day-old puparia from *M. disstria* was 0.0933 g, and from *L. dispar* 0.1194 g. On the other hand, *B. pratensis* did not survive as well in *H. maia*, but those individuals that did survive were not significantly lighter (0.1053 g) than those from *L. dispar*.

With the gypsy moth we have found a close correlation ($r^2 = 0.8548$) between the weight of a pupa and the weight of the *B. pratensis* puparium that develops from it. *M. disstria* pupae are smaller than gypsy moth pupae, so

Table 1.—*Survival of Blepharipa pratensis in host species reared in the laboratory*

Host species	Larvae fed eggs	Maggots emerged	Puparia	Average puparium weight	Pupae	Survival to pupation
	No.	*No.*	*No.*	*g.*	*No.*	*Pct.*
L. dispar	100	53	53	0.1194 ± .0249	49	49.00
M. disstria	62	37	37	.0933 ± .0139	23	37.17
M. americanum	100	38	38	.0643 ± .0104	20	20.00
H. maia	100	12	14[a]	.1053 ± .0321	7	7.00
A. senatoria	100	2	3[a]	.0584 ± .3195	1	1.00
H. guttivitta	30	0	0	0	0	0
D. basiflava	14	0	0	0	0	0
N. antiopa	8	0	0	0	0	0
Acronicta spp.	54	0	0	0	0	0

[a]Radiographic examination of host pupae showed that some maggots did not emerge, but pupariated within the host pupa.

the smaller puparia were to be expected. *H. maia* pupae are as large as gypsy moth pupae.

At the moment, we do not know the relationship of puparium weight to subsequent adult fecundity and survival; nor do we know whether differences in the magnitude of adult survival and fecundity can compensate for differential maggot survival. The interaction of these and other processes will determine, in the end, what species can support *B. pratensis* in the field in the absence of *L. dispar.*

We have shown here only that *B. pratensis* can survive to the pupal stage in a number of native species, given that a *B. pratensis* egg is eaten.

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THE COMPOSTING OPTION FOR HUMAN WASTE DISPOSAL IN THE BACKCOUNTRY

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Abstract.—The disposal of human waste by composting at backcountry recreation areas is a possible alternative to methods that are considered unsafe. The literature indicates that aerobic, thermophilic composting is a reliable disposal method that can be low in cost and in maintenance. A bark-sewage mixture can be composted to produce a pathogen-free substance that might be used in site rehabilitation. Composting in a leakproof bin is odorless, and is largely independent of site conditions.

In the last few years, there has been a significant increase in the number of visitors to backcountry recreation areas. This growth has created several problems for the manager, including the difficulty of disposing of human waste safely at remote shelter sites.

The pit privy was the universal method for disposing of human waste at these remote sites. Privies were located on sites where the soil was deepest. But because of the larger number of visitors to backcountry recreation areas, and the fact that privies must be moved when they are full, there are more privies on sites where the soil is shallow or poorly drained. Managers are increasingly aware that environmental and health hazards might result from placing privies on inadequate sites.

The composting of human waste at backcountry shelter sites might offer some advantages over conventional methods of waste disposal.

The Compost Process

The main concern about using composting for waste disposal in the backcountry has been whether the process produces a pathogen-free substance that can be disposed of easily. Studies show that aerobic, thermophilic (45 to 70°C) composting produces substances that have few, if any, pathogens. In a windrow composting operation where a mixture of raw sewage and ground hardwood bark was used, *Escherichia coli*, *Candida albicans*, and *Salmonella heidleberg* were added to the raw sewage. There was no evidence of these human pathogen indicator organisms after 36 hours of composting at temperatures above 60°C *(Walke 1975)*. Similar results were obtained when *Salmonella*

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newport, Ascaris lumbricoides, Candida albicans, and poliovirus type 1 were added to raw sewage under similar conditions *(Wiley and Westerberg 1969)*. Other studies have shown that pathogenic microorganisms that may be harmful to man are destroyed during composting *(Gotaas 1956; Knoll 1959; Wiley 1962; Straub 1962).*

Most of the information on the destruction of pathogens concerns the effect of heat generated during the composting process on microorganisms. These organisms also are killed during composting by antibiosis, the destruction of pathogens through antagonistic relationships among microorganisms or by substances produced by certain microbes *(Knoll 1959). Salmonella typhimurion, S. cairo, S. infantis, S. typhi,* and *S. paratyphis* B. were killed at a sustained temperature of 50°C as long as the pathogens were exposed to the composting material. The same microorganisms encapsulated in gelatin were not destroyed at that temperature.

This indicates the importance of an active composting process in eliminating health hazards. Good composting conditions directly affect the activity of microorganisms; and it is this activity that generates sufficient heat and antibiotic conditions to destroy pathogens. The difficulty is ensuring that good composting conditions are created.

Microorganisms are controlled to a large extent by the appropriate carbon/nitrogen ratio and moisture content of the compost material. Carbon/nigrogen ratios of from 20:1 to 30:1 are desirable because the organisms use these elements in those proportions *(Nell and Krige 1971; Goleuke 1972; Poincelot 1974)*. A higher ratio slows the composting process because nitrogen may become limiting, while a lower ratio may result in a loss of nitrogen in the form of ammonia.

Desirable moisture levels for composting range from 40 to 70 percent *(Poincelot 1974; Kochtitzky et al. 1969; Schulze 1961; Snell 1957; Wiley 1957; Gray et al. 1971; Nell and Krige 1971).* The lower end of this range generally applies to windrow or heap composting where maintenance may be infrequent; the upper end applies to aerated systems where the material is agitated mechanically. We can assume that when moisture content is less than 40 percent, the activity of microorganisms is reduced to undesirably low levels; when the moisture content is greater than 70 percent, composting conditions become anaerobic.

For composting in backcountry areas, human waste must be mixed with a material that will adjust the moisture content to an acceptable level and help produce the proper C/N ratio. One of the best mixing agents is ground hardwood bark *(Walke 1975).* This material is highly absorbent, is a good source of nutrients, helps eliminate odors, has a desirable C/N ratio, and is easy to handle.

Unfortunately, there is no material already on the site that could be used; the available soil usually does not have an appropriate C/N ratio, and it does not absorb enough liquids unless used in large amounts. And soil is not easily obtained on shallow or rocky sites. The same is true for fresh litter.

So despite the inconvenience of physically carrying ground hardwood bark to a remote site, composting with this material seems to be a satisfactory alternative when other waste disposal methods cannot be used. Noncomposting methods are often far more expensive; in some areas, the only alternative to composting is closing the site.

Other Considerations

Other considerations in composting are the texture of the material, aeration, and the size of the pile. A finely textured material is desirable *(Snell 1957; Poincelot 1974),* particularly for composting raw sewage and hardwood bark.[1] A fine-textured material is more susceptible to invasion by microbes, is more easily moistened, and increases the rate of decomposition. A distribution of particle sizes ranging from 1.2 cm in diameter for materials that are being aerated and mechanically mixed to 5.0 cm in diameter for mixtures that are managed infrequently has been suggested *(Gray et al. 1971).*

Aeration by the "natural chimney effect" is not adequate for maintaining enough oxygen in the pile at times of peak demand for oxygen *(Snell 1957).* Thus it is sometimes necessary to turn even a well-managed pile. The oxygen content in the pile is the best indicator of turning

[1] Included in report by Gregory MacDonald to Environmental Protection Agency on a 1974 composting study in North Stratford, N.H.

time, but unusual odors or declining temperatures also are useful indicators.

Aeration also might be improved by driving perforated tubes through the compost heap *(Wolf and Dunn 1953)* or by composting in wire mesh bins *(Maier et al. 1957)*. These methods might be helpful at remote sites where the pile is turned infrequently.

The size of a compost pile also is important at remote sites where the volume of human waste may be relatively small. There is a minimum size below which the surface area to volume ratio results in a loss of heat that is greater than the amount of heat that is produced. Our pilot study in 1976 showed that a bin that is 3 feet (.91 m) by 4 feet (1.2 m) by 2 feet (.61 m) and that is filled with a bark-sewage mixture can maintain temperatures greater than 60°C. This is one indication of the minimum size for a compost pile. It also has been reported that a 27 ft^3 (0.75 m^3) pile is effective for aerobic composting *(Dunn and Emery 1959)*.

Conclusion

Composting of human waste seems to have strong potential at shelter sites accommodating as many as 50 people—even where soils are shallow—because it can be done in a leakproof bin. This process is safe and odorless, and produces a substance that might be used in site rehabilitation. Composting in a bin also can be low in cost and in maintenance, and the process is largely independent of site conditions. This alternative would be particularly useful at sites where other methods are impractical. A mixture of human waste and ground hardwood bark adjusted to about 50 percent moisture, and that is at least 27 ft^3 in volume, should promote activity by microorganisms that will destroy most pathogens. The destruction process would require that all portions of the pile be exposed to a temperature of at least 60°C for 36 hours.

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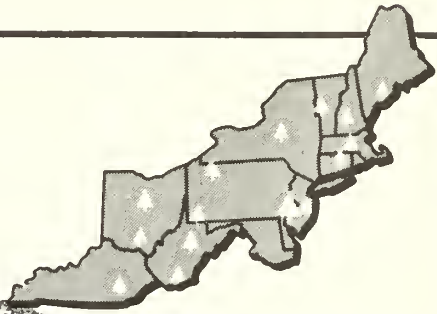

FOREST SERVICE, U.S. DEPT. OF AGRICULTURE, 6816 MARKET STREET, UPPER DARBY, PA. 19082

A HYDRAULIC ASSIST FOR A MANUAL SKYLINE LOCK

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Abstract.—A hydraulic locking mechanism was designed to replace the manual skyline lock on a small standing skyline with gravity carriage. It improved the efficiency of the operation by reducing setup and takedown times and reduced the hazard to the crew.

Two hydraulic cylinders provided the solution to a problem in the cable locking mechanism of a skyline logging system that we are evaluating for harvesting Appalachian hardwoods.

The URUS system, manufactured by Reinhold Hinteregger Company of Villach, Austria,[1] is a small standing skyline with a gravity carriage. The carriage and load of logs are pulled up the skyline by a winch; the empty carriage then returns by gravity. Because the system can reach 1,000 feet down the side of a mountain, logging roads can be placed 1,000 feet apart, which reduces their impact on the forest.

As manufactured, the URUS system uses a manual lock to hold tension on the skyline. Two steel wedges clamp the cable between them. Their narrower ends are toward the load so that as the load increases the clamping force on the cable increases. To lock them, a crewman had to climb the 28-foot tower and drive the wedges out with a hammer.[2] To unlock them he had to climb the tower again and drive the wedges in against the tension on the cable. Several times the lock stuck and once the jammed cable tore the clutch face from the clutch plate on the engine, causing lengthy downtime.

To overcome this problem, we added two hydraulic cylinders to the skyline lock so that the locking wedges could be locked and unlocked from the ground. It is still necessary to climb the tower to tighten or loosen the clamping bolts, because we do not want to depend on hydraulic pressure to hold the cable in place after it is locked—there is a possibility that the hydraulic fluid might leak and allow the lock to slip. But the hydraulic locking device has reduced setup and takedown time by 30 minutes and reduced the hazard to the crew.

[1]The use of a trade, firm, or corporation name in this publication is for the information and convenience of the reader. It does not constitute an official endorsement or approval by the Forest Service or the U. S. Department of Agriculture of any product or service to the exclusion of others that may be suitable.

[2]1,000 feet = 304.8 meters
28 feet = 8.5 meters

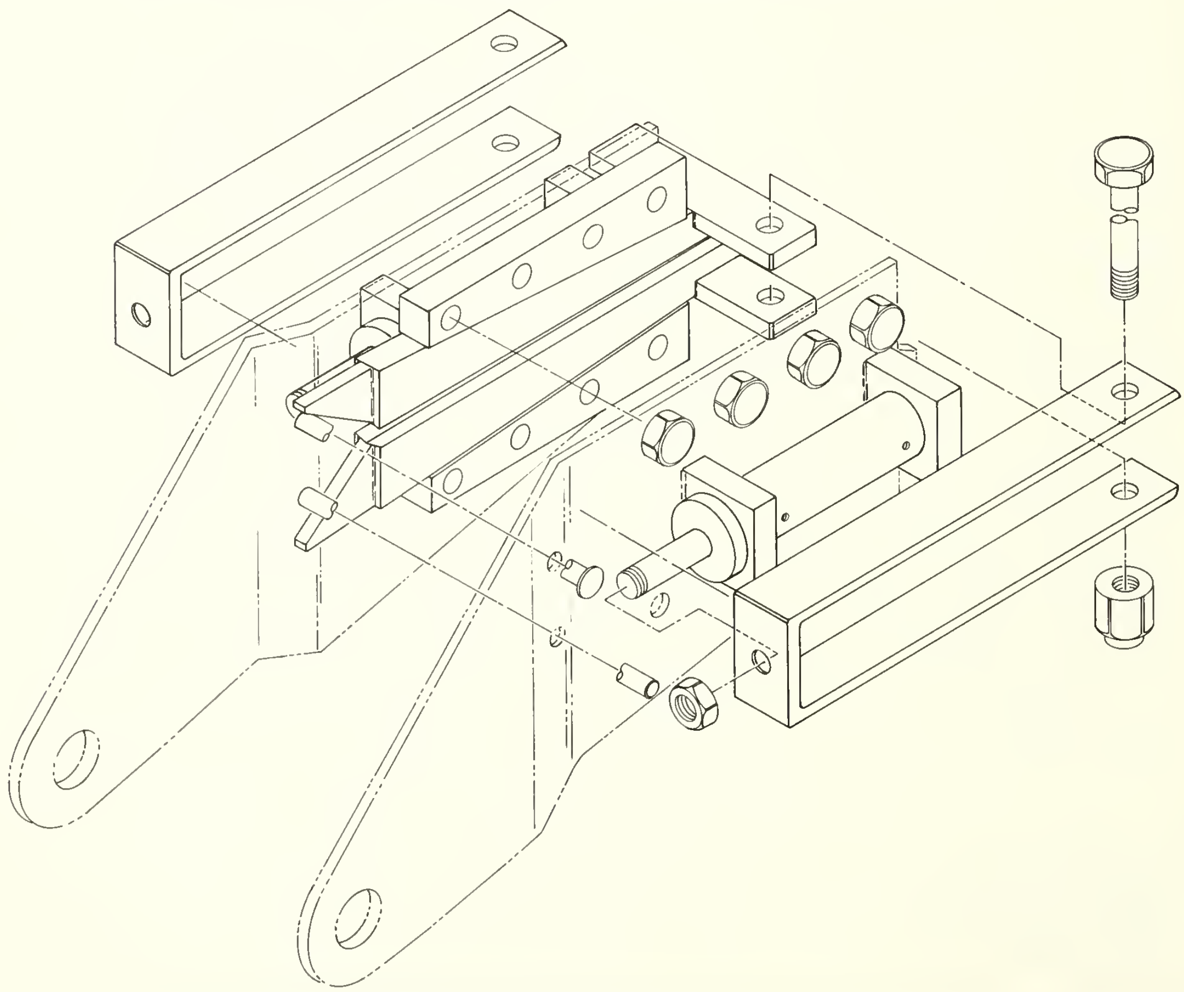
We chose two double-acting cylinders with a travel of 3-1/8 inches, a pushing capacity of 17,-670 lb each, and a pulling capacity of 9,280 lb each. They are rated at 10,000 lb/in^2 hydraulic pressure. The pressure is generated by a two-stage hand pump and delivered to the cylinders by hoses.[3]

[3]3-1/8 inches = 7.9 centimeters
17,670 pounds = 8,015 kilograms
9,820 pounds = 4,454 kilograms
10,000 pounds = 4,536 kilograms

Since unlocking the cable requires more force than locking it (because the load on the cable tightens the lock), we mounted the cylinders with their shafts toward the rear of the lock and fabricated a U-shaped yoke to connect them to the wedges (Fig. 1).

The total cost of parts and material was $869.47. Two man-days of labor were required to build and install the device. The only trouble we have encountered was leakage of hydraulic fluid at the quick disconnects on the pump; this was overcome by replacing the O-ring.

Figure 1.—Hydraulic skyline lock. The skyline cable is clamped between the two wedges in the center. The original manual lock was modified by addition of two hydraulic cylinders, one on each side, and the yokes and crossbars that connect them to the wedges. The bolt at the extreme right is one of a pair used to lock the cable after it has been adjusted.



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1977

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SURFACE MINING AND THE FLOOD OF APRIL 1977

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Abstract.—Data from experimental sites in Breathitt County, Kentucky, and Raleigh County, West Virginia, showed that during a major rainstorm on 4 April 1977 streamflow from surface-mined watersheds peaked lower than that from adjacent or nearby unmined watersheds.

On 4 April 1977 a major storm struck southern Appalachia. Reports were that it caused the worst flooding since 1957, or since 1939, or perhaps the worst in history.

Many possible causes of the flooding have been discussed. Among these are forest fires, logging, agriculture, road building, construction on flood plains, and surface mining. But there are few quantitative data to support these conjectures.

One of the first attempts in the U.S. to evaluate the hydrologic impact of surface mining was at Beaver Creek in southeastern Kentucky. Flow from the mined watershed was more variable than that from the unmined control watershed, and also tended toward higher storm flows and lower base flows (Collier et al. 1970).

Strip-mined watersheds in Indiana showed an increase in base flow, apparently due to increased storage capacity. Agnew and Corbett (1973) reported that during the unusually dry summer of 1964, a number of streams draining strip-mined land were flowing while streams draining adjacent unmined areas of similar or larger size were dry.

Although some studies have been made, the effects of surface mining on the hydrograph of discharge remain largely unmeasured. In 1967 the USDA Forest Service's Northeastern Forest Experiment Station began a study of the effects of surface mining on the water resources of small Appalachian watersheds. Three unmined forested watersheds in Bear Branch, Breathitt County, Ky., were selected and instrumented for collection of streamflow and water quality data. Miller Branch and Mullins Fork are adjacent basins; Jenny Fork is about a mile away. Jenny Fork is unmined; Miller Branch and Mullins Fork have been surface mined. Two more watersheds, Dillon and Stover B, in Raleigh County, W. Va., some 120 miles from the Kentucky site, were selected and instrumented in 1969.

Sedimentation basins were built in Miller Branch and Mullins Fork in November of 1969, shortly after mining began. Their original storage capacities were 15.9 and 15.4 acre feet, respectively. In October of 1976, the remaining storage capacity was about 6.5 acre feet for Miller and 3.5 acre feet for Mullins; sediment from the mining operations occupied the rest.

Descriptive data on the watersheds studied are:

Watershed	*Area (acres)*	*Area disturbed by mining*	*Percent of area disturbed*	*Dates of mining Began*	*Ended*
Jenny	287	0	0	—	—
Miller	190	105	55	Aug. '68	Dec. '71
Mullins	327	151	46	Aug. '69	Oct. '72
Dillon	164	0	0	—	—
Stover B	446	250	56	Sept. '72	June '73

A complete detailed analysis of streamflow in relation to surface mining is underway and will be reported; some results of the study have already been reported (Curtis 1971, 1972, 1973, and 1974). But there presently is considerable interest in the flooding that took place during early April 1977, and it seems appropriate to share now some of the knowledge we gained during that period. Of course, the information from three watersheds in Kentucky and two in West Virginia does not necessarily apply to all watersheds in Appalachia, but it does provide some food for thought.

This case history covers a 9-day period beginning on 1 April 1977. There was no precipitation on 1 April. At the Kentucky site rain began at 1930 on 2 April and ended about 2245 after 0.72 inch of water had fallen. At about 2045 on 3 April it started raining again, and continued with periodic high intensities for about 26 hours, ending just before midnight on 4 April. The total precipitation was 3.70 inches (Fig. 1). At the West Virginia site rain began at 2110 on 2 April and ended about 2345 with 0.31 inch. Rain started again at 2145 on 3 April and by midnight on 4 April, 3.85 inches had fallen on the watersheds. Additional small amounts fell on 5 and 6 April (Fig. 2).

Data collected at other nearby gaging sites suggest that all the watersheds in each group received the same amount of rain; and the rain at the Kentucky site was almost the same as that at the West Virginia site (Fig. 1 and 2).

Figure 1 shows the precipitation on the Kentucky watersheds and the flow from them. At Jenny Fork (the unmined watershed), the 0.72 inch of rain on 2 April had little direct influence on streamflow; most of this water apparently went to recharge a moisture deficit in the soil. By the time the next rain started late on the 3rd, water was already stored in the soil; streamflow responded very quickly to rainfall. Note that during the two periods when rainfall intensity declined, streamflow decreased rather sharply. The peak flow came very near the end of the storm. The plot also shows a fairly rapid depletion rate on 5 April.

Below the streamflow data from Jenny Fork are plotted those from Mullins Fork. Keep in mind that Mullins Fork contains about 150 acres of land disturbed by surface mining; Jenny Fork is completely forested. The two lower curves show the similarity of flow from the two mined watersheds.

Figure 2 shows the streamflow response of the unmined and mined watersheds in West Virginia. The precipitation pattern is nearly the same as that for the Kentucky area. Note that the mined watershed peaked about 16 percent lower than the unmined watershed.

Runoff from Jenny Fork peaked at a rate of 160 cubic feet per second per square mile ($ft^3/s/mi^2$) while Mullins peaked at 93 and Miller at 64. Unmined Dillon peaked at 109 and Stover B at 91. Table 1 summarizes the flow in both mean daily cubic feet per second per square mile and area inches per day for each of the 9 days. An area inch is the volume of water that would cover the entire drainage area to a depth of 1 inch. By comparing area inches for Jenny with those of Mullins or Miller Branch we see that Jenny yielded nearly twice as much flow as Mullins and more than twice as much as Miller on 4 April; furthermore both Miller and Mullins yielded more water than Jenny for each of the next 5 days. In the West Virginia watersheds, unmined Dillon yielded about 18 percent more water on 4 April than Stover B. It is interesting that the West Virginia stream had more discharge on the 5th than on the 4th, just the opposite of the Kentucky streams. This is probably because the general eastward movement of the storm system caused the West Virginia streams to rise and peak later than the Kentucky streams.

According to our calculations, Jenny Fork yielded 4.03 area inches of water while Miller yielded 2.73 and Mullins 2.88 during the first 9

re 1.—Precipitation and streamflow from water-
ls in Kentucky. Jenny Fork is unmined; Mullins
Miller have been mined.

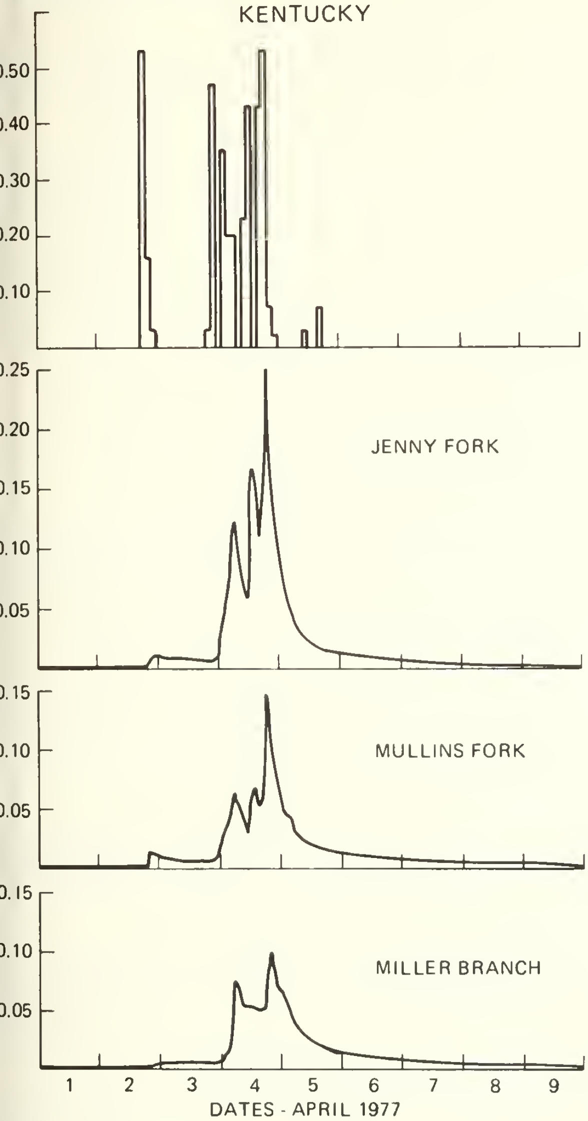
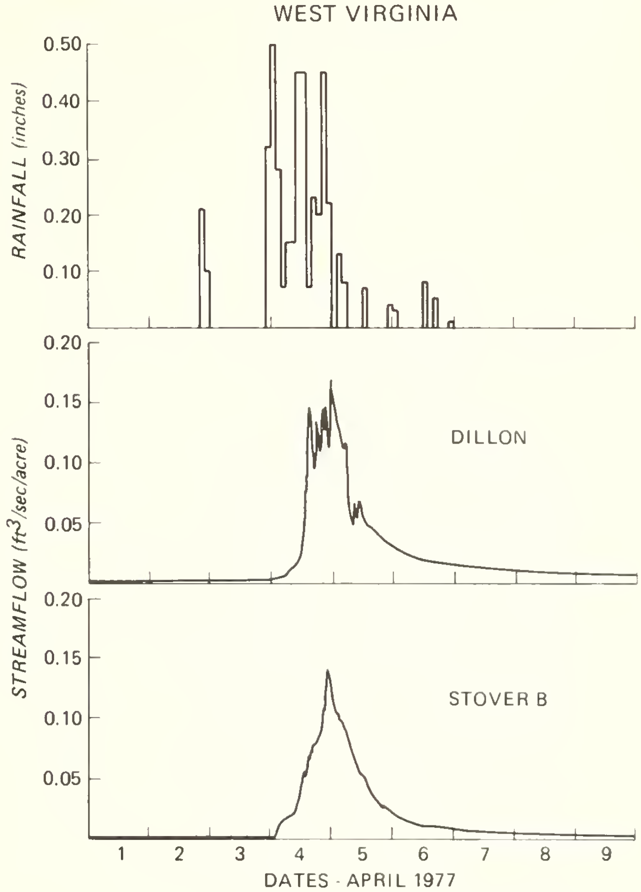


Figure 2.—Precipitation and streamflow from watershed in West Virginia. Dillon is unmined; Stover has been mined.



days of April. This means that more than 1 inch of rain went into retention storage in the two mined watersheds while very little went into storage in the unmined watershed.

Remembering that the data presented here are for only one storm on only two unmined and three mined watersheds, can we discern any implications? The soils in the unmined watersheds are relatively thin, generally from 1 to 3 feet thick. This means that water retention in these soils is about 3 to 10 inches. If this storage is filled, any water added will be available for streamflow. On the other hand, surface mining creates vast quantities of broken-up rock which provide storage space for large quantities of water. This could account for the reduced peak flows and the reduced volume of flow as well as the higher depletion flow rates on the mined watersheds.

Unfilled sediment basins can reduce local peak flows and prolong discharge for a few hours by regulating release from relatively small headwater drainages such as those in this study. However, measurements made along the high water mark in the Kentucky watersheds on 26 April showed that neither of the basins had been filled to capacity during the study period. In fact at maximum storage the basin in Miller Branch held only 38,800 cubic feet—less than

Table 1.—*Summary of stream discharges for the period 1 April to 9 April 1977*

Date in April 1977	Unmined watersheds				Mined watersheds					
	Jenny Fork		Dillon		Miller Branch		Mullins Fork		Stover B	
	Mean daily $ft^3/s/mi^2$	Mean area inches per day	Mean daily $ft^3/s/mi^2$	Mean area inches per day	Mean daily $ft^3/s/mi^2$	Mean area inches per day	Mean daily $ft^3/s/mi^2$	Mean area inches per day	Mean daily $ft^3/s/mi^2$	M a in pe
1	0.577	0.022	1.093	0.041	0.891	0.033	0.884	0.033	0.603	0.
2	1.392	.052	1.312	.049	1.160	.043	2.091	.078	.582	.
3	4.176	.155	1.313	.049	3.116	.116	3.578	.133	.672	.
4	70.060	2.606	40.508	1.506	33.808	1.257	38.488	1.432	33.016	1.
5	19.481	.725	42.449	1.579	19.230	.715	16.047	.597	38.393	1.
6	5.475	.204	12.422	.462	5.961	.222	5.768	.214	8.550	.
7	3.356	.125	7.260	.270	4.059	.151	4.169	.155	4.250	.
8	2.309	.086	5.512	.205	2.897	.108	3.424	.127	3.028	.
9	1.646	.061	4.224	.157	2.206	.082	3.083	.115	2.386	.
Totals		4.036		4.318		2.727		2.884		3.

one acre foot. The Mullins Fork basin held less than 3,000 cubic feet during maximum storage. These volumes are so small relative to the total storm discharges that they could not have had any significant influence on either peak flow rates or total streamflow. This tends to support our theory that retention and detention storage is in or on the mine spoil.

The same pattern of streamflow response on surface-mined watersheds was documented for a major storm on 4 April 1977 in areas more than 120 miles apart. The magnitude of the response was less pronounced at the West Virginia site where a smaller percentage of the watershed had been disturbed by mining.

Data on the effects of surface mining on our water resource are badly needed by resource managers. These preliminary results suggest that conventional wisdom about disturbed land may not be a good guide to hydrologic effects.

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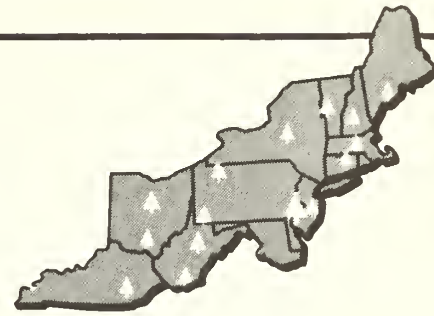

FOREST SERVICE, U.S. DEPT. OF AGRICULTURE, 6816 MARKET STREET, UPPER DARBY, PA. 19082

A PREVIEW OF WEST VIRGINIA'S FOREST RESOURCE

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Resources Evaluation

Abstract.—Forest land occupies 75 percent of the total land area of West Virginia. Sixty percent of the forest land is classified in the oak-hickory forest type and only 6 percent in all the softwood forest types. Since 1961, growing-stock volume increased 24 percent. Yellow-poplar increased 39 percent in volume and is now the prevalent species in the State.

Keywords: Forest surveys (West Virginia), forest area, resources (timber), statistics (forestry).

Forest is the dominant land use of the rugged West Virginia landscape. Inventories of this resource have been made by the Forest Service three times in the past quarter century. Each survey was designed to provide a reliable estimate of the extent and condition of the forest resource and to indicate what changes were occurring. A detailed statistical and analytical report of the most recent inventory is being prepared for publication. It will give a comprehensive analysis of the current situation and trends in the forest resource. This is a preview of that report.

Forest Land Area Continues to Increase

In 1949 forest occupied 64 percent of the total land area of West Virginia. The second inventory in 1961 showed a dramatic increase of forest area to 74 percent of the land area. The most recent inventory shows that this trend has continued although the rate has declined. In 1975 the forest area was 11.6 million acres—75 percent of the total land area. Considering the area of land affected since 1961 by the construction of major segments of the Interstate

Highway System, new pipeline and powerline rights-of-way, mining activity, and the growth of urban areas, the continued increase in total forest area is more significant than indicated by the percentage increase.

Ninety-nine percent of the 11.6 million acres of forest is classified as commercial forest land; the remainder is classified as either unproductive forest or productive-reserved. Land area in the productive-reserved category increased as a result of administrative reclassification of public forest lands. Since 1961, the area in productive-reserved status has increased from 46,000 to 115,000 acres.

Forests are distributed quite uniformly across the entire state. All counties except Brooke and Jefferson are 50 percent or more forested. Six counties are over 85 percent forested. Webster County has the distinction of being the most heavily forested with 92 percent of its land area in forest.

Hardwood types predominate in West Virginia. Sixty percent of the forest land is classified in the oak-hickory forest type and only 6 percent in all the softwood forest types. The distribution of the hardwood forest types shows some significant shifts since 1961. The area in the oak-hickory type declined but an important local type in this group—yellow-poplar—showed a significant increase. The area in the oak-pine, the elm-ash-red maple, and the maple-beech-birch types increased.

A study of forest-land owners was conducted in conjunction with this inventory. Two objectives of this study were to define the pattern of forest-land ownership more clearly and to seek an understanding of the motives and intentions of forest-land owners. Over 1 million acres of commercial forest land is publically owned. All of the Monongahela plus parts of the George Washington and Jefferson National Forests account for 873 thousand acres. Most of the remaining public lands are State-owned. An estimated 207,500 individuals, groups, or corporations each own 1 acre or more of the 10,342,900 acres of private commercial forest land. In the past, 31 percent of these owners have harvested timber from their lands. The forest land owned by those who have harvested timber makes up 61 percent of the total private commercial forest area.

Volume Change

Data from a second remeasurement of field plots established in 1949 provided a history of growth, mortality, and removals in the forest during the past quarter century. Average annual net growth of all growing stock was 35 cubic feet per acre during the past 14 years and 32.5 cubic feet per acre during the preceeding 12 years. In 1974 the annual growth of growing stock was 41 cubic feet per acre and the ratio of growth to removals was nearly 3 to 1.

Part of the analysis of the current volume and growth includes a procedure to determine whether past volume and growth estimates are directly comparable with the present estimate. This procedure helps to locate inconsistencies in the data and to evaluate differences that may have occurred because of procedural or definitional differences between inventory occasions. This analysis of the West Virginia inventory resulted in an adjustment of the 1961 inventory to reflect the standards, procedures, and definitions used in 1975.

Here are the figures, adjusted as described above, showing the trends:

	1961	1975	Change
Growing stock volume: (million cubic feet)			
Softwoods	557	995	+438
Hardwoods	10,320	12,520	+2,200
Total	10,877	13,515	2,638
Sawtimber volume: (million board feet)			
Softwoods	1,378	2,600	+1,222
Hardwoods	20,560	25,031	+4,471
Total	21,938	27,631	5,693

Growing Stock and Sawtimber Volume Continue to Increase

Timber volume increased rapidly in West Virginia between 1949 and 1961. Much of this increase resulted from ingrowth, i.e., trees previously too small to be measured for volume had reached the minimum size required to be classified as growing stock. This surge of ingrowth into the minimum recognized diameter class has slowed. Three-fifths of the gross growth between 1961 and 1975 was accretion, i.e., volume added to trees that were already of growing-stock size. The average growing-stock volume per acre in West Virginia was 1,177 cubic feet in 1975; a 23 percent increase since 1961. The sawtimber portion of growing stock averaged 2,406 board feet per acre in 1975; a 25 percent increase since 1961.

The growing-stock volume increase among the major species has not been uniform. The relative positions of the 10 species with the largest cubic-foot volume in 1961 and 1975 reflect these uneven changes:

Species	Rankings 1961	Rankings 1975
Red oak	1	3
Chestnut oak	2	2
Yellow-poplar	3	1
Hickory	4	5
White oak	5	4
Black oak	6	6
Beech	7	9
Sugar maple	8	8
Red maple	9	7
Basswood	10	—
Black cherry	—	10

Yellow-poplar increased 39 percent in volume and is now the most prevalent species in the State. The oaks as a group exceed yellow-poplar in volume, but red oak dropped from first to third position. All oaks showed increases in volume and white oak replaced hickory as the fourth most abundant species. The volume of black cherry increased 67 percent and it became the tenth most abundant species. The volume of red maple increased 49 percent and the species moved from ninth to seventh position. The volume of both beech and basswood declined. Beech dropped to ninth position and basswood is no longer among the 10 most abundant species. Black oak and sugar maple maintained their same relative positions. Although no softwood is on the list of top ten species, softwoods as a group have increased 79 percent. All softwoods accounted for 5 percent of the total volume in 1961 and 7.4 percent of total volume in 1975.

Sawtimber volume has increased 26 percent since 1961. For hardwoods, much of the increase was in the 12- and 14-inch diameter classes. Logs in trees of this size usually do not meet the minimum size specifications for standard lumber log grades 1 or 2. Most of the hardwood sawtimber increase was in grade 3 standard lumber logs. Forty-six percent of the hardwood sawtimber volume is now grade 3. We found little change in the proportion of hardwood volume in grades 1 and 2 combined. However, more of this higher quality timber is now classed as grade 1 than in 1961. Of the softwoods, only the pines are segregated into quality classes by standard lumber log grades. More than 88 percent of the sawtimber volume of the pines is grade 3 or poorer quality. Here, as in the hardwoods, the high proportion of sawtimber volume in the smaller diameter classes is the reason for the low quality.

The following tables describe the forest resource of West Virginia.

Table 1.—*Land area in West Virginia, by land classes, counties, and geographic units, 1975*

County	Total land area[a]	Nonforest land area	Forest land: Non-commercial[b]	Forest land: Commercial	Forest land: Sampling error of total[c]
	Thousand acres				*Percent*
Barbour	218.2	81.4	0.9	135.9	10
Berkeley	202.2	83.0	1.2	118.0	12
Braxton	330.9	77.9	1.0	252.0	6
Grant	305.9	67.6	2.1	236.2	6
Hampshire	409.0	87.7	1.7	319.6	5
Hardy	374.4	71.6	5.1	297.7	5
Harrison	267.5	120.2	2.5	144.8	13
Jefferson	134.9	96.3	2.1	36.5	35
Lewis	250.9	82.6	.7	167.6	9
Mineral	211.2	44.6	.7	165.9	6

CONTINUED

Table 1.—Continued

County	Total land area[a]	Nonforest land area	Forest land: Non-commercial[b]	Forest land: Commercial	Forest land: Sampling error of total[c]
	Thousand acres				*Percent*
Morgan	149.1	32.2	6.6	110.3	7
Pendleton	444.8	109.4	34.2	301.2	6
Pocahontas	603.5	84.9	15.3	503.3	7
Preston	412.8	110.7	1.4	300.7	6
Randolph	663.0	80.6	13.3	569.1	4
Taylor	111.4	45.1	1.4	64.9	15
Tucker	269.5	38.6	20.2	210.7	9
Upshur	225.3	70.5	.8	154.0	8
Webster	352.6	27.7	8.1	316.8	3
Northeastern Unit	5,937.1	1,412.6	119.3	4,405.2	1.4
Boone	320.6	56.6	—	264.0	10
Clay	219.5	29.8	—	189.7	6
Fayette	424.3	84.7	3.9	335.7	5
Greenbrier	656.7	154.8	1.0	500.9	4
Kanawha	580.4	122.3	—	458.1	4
Logan	291.9	56.0	3.3	232.6	10
McDowell	341.1	64.1	—	277.0	11
Mercer	266.8	77.1	.5	189.2	6
Mingo	270.7	47.9	—	222.8	10
Monroe	302.5	116.5	—	186.0	8
Nicholas	416.0	78.4	.3	337.3	6
Raleigh	387.3	88.5	1.4	297.4	5
Summers	223.8	60.4	4.4	159.0	6
Wyoming	322.6	52.3	6.8	263.5	5
Southern Unit	5,024.2	1,089.4	21.6	3,913.2	1.8
Brooke	56.4	29.8	—	26.6	27
Cabell	178.7	47.0	0.3	131.4	8
Calhoun	179.8	41.3	—	138.5	9
Doddridge	204.2	53.9	—	150.3	9
Gilmer	217.0	54.0	2.1	160.9	9
Hancock	53.2	26.4	1.5	25.3	27
Jackson	294.7	103.3	.2	191.2	8
Lincoln	280.3	33.4	—	246.9	4
Marion	199.0	65.6	1.2	132.2	10
Marshall	194.7	78.2	—	116.5	12
Mason	276.8	113.4	.4	163.0	10
Monongalia	233.5	83.8	.2	149.5	11
Ohio	68.0	30.6	—	37.4	21
Pleasants	82.7	14.2	.1	68.4	8
Putnam	222.7	66.4	—	156.3	7
Ritchie	289.3	72.1	1.8	215.4	6
Roane	311.0	99.6	—	211.4	9
Tyler	163.6	44.3	—	119.3	9
Wayne	328.6	63.4	.1	265.1	5
Wetzel	232.1	50.1	.1	181.9	6
Wirt	150.4	27.3	—	123.1	6
Wood	235.8	81.1	—	154.7	9
Northwestern Unit	4,452.5	1,279.2	8.0	3,165.3	1.9
Total for state	15,413.8	3,781.2	148.9	11,483.7	1.0

[a] Source: Area Measurement Report, Bureau of the Census, Areas of West Virginia: 1960 (April 1967).

[b] Includes nonproductive and productive-reserved forest land.

[c] In percent at the 68 percent probability level for commercial forest land.

Table 2.—*Area of commercial forest land in West Virginia, by ownership classes and geographic units, 1975*

[In thousands of acres]

Ownership classes	Northeastern	Southern	Northwestern	Total
National Forest	733.8	138.8	—	872.6
Other Federal	14.0	3.1	22.0	39.1
State	88.1	78.7	62.1	228.9
County and municipal	.2	—	—	.2
Total public	836.1	220.6	84.1	1,140.8
Forest industry	234.5	491.5	153.7	879.7
Farmer-owned	876.0	391.5	660.1	1,927.6
Miscellaneous private:				
Individual	1,634.4	1,289.6	1,863.8	4,787.8
Corporate	402.8	1,254.1	95.4	1,752.3
Other	421.4	265.9	308.2	995.5
Total private	3,569.1	3,692.6	3,081.2	10,342.9
All ownerships	4,405.2	3,913.2	3,165.3	11,483.7

Table 3.—*Form of ownership by number of owners and acres of privately-owned forest land with number of owners who have harvested timber and the acres they own, West, Virginia, 1975*

Form of ownership	All owners		Owners who have harvested timber	
	Number	Thousand acres owned	Number	Thousand acres owned
Individual	182,100	6,517.5	55,900	3,149.6
Partnership	4,300	290.3	800	187.2
Corporation	3,000	2,591.0	500	2,417.8
Other[a]	18,100	944.1	6,400	564.9
Total	207,500	10,342.9	63,600	6,319.5

[a] Includes associations, clubs, and undivided estates.

Table 4.—*Area of commercial forest land, by forest types and stand-size classes, West Virginia, 1975*

[In thousands of acres]

Forest type	All stands	Saw-timber stands	Pole-timber stands	Sapling-seedling stands	Non-stocked areas
White pine	101.2	36.8	54.1	10.3	—
Spruce-fir	59.0	43.6	14.0	1.1	0.3
Virginia and pitch pine	485.2	163.7	173.9	147.6	—
Oak-pine	568.2	221.6	172.7	164.3	9.6
Oak-hickory[a]	6,828.1	2,794.4	2,455.5	1,465.7	112.5
Elm-ash-red maple	814.5	258.4	282.1	274.0	—
Maple-beech-birch	2,618.6	1,557.2	807.3	243.1	11.0
Aspen-birch	8.9	—	—	—	8.9
All types	11,483.7	5,075.7	3,959.6	2,306.1	142.3

[a] Includes the yellow-poplar forest type.

Table 5.—*Area of commercial forest land in West Virginia, by forest type, county, and geographic unit, 1975*

[In thousands of acres]

County	Virginia and pitch pine	Other softwood types	Oak-hickory	Maple-beech-birch	Other hardwood types	All types
Barbour	0.7	1.9	74.5	37.4	21.4	135.9
Berkeley	13.5	1.5	72.9	8.0	22.1	118.0
Braxton	1.2	3.9	136.9	73.2	36.8	252.0
Grant	26.1	2.4	142.3	20.9	44.5	236.2
Hampshire	31.9	3.9	199.3	19.4	65.1	319.6
Hardy	32.4	3.2	183.5	18.8	59.8	297.7
Harrison	.6	2.7	73.6	36.3	31.6	144.8
Jefferson	3.4	.3	23.3	3.0	6.5	36.5
Lewis	1.2	2.7	93.6	44.8	25.3	167.6
Mineral	24.7	1.7	96.2	10.1	33.2	165.9
Morgan	16.4	1.0	62.8	6.5	23.6	110.3
Pendleton	27.5	5.3	178.5	26.4	63.5	301.2
Pocahontas	1.6	33.5	177.8	242.2	48.2	503.3
Preston	1.8	4.2	167.3	84.9	42.5	300.7
Randolph	1.6	9.1	270.6	236.2	51.6	569.1
Taylor	.3	1.1	34.1	16.8	12.6	64.9
Tucker	.5	5.8	102.7	77.4	24.3	210.7
Upshur	.8	2.1	84.5	44.0	22.6	154.0
Webster	1.3	3.5	162.6	119.0	30.4	316.8
Northeastern Unit	187.5	89.8	2,337.0	1,125.3	665.6	4,405.2
Boone	—	2.8	160.4	92.3	8.5	264.0
Clay	2.6	3.2	127.3	43.8	12.8	189.7
Fayette	4.9	4.4	225.2	78.1	23.1	335.7
Greenbrier	5.5	12.4	281.4	166.2	35.4	500.9
Kanawha	7.4	8.5	305.3	105.4	31.5	458.1
Logan	—	3.6	150.4	68.1	10.5	232.6
McDowell	—	4.6	174.0	81.8	16.6	277.0
Mercer	2.2	2.6	126.3	45.6	12.5	189.2
Mingo	—	3.3	139.8	68.7	11.0	222.8
Monroe	7.0	3.9	122.3	37.5	15.3	186.0
Nicholas	6.1	3.9	217.8	85.8	23.7	337.3
Raleigh	4.5	3.1	199.7	69.5	20.6	297.4
Summers	2.3	2.8	104.7	38.3	10.9	159.0
Wyoming	5.7	11.3	171.4	57.7	17.4	263.5
Southern Unit	48.2	70.4	2,506.0	1,038.8	249.8	3,913.2
Brooke	1.2	—	17.7	3.8	3.9	26.6
Cabell	13.1	—	79.7	17.8	20.8	131.4
Calhoun	17.1	—	79.7	18.4	23.3	138.5
Doddridge	4.2	—	103.1	21.7	21.3	150.3
Gilmer	5.1	—	109.7	22.2	23.9	160.9
Hancock	.9	—	16.5	4.3	3.6	25.3
Jackson	19.4	—	116.3	27.1	28.4	191.2
Lincoln	7.8	—	161.0	39.5	38.6	246.9
Marion	4.5	—	91.3	18.2	18.2	132.2
Marshall	4.8	—	75.3	18.6	17.8	116.5
Mason	27.4	—	90.6	20.9	24.1	163.0
Monongalia	4.2	—	102.5	21.6	21.2	149.5
Ohio	1.5	—	24.6	5.9	5.4	37.4
Pleasants	3.3	—	45.7	10.0	9.4	68.4
Putnam	23.3	—	89.2	21.6	22.2	156.3
Ritchie	12.2	—	139.9	31.0	32.3	215.4
Roane	19.4	—	128.8	31.4	31.8	211.4
Tyler	7.4	—	76.6	17.2	18.1	119.3
Wayne	21.1	—	163.1	38.1	42.8	265.1
Wetzel	5.4	—	120.3	27.7	28.5	181.9
Wirt	20.9	—	67.1	16.9	18.2	123.1
Wood	25.3	—	86.4	20.6	22.4	154.7
Northwestern Unit	249.5	—	1,985.1	454.5	476.2	3,165.3
Total for state	485.2	160.2	6,828.1	2,618.6	1,391.6	11,483.7

Table 6.—*Net volume of growing stock on commercial forest land in West Virginia, by forest type, county, and geographic unit, 1975*

[In millions of cubic feet]

County	Virginia and pitch pine	Other softwood types	Oak-hickory	Maple-beech-birch	Other hardwood types	All types
Barbour	0.6	3.2	77.8	46.0	19.3	146.9
Berkeley	7.8	1.2	62.4	9.9	17.7	99.0
Braxton	1.1	8.3	155.4	94.7	36.4	295.9
Grant	18.6	2.1	144.8	30.5	39.0	235.0
Hampshire	19.8	3.0	192.6	26.7	56.6	298.7
Hardy	22.3	2.8	183.5	28.6	53.8	291.0
Harrison	.5	3.4	63.0	34.1	18.9	119.9
Jefferson	2.0	.2	13.5	2.1	4.2	22.0
Lewis	1.0	4.1	93.9	51.5	21.2	171.7
Mineral	15.4	1.2	93.6	15.8	29.2	155.2
Morgan	12.2	.6	58.5	10.7	20.3	102.3
Pendleton	18.5	5.7	177.6	33.7	53.7	289.2
Pocahontas	1.7	88.2	265.3	451.6	51.0	857.8
Preston	1.6	7.7	183.7	107.8	40.8	341.6
Randolph	1.4	26.9	421.3	474.8	65.2	989.6
Taylor	.3	1.4	31.1	16.8	8.2	57.8
Tucker	.4	16.7	164.4	140.5	19.6	341.6
Upshur	.7	4.2	93.5	57.0	22.4	177.8
Webster	1.2	8.3	237.2	230.2	39.1	516.0
Northeastern Unit	127.1	189.2	2,713.1	1,863.0	616.6	5,509.0
Boone	—	7.0	171.7	85.0	6.6	270.3
Clay	1.6	5.7	150.1	53.7	14.0	225.1
Fayette	3.1	6.2	264.3	94.3	25.1	393.0
Greenbrier	3.9	29.2	371.1	277.5	46.7	728.4
Kanawha	4.9	16.1	355.6	127.3	34.6	538.5
Logan	—	8.9	157.3	62.1	8.0	236.3
McDowell	—	11.3	161.6	74.3	12.3	259.5
Mercer	1.4	4.6	153.2	56.2	14.9	230.3
Mingo	—	8.0	141.4	62.3	8.2	219.9
Monroe	5.0	7.2	124.7	41.1	13.7	191.7
Nicholas	3.7	4.7	250.0	134.6	23.4	416.4
Raleigh	2.8	3.7	233.4	83.3	22.9	346.1
Summers	1.5	5.4	125.7	45.7	12.8	191.1
Wyoming	4.0	27.3	191.6	68.7	18.3	309.9
Southern Unit	31.9	145.3	2,851.7	1,266.1	261.5	4,556.5
Brooke	0.8	—	15.7	4.2	3.1	23.8
Cabell	13.5	—	78.6	21.2	18.2	131.5
Calhoun	17.7	—	74.0	21.6	19.5	132.8
Doddridge	2.8	—	123.7	29.5	20.1	176.1
Gilmer	3.2	—	126.5	28.9	22.3	180.9
Hancock	.8	—	15.9	5.5	3.2	25.4
Jackson	22.9	—	118.9	33.0	26.7	201.5
Lincoln	5.8	—	182.1	53.3	35.6	276.8
Marion	2.8	—	104.6	24.3	16.3	148.0
Marshall	3.4	—	70.4	22.1	14.7	110.6
Mason	32.5	—	89.1	24.5	22.7	168.8
Monongalia	3.0	—	120.8	29.1	20.4	173.3
Ohio	1.1	—	24.6	7.3	4.9	37.9
Pleasants	4.5	—	64.1	14.4	11.0	94.0
Putnam	29.6	—	101.1	27.1	23.2	181.0
Ritchie	13.5	—	167.9	41.0	33.0	255.4
Roane	20.2	—	120.2	37.1	27.1	204.6
Tyler	7.2	—	85.2	21.5	16.7	130.6
Wayne	19.8	—	162.8	45.9	37.0	265.5
Wetzel	3.9	—	136.7	36.2	26.9	203.7
Wirt	29.7	—	81.4	22.8	20.4	154.3
Wood	32.5	—	93.0	25.9	22.0	173.4
Northwestern Unit	271.2	—	2,157.3	576.4	445.0	3,449.9
Total for state	430.2	334.5	7,722.1	3,705.5	1,323.1	13,515.4

Table 7.—*Net volume of sawtimber on commercial forest land in West Virginia, by forest type, county, and geographic unit, 1975*

[In millions of board feet]

County	Virginia and pitch pine	Other softwood types	Oak-hickory	Maple-beech-birch	Other hardwood types	All types
Barbour	0.7	8.2	134.5	87.5	34.3	265.2
Berkeley	11.3	2.3	104.4	17.6	31.7	167.3
Braxton	1.4	21.8	284.3	186.9	66.2	560.6
Grant	35.4	3.6	232.7	56.1	73.9	401.7
Hampshire	29.4	5.8	329.0	41.0	102.7	507.9
Hardy	38.0	5.0	306.0	48.1	99.0	496.1
Harrison	.6	9.9	97.4	62.3	31.2	201.4
Jefferson	3.3	.5	21.1	3.8	7.0	35.7
Lewis	1.2	9.7	155.6	96.7	35.8	299.0
Mineral	26.3	2.4	149.7	28.1	53.8	260.3
Morgan	23.1	1.3	86.3	20.4	38.3	169.4
Pendleton	32.2	9.5	290.2	52.1	96.7	480.7
Pocahontas	2.6	256.8	438.0	949.9	109.5	1,756.8
Preston	1.9	18.6	324.3	209.1	72.1	626.0
Randolph	1.6	77.2	859.5	1,035.1	125.2	2,098.6
Taylor	.4	4.0	49.2	31.0	13.5	98.1
Tucker	.5	54.7	343.2	326.6	36.0	761.0
Upshur	.8	10.9	169.0	111.1	40.6	332.4
Webster	1.4	21.4	505.8	569.9	72.9	1,171.4
Northeastern Unit	212.1	523.6	4,880.2	3,933.3	1,140.4	10,689.6
Boone	—	9.2	424.8	206.0	17.8	657.8
Clay	3.4	11.9	311.7	113.6	29.2	469.8
Fayette	6.3	14.2	550.5	199.9	52.0	822.9
Greenbrier	8.1	53.8	792.1	583.7	109.9	1,547.6
Kanawha	10.3	31.6	746.5	271.2	71.6	1,131.2
Logan	—	11.4	390.2	150.8	21.9	574.3
McDowell	—	14.6	378.9	175.5	34.4	603.4
Mercer	2.8	9.4	332.2	122.5	32.8	499.7
Mingo	—	10.1	343.3	150.2	22.9	526.5
Monroe	11.1	13.5	237.7	83.0	21.6	366.9
Nicholas	7.3	11.7	506.4	306.8	43.5	875.7
Raleigh	5.4	9.2	492.3	177.9	47.3	732.1
Summers	3.3	10.4	271.4	98.7	26.9	410.7
Wyoming	9.1	48.4	391.4	143.9	36.7	629.5
Southern Unit	67.1	259.4	6,169.4	2,783.7	568.5	9,848.1
Brooke	1.8	—	30.0	9.4	6.1	47.3
Cabell	25.4	—	150.0	48.8	34.3	258.5
Calhoun	32.3	—	138.8	49.4	36.0	256.5
Doddridge	5.6	—	268.7	75.6	39.0	388.9
Gilmer	6.3	—	266.8	72.2	43.6	388.9
Hancock	1.9	—	30.2	12.2	6.4	50.7
Jackson	45.8	—	230.0	75.5	51.9	403.2
Lincoln	11.4	—	356.0	124.4	71.1	562.9
Marion	5.7	—	228.0	63.2	31.0	327.9
Marshall	7.2	—	129.4	50.0	28.1	214.7
Mason	62.6	—	175.6	55.7	43.6	337.5
Monongalia	6.5	—	260.9	73.0	40.0	380.4
Ohio	2.5	—	47.0	16.7	9.8	76.0
Pleasants	9.0	—	144.5	37.3	22.1	212.9
Putnam	58.0	—	203.4	62.8	46.2	370.4
Ritchie	27.0	—	350.2	98.7	66.1	542.0
Roane	39.7	—	216.8	83.7	52.3	392.5
Tyler	13.7	—	174.1	52.1	32.6	272.5
Wayne	36.1	—	304.8	104.7	70.6	516.2
Wetzel	7.7	—	274.3	85.3	53.2	420.5
Wirt	60.0	—	164.4	52.7	41.4	318.5
Wood	64.4	—	186.0	60.1	43.7	354.2
Northwestern Unit	530.6	—	4,329.9	1,363.5	869.1	7,093.1
Total for state	809.8	783.0	15,379.5	8,080.5	2,578.0	27,630.8

Table 8.—*Net volume of growing-stock trees[a] on commercial forest land, by species and tree size, West Virginia, 1975*

Species	All trees	Poletimber trees	Sawtimber	
	Million cubic feet			*Million board feet*[b]
White pine	125.5	43.7	81.8	328.8
Virginia pine	416.5	154.9	261.6	903.2
Other yellow pines	115.1	29.8	85.3	300.2
Red spruce	153.3	18.1	135.2	565.2
Hemlock[c]	184.6	55.3	129.3	502.3
Total softwoods	995.0	301.8	693.2	2,599.7
Select white oaks	1,293.0	511.9	781.1	2,668.1
Select red oaks	1,294.1	351.0	943.1	3,203.8
Other white oaks	1,384.7	559.9	824.8	2,768.6
Other red oaks	1,427.1	471.7	955.4	3,354.4
Red maple	829.9	486.3	343.6	1,085.9
Sugar maple	758.6	416.8	341.8	1,158.0
Yellow birch	142.5	94.5	48.0	164.8
Sweet birch	250.7	180.8	69.9	228.2
Hickory	1,173.8	658.7	515.1	1,720.6
Beech	612.3	196.3	416.0	1,459.3
Ash	282.2	102.3	179.9	591.0
Black walnut	107.2	46.1	61.1	206.8
Yellow-poplar	1,412.8	463.5	949.3	3,267.7
Cucumbertree	124.7	50.7	74.0	247.3
Blackgum	132.5	48.4	84.1	296.1
Black cherry	453.6	138.6	315.0	1,112.1
Basswood	207.5	77.1	130.4	417.5
Other hardwoods	633.2	309.9	323.3	1,080.9
Total hardwoods	12,520.4	5,164.5	7,355.9	25.031.1
All species	13,515.4	5,466.3	8,049.1	27,630.8

[a] Growing-stock trees are trees that satisfy national specifications for form and allowable cull. Net volumes are given for all such trees 5.0 inches dbh and larger.

[b] International ¼-inch rule.

[c] Includes a small amount of redcedar.

Table 9.—*Net volume of sawtimber on commercial forest land, by species and quality classes, West Virginia, 1975*

[In millions of board feet] [a]

Species	All classes	Standard lumber logs			
		Grade 1	Grade 2	Grade 3	Grade 4 [b]
Softwoods:					
White pine	328.8	22.1	68.7	185.0	53.0
Virginia pine	903.2	16.5	27.1	859.6	—
Other yellow pines	300.2	18.2	21.7	260.3	—
Other softwoods [c]	1,067.5	—	—	—	—
Total softwoods	2,599.7	56.8	117.5	1,304.9	53.0
Hardwoods:					
Select white oak	2,668.1	182.0	431.1	1,370.6	684.4
Select red oak	3,203.8	742.4	706.0	1,341.3	414.1
Other white oaks	2,768.6	297.3	518.6	1,289.8	662.9
Other red oaks	3,354.4	495.4	533.1	1,434.1	891.8
Red maple	1.085.9	123.6	145.7	545.8	270.8
Sugar maple	1,158.0	144.3	187.9	545.2	280.6
Yellow birch	164.8	25.5	28.6	76.5	34.2
Sweet birch	228.2	26.6	44.7	114.5	42.4
Hickory	1,720.6	161.0	237.3	799.2	523.1
Beech	1,459.3	120.7	193.2	691.3	454.1
Ash	591.0	79.2	137.7	261.4	112.7
Black walnut	206.8	5.2	27.5	131.4	42.7
Yellow-poplar	3,267.7	658.8	600.0	1,337.3	671.6
Cucumbertree	247.3	23.2	47.5	125.0	51.6
Blackgum	296.1	54.7	76.7	125.9	38.8
Black cherry	1,112.1	169.7	218.9	483.8	239.7
Basswood	417.5	57.1	95.7	203.3	61.4
Other hardwoods	1,080.9	65.8	149.8	619.6	245.7
Total hardwoods	25,031.1	3,432.5	4,380.0	11,496.0	5,722.6
Percentage of hardwoods	100	14	17	46	23

[a] International ¼-inch rule.
[b] Grade-4 applies only to the pines. For hardwoods the volumes in this column are for construction logs.
[c] Species other than pine are not graded into standard lumber grades.

Table 10.—*Annual net growth and removals of growing stock and sawtimber on commercial forest land, softwoods and hardwoods, West Virginia, 1974*

Species group	Growing stock		Sawtimber	
	Net growth	Removals	Net growth	Removals
	Thousand cubic feet		*Thousand board feet*	
Softwoods	58,600	10,600	172,000	27,800
Hardwoods	414,900	155,500	651,000	405,300
Total	473,500	166,100	823,000	433,100
	Percent			
Sampling error of totals	8	15	11	19

[a] International ¼-inch rule.

METRIC EQUIVALENTS
OF UNITS USED IN THIS REPORT

1 acre = 4,046.86 square meters or 0.405 hectare.
1,000 acres = 405 hectares.
1,000,000 acres = 405,000 hectares.
1,000 board feet (International ¼-inch log rule) = 3.48 cubic meters.
1,000,000 board feet (International ¼-inch log rule) = 3,480 cubic meters.
Breast height = 1.4 meters above ground level.
1 cubic foot = 28,317 cubic centimeters or 0.028317 cubic meter.
1,000 cubic feet = 28.317 cubic meters.
1,000,000 cubic feet = 28,317 cubic meters.
1 cord (wood, bark, and airspace) = 3.6246 cubic meters.
1 cord (solid wood, pulpwood) = 2.4069 cubic meters.
1 cord (solid wood, other than pulpwood) = 2.2654 cubic meters.
1,000 cords (pulpwood) = 2,406.9 cubic meters.
1,000 cords (other products) = 2,265.4 cubic meters.
1 foot = 30.48 centimeters or 0.3048 meter.
1 inch = 25.4 millimeters or 2.54 centimeters or 0.0254 meter.
1 mile = 1.609 kilometers.
1 square foot = 929.03 square centimeters or 0.0929 square meter.

Source: A. Binek. 1973 Forest products in terms of metric units. Published by the author, P.O. Box 7 Westmount, Quebec H3Z2T1 Canada

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Northeastern Forest Experiment Station

FOREST SERVICE, U.S. DEPT. OF AGRICULTURE, 6816 MARKET STREET, UPPER DARBY, PA. 19082

A SAMPLING DEVICE FOR COUNTING INSECT EGG CLUSTERS AND MEASURING VERTICAL DISTRIBUTION OF VEGETATION

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Abstract. The use of a vertical sampling pole that delineates known volumes and position is illustrated and demonstrated for counting egg clusters of *N. sertifer*. The pole can also be used to estimate vertical and horizontal coverage, distribution or damage of vegetation or foliage.

INTRODUCTION

Field entomologists often have to estimate numbers of insects by examining branches, buds, or twigs. Insect eggs are especially difficult to find and count for population studies or surveys. Several years ago, we investigated ways to estimate numbers of sawfly eggs or egg clusters in a pine plantation. We built a sampling pole that delineates known volumes for sampling to estimate population parameters of interest. For instance, it can be used for estimates of vegetation coverage, vertical and horizontal distribution of vegetation or foliage, and estimates of damage to vegetation caused by defoliation or deer browse.

We will illustrate the use of the sample pole on an insect problem, but the same procedure can be used for vegetation or damage assessment. Larvae of the European pine sawfly (*Neodiprion sertifer* (Geoffroy)) are spring colonial defoliators of Scotch, red, jack, mountain, and mugho pines. The economic impact of defoliation is particularly severe in plantations of Christmas trees approaching marketable size.

Several techniques are available for counting *N. sertifer* eggs, larvae and cocoons. Lyons (1964) utilized quadrats of various sizes for sampling cocoons and found that the optimal size of the quadrat is related to cocoon density and degree of aggregation, soil type, and method of cocoon extraction. To estimate densities of egg clusters and larval colonies, he used the quadrats and whole trees as sampling units. He concluded that using whole trees generally gave more precise results. Wilson and Gerrard (1971) have proposed a method of estimating the mean number of egg clusters or larval colonies per tree from an estimate of the proportion of trees that are infested.

Working with 6- to 8-foot tall trees, we found it difficult to count egg clusters accurately. Sawfly eggs are laid in the fall in loose clusters on the current year's needles. Foliage must be examined thoroughly and systematically to make sure none of the clusters is missed or counted more than once. Examination of whole trees is expensive unless the trees are quite small. The sampling pole was used to overcome these problems by delineating a volume of known size and position.

Figure 1.—General view of the sampling pole being used to delineate vertical sampling units.

The sampling device

In field situations it is very difficult to locate the boundaries of vertical sampling units. To overcome this problem, a hardwood pole, 1 inch in diameter and 6 feet long, was fitted with 3/8-inch hardwood dowels at 1-foot intervals from the base to the top (Fig. 1). Each dowel is at a right angle to the one below. Near each end of each dowel, a 3/16-inch vertical hole was drilled; the two holes being 8.478 inches apart. A 1/8-inch sighting wire can be inserted vertically through the holes. The dowels and sighting wires delineate a 0.25 cubic foot (0.5 x 0.5 x 1.0 ft) space (Fig. 2). For trees taller than 6 feet, two poles can be joined with an aluminum sleeve to provide a stack of 11 cubes. Larger or smaller volumes can be sampled by using different distances between the dowels and sighting wires. Each cube is a vertical sampling unit. Numbers of egg clusters and the presence or absence of vegetation can be recorded for each vertical unit.

During the preliminary field trials, it became apparent that the convenient size of sample unit depends on stand conditions. In open stands, cubes as large as 2 feet on a side are convenient. Smaller cubes are easier to use when the foliage is dense. In our judgement a 0.25 cubic foot unit is satisfactory in such conditions. The sampling pole should be as long as the tallest tree expected to be encountered.

Field test

To gain experience with the sampling pole, we sampled a 20-acre Scotch pine plantation at Pine Plains, Dutchess County, New York, that was infested with the European pine sawfly. The plantation was established in 1958. Data were collected during the winters of 1969 and 1970.

Four 208- by 208-ft blocks were selected at random in the plantation. A map of each block was divided into quarters five times in succession, producing 1024 squares 6.5 by 6.5 feet.

Figure 2.—Detailed view of the sampling pole in use. Sighting wires are being used to locate position for clipping a branch with a hand pruning tool.

Each square was partioned into 169 smaller squares measuring 0.5 by 0.5 foot, the outer dimensions of the sampling pole.

We used cluster sampling to select the sampling units. In cluster sampling terminology, the blocks are called primary units and the 0.5- by 0.5-ft squares are the elementary sampling units.

We selected at random two secondary units in each block, two tertiary units within each selected secondary unit, and so on. Altogether we selected 128 sampling units per block.

In the plantation, the sampling pole was placed as close as possible to the sampling location indicated on the map. The current year's foliage within each vertical sampling unit was collected and logged for later examination. The number of eggs and egg clusters and the presence or absence of foliage was recorded for each vertical unit.

RESULTS AND DISCUSSION

In our sample, we found 28 egg clusters ranging in size from 60 to 170 eggs, with a mean size of 59.3 ± 6.28 eggs per cluster. The average size of the egg clusters did not differ significantly, nor is there any evidence that size of egg cluster varied with density of egg clusters (Table 1).

However, there is evidence that egg clusters higher in the tree were larger (Table 2). The mid-crown mean differs little from the overall mean. Lyons (1964) noted that the largest egg clusters of *N. sertifer* are most often found in the upper crowns of red pines.

The number of egg clusters also varied with height in the crown (Table 2). In this plantation, the tree crowns extended to the ground, but crown closure was nearly complete. The egg

Table 1.—Characteristics of the Scotch pine plantation and *N. sertifer* egg populations in the four blocks sampled.

Item	Block				
	A	B	C	D	All
Mean tree dbh (inches)	0.9	1.6	2.4	1.4	
Mean height of dominants (feet)	5.8	8.6	7.9	8.0	
Trees per acre	644.5	1,482.4	999.0	1,192.4	
Eggs per tree	638	867	1,504	1,203	
Eggs per square foot	9	29	34	34	
Eggs per acre	411,000	1,285,000	1,521,000	1,435,000	
Mean number of eggs per cluster	50.3(3)[a]	71.8(6)	55.2(10)	58.6(9)	59.3(28)
Standard error	12.6	21.3	7.4	10.3	6.3

[a] Sample size in parenthesis.

Table 2.—Number and relative density of *N. sertifer* egg clusters according to vertical position in the tree crown canopy.

Item	Height Above Ground (ft)			
	6-9	3-6	0-3	All
Mean number of eggs per cluster	72.6(5)[a]	59.0(16)	50.6(7)	59.3(28)
Standard error	26.5	61.2	11.4	6.3
Proportion of egg clusters in the sample	.18	.57	.25	1.00
Current foliage space in the sample - ft^3	7	34	59	100
Egg clusters per cubic foot of foliage space (no.)	.71	.47	.12	.28

[a] Sample size in parenthesis.

clusters were distributed in the upper, middle, and lower thirds of the tree height in the ratio of 1:2:1. When the number of clusters is compared with the amount of space occupied by current foliage (where the eggs are deposited) in each height level, it is apparent that the density of clusters increases from 0.12 per cubic foot of foliage space in the lower crown to 0.71 per cubic foot in the upper crown. This substantiates the conclusion of Lyons (1964), that the sawfly preferred to oviposit on the exposed portions of the crown.

These examples show the wide range of data that can be obtained with our vertical sampling pole. We feel that it is widely applicable to the investigation of other problems.

ACKNOWLEDGMENTS

The field assistance of David L. Hubbard, forestry technician, and Alan A. Squires, biological technician, is greatly appreciated.

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OREST SERVICE RESEARCH NOTE NE-251
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FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE, 370 REED ROAD, BROOMALL, PA. 19008

EFFECT OF NUCLEOPOLYHEDROSIS VIRUS ON TWO AVIAN PREDATORS OF THE GYPSY MOTH[1]

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ABSTRACT. The nucleopolyhedrosis virus (NPV) of the gypsy moth was fed to black-capped chickadees and house sparrows in the form of NPV-infected gypsy moth larvae. Body weight and results of histological examination of organs of treated and control birds indicated that NPV had no apparent short term effect on these two important predators of the gypsy moth.

Keywords: biological control, gypsy moth, nucleopolyhedrosis virus.

The nucleopolyhedrosis virus (NPV) of the gypsy moth *(Lymantria dispar* L.) is being developed by the U.S. Department of Agriculture as a biological control agent. After an aerial application of NPV, many avian predators of the gypsy moth are likely to ingest infected larvae, pupae, and adults. Studies have indicated that some insect viruses do not harm birds (Ignoffo 1975), but the effects of gypsy moth NPV have not been determined. This paper reports the effects of NPV on the black-capped chickadee (*Parus atricapillus* L.), and the house sparrow (*Passer domesticus* L.). These species were chosen because of their importance as gypsy moth predators,[2] ease of capture, and adaptability to caged conditions.

Methods

In September 1975, six black-capped chickadees and nine house sparrows were captured in mist nets (ATX mesh) and in box traps that had been placed in wooded areas of Bethany, Connecticut. The birds were transported to the laboratory and caged individually in 0.9-m^3 wooden enclosures that were fitted with wire- mesh tops and fronts. The bottom of each enclosure was lined with paper, which was changed daily to maintain sanitary conditions. The birds were fed wild bird seed, sunflower seeds, healthy gypsy moth larvae, and mealworms. Water was provided through a standard J-tube. After a 3-day adjustment period, the birds were weighed and placed in treated or control groups. Treated birds included three chickadees and five sparrows; three chickadees and four sparrows served as controls.

On day 1 and on alternate days for 3 weeks, treated birds were fed NPV-infected 4th-instar gypsy moth larvae rather than the normal diet. Infected larvae were produced by allowing 3rd-instar larvae to feed on a diet containing 1.0×10^6 polyhedral inclusion bodies (PIB) of the gypsy moth NPV per ml. These larvae were in their 8th day of infection when fed to the treated birds; each larva contained from 3.3×10^7 to 2.1×10^8 PIB. During the test period, each treated

[1]The work herein was funded in part by a U.S. Department of Agriculture sponsored program entitled "The Expanded Gyspy Moth Research and Development Program".

[2]Galipeau, P.R. 1974. Avian Predators of the gypsy moth. Unpublished report. Forest Insect and Disease Laboratory, Hamden, Conn.

chickadee ate 70 to 80 infected larvae (2.3×10^9 to 1.7×10^{10} PIB), while each treated sparrow ate 90 to 100 infected larvae (3.0×10^9 to 2.1×10^{10} PIB).

Control animals were fed a normal diet throughout the test period. All birds were observed daily for mortality or signs of disease.

On day 22, birds were weighed and then delivered to the Department of Pathobiology at the University of Connecticut, Storrs, for necropsy and histopathological examination. After necropsy, the following organs were fixed in 10-percent neutral formalin: brain, lung, heart, kidney, liver, spleen, gizzard, pancreas, and intestine. Organs were embedded in paraffin, processed routinely, sectioned at 5 to 7 μm, stained with hematoxylin and eosin, and examined by light microscopy.

Results and Discussion

All birds adjusted to captivity, and neither treated nor control birds displayed signs of disease during the test period. The weight of treated and control birds is shown in Table 1. Most of the birds lost weight, as might be expected when they were caged, but only one treated chickadee lost a significant amount (28 percent). Also, t-tests to compare means revealed no significant changes in weight in treated or control birds.

Necropsy and histological examination revealed no lesions of disease in chickadees. Examination of sparrows revealed foci of lymphoid cells in the livers and lungs of both treated and control birds. However these lesions are common to these species, so their presence was not considered important. We found severe lesions only in one study bird—there was evidence of diffuse infiltration by lymphocytes in the liver of a control sparrow.

The results of this study, though limited by the small number of birds available, indicate that eating NPV-infected gypsy moth larvae has no apparent short term effect on black-capped chickadees or house sparrows.

Acknowledgments

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Table 1.-Weight comparisons for treated and control black-capped chickadees and house sparrows, in grams.

Treatment group	Bird no.	Weight		
		Before treatment	After treatment	Percent change
Black-capped chickadees				
Treated	1	16.9	12.2	−27.8
	2	10.5	10.0	− 4.8
	3	11.0	11.0	.0
Mean and SD		12.8 ± 3.6	11.1 ± 1.1	—
Control	1	10.0	9.6	− 4.0
	2	11.3	11.8	+ 4.4
	3	11.2	10.6	− 5.4
Mean and SD		10.8 ± 0.7	10.7 ± 1.1	—
House sparrows				
Treated	1	29.8	28.0	− 6.0
	2	29.0	26.7	− 7.9
	3	25.8	25.9	.0
	4	24.8	22.7	− 8.5
	5	23.5	22.7	− 3.4
Mean and SD		26.6 ± 2.7	25.2 ± 1.1	—
Control	1	27.8	26.5	− 4.7
	2	28.6	26.8	− 6.3
	3	24.9	25.9	+ 4.0
	4	26.4	24.7	− 6.4
Mean and SD		26.9 ± 1.6	26.0 ± 0.9	—

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FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE, 370 REED ROAD, BROOMALL, PA. 19008

A PREVIEW OF MARYLAND'S FOREST RESOURCE

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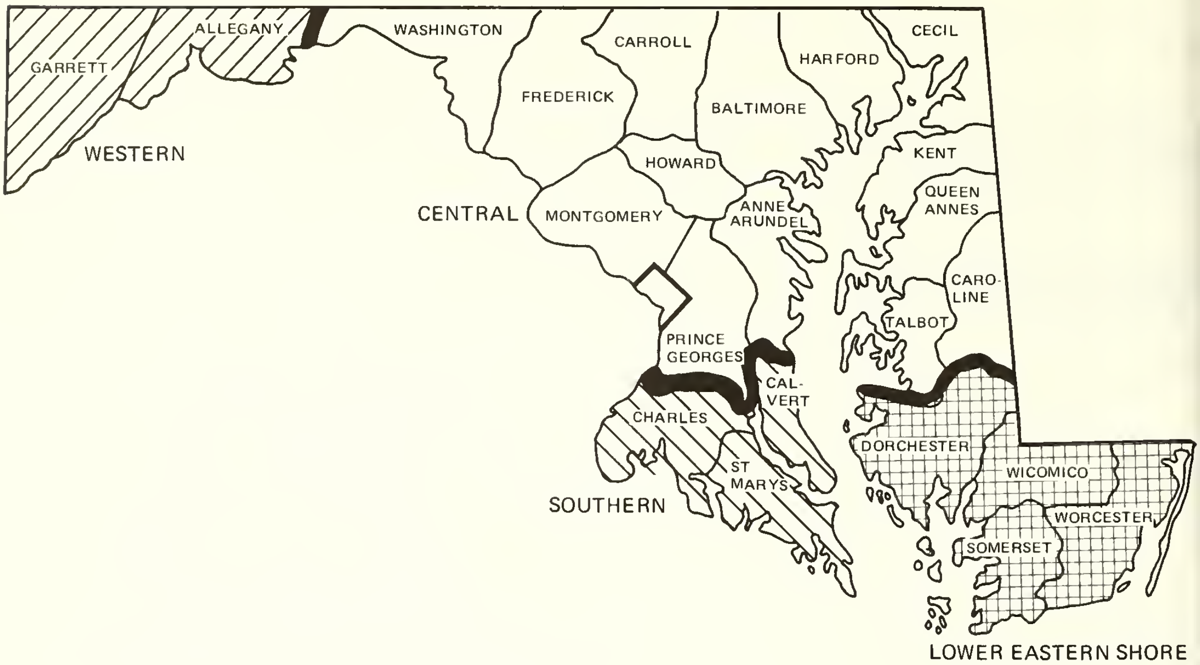
ABSTRACT. The 1976 forest survey of Maryland shows that the State has 2.5 million acres of commercial forest land, a decline of 13 percent since 1964. Ninety percent of it is in private ownership; 56 percent in sawtimber stands; 46 percent in the oak-hickory forest type. Timber volume has increased to 3.5 billion cubic feet of growing stock and 8.2 billion board feet of sawtimber. Seventy-three percent of the growing-stock volume is in sawtimber stands and 49 percent is in oak-hickory types. In a State that is dominated by hardwoods, loblolly pine is the single species with the most volume. Net growth exceeds removals for the State as a whole, but overcutting is occurring in certain units and in certain species.

KEYWORDS: Forest survey, timber resource, forest area, timber volume, growth, removals, forestry statistics.

Forest is a common land use in Maryland, often dominating the landscape. The U. S. Forest Service in cooperation with the Maryland Forest Service has conducted three forest surveys of the State to inventory its forest resources. Each survey was designed to provide a reliable estimate of the extent and condition of the forest resource. A detailed statistical and analytical report of the most recent—1976—inventory is being prepared for publication. It will contain a comprehensive discussion of the current situation and apparent trends of the forest resource. This is a preview of that report.

Because of the geography of the State, there are tremendous ranges of climatic conditions, soils, topography, plant communities, and land uses. In an effort to reduce this range and discuss similar resource situations together, we divided the State into four geographic units (Fig. 1). These units form the building blocks of our statewide information as well as providing more specific regional timber statistics.

Figure 1.—The four geographic units of Maryland, 1976.



FORESTS COVER 42 PERCENT OF THE LAND AREA

Forest land accounts for 2.7 million acres of the total 6.3 million acres of land in Maryland. Commercial forest land, which is land that is capable of producing at least 20 cubic feet of wood per acre per year and that is not withdrawn from timber production (as forested park land is, for example), makes up 40 percent of the land area or 2.5 million acres. This represents a decline of nearly 13 percent since the previous survey in 1964, most of it in the Central Unit where the population in the Baltimore-Washington corridor has been increasing rapidly.

The Central Unit has 44 percent of the commercial forest land in the State; the Lower Eastern Shore Unit, 21 percent; the Western Unit, 20 percent; and the Southern Unit, 15 percent. The proportion of commercial forest land in the total land area differs considerably among units. The Western Unit is 74 percent commercial forest land; the Southern Unit, 56 percent; the Lower Eastern Shore Unit, 46 percent; and the Central Unit, 29 percent.

Ninety percent of the commercial forest land—2.3 million acres—is in private ownership. This proportion ranges from 78 percent in the Western Unit to 98 percent in the Southern Unit. The results of an ownership study conducted in conjunction with this forest survey show that approximately 95,800 private owners control this 2.3 million acres of commercial forest land. Some 53,900 are individuals (excluding farmers) such as doctors, truck drivers, retired people, and housewives. Together they control 734,600 acres of woodland. Almost half of the private woodland—over one million acres—is owned by farmers. Only 22 percent of private owners have harvested timber, but they own 53 percent of the private forest acreage. A more detailed report on these private landowners is currently being prepared for publication.

Timber stands can be divided on the basis of the size of the trees they contain—sawtimber, poletimber, and other smaller material. Maryland has a preponderance of sawtimber stands—1.4 million acres or 56 percent of the total. This proportion ranges from 38 percent in the Western Unit to 65 percent in the Central Unit. Poletimber stands rank second in all units, followed by other stands, which consist of sapling and seedling stands and nonstocked areas.

Timber stands may also be grouped by forest cover types. In Maryland 32 forest types recognized by Resources Evaluation were encountered, and these were put into eight forest type groups. The Western Unit, because of its high elevation and cool average temperatures, has a majority of the acreage of the three type groups most commonly found in more northern latitudes—spruce-fir, white and red pine, and maple-beech-birch. The Lower Eastern shore has most of the bottomland oak-gum-cypress acreage and nearly half of the land in the loblolly and shortleaf pine type group. The other three groups—oak-pine, oak-hickory, and elm-ash-red maple—are found throughout the State. The oak-hickory group dominates, occupying 46 percent of the commercial forest land.

GROWING-STOCK VOLUME REACHES 3.5 BILLION CUBIC FEET

The volume of timber in Maryland has been increasing since the first Forest Service survey in 1950. Growing-stock volume is now 3.5 billion cubic feet and the sawtimber component is 8.2 billion board feet. Volume per acre figures have increased along with volume. The average acre of commercial forest land has 1,384 cubic feet or 3,237 board feet of net volume. There are large differences among units, however. For growing-stock volume, the Western Unit is lowest, with only 897 cubic feet per acre, while the Lower Eastern Shore Unit is highest, with almost twice that amount—1,655 cubic feet per acre. For sawtimber volume, the Western Unit is again lowest, with 1,486 board feet per acre, while the Central Unit edged out the Lower Eastern Shore for highest honors with 3,869 board feet per acre. These differences are a reflection of differences in species composition, growing conditions, timber management intensities, and past land use.

Just as sawtimber stands dominate the area, they account for 73 percent of the growing-stock volume and 86 percent of the sawtimber volume. Units with an above average proportion of sawtimber stands also have a higher than average proportion of their volume in these stands.

The oak-hickory forest type group dominates the timber of Maryland, accounting for 1.7 billion cubic feet or almost one-half of the growing-stock volume. Two-thirds of this volume is in the Central Unit. The loblolly and shortleaf pine type group accounts for nearly a quarter of the total, some 830 million cubic feet. Over half of this volume is in the Lower Eastern Shore Unit. The third major type group is elm-ash-red maple; its 388 million cubic feet, found primarily in the Lower Eastern Shore and Central units, make up 11 percent of the growing-stock volume. The remaining five groups, oak-pine, maple-beech-birch, oak-gum-cypress, white and red pine, and spruce-fir (in order of decreasing volume) account for the remaining 16 percent of the growing-stock volume. The sawtimber volume is similarly distributed.

Maryland is predominately a hardwood State, with 2.7 billion cubic feet or 77 percent of its growing-stock volume in broad-leaved species. Hardwoods are common throughout Maryland, but over half—53 percent—of the volume is in the Central Unit. The oaks are the most common species group, accounting for 46 percent of the hardwood volume. The softwood volume—793 million cubic feet—is concentrated in the Lower Eastern Shore Unit where loblolly pine, the species with the most volume in the State (see the box on this page) dominates the woodlands.

THE TOP TEN

Here are the ten species that dominate the timber resource of Maryland:

	Million cubic feet	*Percent of total*
1. Loblolly pine	470	14
2. White oak	368	11
3. Yellow-poplar	351	10
4. Red maple	279	8
5. Virginia Pine	237	7
6. Sweetgum	221	6
7. Northern red oak	182	5
8. Chestnut oak	171	5
9. Black oak	155	4
10. Scarlet oak	136	4
Total	2,570	74

GROWTH EXCEEDS REMOVALS

In general, the timber resource is in a favorable situation when more timber is grown each year than is cut. At first glance, this appears to be the case in Maryland; our latest estimates (1975) show annual removals to be only 77 percent of annual net growth for growing stock and only 74 percent for sawtimber. For softwoods the level of growing-stock removals, 23.6 million cubic feet, is only

1.3 million cubic feet short of the annual net growth. The hardwood resource is not in danger of depletion; its growing-stock removals equal 72 percent of its net growth. Sweetgum is the only species that appears to be overcut statewide, and it is the only species that showed a decline in volume since 1963.

Although the situation statewide appears encouraging, some species are being overcut in some units. In general, softwoods are being removed faster than they are growing in the Central and Western units, while hardwood removals exceed hardwood growth in the Southern and Western units. The large amount of land clearing and loss of commercial forest land to nonforest land uses is perhaps the primary reason that removals exceed growth in the Central and Southern units. The volume of growing stock on land that has been cleared or otherwise changed from commercial forest land use during the period between inventories is considered as timber removals. In the Western Unit timber is a more important component of the local economy than it is in the less timbered farm and urban areas to the east. There are many small sawmills and a good-sized woodpulp mill in the area that require steady supplies of raw material. Also, the annual net growth per acre is low in this region, so it does not take too high a level of removals before overcutting occurs.

Another factor that must be considered in discussing growth and removals is the attitude of private landowners about harvesting timber. The objectives of some landowners preclude logging on their property. If enough of these owners make their timber unavailable, then overcutting may occur more frequently on those lands that are available and may cause serious problems in local areas. This is the case in certain sections of Maryland. The question of how much timber is available will be dealt with in more detail in the forthcoming ownership report.

Table 1.—*Land area of Maryland by land classes and geographic units, 1976*
(In thousands of acres)

Geographic unit	Commercial forest land	Unproductive forest land	Productive-reserved forest land	Total forest land	Nonforest land	All land
Central	1,105.5	—	113.7	1,219.2	2,596.5	3,815.7
Southern	376.1	0.6	5.0	381.7	289.6	671.3
Lower Eastern Shore	523.0	—	3.1	526.1	621.4	1,147.5
Western	518.1	—	8.1	526.2	169.5	695.7
Total, all units	2,522.7	0.6	129.9	2,653.2	3,677.0	6,330.2

Table 2.—*Area of commercial forest land in Maryland, by ownership classes and geographic units, 1976*
(In thousands of acres)

Ownership class	Central	Southern	Lower Eastern Shore	Western	Total
Federal	20.9	3.7	—	0.3	24.9
State	38.7	4.9	27.8	113.8	185.2
County and municipal	30.4	—	—	2.2	32.6
Total public	90.0	8.6	27.8	116.3	242.7
Forest industry	16.9	11.7	97.7	12.9	139.2
Farmer-owned	478.3	181.0	225.9	143.0	1,028.2
Miscellaneous private:					
Individual	316.8	125.9	124.1	167.8	734.6
Corporate	135.0	27.9	29.2	56.8	248.9
Other	68.5	21.0	18.3	21.3	129.1
Total private	1,015.5	367.5	495.2	401.8	2,280.0
All ownerships	1,105.5	376.1	523.0	518.1	2,522.7
Sampling error (in percent)	3	3	2	2	2

Table 3.—*Form of private ownership by number of owners and acres of privately-owned commercial forest land with number of owners who have harvested timber and the acres they own, Maryland, 1976*

Ownership	All owners		Owners who have harvested timber	
	Number	Thousand acres owned	Number	Thousand acres owned
Forest industry[a]	100	139.2	100	139.2
Farmer[b]	31,500	1,028.2	11,200	580.0
Miscellaneous:				
Individual	53,900	734.6	8,500	322.8
Corporate	5,500	248.9	400	112.0
Other	4,800	129.1	900	56.9
Total private	95,800	2,280.0	21,100	1,210.9

[a] Includes unincorporated forest industry.
[b] Includes part-time farmers.

Table 4.—*Area of commercial forest land in Maryland, by stand-size classes and geographic units, 1976*
(In thousands of acres)

Geographic unit	Sawtimber stands	Poletimber stands	Other stands	All classes
Central	717.4	236.2	151.9	1,105.5
Southern	227.8	85.1	63.2	376.1
Lower Eastern Shore	273.0	172.1	77.9	523.0
Western	194.9	172.1	151.1	518.1
Total, all units	1,413.1	665.5	444.1	2,522.7
Sampling error (in percent)	4	7	11	2

Table 5.—*Area of commercial forest land in Maryland, by forest type groups and geographic units, 1976*

Forest type group	Central	Southern	Lower Eastern Shore	Western	Total	Sampling error
	Thousand acres					*Percent*
White and red pine	12.0	—	—	31.4	43.4	37
Spruce-fir	—	—	—	11.2	11.2	[a]
Loblolly and shortleaf pine	142.0	94.9	253.5	31.6	522.0	7
Oak-pine	47.3	52.8	44.0	19.0	163.1	15
Oak-hickory	680.1	172.8	68.8	240.0	1,161.7	5
Oak-gum-cypress	23.7	21.2	53.8	—	98.7	19
Elm-ash-red maple	116.3	26.4	96.8	83.2	322.7	12
Maple-beech-birch	84.1	8.0	6.1	101.7	199.9	19
Total, all type groups	1,105.5	376.1	523.0	518.1	2,522.7	2

[a] Sampling error of 50 to 99 percent.

Table 6.—*Net volume of growing stock and sawtimber on commercial forest land in Maryland, by stand-size classes and geographic units, 1976*

Geographic unit	Stand-size Class: Sawtimber stands	Poletimber stands	Other stands	All stands	Sampling error
		GROWING STOCK			
		Million cubic feet			*Percent*
Central	1,298.7	323.3	41.2	1,663.2	4
Southern	375.1	91.9	31.8	498.8	5
Lower Eastern Shore	622.3	212.9	30.2	865.4	4
Western	261.8	170.7	32.2	464.7	6
Total, all units	2,557.9	798.8	135.4	3,492.1	2
Sampling error (in percent)	3	9	14	2	
		SAWTIMBER			
		Million board feet[a]			*Percent*
Central	3,839.1	345.4	92.5	4,277.0	5
Southern	981.3	122.8	45.3	1,149.4	6
Lower Eastern Shore	1,640.9	273.8	55.4	1,970.1	5
Western	586.3	165.6	18.2	770.1	10
Total, all units	7,047.6	907.6	211.4	8,166.6	3
Sampling error (in percent)	3	11	19	3	

[a] International ¼-inch rule.

Table 7.—*Net volume of growing stock and sawtimber on commercial forest land in Maryland, by forest type groups and geographic units, 1976*

Forest type group	Geographic Unit: Central	Southern	Lower Eastern Shore	Western	Total	Sampling error
			GROWING STOCK			
			Million cubic feet			*Percent*
White and red pine	26.6	—	—	16.4	43.0	a
Spruce-fir	—	—	—	4.8	4.8	b
Loblolly and shortleaf pine	205.7	126.5	474.4	23.2	829.8	7
Oak-pine	57.5	60.6	63.0	7.7	188.8	17
Oak-hickory	1,134.1	244.6	95.7	246.9	1,721.3	5
Oak-gum-cypress	45.2	24.5	78.3	—	148.0	22
Elm-ash-red maple	125.4	26.2	153.8	82.9	388.3	14
Maple-beech-birch	68.7	16.4	.2	82.8	168.1	21
Total, all type groups	1,663.2	498.8	865.4	464.7	3,492.1	2
			SAWTIMBER			
			Million board feet			*Percent*
White and red pine	10.6	—	—	14.3	24.9	a
Spruce-fir	—	—	—	9.5	9.5	b
Loblolly and shortleaf pine	389.3	240.7	1,058.0	32.4	1,720.4	9
Oak-pine	110.5	129.5	120.6	10.1	370.7	18
Oak-hickory	3,142.1	625.7	203.6	428.9	4,400.3	6
Oak-gum-cypress	88.6	58.0	204.7	—	351.3	24
Elm-ash-red maple	343.5	59.7	383.2	144.0	930.4	15
Maple-beech-birch	192.4	35.8	—	130.9	359.1	24
Total, all type groups	4,227.0	1,149.4	1,970.1	770.1	8,166.6	3

[a] Sampling errors of 50 to 99 percent.
[b] Sampling errors of over 100 percent.
[c] International ¼-inch rule.

Table 8.—*Net volume of growing-stock trees on commercial forest land in Maryland, by species and tree-size class, 1976* [a]

Species	Growing stock: Poletimber trees	Growing stock: Sawtimber trees	Growing stock: All trees	Sampling error [b]	Sawtimber	Sampling error [b]
	Million cubic feet			*Percent*	*Million board feet* [d]	*Percent*
White-red pine	33.0	9.1	42.1	c	29.1	c
Loblolly pine [e]	104.2	378.7	482.9	7	1,238.9	8
Virginia pine	117.2	119.6	236.8	12	378.1	14
Other yellow pines	1.6	12.3	13.9	39	42.3	42
Other softwoods	6.8	10.5	17.3	31	38.0	37
Total softwoods	262.8	530.2	793.0	6	1,726.4	7
Soft maples	138.0	142.6	280.6	8	515.3	11
Hard maple	16.9	16.6	33.5	31	50.5	42
Hickory	41.8	73.0	114.8	11	253.4	14
Beech	19.1	76.1	95.2	16	287.8	19
Sweetgum	95.4	125.7	221.1	9	454.8	12
Yellow-poplar	62.8	287.7	350.5	10	1,070.0	11
Blackgum	40.8	58.0	98.8	10	213.2	14
Ash-walnut-cherry	55.6	61.6	117.2	14	211.0	16
Select white oaks	123.7	275.8	399.5	7	1,005.4	8
Select red oaks	42.7	143.3	186.0	12	481.0	14
Other white oaks	69.4	110.8	180.2	13	381.5	16
Other red oaks	134.2	333.9	468.1	7	1,216.0	9
Black locust	17.5	15.3	32.8	25	49.8	40
Other hardwoods	50.4	70.4	120.8	13	250.5	17
Total hardwoods	908.3	1,790.8	2,699.1	3	6,440.2	4
All species	1,171.1	2,321.0	3,492.1	2	8,166.6	3

[a] Growing-stock trees are trees that satisfy national specifications for form and allowable cull. Poletimber trees are 5.0 to 8.9 inches dbh for softwoods and 5.0 to 10.9 inches dbh for hardwoods. Sawtimber trees are 9.0 inches dbh and larger for softwoods and 11.0 inches dbh and larger for hardwoods.

[b] Sampling errors apply to the species totals for both growing-stock and sawtimber volumes.

[c] Sampling error of 50 to 99 percent.

[d] International ¼-inch rule.

[e] Includes 9.5 million cubic feet and 20.4 million board feet of pond pine and 3.0 million cubic feet and 6.8 million board feet of shortleaf pine.

Table 9.—*Annual net growth and removals of growing stock and sawtimber on commercial forest land in Maryland, by softwoods and hardwoods, 1975* [a]

Species group	Growing stock: Net growth	Growing stock: Removals	Sawtimber: Net growth	Sawtimber: Removals
	Thousand cubic feet		*Thousand board feet* [b]	
Softwoods	24,900	23,600	75,000	68,000
Hardwoods	86,100	61,800	223,000	153,000
Total	111,000	85,400	298,000	221,000
	Percent			
Sampling error of totals	31	18	42	20

[a] Based on trends of growth and removals for the period between inventories as estimated from remeasured plots.

[b] International ¼-inch rule.

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PRECIPITATION AND RUNOFF WATER QUALITY FROM AN URBAN PARKING LOT AND IMPLICATIONS FOR TREE GROWTH

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ABSTRACT.—The water quality of precipitation and runoff from a large parking lot in New Brunswick, New Jersey was studied during the early growing season, from March to June 1976. Precipitation and runoff from 10 storms were analyzed. The runoff was higher in all constituents considered except for P, Pb, and Cu. Compared with published values for natural waters, sewage effluent, and storm-water drainage from urban land, the parking lot runoff was not highly polluted during the study period, and it appears that such runoff is a satisfactory source of water for urban trees.

INTRODUCTION

Trees and forests in and near urban regions provide a variety of amenity values for urban populations. But urbanization tends to replace the forest with impermeable surfaces, such as parking lots, buildings, and other man-made constructions. Forest amenities, such as esthetic values and climatic moderation, are lost. Parking lots are a significant fraction of urban impervious areas (Lull and Sopper 1969) and are usually not considered esthetically appealing. Various attempts are made to correct the unattractive appearance of parking areas, and planting trees within the lot boundary is one solution; occasionally this is required by municipal ordinance (see Cherry Hill NJ Ordinance 69-24 and Hillsborough NJ Ordinance 75-13).

Such urban sites as parking lots are harsh environments for trees. Trees may be stressed by poor soil moisture or fertility or inadequate or polluted water. In a current study, we are investigating soil moisture and fertility stresses on trees planted in soil that is exposed by gaps cut through a new asphalt parking lot surface. Since surface runoff could contribute to the water supply, we examined the chemical properties of surface runoff from the lot. Because of limited resources, the study was carried out only during the period which we felt was critical for tree establishment and survival. We evaluated the water quality by comparing it

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with water yielded from other sources because the study period was too short for significant differences to appear in the test trees.

STUDY SITE AND PROCEDURES

A university parking lot at New Brunswick, New Jersey, was chosen as the experimental area. The surface is 3-year-old asphalt, sealed to prevent water infiltration. The lot is 192 m by 50 m, covering an area slightly less than a hectare. The lot slopes eastward across the narrow dimension with a 1 percent grade to promote drainage. There is a curb on the east edge to channel runoff to nine drains. There is almost no relief in the parking lot surroundings. There are turf plots to the north and west, yearly feed crops to the south and west, and a lawn and row of red maples on the east. Lot-use was not controlled during the study period; but the number of parked vehicles varied around an average of 225 on weekdays.

In April 1976, 2-m-square gaps were cut in the asphalt surface of the lot and 32 trees were planted in the underlying soil. Water for these trees is partially supplied by overland flow from the lot, so materials washed to the soil around the trees may affect their survival. The area was not designed to direct runoff to tree locations, so estimates of water supplied to each tree were not made.

Samples of both rainfall and runoff were collected during the early growing season, from March through June 1976. Water samples were collected during 10 storms when precipitation was heavy enough to cause collectable surface runoff (Table 1).

Runoff was collected in polyethylene containers at the drains. Precipitation was collected about 30 m directly west of the parking lot in a polyethylene bin lined with a polyethylene bag. The bin was uncovered and the liner installed just before each storm to minimize the accumulation of dry particulates in the rain sample. Contamination from the plastic liner was measured and found negligible.

Separate 2-liter samples were analyzed for oil and grease by the wet extraction method with petroleum ether. The remaining water was filtered through 0.5μm filter paper and stored at 4°C until analyzed. The pH was determined by a glass electrode and meter. We identified PO_4 by the chloromolybdic method, NO_3-nitrogen by reaction with Nitraver IV reageant, and NH_4-nitrogen by Nessler reaction; then the concentration of each chemical was measured with a colorimeter. The Cl was determined by colorimetric methods with an autoanalyzer. The concentrations of Na, Ca, Mg, K, Pb, Cd, Ni, Mn, Cu, and Fe were determined by atomic absorption techniques after concentration (10:1) in a water bath with 5 ml of concentrated HNO_3 per 500 ml of filtered sample water.

Table 1.—Dates of water collections and precipitation at New Brunswick, N.J., 1976

Date	Precipitation (cm)
4 March	0.53
10 March	1.06
14 March	.53
17 March	1.24
1 April	2.89
23 April	.33
8 May	2.36
30 May	.38
21 June	.28
30 June	.43

RESULTS AND DISCUSSION

Results of the analysis of precipitation and runoff are given as monthly averages in Tables 2 and 3. The quality of precipitation in other locations, runoff from undisturbed forested watersheds, and sewage effluent used for forest irrigation are included for comparison. Comprehensive long-term measurements of runoff and precipitation quality do not exist for the Northeast except for the Hubbard Brook watersheds (Cowling and Wood 1976). Therefore, some comparisons are made with areas outside the Northeast. Table 4 shows the minimal and maximal pH of the New Brunswick samples and concentration of pollutants in them.

Oil and grease

The concentration of oil and grease in all precipitation samples was found negligible. The concentration in the runoff water of individual storms ranged from 1.5 for a storm in June to 142.0 mg/liter for a storm in March. The highest monthly average of oil and grease in the runoff was also in March (Table 3). Thus oil and grease contamination from the parking lot surface was relatively low except for the first month of the growing season. We attribute the initial high concentration to material stored on the lot surface during the cold winter.

Table 2.—Monthly average ph and concentrations of chemical constituents and oil and grease in precipitation at New Brunswick, N. J., in spring 1976 compared with precipitation for several watersheds near urban areas

Item	New Brunswick				Other areas[a]			
	March	April	May	June	1	2	3	4
pH	4.39	3.95	3.85	3.92	4.0	4.1	3.98	
				mg/liter				
Oil and Grease	None							
NH_4-N	1.39	1.01	1.37	0.77	0.05	0.22	0.51	
NO_3-N	.56	.34	1.62	.78	1.8	1.47	.44	
Cl	2.8	1.0	.8	.8	.7	.47	1.19	
Na	2.79	.80	.73	.19	.04	.12	.79	
Ca	.99	.56	.75	.50	.09	.16	1.32	
Mg	.40	.26	.35	.10	.02	.04	.21	
K	1.42	.35	.26	.18		.07	.34	
P	.011	.041	.042	.070	.08	.008	.03	
Pb	.127	.053	.255	.068				0.025
Cd	all samples < .002							
Ni	.016	.010	.016	.059				.006
Mn	.007	.006	.002	.005				
Zn	.112	.067	.065	.061				.120
Cu	.017	.033	.026	.006				.009
Fe	.588	.084	.180	.070				.21

[a]1 Hornbeck and Likens (1974), snow only, New Hampshire.
2 Jacobson, Heller, and Van Leiken (1976), Yonkers, New York.
3 Calculated from data of Richardson and Merva (1976), for New York locations.
4 Gorham (1976), Sudbury, Ontario.

Table 3.—Monthly average pH and concentrations of chemical constitutents and oil and grease in runoff from New Brunswick parking lot compared with other areas and with sewage effluent

Item	New Brunswick				Other areas[a]				Sewage effluent[a]
	March	April	May	June	1	2	3	4	5
pH	5.95	5.45	4.50	4.37	6.91			3.6	7.9
					mg/liter				
Oil and grease	72.0	5.2	5.0	3.5					
NH_4-N	2.21	2.04	1.30	2.08	.002		0.06	.35	6.9
NO_3-N	.61	1.13	1.22	.87	.004	0.02	.88	.31	13.3
Cl	25.0	1.7	1.0	1.1	.673		.58	.9	41.3
Na	208.0	4.33	.73	1.23	1.351	.97	1.1	.6	20.6
Ca	61.0	12.8	3.10	5.00	.713	4.36	1.8	2.6	31.3
Mg	6.07	2.09	.45	.39	.359	1.96	.40	.9	15.1
K	2.45	7.40	8.50	15.0	.589	1.18	.24	1.1	12.3
P	.009	.061	.042	.062	.006			.15	4.9
Pb	.146	.161	.050	.050				.06	.104
Cd	.010	.003	.100	.100					.009
Ni	.014	.105	.200	.180					.093
Mn	.130	.092	.320	.600				.06	.061
Zn	.299	.181	.122	.132				Trace	.211
Cu	.048	.057	.018	.040				.01	.109
Fe	.565	.416	2.02	2.400				1.4	.4

[a]1 Douglass and Swank (1975), North Carolina.
2 Corbett, Lynch, and Sopper (1975), Virginia.
3 Likens et al. (1970), New Hampshire.
4 Verry (1972), Minnesota.
5 Richenderfer, Sopper, and Kardos (1975).

Table 4.—Minimum and maximum pH and pollutant concentrations in precipitation and runoff from 10 storms at New Brunswick, N.J.

Item	Precipitation		Runoff	
	Minimum	Maximum	Minimum	Maximum
pH	3.10	4.80	4.37	6.20
	- - - - - - - - - - -	mg/liter	- - - - - - - - - - -	
Oil and grease			1.5	142.0
NH_4-N	0.56	2.80	.95	3.52
NO_3-N	.30	1.62	.30	1.93
Cl	.8	3.0	1.0	40.0
Na	.10	5.50	.73	415.0
Ca	.40	1.15	2.88	120.0
Mg	.10	.45	.39	11.25
K	.10	3.25	.75	15.00
P	.005	.085	.009	.082
Pb	.050	.283	.050	.271
Cd	<.002	<.002	.002	.100
Ni	.005	.100	.010	.200
Mn	.002	.010	.002	.600
Zn	.019	.219	.017	.445
Cu	<.002	.163	.016	.097
Fe	.002	1.190	.050	2.400

pH

The pH of precipitation ranged from 3.10 to 4.80 (Tables 2 and 4). Normally, water in the atmosphere in equilibrium with CO_2 has a pH near 5.7. So precipitation was moderately acid, but not as acid as that reported in other studies in the Northeast where the pH was as low as 3.0 (Hornbeck and Likens 1974). The pH of the runoff ranged from 4.37 to 6.20 (Tables 3 and 4). The pH of runoff was higher than that of precipitation because of various salts in the runoff.

Inorganic nitrogen

The monthly concentrations of NH_4 and NO_3 nitrogen in precipitation ranged from 0.77 to 1.39 mg/liter for the former, and 0.34 to 1.62 mg/liter for the latter (Table 2). The ratio of NH_4 to NO_3 in New Brunswick precipitation was about 2:1. The concentration of NO_3 in precipitation in the study area was attributed to use of fossil fuels. But, pollution by N in New Brunswick precipitation was modest.

The concentration of NH_4 in runoff ranged from 0.95 to 3.52 mg/liter, and NO_3 ranged from 0.30 to 1.93 mg/liter, which indicates that only nominal amounts of inorganic N were added to the water during surface flow.

Chloride

Chloride concentration in the precipitation ranged from 0.8 to 3.0 mg/liter. Chloride concentrations were higher than those reported for other areas (Tables 2 and 4). The high concentration of Cl may be due to below-cloud scavenging of salt from the ocean during precipitation or residue from road salting. In fact, Cl:Na ratios were similar to that of salt, approximately 1:1, except in June, a month with little precipitation.

Chloride concentration in the runoff ranged from 1.0 for a storm in May to 40.0 mg/liter for a storm in March, when sodium chloride was used for street and highway deicing (Tables 3 and 4). Even deicing compounds did not raise chloride concentrations to sewage effluent levels (Table 3), and compared with concentrations that ranged from 3 to 390 mg/liter in storm-water drainage from urban land in North Carolina (Bryan 1972), the pollution due to Cl in the parking lot was moderate.

Sodium, calcium, magnesium, and potassium

The mean concentrations of Na, Ca, Mg, and K in the precipitation were 1.71, 0.79, 0.32, and 0.75 mg/liter, but concentrations for individual storms ranged widely (Table 4). Concentrations of these elements were generally greater than those reported for the Northeast (Table 2). The higher rank of Na in New Brunswick may be attributed to scavenging from the sea and residue from road deicing chemicals.

The runoff contained much more of these four elements than the precipitation, especially in March when the average concentrations were 208, 61, 6, and 2 mg/liter for Na, Ca, Mg, and K (Table 3). Although peak Na concentrations were greater in the runoff than in sewage effluent, the peak was temporary and occurred only in March when salt was washed from the lot surface.

Phosphate

The PO_4 concentration of the precipitation ranged from 0.005 to 0.085 mg/liter while the range of the runoff was essentially the same—0.009 to 0.082 mg/liter (Table 4). Thus it seemed that little additional PO_4 was added to the runoff from soil particulates on the parking lot surface. Compared with the storm-water drainage from urban land in North Carolina, where the PO_4 ranged from 0.15 to 2.50 mg/liter (Bryan 1972), the runoff was low in phosphate.

Lead

The lead concentration in the precipitation ranged from 0.050 to 0.283 mg/liter (Table 4). This relatively high concentration probably reflects the amount of airborne lead in urban areas.

The Pb concentration in the runoff ranged from 0.050 to 0.271 mg/liter, with a slightly higher mean value (0.041 versus 0.031 mg/liter) than the precipitation (Table 4). Thus there was little lead pollution from the parking lot surface, which was somewhat unexpected. Compared with the lead concentration of storm-water drainage from urban land in North Carolina—a range of 0.10 to 1.85 mg/liter (Bryan 1972)—the runoff was slightly polluted, as was sewage effluent (Table 3).

Cadmium

The cadmium concentration in the precipitation samples was less than 0.002 mg/liter—an indication of low Cd pollution in precipitation in New Brunswick. The greater concentrations of Cd in the runoff (Table 4) shows that Cd was picked up as water moved across the lot surface. Cadmium sources were not identified, but they possibly include petroleum products and tire fragments.

Nickel, manganese, zinc, copper, and iron

The concentration of the five trace elements Ni, Mn, Zn, Cu, and Fe in precipitation was above regional means (Tables 2 and 4). Pollution on the parking lot surface was significant for all of these elements except Cu, which, like phosphate and Pb, was not significant. The high concentrations of trace elements in the precipitation may be due to air particulates. Gorham (1976) reviewed several studies and found that these elements appear in greater concentrations in the atmosphere in urban centers.

CONCLUSIONS

Precipitation

The comparison of the water quality of precipitation from urban New Jersey with that from other states showed only modest differences. Levels of ammonium nitrogen, chlorine, and sodium were slightly higher, while nitrate concentrations were below regional levels. Traces of heavy elements were present, but in lower concentrations than in the soil solution as determined by Alloway (1968). Acidity was within the regional range, and the acid precipitation effects on forest vegetation would be expected to follow the direct and indirect effects listed by Tamm and Cowling (1976).

Surface runoff

The quality of surface runoff was compared with water from undisturbed watersheds. A comparison was also made with processed sewage effluent. Most constituent concentrations were intermediate between water from forested, undisturbed watersheds and processed municipal sewage effluent. The exceptions were petroleum-based oil and grease, sodium, and calcium, which exceeded sewage effluent levels during March. This can be attributed to a winter accumulation of oil and deicing compounds that appeared in early season runoff. After March, concentrations of these materials dropped well below the levels in sewage effluent.

Sewage effluent has been used to spray-irrigate hardwood, softwood, and old field vegetation. Applications of 1 and 2 inches per week have continued for about 15 years in central Pennsylvania. After 9 years, an extensive soil analysis showed no detrimental effects attributable to the effluent, although some ion concentrations had changed

(Richenderfer, Sopper, and Kardos 1975). Forest vegetation response has generally been positive, except for a red pine (*Pinus resinosa* Ait.) stand which deteriorated during treatment. On other plots, growth was increased and the vegetation proved to be a vital renovating agent for the water (Sopper and Kardos 1973).

Based on our findings, runoff from a parking lot surface appears to be a satisfactory source of water for urban trees in the early growing season, provided the soil has good drainage. Concentrations of most ions are not excessive and may even correct some micronutrient deficiencies in the soil. Sodium, chloride, and oil and grease concentrations could present problems for urban forest vegetation. However, both sodium and chloride had infrequent peak concentrations, so vegetation not unusually sensitive to salt should not be affected. Plant responses to petroleum-based oil and grease deposited in the soil at the base of trees are not fully known, but we suspect occasional deposits could be tolerated. However, the effects of modest, intermittent additions of oil to the soil around trees merits further study. Also, precipitation and runoff should be analyzed for a full year to compare pollutant concentrations during other seasons and to determine if they exceed those we measured.

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FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE, 370 REED ROAD, BROOMALL, PA. 19008

A COMPOST BIN FOR HANDLING PRIVY WASTES: ITS FABRICATION AND USE

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Abstract. A 24-ft^3 (6.8-m^3) fiberglass bin was constructed and tested for its effectiveness in composting privy wastes. A mixture of ground hardwood bark and raw sewage was used for composting. Temperatures in excess of 60°C for 36 hours were produced in the bin by aerobic, thermophilic composting. This temperature is sufficient to destroy most pathogenic microorganisms. Composting in a leak-proof bin seems a safe, practical, and economical method of handling privy wastes.

The safe disposal of human wastes is a common problem at backcountry recreation sites. Pit privies often are not effective in these remote areas because the soil usually is too shallow or poorly drained. Other methods of waste disposal such as leachfields or incineration are often too expensive or impractical; most overnight shelter sites are located at high elevations and are situated on bedrock (Fig. 1). We found that composting seems a safe, practical, and economical method of disposing of privy waste.

Some of the available information on composting (Golueke 1972; Poincelot 1974; Gray et al. 1971) describes configurations of compost piles and containers for a variety of conditions; much of this information is applicable for composting privy wastes. We constructed a leak-proof, fiberglass container and tested its effectiveness in composting privy wastes at shelter sites that accommodate as many as 30 visitors per night.

CONSTRUCTION

The container, called the "Bin Composter", is a 24-ft^3 (6.8-m^3) fiberglass box (Fig. 2). Its inside dimensions are 3 feet (.99 m) x 4 feet (1.2 m) x 2 feet (.61 m); the highest end is 3 feet (Figs. 3a, 3b, 3c, 3d). At the low end is a small slide-out door that allows access to the compost pile for loading or mixing. All sections, including the bottom of the unit, were made from 1/2-inch (1.27-cm) exterior-grade plywood. The sections were nailed together and the entire unit was covered with fiberglass for leak-proofing. We used polyester resin and 1-1/2-ounce (42.5-g) fiberglass mat.

We constructed a unit large enough to ensure that (when full) heat production exceeded heat

Figure 1.—Note the absence of roads at this backcountry shelter site. The high elevation is evident from the exposed bedrock, shallow soil, and exposed ridgeline in background.

Figure 2.—The 24-ft^3 fiberglass Bin Composter.

Figure 3a.—Full view of composting bin.

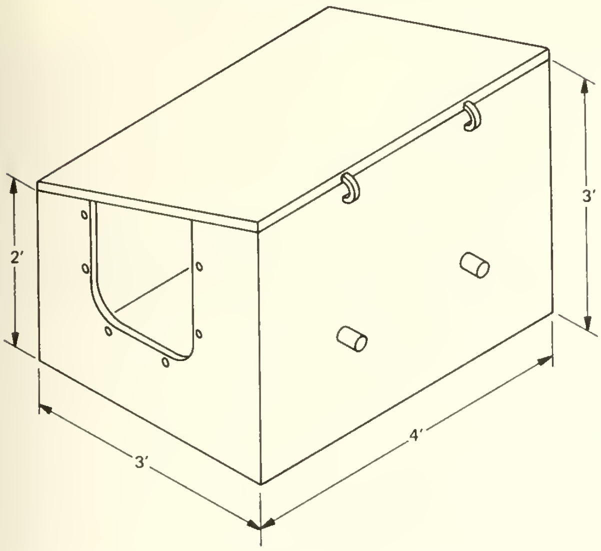


Figure 3b.—Top view of composter, solar panel cover removed.

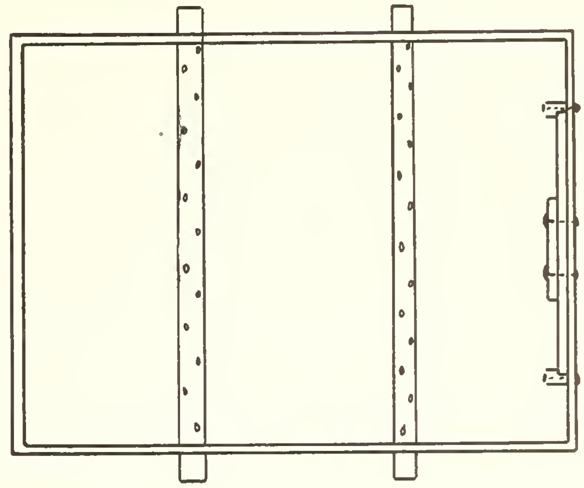


Figure 3c.—Side view of composter.

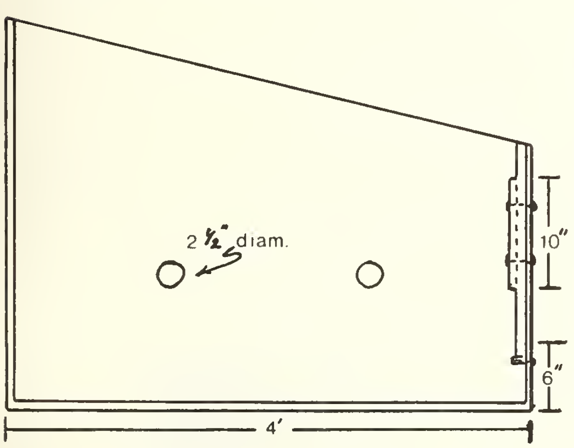
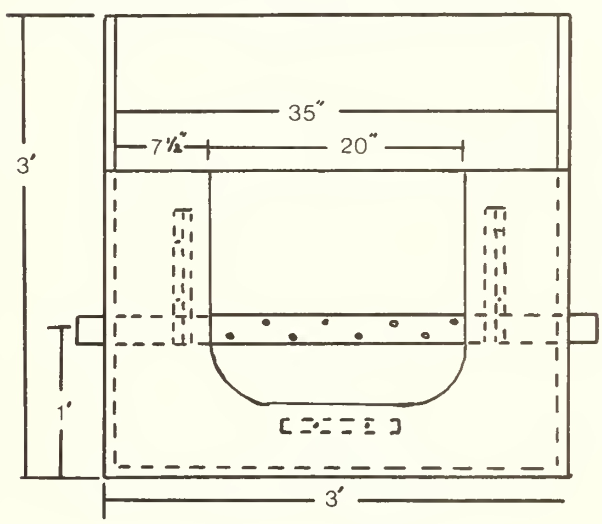


Figure 3d.—Rear view of composter.



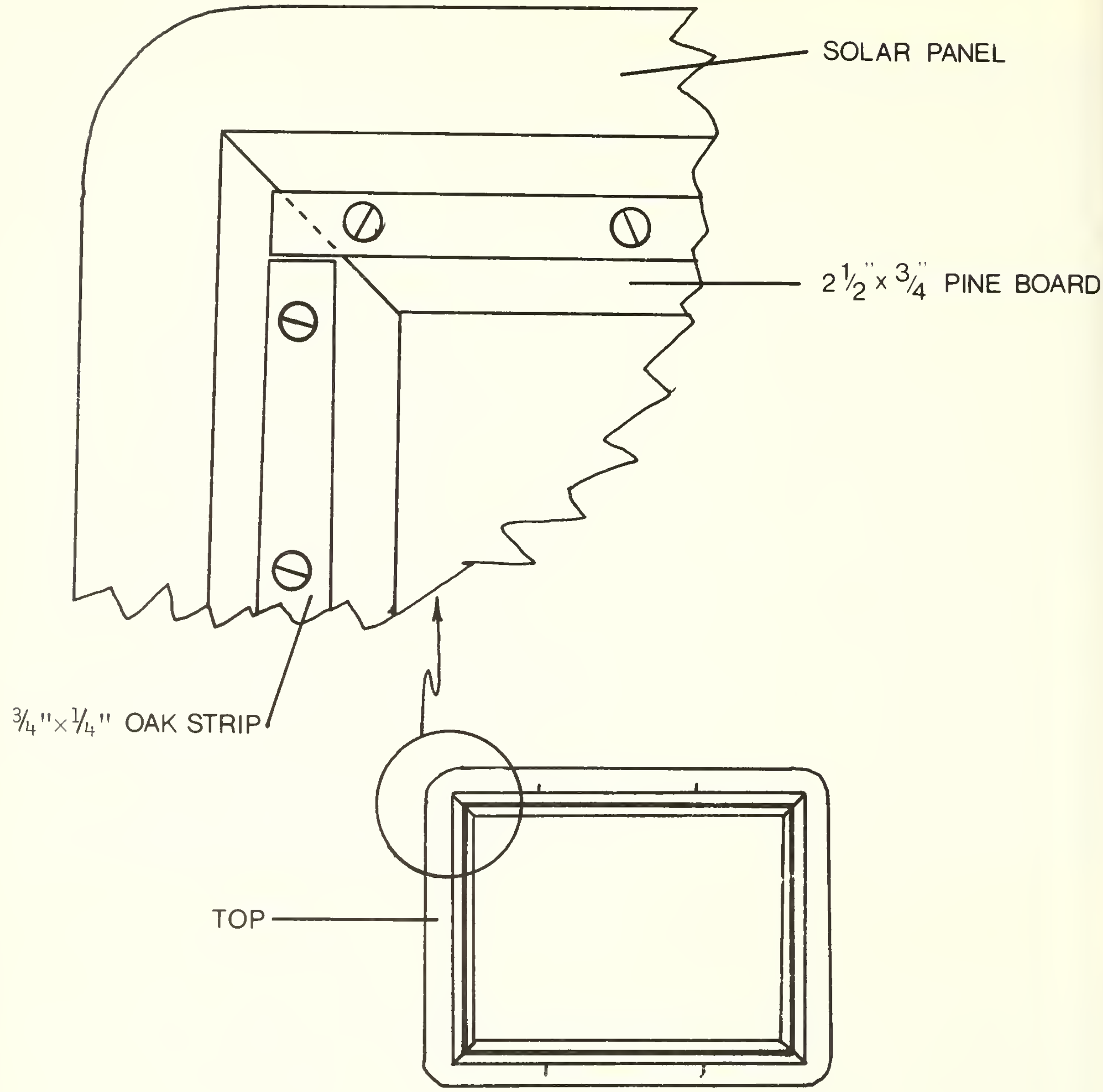
loss in the compost pile. The result was a small, transportable unit that produced and maintained relatively high temperatures.

The top of the bin was made of solar panel .040-inch (.1016-cm) in a wooden frame of 2-1/2 x 3/4-inch (6.35 x 1.90-cm) stock softwood, and 3/4 x 1/4-inch (1.90 x .635-cm) hardwood (Fig. 4). The top is attached to the box by hooks and eyes for easy removal. When attached correctly, the top prevents rain from entering the container, and helps collect and retain heat, though this is not essential.

Two perforated tubes, each 2-1/2 inches inside diameter, were driven through the pile (Fig. 3b). Each tube was a 3-1/2-foot section of PVC pipe; a 1/4-inch hole was drilled on three sides. These tubes increase the aeration in the interior of the pile when the bin is full.

The compost bin is designed for use with a privy. Human waste is collected in a container under the privy seat, and is transferred to the bin periodically. In some privies, the space under the seat is large enough to accommodate a fiberglass container holding as many as 60 gallons (227 liters) of waste. A small space could accommodate a 10-gallon (37.8-liter) galvanized bucket. The privy and bin should be placed close together to simplify the transfer of wastes.

Figure 4.—Solar panel cover for composter.



OPERATION

The bin promotes aerobic, thermophilic composting by a combination of ground hardwood bark or other dry organic materials—such as peat moss or leaves—and raw sewage. The bark that we used was ground from northern hardwood debarker waste to about the texture of peat moss. This material is effective for composting because it eliminates odor from the sewage, absorbs moisture, and provides a source of nutrients for the decomposing microorganisms.

The bark-sewage mixture should be of a consistency that allows it to be picked up with a standard manure fork. It should be moist but not dripping. The amount of bark needed for this consistency was determined by the fecal-urine ratio of the waste. We used from 4 to 7 pounds (1.8 to 3.2 kg) of ground bark for each gallon of waste.

We thoroughly mixed the bark and raw waste in a series of small batches to prevent the formation of clods, in which anaerobic conditions can exist. The bins were filled to the height of the lower end of the unit (a depth of 2 feet).

Figure 5.—The compost pile must be exposed to a temperature of 60°C for 36 hours for destruction of human pathogen indicator organisms. Temperatures in the bin reached or exceeded 60°C for 7 days.

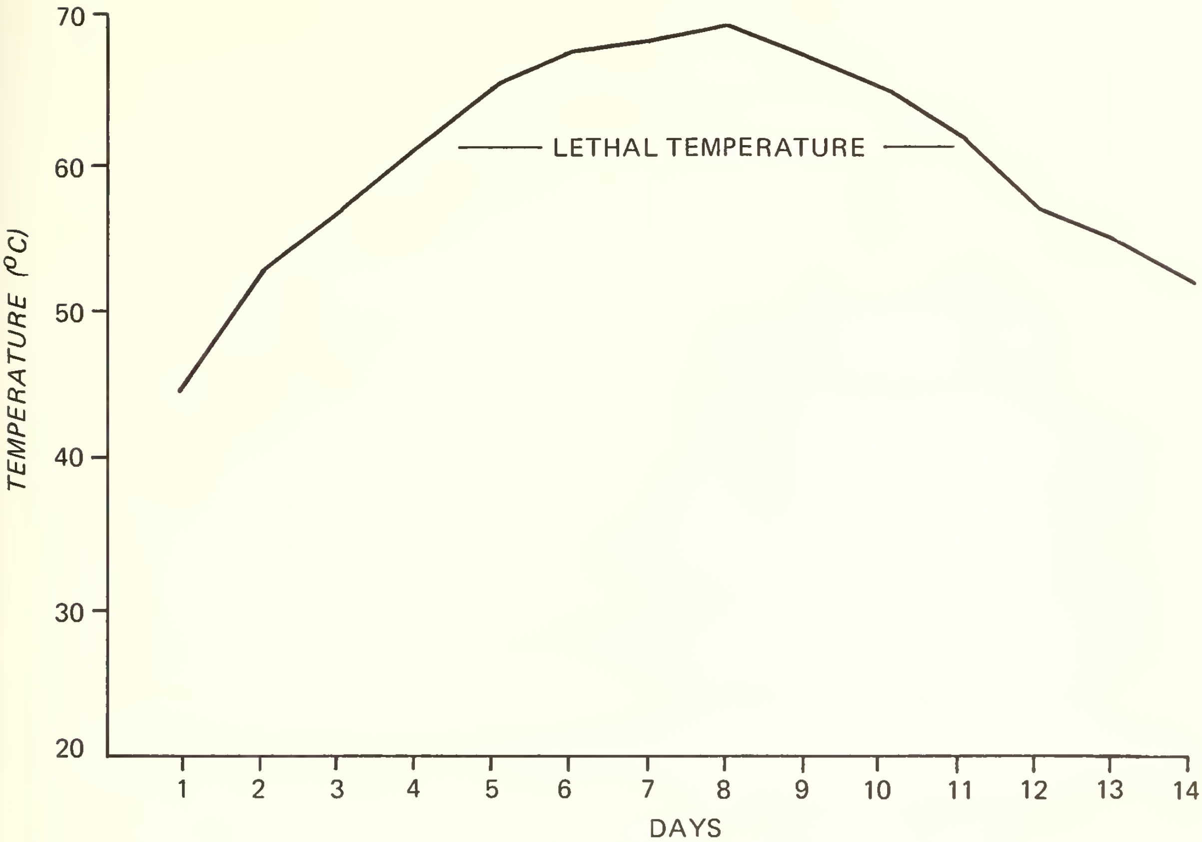


Figure 6.—Composted hardwood bark and raw sewage.

A thermograph probe was inserted into the center of the pile to monitor the temperature, an important indicator of aerobic decomposition. In our test run (Fig. 5), the temperature inside the pile exceeded 60°C for 7 days. A temperature of 60°C must be maintained for at least 36 hours to destroy human pathogenic indicator organisms in windrow (ground bark/raw sewage) compost piles (Walke 1975). Because the exterior of the pile does not reach this lethal temperature, the pile must be turned "inside out" to ensure that the entire pile is composted. The pile should be turned after the first 36 hours at 60°C.

The final product of the composting process is a dark brown, humuslike substance which can be re-used in at least one more "compost run" (Fig. 6). Once the ratio of carbon to nitrogen in the composted bark reaches an acceptable level (for controlling microorganisms), the compost can be scattered on the forest floor or used to recondition the soil in worn areas (campsites and along trails). As with any nutrient-rich mixture, this material should not be used near water sources.

The number of compost runs each season depends on the amount of use the privy receives. Most backcountry overnight sites in New England collect 100 to 150 gallons (378.5 to 567.7 liters) of privy waste. This results in two compost runs each year.

DISCUSSION

There are several points to consider in operating a bin composter. Most important, composting is as much an art as it is a science. For example, no manual can adequately describe the appearance of the bark-sewage mixture when it attains the proper moisture content; so the caretaker must have some experience or receive training in the field.

The unit may emit an ammonia odor that is barely detected or unimportant to many. However this odor is an indication that the pile is becoming anaerobic. The earthy odor of a properly operated pile is equally difficult to describe, yet it is an important indication that the process is working well.

The temperature of a compost pile is probably the best indicator of good, aerobic composting. A thermometer that reads to 60°C and beyond can be placed in the center of the pile after the material has been mixed. There should be a fairly rapid increase in temperature within a few days of starting the pile. If this increase does not occur, the most likely problem is too much moisture. Turning the pile with a pitchfork or adding more bark usually will solve this problem.

We know that bark is a good mixing agent, and experience suggests that the bark should be fairly fresh—not more than 3 or 4 months old—when used. At this age, the nutrient supply in the bark is at a maximum. Also, the bark should not be dried before use; drying seems to draw out oily substances, and reduces the capacity of the bark to hold moisture.

Little time is needed to operate a compost bin. Depending on location, packing the bark to the site requires about 4 days during the summer; actual operation of the unit requires 2 to 3 hours each week.

SUMMARY

The primary advantage of composting wastes in a leak-proof bin is that the unit is largely independent of site conditions; that is, the self- contained system can be used regardless of soil conditions—even when there is no soil. This feature is especially advantageous at high elevations.

The price of the bin is about $100, including materials and labor. The most expensive material is the fiberglass; however, the use of fiberglass makes the unit leak-proof, durable, and resistant to damage by animals, including porcupines.

The size and weight (about 70 pounds) of the bin allows it to be transported on a packframe by one person. It has been our experience, though, that it is difficult to carry the unit where there are low-hanging limbs or closely spaced trees, so it is best to use a trail that is wide and brushed.

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SEXING SPRUCE BUDWORM PUPAE

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Abstract. Spruce budworm pupae can be sexed by the location and shape of the genital opening. The opening spans the 8th abdominal segment in female pupae and is found on the 9th segment in male pupae.

For biological studies of the eastern spruce budworm, *Choristoneura fumiferana* (Clem.), we need to know how to differentiate the pupal sexes. A method for sexing pupae is required to determine pupal sex ratios, to segregate and rear virgin female moths to be used in sex-attractant studies, and to determine sex of pupae killed by a variety of natural enemies. Both Gibson (1925) and Lambden (1950) illustrated male and female spruce budworm pupae. However, because these papers are generally not available to most field workers, an updated pictorial guide is presented. This Note describes an easy, reliable method for sexing pupae of *C. fumiferana*.

External morphological characters that distinguish pupal sex have been described for a number of lepidopterous pupae. The chief and most reliable character is the location and shape of the genital pore or opening.

In the female pupa, the genital opening is found on the ventral aspect of the 8th abdominal segment (Fig. 1A). The genital opening of the female is longer than that of the male. This opening spans the 8th segment and bisects its caudal margin, extending posteriorly into the cephalic region of the 9th segment. Mesially, the caudal margin of the 8th and the cephalic margin of the 9th segment project cephalad, thus forming an inverted V-shaped marking.

The genital opening of the male pupa is found ventrally on the 9th abdominal segment (Fig. 1B), and is easily recognized by distinctly elevated tubercles, one on each side of the opening.

In both sexes of the spruce budworm, the anal opening is found on the 10th abdominal segment. The cremaster, which is an elongation of the 10th segment, is longer than wide and bears eight strongly hooked setae. Four of the hooked setae are at the apex of the cremaster; two each are located laterally on either side of the cremaster.

Dorsally, the 1st and 10th abdominal segments of spruce budworm pupae are devoid of spines. Two rows of spines, a cephalic row and a caudal row, are found on segments 2 through 8. The cephalic row is generally stouter and more pronounced than the caudal row. Dorsal spines are usually reduced to a single row on segment 9. The thoracic region is considerably enlarged, especially in the region of the wing pads, while the abdomen tapers posteriorly.

Laterally, spiracles are conspicuous on abdominal segments 2 through 7; they are circular and are surrounded by a protruding ring. On segment 8, spiracle vestiges are slitlike and lack a distinct opening.

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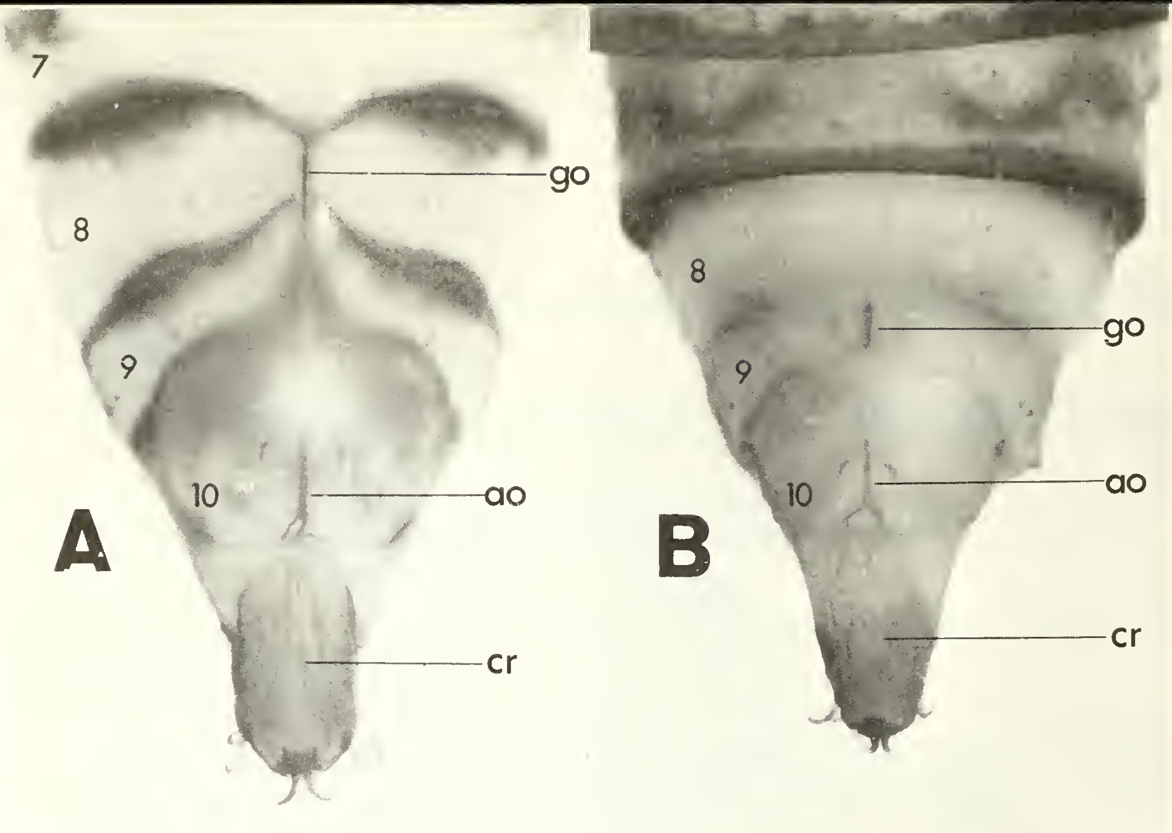

Figure 1.—Ventral view of female (A) and male (B) *Choristoneura fumiferana* pupae, showing genital (go) and anal (ao) openings, cremaster (cr), and abdominal segments 7-10.

Harvey and Stehr (1967) reported differences in hemolymph pigmentation for several spruce- and pine-feeding *Choristoneura.* They found that only *C. pinus pinus* Freeman was sexually dimorphic in color, with 100 percent of the males yellow and 100 percent of the females green. About 33 percent of the *C. fumiferana* females they examined were yellow, while 67 percent were green; 54 percent of the males were yellow, while 46 percent were green. Thus, coloration is not a good sexing character for *C. fumiferana.*

Because lepidopterous pupae sometimes "curl" or "telescope," counting the number of abdominal segments visible ventrally and posterior to the wing pads is not a reliable method for sexing pupae. The best criteria for separating pupal sexes of *C. fumiferana* are the relative position and the shape of the genital opening. Intact pupae, and even pupal cases from which adult moths have emerged, can be quickly and accuractly sexed using this method. The method is particularly useful for sexing pupal fragments when the 8th or 9th segment is present. As often happens with pupae parasitized by dipterous parasitoids, the host pupa breaks into fragments when the parasitoid emerges. The posterior portion of the host pupa is usually left intact and remains anchored to the foliage by the cremaster hooks. These fragments can easily be sexed by the method described here.

Spruce budworm pupae can be sexed in the field with a 10× hand lens. Confirmation of sex depends on the position and shape of the genital opening. The anal opening, located on the 10th (last) abdominal segment in both sexes, can be used as a reference point for counting anteriorly.

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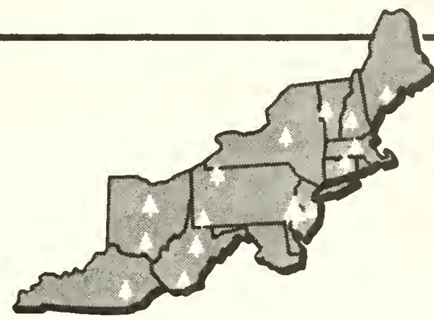

FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE, 370 REED ROAD, BROOMALL, PA. 19008

CORRELATIONS OF LEAF AREA WITH LENGTH AND WIDTH MEASUREMENTS OF LEAVES OF BLACK OAK, WHITE OAK, AND SUGAR MAPLE

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Abstract. Correlations of leaf area with length, width, and length times width of leaves of black oak, white oak, and sugar maple were determined to see if length and/or width could be used as accurate estimators of leaf area. The correlation of length times width with leaf area was high ($r > +.95$) for all three species. The linear equation $Y = a + bX$, where X = length times width, can be used to estimate leaf area where it is not possible or practical to make actual area measurements.

INTRODUCTION

Leaf area of trees is an important component of models of photosynthesis, growth, and primary productivity. Area measurements can now be made with portable electronic area meters, and are most easily made if the leaves are detached from the plant and passed through the meter. Measuring attached leaves with the electronic meter is cumbersome, not as accurate, and can be hazardous. However, for some experiments, it would be detrimental to the results of the study if leaves were removed.

An easier measurement to make on attached leaves is length or width. These measurements are highly correlated with leaf area in grape species (Manivel and Weaver 1974). Therefore, this study was made to determine if length and width were correlated highly enough with leaf area to be substituted as an accurate estimate of leaf area in species of forest trees.

MATERIALS AND METHODS

Three species of deciduous hardwoods were chosen: sugar maple, *Acer saccharum* Marsh, white oak, *Quercus alba* L., and black oak, *Q. velutina* Lamarck. Trees were 5 to 8 cm in diameter at 1.4 m, and were 5 to 7 m tall. The sugar maples were part of a thicket that had seeded into an abandoned field. The oaks were growing in a stand that had been recently cut over. All trees were 15 to 20 years old.

Ten leaf clusters were randomly selected from the upper two-thirds of the crown of each of 10 trees for each species. Leaf length was measured to the nearest .1 cm along the midrib. Width was measured perpendicular to the midrib between two points projected at the widest margins of the blade. Leaves were measured with an electronic leaf area meter. Each leaf was measured 10 times, and an average area in cm^2 recorded. If leaves were too large for the meter they were cut in half, each half was measured, and the areas were combined. Holes in leaves were covered with masking tape to prevent underestimates. Portions of the margin that were missing, but which could be projected, were cut from paper and attached to the leaf. Unfortunately many of the leaves had portions missing that could not be projected; these leaves were eliminated. This may have caused a bias. Leaves were treated as the unit of observation in the analysis.

Regression analyses were used to fit leaf area using functions of length and width. Linear, parabolic, and allometric models were tested and R^2 values compared. For the equation $Y = a + bX$ where X was the length times width, an analysis of variance was made to determine differences in slope and intercept among species, and to determine variance within and among trees. For the allometric regression model $Y = aX^b$, the values for a and b were determined by regression using the equation $\log Y = \log a + b \log X$. The R^2 value for the equation $Y = aX^b$ was then calculated with the formula $1 - \frac{S^2Y \cdot X}{S^2Y} = R^2$,

where $S^2Y \cdot X = \frac{\Sigma (Y - \hat{Y})^2}{n - 2}$ and

$$S^2Y = \frac{\Sigma (Y - \bar{Y})^2}{n - 1}$$

$\hat{Y}$ values were calculated with the equation $Y = aX^b$ using the b value and the antilog of the a value determined above by regression.

RESULTS

Correlations of length, width, and length times width with leaf area in black oak, white oak, and sugar maple were high (Table 1); the highest were with length times width.

The allometric model, $Y = aX^b$, and the parabolic model, $Y = a + bX + cX^2$, were compared with the linear model. The R^2 values of the linear model were similar to those of the other models (Table 1), and the linear model seems to be adequate. An analysis of variance was performed on the data using the linear equation with length times width as the independent variable.

The analysis indicated that the three species tested had a common intercept but significantly different slopes (Table 2). Slopes for white and black oak were not significantly different from each other, but they were significantly different from sugar maple ($P < .01$). Within-tree variance ($\hat{\sigma}_e^2$) was 72.595 $(cm^2)^2$ and the additional between-tree variance component ($\hat{\sigma}_T^2$) equaled 19.964 $(cm^2)^2$.

Table 1. Coefficients of determination (R^2) for three models relating leaf area (Y) to leaf length (L), width (W), and length times width (LxW) in black oak, white oak, and sugar maple

Species	Independent variable	Model		
		Linear $Y = a + bX$	Parabolic $Y = a + bX + cX^2$	Allometric $Y = aX^b$
Black oak	L	0.855	0.855	0.841
	W	.838	.850	.849
	LxW	.938	.939	.938
White oak	L	.881	.901	.897
	W	.858	.861	.858
	LxW	.942	.943	.942
Sugar maple	L	.856	.874	.873
	W	.880	.881	.855
	LxW	.918	.923	.915

Table 2. Estimates and precision of the intercept and slope for estimating leaf area for black oak, white oak, and sugar maple using the linear model Y = a + bX, where X equals length times width

Variable	Estimated	Standard error	Covariance with mean
Common intercept (a)	3.676	0.656	
Regression coefficient			
Black oak	.537	.00336	$-.122287 \times 10^{-4}$
White oak	.514	.00780	$-.165082 \times 10^{-4}$
Sugar maple	.490*	.00588	$-.170606 \times 10^{-4}$

*Difference significant at $P < .01$.

For N_T randomly selected trees and N_L randomly selected leaves per tree of a given species, the area per leaf and its variance can be estimated by the following formulas, where

X = leaf length times width in centimeters,
Y = average leaf area in square centimeters,
i = tree index,
j = leaf index, within tree.

White oak:

$$\hat{Y} = 3.676 + \frac{.514}{N_L N_T} \Sigma X_{ij}$$

$$\hat{\sigma}^2(\hat{Y}) = \frac{72.5953}{N_L N_T} + \frac{19.9643}{N_T} + .43229 + \frac{1}{N_L N_T}(.608062 \times 10^{-6} \Sigma X_{ij}^2 - .330164 \times 10^{-4} \Sigma X_{ij})$$

Black oak:

$$\hat{Y} = 3.676 + \frac{.537}{N_L N_T} \Sigma X_{ij}$$

$$\hat{\sigma}^2(\hat{Y}) = \frac{72.5953}{N_L N_T} + \frac{19.9643}{N_T} + .43229 + \frac{1}{N_L N_T}(.113084 \times 10^{-6} \Sigma X_{ij}^2 - .244594 \times 10^{-4} \Sigma X_{ij})$$

Sugar maple:

$$\hat{Y} = 3.676 + \frac{.490}{N_L N_T} \Sigma X_{ij}$$

$$\hat{\sigma}^2(\hat{Y}) = \frac{72.5953}{N_L N_T} + \frac{19.9643}{N_T} + .43229 + \frac{1}{N_L N_T}(.345815 \times 10^{-6} \Sigma X_{ij}^2 - .341212 \times 10^{-4} \Sigma X_{ij})$$

DISCUSSION

The correlation of length times width with area in leaves from black oak, white oak, and sugar maple is high enough that length times width can be used as an accurate estimator of leaf area. In conjunction with a random sampling scheme, these equations can be used to estimate leaf area where the use of an area meter is not possible or when repeated measurements of the same leaf are needed and leaves cannot be detached.

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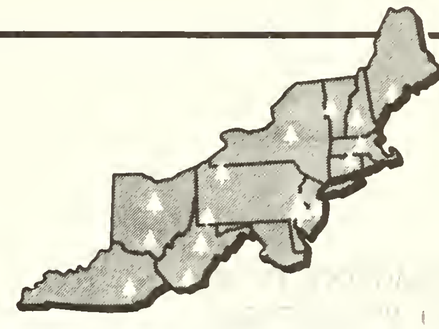

FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE, 370 REED ROAD, BROOMALL, PA. 19008

RELATIONSHIPS OF FOREST VEGETATION TO HABITAT ON TWO TYPES OF GLACIAL DRIFT IN NEW HAMPSHIRE

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Abstract.—Species composition and site index were determined on nine tree habitats in an area of schistose drift and compared with previous findings on habitats with granitic drift. Habitats on schistose drift supported more sugar maple and had somewhat higher site indexes. Compact tills in schistose drift supported northern hardwoods, and the site indexes for yellow birch were 66 to 71 feet. Compact tills in granitic drift supported softwood-hardwood mixtures and had a softwood climax; the site indexes for yellow birch were 56 to 57 feet. Species composition and site index for a given habitat may vary between glacial drifts with different mineralogies.

Previous research on tree habitat in the White Mountains of New Hampshire showed the relationship of habitat to species composition and site index (Leak 1976, 1977). This work was done in areas covered with glacial drift derived from coarse granitic bedrock.

To explore the possibility that the relationship between habitat and vegetation might be different in areas with drift of a different mineral composition, a small study was conducted during the summer of 1977 on the Hubbard Brook Experimental Forest. Much of this forest is covered with glacial drift derived from crystalline schist (Goldthwaite 1948).

Twenty plots were chosen at Hubbard Brook in essentially even-aged stands about 50 to 100 years old. On each plot, basal area by species was measured for all stems greater than 6 m in height, using a 3-m^2 prism factor. Age at breast height (from an increment core) and total height (from several measurements with a clinometer) of about one tree per plot were determined, and later converted to site index (base age 50 years), using curves by Curtis and Post (1962) and Hampf (1965).

One or two pits were dug on each plot—to a depth of 1 m where possible. The habitat on each plot was determined primarily on the basis of soil materials or substrate. Table 1 shows the number of plots and site-index trees by habitat. These habitats have been fully defined elsewhere (Leak 1976, 1977), and can be briefly described as:

Poorly drained. Flat, wet areas with gray or heavily mottled subsoil.

Table 1.—Numbers of plots and site-index trees by habitat

Habitat	Plots	Site-index trees
Poorly drained	1	1
Rock	3	2
Outwash	1	1
Wet compact till	1	1
Dry compact till	6	6
Sediment	2	1
Coarse till	3	3
Fine till	2	2
Enriched	1	1

Rock. Areas with bedrock, boulders, or weathered rock fragments at 65 cm or less below the top of the mineral soil.

Outwash. Sands or gravels. Stones, if any, are without silt caps.

Wet compact till. Compact tills that are moderately to somewhat poorly drained.

Dry compact till. Well-drained compact tills.

Sediment. Fine sands and silts.

Coarse till. Loose, washed till.

Fine till. Till deposits with no evidence of washing.

Enriched. Coves or benches with organic matter incorporated into the mineral soil.

RESULTS

Species composition varied in certain respects between areas with schistose and those with granitic drift. This variation is shown in Figures 1 (schistose) and 2 (granitic) where the habitats are listed in the approximate order of decrease in basal area for red spruce and hemlock, and increase for sugar maple and white ash.

Habitats in both the schistose and granitic areas that were characterized by outwash, rock, poor drainage, and sediments supported appreciable amounts of softwoods along with red maple and paper or yellow birch. However, sugar maple was more abundant on those habitats with schistose drift.

All habitats with coarse till were dominated by beech, red maple, and birch.

With either type of glacial drift, fine-till habitats were characterized by sugar maple, and enriched habitats by sugar maple-white ash.

The wet and dry compact tills with schistose drift supported northern hardwoods—beech, birch, and sugar maple. In areas with granitic drift, both types of compact till supported softwoods, red maple, and birches with very little sugar maple. Earlier research had shown that softwoods are the climax vegetation on compact tills with granitic drift (Leak 1976). The work at Hubbard Brook indicates that hardwoods probably will be the climax vegetation on the compact tills with schistose drift.

Site index for a given species in schistose drift tended to be lower on strong softwood habitats than on the strong hardwood habitats; however, the range in site index for a given species is not great, especially for red maple (Table 2). (Similar trends are evident on granitic drift.) Site index of paper birch, sugar maple, and white ash tended to be slightly higher in habitats with schistose drift than in those with granitic drift; but the reverse appears true for red maple. The site index of yellow birch on the compact tills appears to be 10 to 14 feet higher in schistose drift than in granitic drift. Remember that northern hardwoods predominated on schistose compact tills, whereas, softwoods were abundant on granitic compact tills.

DISCUSSION

Although the study consisted of only 20 plots, observations in additional areas on the Hubbard Brook Forest supported the findings. The habitat classes developed for granitic drift were sufficient for describing the conditions found in schistose drift. However, the schistose drift (1) supported more sugar maple on several habitats, (2) supported northern hardwood stands on the compact till in place of the softwood- hardwood stands found on the compact granitic till, and (3) often exhibited higher site indices than those measured on granitic drift—especially for yellow birch on compact till. The present habitat descriptions based primarily on soil materials probably can be applied to many glaciated areas in New England. However, species and site relations will be somewhat different on drifts with different mineralogies.

Habitat classes should be useful in natural stand management because they indicate the range of species that are likely to grow in a certain area, and which species grow best. However, additional information still is needed on the relationships of

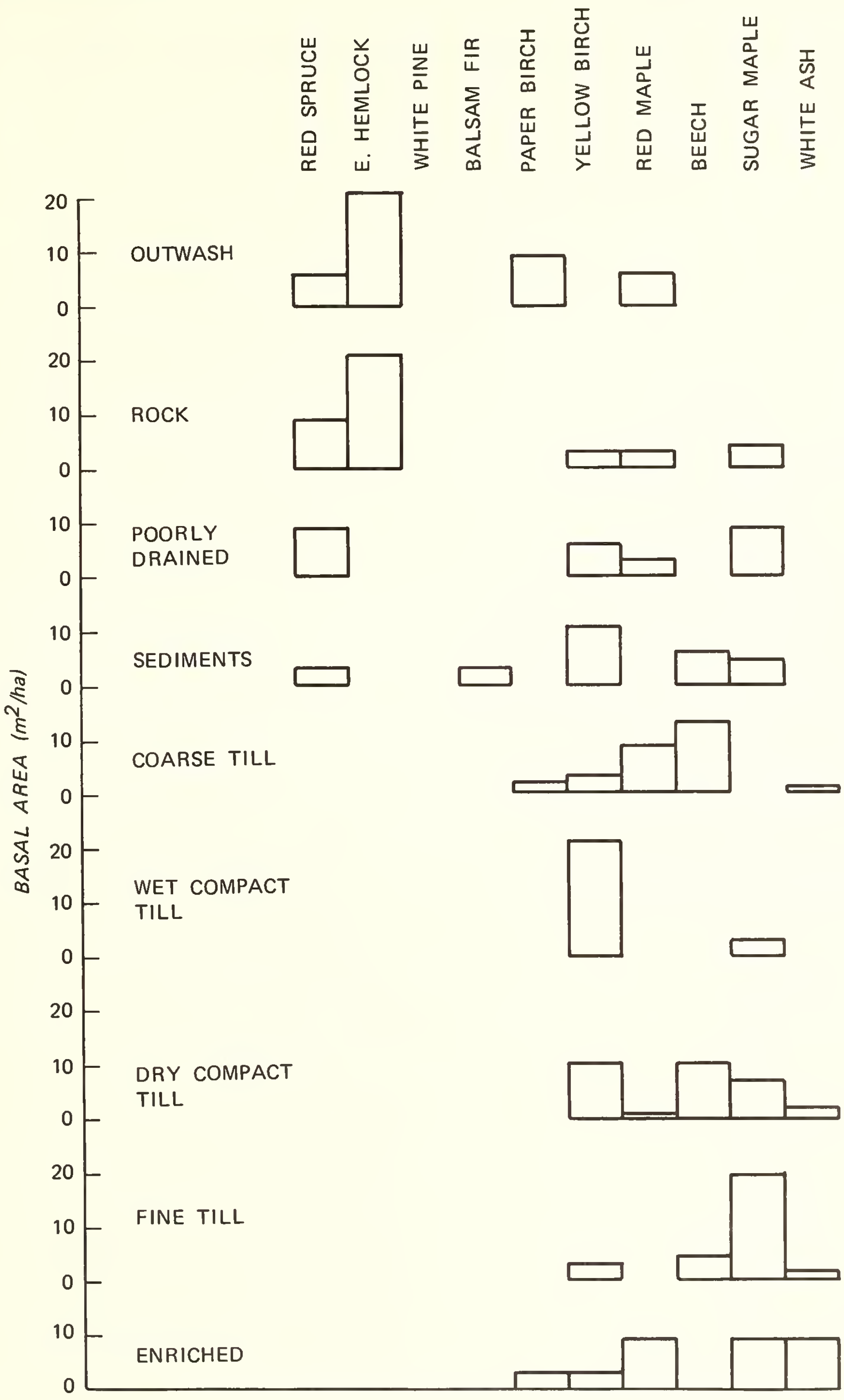

Figure 1.—Basal areas by species and habitat in schistose drift at Hubbard Brook (m^2/ha).

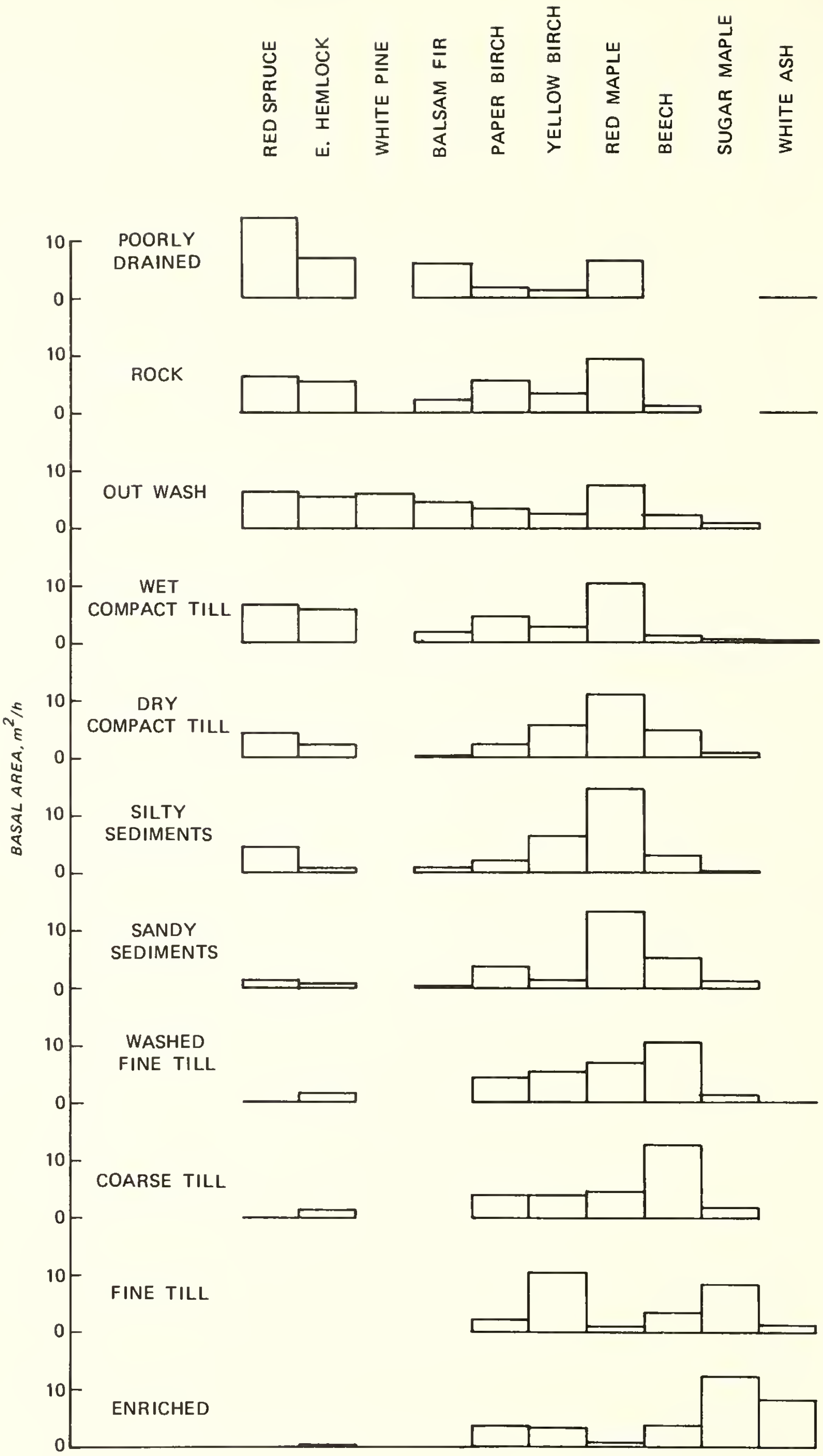

Figure 2.—Basal areas by species and habitat in granitic drift (m^2/ha).

Table 2.—Site index (base age 50) by habitat and species on schistose drift, with some comparative figures for granitic drift (in feet)

Habitat	Red maple		Yellow birch		Paper birch/sugar maple/white ash	
	Schist	Granite	Schist	Granite	Schist	Granite
Outwash	—	63	—	60	—	—
Rock	56	60	—	48	62	56
Poorly drained	—	—	—	48	65	48
Sediment	—	64	69	62	—	62
Coarse till	54	—	—	55	71–74	50–66
Wet compact till	—	52	71	57	—	54–70
Dry compact till	—	60	66	56	62–80	70
Fine till	—	—	—	68	69	68–77
Enriched	—	—	—	63	85	72–81

habitat to the occurrence of competing weed species and the response to intensive cultural practices such as scarification, planting or seeding, fertilization, and precommercial thinning.

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A TRAP FOR TREE-INHABITING CERAMBYCIDS

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Abstract. To determine species and numbers of insects visiting a tree, a paper trap for cerambycids was designed and tested on locust borers, *Megacyllene robiniae* (Forster), and red oak borers, *Enaphalodes rufulus* (Haldeman), under plantation and forest conditions. Test results showed that the trap could be used successfully to capture locust borers but it requires some modification for red oak borers. Several other cerambycid species were also captured in the trap.

Most traps for treeclimbing insects are designed as barriers to repel the insects. These barriers of sticky bands are not useful for determining species and numbers of insects visiting a tree because the insects usually are repelled or manage to escape. Compton and Flint (1927) found that locust borers, *Megacyllene robiniae* (Forster), were readily caught in Tanglefoot[1] bands on trees but were not killed and soon freed themselves of most of the substance.

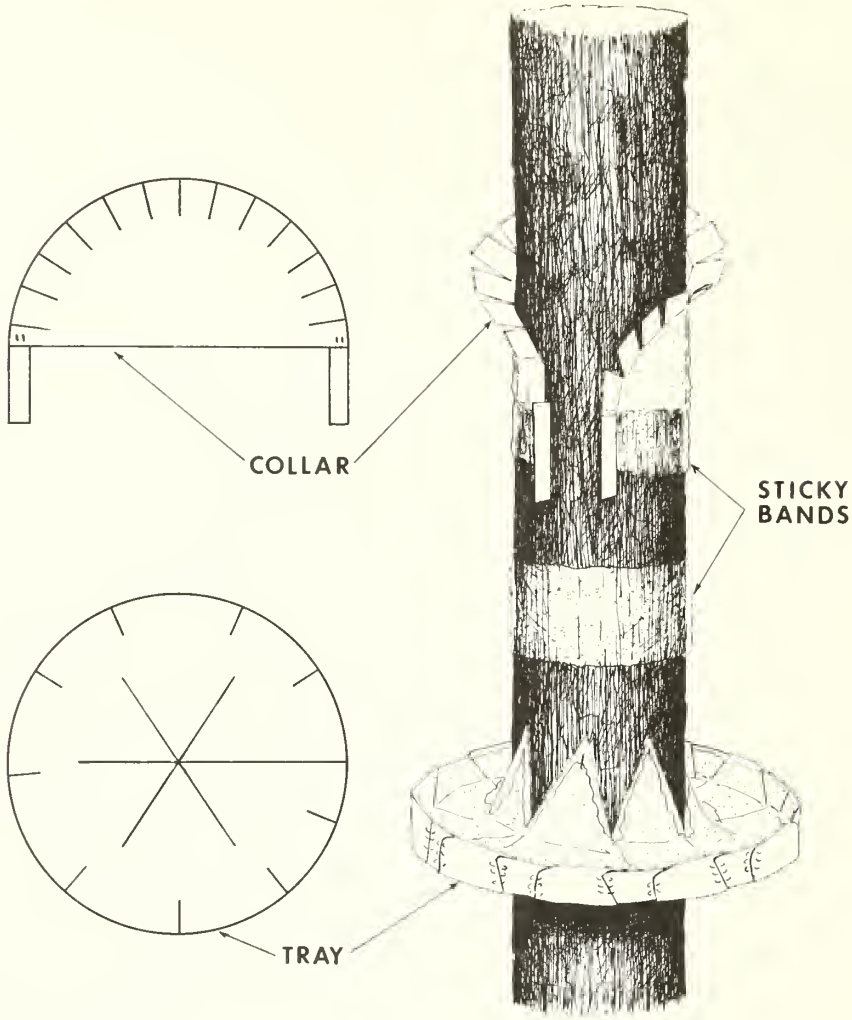
Studies I am now conducting on cerambycid pheromones required a trap that would capture the locust borer and the red oak borer, *Enaphalodes rufulus* (Haldeman), so that the approximate number of beetles visiting a tree could be determined. Following is the description of a trap that I designed and field tested in September and October of 1976 on locust borers, and in June and July of 1977 on red oak borers.

MATERIALS AND METHODS

The trap was constructed as follows: circles of 20, 25, 30, 35, 40, and 50 cm diameter were cut out of Insect Trap Paper, .016 grade, polyethylene coated 2-sides (Griff Associates, Fort Washington, Pa. 19034).[1] A circle that was 20 cm in diameter made a tray trap for a tree that was 10 cm dbh. Each increase of 5 cm in circle diameter made a tray that would fit a tree 2.5 cm larger. Two circles were stapled together to provide more rigidity for traps 35 cm in diameter and larger.

[1]The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U. S. Department of Agriculture or the Forest Service of any product or service to the exclusion of others that may be suitable.

Figure 1.—Components of paper trap designed to capture locust borers and red oak borers, and its placement on the tree.



From one edge of each circle, a cut was made through the center to within approximately 5 cm of the opposite edge (Fig. 1). Four more cuts, equidistant from the first cut, were made radially from the center of the circle to within 5 cm of the edge. Along the outside edge, cuts were then made about 9 cm apart and 2 cm toward the center of the circle. The cut edges were then folded vertically so that they overlapped, and they were all stapled together except the original cut from the outside edge.

The collar with funneling tabs was constructed as follows: a circle was cut in half and cuts about 3 cm apart and 3 cm deep were made along the curved edge of the hemisphere; an aluminum tag (2 x 9 cm) with cardboard backing was stapled at each end of the straightangle edge.

The tray and collar were fastened to the tree as shown in Figure 1. A thick application of Tack Trap (Animal Repellents, Inc., Griffin, Ga. 30224)[1] was spread inside and up onto the fingers of the trap with a spatula. Tack Trap was applied around the stem about 10 cm above the trap and along the back edge of the collar and tabs to make sticky bands. The Tack Trap used for the bands had been heated to the boiling point to drive off some of the solvent so it could be applied thickly without running down the tree.

In 1976, 53 traps were placed in black locust trees in a plantation near Delaware, Ohio, to capture locust borers. Thirty-three traps had funneling collars, 20 were without. In 1977, 50 traps without funneling collars were placed on red, black, white, and scarlet oaks in southern Ohio to capture red oak borers.

RESULTS

In 1976, 1,148 female and 947 male locust borers were caught. Traps with funneling collars caught many more female than male borers while traps without collars caught more male. Evidence from visual observations showed that males ran rapidly up and down trees, especially when they detected female pheromone (Galford 1977). Thus they readily ran into the sticky band, and eventually fell into the tray. However, if they ran into the funneling collar, they often turned and ran back up the tree. Females, however, moved slowly, feeling the surface of the tree with their ovipositors, seeking oviposition sites; those on trees without collars would often contact the sticky band and back away without being caught. When they ran into a collar, however, many worked their way around it and down between tne tabs. Then, when one contacted the sticky band and backed away, it usually was unable to find the opening between the tabs and eventually was caught. None of the beetles was observed to fly away.

The importance of tree location and temperature to number of beetles caught was shown by the fact that more beetles were caught in traps in trees receiving late afternoon sunlight than those in the shade, except when the temperature exceeded 26°C. Then as many or more beetles were caught in traps that were in the shade.

Tree diameter and roughness of bark did not influence the number of beetles caught. In a trap on the largest tree—17 cm dbh with very rough bark—121 beetles were caught, while in one on the smallest tree—8 cm dbh and with smooth bark—97 were caught.

Proximity of locust trees to goldenrod (*Solidago* spp.), which adult beetles frequent, became a factor in the number of beetles caught. Late in the insects' flight period, when they apparently were moving from the flowers to the trees, more beetles were caught in traps in trees near goldenrod.

Hourly checks of the traps on certain days indicated that about 2 to 3 percent of the beetles caught in the sticky band managed to escape by falling between the finger openings, or by locating the opening between the funneling tabs.

The average trap was effective for about 3 weeks. The Tack Trap could be partially rejuvenated by scuffing it when it developed a dull, hazy gloss.

In 1977, 19 red oak borers were caught in 50 traps in southern Ohio. While this was a low catch, examinations of the trees indicated that there were few beetles per acre. Twenty-three of the traps were in areas of very low beetle populations and yielded only two beetles. Seventeen of the beetles were caught in the 27 traps in areas of moderate to high beetle population.

Eighteen of the 19 beetles caught were females, which indicates a selective catch for females because the sex ratio of red oak borers is 1:1 according to laboratory and field data. Male beetles may not have ventured as far down the tree as the height of the traps, or they may have detected the sticky band with their long antennae and backed away before they were caught. Females, however, feel the bark surface more with their ovipositors and less with their antennae and thus are more likely to be caught. However, since it was felt that collars might reduce the catch of beetles and so were not used, some beetles may have escaped. A very large opening between the funneling tabs would have been necessary to accommodate the long antennae of the beetles and on trees 10 to 20 cm dbh, this would have cancelled the effectiveness of collars.

In addition to the locust borers and red oak borers, many other species of cerambycids frequenting oak were caught, some in greater numbers than the red oak borers. The species were: oak sapling borer, *Goes tesselatus* (Hald.); living-beech borer, *Goes pulverulentus* (Hald.); red- headed ash borer, *Neoclytus acuminatus* (F.); oak-stem borer, *Aneflormorpha subpubescens* (Lec.); tile-horned prionus, *Prionus imbricornis* (L.); rustic borer, *Xylotrechus colonus* (F.); brown prionid, *Orthosoma brunneum* (Forst.); *Sarosesthes fulminans* (F.); *Elaphidionoides incertus* (Newman); ivory-marked beetle, *Eburia quadrigeminata* (Say); *Graphisurus fasciatus* (DeG.); and *Leptura emarginata* (F.).

Wildlife—such as birds, mice, and flying squirrels—did not cause problems in 1976 in the black locust plantation. In 1977, however, under forest conditions, some animals were caught in the traps. Mice climbed the trees and got stuck in the Tack Trap, which in turn attracted blow flies and carrion beetles; this quickly made the traps useless. A small band of Tack Trap applied on the tree about 30 cm above the ground will keep mice out of the traps. Flying squirrels and birds were readily trapped until it was discovered that if the diameter of the trap did not exceed the diameter of the tree by more than 16 cm the animals were apparently able to jump clear of the tray after contacting the sticky band. No birds or flying squirrels were caught in the smaller traps. Thus the traps appear to be useful for some survey and test situations. Some modifications of the traps may be necessary, depending upon the research situation and the insect species involved.

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VESICULAR-ARBUSCULAR MYCORRHIZAE ESTABLISHED WITH *GLOMUS FASCICULATUS* SPORES ISOLATED FROM THE FECES OF CRICETINE MICE

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Abstract. Cricetine mice were trapped on two revegetated surface-mined areas—one with a freshly seeded grass-legume cover and one with an early successional grass-forb cover. Chlamydospores of *Glomus fasciculatus* isolated from the feces of these animals produced representative endomycorrhizae with corn under greenhouse conditions.

INTRODUCTION

Mycorrhizae are essential to the growth and development of many plants. Most species of ectomycorrhizal fungi produce copious quantities of air-borne spores in nature. Many of these fungi have been cultured on laboratory media, and the dissemination of propagules for natural (Trappe 1962) or artificial (Palmer 1971; Marx and Bryan 1969) inoculation is thus readily accomplished. Conversely, the vesicular-arbuscular (VA) fungi are much more limited in their dispersal because of their subterranean sporulation, and spores are now thought to be distributed through host transplants and when they adhere to soil that is moved. A third means of dispersal considered is through the defecation of viable spores that have been ingested by small mammals and insects (Gerdemann and Trappe 1974). More recently Trappe and Maser (1976) demonstrated the viability of *Glomus macrocarpus* Tul. and Tul. spores that were removed from rodent feces and germinated in distilled water. In addition to spore germination as a requisite in defining the role of small mammals as likely vectors of the Endogonaceae, it is also necessary that excreted spores be capable of forming VA mycorrhizae. Accordingly, we report here on the isolation of spores of *Glomus fasciculatus* (Thaxter sensu Gerdemann) Gerdemann and Trappe from the feces of the eastern harvest mouse (*Reithrodontomys humulis* Audubon and Bachmann), the white-footed mouse (*Peromyscus leucopus* Rafinesque), and the prairie deer mouse (*P. maniculatus bairdii* Hoy and Kennicott), and the subsequent establishment of VA mycorrhizae—typical of those produced by soil-borne spores—with corn (*Zea mays* L.).

MATERIALS AND METHODS

The mice used in this study were trapped on two surface-mined areas in Pulaski County, Kentucky. One of these areas, the Woodall Branch plot, had a 3-month plant cover consisting of grasses and legumes. Vegetation on the other area, the Bolthouse Ridge plot, was in its second year of growth and consisted of introduced grasses and legumes as well as a variety of volunteer grasses and forbs. Trap lines extended out onto a reclaimed bench from just inside the adjacent residual stand of early successional shrub-forb growth. Trap stations were situated at prescribed locations along the lines. Two traps were set at each station with peanut butter and rolled oats as bait.

After mice were trapped, within 24 hours their gastrointestinal tracts were dissected intact from the animals. Fecal pellets removed from the lower tract were macerated in tap water and examined under a stereomicroscope. Specimens that contained spores were washed thoroughly in a nest of sieves having 90, 63, and 45 μm openings. Spores of *G. fasciculatus* that were retained by each of the sieves were selected and subsequently composited in 150 ml of distilled water. Fifty ml of a homogeneous suspension of the composite were added to each of three 4-in (10.16 cm) clay pots half-filled with sterile sand, then the pots were filled up with sterile sand and five grains of corn were planted in each. After the seeds germinated, 50 ml of a full nutrient growth solution were added on a weekly basis for 4 weeks. Distilled water was added throughout the growth period to maintain proper moisture conditions. At intervals of 18, 26, and 35 days after the seeds germinated, corn plants were removed from the pots and the root system washed free of sand. Small root segments were cut into a lactophenol-aniline blue solution, autoclaved for 10 minutes to stain the fungi, and examined microscopically for external and internal structures.

RESULTS AND DISCUSSION

Germination of spores (Fig. 1B) and appressoria produced by the developing mycelium were observed as early as 18 days. Thin-walled vesicles as well as inter- and intracellular mycelium were observed after 26 days; these were much more abundant 35 days after seed germination (Fig. 1 C–E). This study presents the initial evidence that *G. fasciculatus* spores that passed through the gastrointestinal tracts of small mammals are capable of producing representative VA mycorrhizae. Although the interval between the time feces are deposited by small mammals and when VA mycorrhizae develop in plants growing on mine spoil is unknown, climatic and edaphic factors undoubtedly influence the disintegration of feces and the subsequent distribution of fungal spores in the plant root zone. The absence of VA associates in plant roots examined from the recently seeded Woodall Branch plot would appear to reflect this.

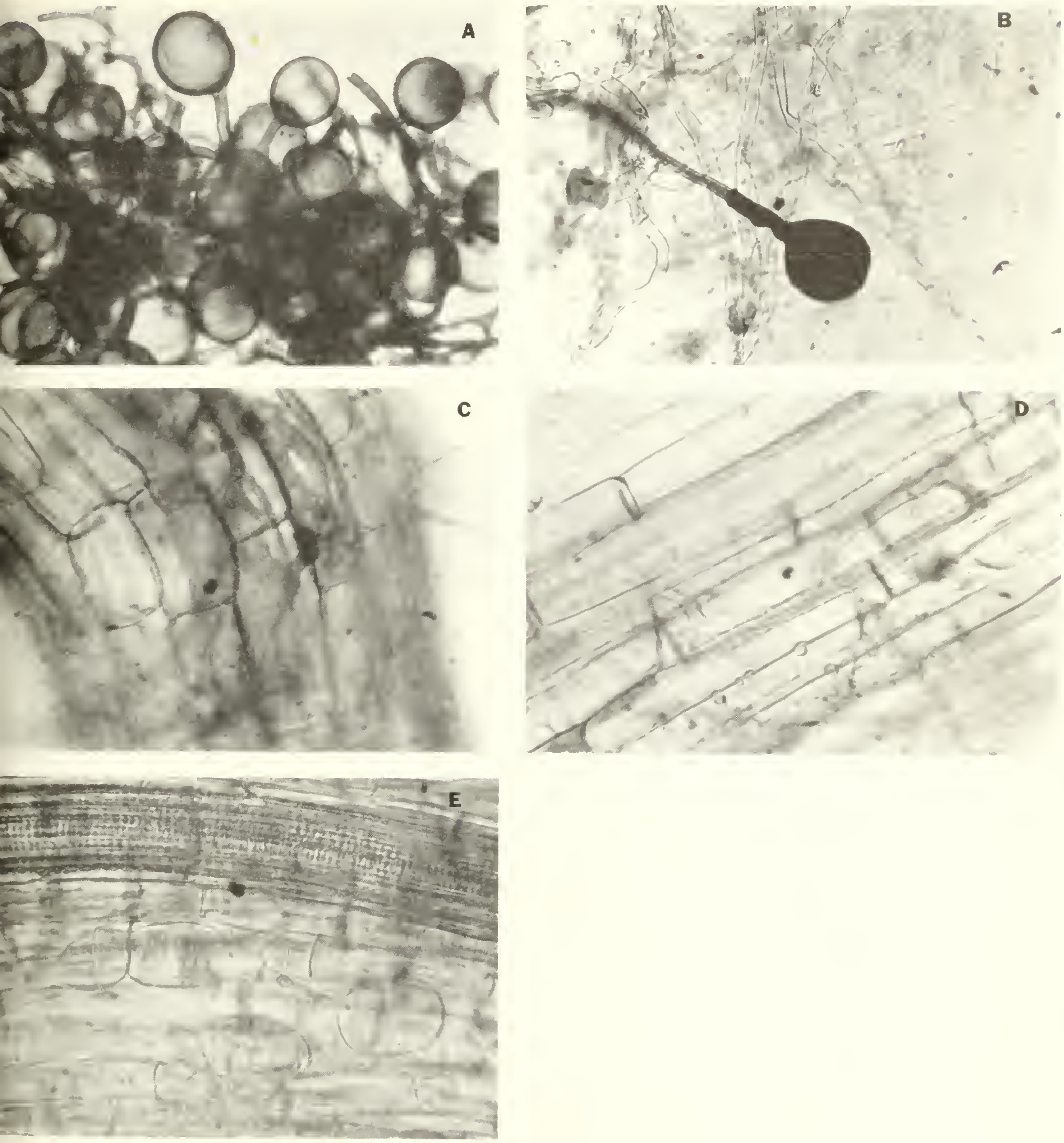
Data from trapping indicate that the prairie deer mouse, the white-footed mouse, and the eastern harvest mouse are early arrivals after mining. A specimen of the eastern harvest mouse was trapped on the Woodall Branch plot approximately 275 ft (84 m) from cover. Likewise, on nearby mine spoils with plant composition and age comparable to this sample plot, *Peromyscus* spp. have been trapped up to 392 ft (119.5 m) away from protective vegetative cover. In both cases the mice were apparently feeding on ungerminated grains from the reclamation seeding.

A random sampling of the vegetation from the plot on Bolthouse Ridge showed that plants of all species had VA mycorrhizae approximately 2 years after reclamation (Table 1). On other mined sites with early successional plants, volunteer species of blackberry and dewberry (*Rubus* spp. L.), sassafras (*Sassafras albidum* (Nutt.) Nees), smooth sumac (*Rhus glabra* L.), and winged sumac (*R. copallina* L.) have all shown VA infection. Thus, it would appear that as plant growth on freshly graded surface-mined areas increases to early-successional and finally late successional growth on older sites similar to those described by Daft and Hacskaylo (1976), the introduced and/or

Table 1.—VA mycorrhizal species from an early successional grass-forb trapping plot, collected in October 1977

Species	Common name
Lespedeza stipulacea Maxim.	Korean lespedeza
Aster pilosus Willd.	Narrow-leafed aster
Aster sp.	—
Trifolium repens forma lodigens Hort. ex. Gams.	Ladino clover
Iva ciliata Willd.	Sumpweed
Bidens polylepsis Blake	Stick-tight

Figure 1.—Stages in development of VA mycorrhizae in *Zea mays* inoculated with *Glomus fasciculatus* chlamydospores. Days indicate time interval following seed germination. A.—Representaive cluster of chlamydospores used as inoculum. B.—Single spore germination after 18 days. C-D.—Intracellular hyphae (coils) after 35 days. E.—Vesicle formation from intercellular mycelium after 35 days.



volunteer plant species show an increased prevalence of VA mycorrhizal fungi. Since VA associates are essential to the growth and development of many plant species, and inasmuch as small mammals are encountered in surprisingly large numbers on revegetated surface-mined areas, it is probable that these animals are active vectors in the colonization of the ecologically important endophytes on surface-mined areas.

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PROCESSING HARDWOOD BARK RESIDUES BY SCREENING

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Abstract. Most of the hardwood bark residues removed by floating-cutterhead or rosserhead debarkers can be processed into acceptable bark products by screening alone. And by prescreening bark residues, operators of bark processing plants can use smaller hammermills than otherwise are required, thus lowering investment and energy costs.

The most promising commercial uses of hardwood bark products are as mulches for revegetating severely disturbed soils, as a component of growing media in greenhouses, as raw material for producing charcoal, and as fuel for generating steam. For most of these products, bark residues from sawmills require additional processing to obtain the desired particle sizes.

Bark processing facilities usually include a hammermill for reducing the sizes of large pieces of bark, a screen or screens for sorting the milled bark into desirable size classes, and conveyors and transport and storage equipment. Hammermilling requires substantial capital investment, and accounts for much of the investment and operating costs for bark processing. Screening requires less investment and much less energy than hammermilling.

To determine the kinds and amounts of hammermilling necessary for producing products from bark residues, we compared the distribution of particle sizes of bark residues from six sawmills with that of particle sizes of commercial bark products from four plants.

PROCEDURES

We collected samples of bark residue from debarkers at six sawmills in West Virginia and Virginia. Floating-cutterhead debarkers were used at two of the sawmills; rosserhead debarkers were used at the other mills. We also obtained samples of shredded bark mulch and soil conditioner from four commercial bark plants in the same states.

All bark samples were air-dried on plastic sheets for 1 week. Then the samples were weighed and screened with a Gilson shaker. We used screens with openings of 2 inches, and ½, 3/16, 3/32, 3/64, and 1/64 inch. Material that passed through the smallest screen was collected in a pan. After each sample was sieved for 5 minutes, the bark particles retained on each screen and in the pan were weighed and calculated as a percentage of the total weight of the sample.

Table 1.—Distribution of particle sizes of commercial hardwood bark products, by percent of dry weight retained on screen or collected in pan

Product	Bark Plant	Sieve opening (inches)						
		2	1/2	3/16	3/32	3/64	1/64	<1/64
	1	0.0	22.0	24.5	19.1	14.8	12.9	6.7
Shredded bark mulch	2	.1	14.6	41.8	21.0	11.4	6.7	4.4
	3	.0	5.3	34.8	17.7	17.0	17.2	8.0
	4	.0	18.2	46.7	15.3	10.2	6.2	3.4
Soil conditioner	1	.0	.0	.4	14.8	27.6	41.3	16.0
	4	.0	.2	2.6	16.1	28.2	37.7	15.2

Table 2.—Distribution of particle sizes of hardwood bark residues from floating-cutterhead debarker, by percent of dry weight retained on screen or collected in pan

Sawmill	Species	Sieve opening (inches)						
		2	1/2	3/16	3/32	3/64	1/64	<1/64
1	Red oak	5.0	13.4	27.6	16.8	14.1	15.8	7.3
2	Red oak	.5	22.7	40.9	16.9	9.9	5.7	3.4
2	Yellow-poplar	.2	22.3	46.2	14.3	6.8	5.1	5.2
2	Chestnut oak	2.2	41.9	28.5	12.5	6.7	4.0	4.2
2	Hickory	21.2	31.5	27.6	10.1	4.6	2.3	2.7
2	Maple	.0	36.9	39.6	11.1	4.6	4.3	3.5
2	Beech	.0	10.5	33.0	20.1	13.7	15.1	7.6
2	White oak	11.0	29.4	29.0	14.1	7.5	4.6	4.3
2	Basswood	8.7	30.1	35.6	13.1	5.9	4.0	2.6
	Mean (sawmill 2)	5.0	27.5	35.2	14.3	7.8	6.0	4.3

Table 3.—Distribution of particle sizes of hardwood bark residues from rosserhead debarker, by percent of dry weight retained on screen or collected in pan

Sawmill	Species	Sieve opening (inches)						
		2	1/2	3/16	3/32	3/64	1/64	<1/64
1	Mixed	0.9	14.2	43.7	15.3	9.5	10.2	6.2
2	Red oak	2.1	27.6	32.7	12.9	9.0	10.3	5.4
3	Red oak	4.2	33.7	33.6	10.9	6.8	6.5	4.2
4	Red oak	5.5	26.7	35.4	12.5	7.5	8.0	4.3
4	Yellow-poplar	13.1	34.2	33.4	7.1	4.4	4.3	3.5
4	Chestnut oak	.0	24.3	34.6	13.8	10.7	11.0	5.6
4	Hickory	13.9	32.1	35.7	8.1	4.1	3.1	3.0
4	Maple	.0	23.3	40.3	15.6	8.1	7.3	5.4
4	Beech	2.0	15.9	47.1	13.9	7.9	8.1	5.0
	Mean (sawmill 4)	6.2	25.8	38.7	11.6	6.8	6.5	4.4

RESULTS AND DISCUSSION

The distribution of particle sizes for the two commercial bark products is shown in Table 1. Virtually all of the shredded bark mulch passed through a 2-inch sieve opening. And the shredded bark mulch from all four plants contained substantial amounts of particles that would pass through a $^3/_{16}$-inch opening (from 35.1 to 59.9 percent). Nearly all of the soil conditioner from both sources passed through a $^3/_{16}$-inch opening.

The distribution of particle sizes for residue samples from sawmills is shown in Table 2 for floating-cutterhead debarkers, and in Table 3 for rosserhead debarkers. Except for maple and beech (Table 2), and maple and chestnut oak (Table 3), the bark residue from both types of debarkers contained more large particles (those retained on the 2-inch screen) than the commercial shredded bark mulch. The amount of the larger particles ranged from zero to 21.2 percent, by weight, of the residue samples.

During the spring, sawmill bark residue probably contains a higher percentage of the larger particles than was indicated by our sample data. But we believe that the larger particles will not exceed 25 percent of the total on a year-round basis.

Particles larger than 2 inches are objectionable in bark mulch because it is difficult to spread this mulch with a machine. However, our research has shown that unprocessed sawmill bark residue is suitable as mulch for revegetating disturbed soil (Sarles and Emanuel 1977). By using a single 2-inch screen, sawmill operators could produce bark mulch—from either type of debarker—without hammermilling. On the basis of the mills we sampled, the yield of acceptable mulch would range from 75 to 100 percent, depending on species and time of year.

By using both 2- and $^3/_{16}$-inch screens, sawmill operators could produce bark mulch and soil conditioner. These products would meet the standards of the National Bark Producers Association for base bark and soil conditioner products.[1]

In mills where a hammermill is used along with screening, it may be advantageous to screen first, then hog or shred only the larger material. This procedure would help provide an even flow of bark to the hog, permit the use of a smaller hog, and result in lower energy costs.

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[1] Category 1, Decorative Bark: product must be ¼ inch or larger in size, with cambium and wood extraction applied. Category 2, Soil Conditioner: 90 percent of composition of product must be ¼ inch or less in size. Category 3, Base Bark: any bark product that does not meet requirements of Category 1 or 2; wood-fiber content must not exceed 10 percent (specifically includes pine cambium and shredded hardwood bark).

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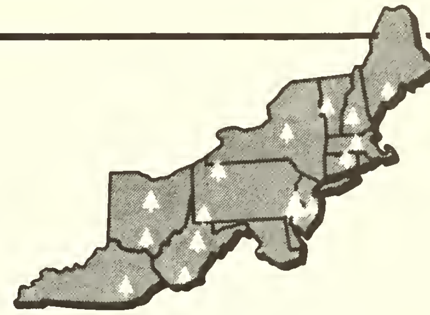

FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE, 370 REED ROAD, BROOMALL, PA. 19008

DEVELOPMENT OF MINIMUM STANDARDS FOR HARDWOODS USED IN PRODUCING UNDERGROUND COAL MINE TIMBERS

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Abstract. This note presents minimum standards for raw material used in the production of sawn, split, and round timbers for the underground mining industry. The standards are based on a summary of information gathered from many mine-timber producers.

Each year the coal mining industry in the United States uses millions of board feet of wood products in underground mining operations. Each ton of coal mined required an estimated 1.3 board feet of sawed timbers and 0.5 linear feet of round or split props.[1] In 1975, nearly 290 million tons of coal were produced from underground mines, 78 percent of which came from the eastern hardwood timber area of the Appalachian Region (West Virginia Coal Association of 1976).

Some mine timbers are manufactured by large sawmills from the poorer sections of grade logs. However, the largest portion of sawed material is manufactured by specialized small sawmills. The raw material used by these small mills is mostly low-quality logs and bolts.

How poor in quality can a piece of wood be for use as a mine timber? This question is important to researchers investigating uses for logging residue and thinnings, and to producers of logs and bolts for mine-timber production.

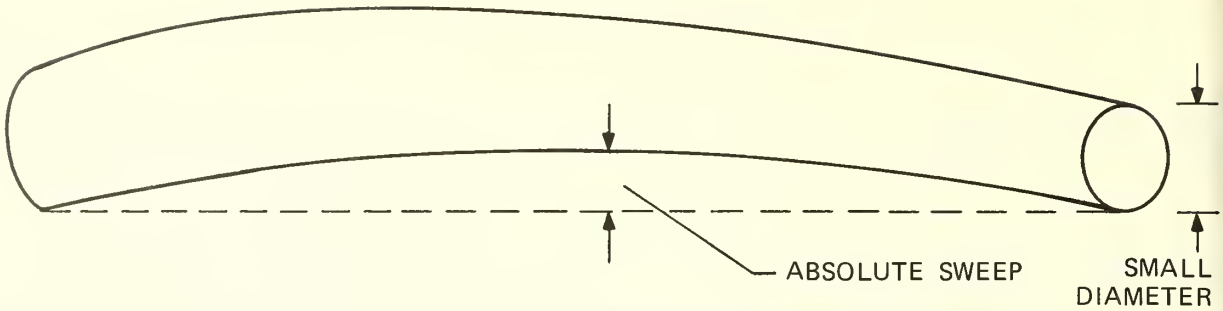
Since there are no published data on standards for raw material used in mine timbers, I developed standards for minimum logs and bolts.

I visited mine-timber producing firms in eastern Kentucky, eastern Ohio, western Pennsylvania, southwestern Virginia, and West Virginia. These firms represented all sizes of operation and all phases of mine-timber production—sawed timbers, round and split props, and single or specialty items such as blocks or wedges. At each location, I obtained quality and size requirements and specifications for raw material for both sawed timber and props.

From the information collected, I developed the following minimum standards for determining

[1] Knutson, Robert G. 1970. Wood use in mines. Unpublished report on file at Forestry Sciences Laboratory, Princeton, W. Va., 35 p.

Figure 1.—Sweep calculation.



MAXIMUM ABSOLUTE SWEEP PERMITTED: 1/2 SMALL DIAMETER

EXAMPLE:

SMALL DIAMETER	MAXIMUM ABSOLUTE SWEEP
18 INCHES	9 INCHES
12 INCHES	6 INCHES
6 INCHES	3 INCHES

characteristics of roundwood suitable in manufacturing sawed timbers and round or split props.

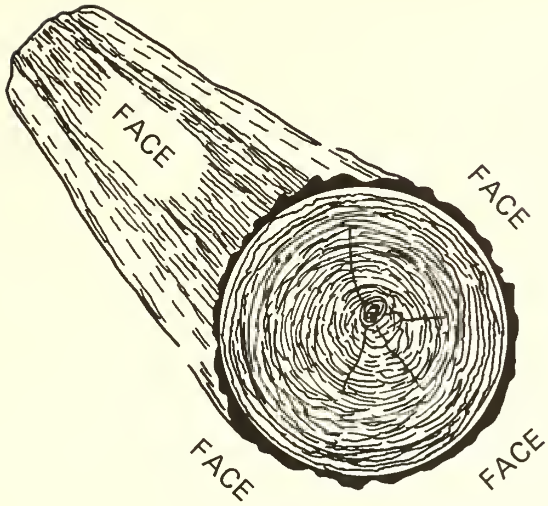
I. For producing sawed products — standard mill.
  A. Minimum diameter: 7 inches (small end).
  B. Minimum length: 6 feet (Maximum: 16 feet).
  C. Sweep. Absolute sweep (Fig. 1) not to exceed one-half the diameter of the small end, and allowed only in sound pieces without large knots.[2]
  D. Decay or hollowness.
    1. Pieces up to and including 10 inches: none.
    2. Eleven inches up to and including 15-inch diameter: one-fourth diameter.
    3. Over 15 inches: one-half diameter.
  E. Surface defects.
    1. No surface defects larger than width of 1 face (Fig. 2).
    2. Seam.
      (a) Straight allowed.
      (b) Spiral allowed only when limited to 1 face of log or bolt.

II. Sawed products — bolter mill.
  A. Minimum diameter: 6 inches, small end.
  B. Minimum length: 2.5 feet.
  C. No decay or hollowness.
  D. No sweep.
  E. Surface defects: none larger than width of 1 face.

III. Sawed products — special.
  A. Minimum diameter: 12 inches.
  B. Minimum length: 18 inches.
  C. No decay or hollowness.
  D. No defect larger than 1 face.
  E. Maximum defect: 1 large defect per piece.

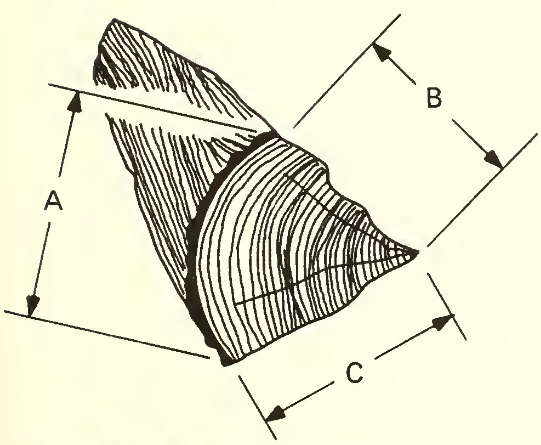
[2] Diameter greater than one-half width of 1 face.

Figure 2.—Face description.



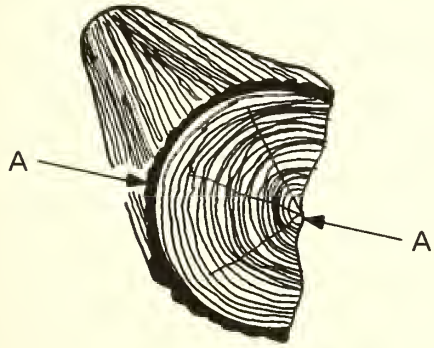
FACE: ONE-FOURTH CIRCUMFERENCE ALONG SURFACE OF ROUNDWOOD (STARTING POINT OPTIONAL)

Figure 3.—Split prop measure.



MORE THAN 1 SPLIT FACE

TWO OF THREE MEASUREMENTS "A", "B", OR "C" MUST EQUAL 1 INCH PER FOOT OF LENGTH: 4-1/2-INCH MINIMUM



1 SPLIT FACE

MEASUREMENT "A" MUST EQUAL 1 INCH PER FOOT OF LENGTH: 4-1/2-INCH MINIMUM

IV. Props.

A. Round.

1. Minimum size: 4 1/2-inch diameter, small end, and 4 1/2 feet long. Over 4 1/2 feet long, 1-inch diameter for each foot of length.[3] (Some props under 4 1/2 feet long sold but must have 4 1/2-inch diameter).
2. Only slight crook or sweep.
3. Decay or hollowness — none.
4. Knot size no greater than width of face and cannot interfere with strength.

B. Split.

Same specifications as round prop.

End measurement (Fig. 3).

One split surface.

Measure between bark and split surface perpendicular to split surface; distance in inches must equal prop length in feet.
Minimum: 4 1/2 inches.

Two or more split surfaces.

Measure along split surfaces (bark portion considered a split surface). Each of two surfaces measured in inches must equal prop length in feet.
Minimum: 4 1/2 inches.

[3] The Federal Mine Safety Law allows no less than 1-inch diameter for each 15 inches of length with a minimum diameter of 4 inches. The minimum standards presented in this report are based on current practices.

These standards express existing minimum quality and size requirements for mine-timber raw materials. They should help increase the understanding of the type of raw material acceptable for a regional market that in 1975 consumed an estimated 300 million board feet of sawn timbers and 125 million linear feet of round and split props. The standards should prove particularly useful to (1) those involved in developing markets for low-grade timber, particularly logging residues and thinnings; and (2) the suppliers of mine-timber raw material in evaluating presently unused or underused sources of acceptable wood.

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HIKER PREFERENCES FOR TRAIL FEATURES AND MAPS

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Abstract. Hikers at a Pennsylvania state park were asked what items were essential to their trail experience. From a list of 18 items, an overwhelming majority of hikers wanted to see trail names and directional signs along a natural surfaced trail.

INTRODUCTION

Walking was once the only way to get from one place to another. Times have changed. We now have faster ways of traveling, but people still walk. They walk, or hike, on city sidewalks, along suburban streets, and in wooded areas. The number of hikers has increased to the point where city planners, park supervisors, and resource managers have become concerned about their needs.

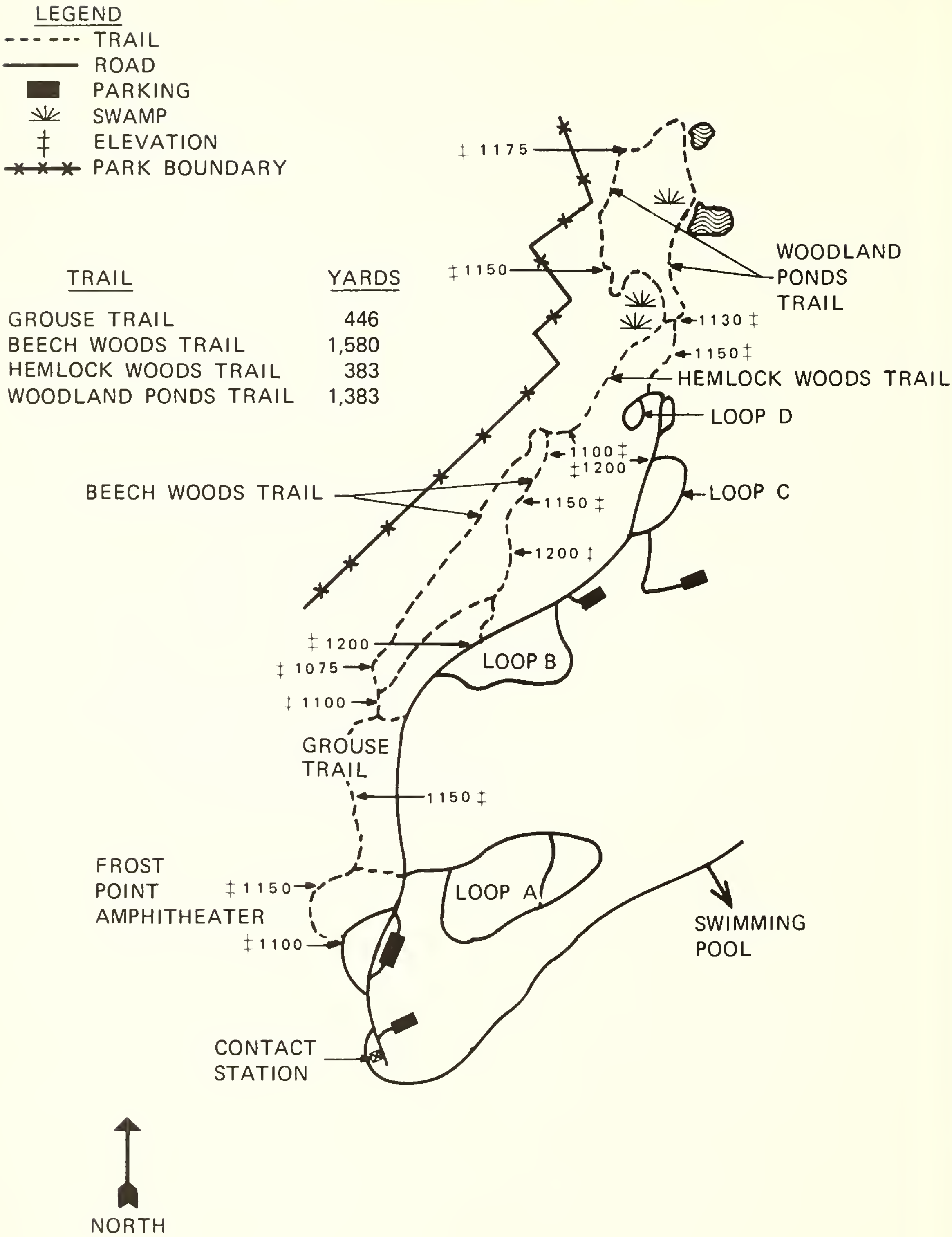
Within limited budgets, trails and trail maps are being developed every day. Trail builders and managers want to design each trail so that it gives hikers the most from their trail experience, but they often lack information about what the users want. The purpose here is to provide a better understanding of what hikers feel is essential to their trail experience. This will help to bridge the gap between what users want and what trail managers provide.

STUDY AREA

The study was conducted at Lackawanna State Park, Dalton, Pa., which opened in 1972. The trail system was designed and built during the spring and summer of 1976. The estimated number of people who used the trail during the summer of 1977 was 800.

Eighty-five percent of the park visitors live in the Scranton urban area. Almost all of the trail users camp at the park. A few special groups—Girl Scouts, birdwatching clubs—join the park naturalist for nature walks.

Figure 1.—Lackawanna State Park Trail System.



TRAIL	YARDS
GROUSE TRAIL	446
BEECH WOODS TRAIL	1,580
HEMLOCK WOODS TRAIL	383
WOODLAND PONDS TRAIL	1,383

Table 1.—Percentage of hikers' responses to "This item was absolutely essential to the trail experience" for 18 items

Item	Strongly agree	Tend to agree	Hard to decide	Tend to disagree	Strongly disagree
A trail map	64	19	4	9	4
Items on map					
Trail distances	51	33	12	2	2
North arrow	41	41	10	5	3
Elevations at selected points	37	40	12	7	4
Contour lines	39	25	20	12	4
Property boundaries	45	39	9	5	2
Trail names	66	27	2	3	2
Major features	76	16	4	4	—
Rest stops	52	25	7	14	2
Items on trail					
Trail name signs	75	19	—	1	5
Direction signs	80	13	3	2	2
Rest stops	54	23	5	16	2
Wildlife feeding stations	53	29	8	10	—
Natural surface	77	13	5	3	2
Manmade surface	24	21	12	22	21
Litter containers	51	26	11	9	3
One-way trails	41	20	12	20	7
Guide books	59	26	11	2	2

PROCEDURE

The study was conducted in two phases. During the first phase, in the summer of 1976, we solicited general information about what trail features are important to users and what should be included on trail maps. About 65 hikers responded to a map-and-questionnaire form that had been placed in a box on each trail. This information was used to develop the map (Fig. 1) and the response form (Table 1) for the second phase of the study.

Data for the second phase were collected in two ways. A box with an instruction sign was placed on each trail head. Hikers took a map from a box, walked the trail, filled out the response form on back of the map, and returned it to a box. Also, the park naturalist asked each individual who attended his Saturday and Sunday afternoon nature walks to fill out a response form. A total of 166 usable responses were returned.

The form asked the trail user to respond to the statement "This item was absolutely essential to the trail experience" for each of 18 items. One of five responses, which ranged from "strongly agree" to "strongly disagree," could be checked.

RESULTS

Hikers strongly agreed or tended to agree that all but 1 of the 18 items listed were essential to their trail experience (Table 1). Hikers were about equally divided between those who agreed a manmade surface was essential (45 percent) and those who did not (43 percent), with 12 percent undecided.

An overwhelming majority of the hikers wanted trail names on the trails (94 percent). The majority also indicated that directional signs (93 percent), natural surface (90 percent), guide books (85 percent), and wildlife feeding stations (82 percent) were essential to their trail experience.

The item hikers most wanted to see on trail maps were trail names (93 percent), major features

(92 percent), distances (84 percent), property boundaries (84 percent), and a north directional arrow (82 percent).

Data in this study indicate that hikers at Lackawanna State Park agree that many items are essential to their trail experience. They especially want to know where a trail leads, length of the trail, and what can be found along the trail. Within the limits of his trail budget, the trail manager can use this information to provide those items the hikers want.

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SUMMER PLANTING OF CONTAINER-GROWN NORTHERN HARDWOODS

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Abstract. Seedlings of paper birch and yellow birch were grown in styrofoam blocks of two cavity sizes, 40 cc and 125 cc, in four different soil mixes. After 16 weeks, the seedlings were outplanted on a cleared forest site in mid July. Seedling survival for all treatments after two growing seasons was very good (98.8 percent). The effects of container size and soil mix were relatively small and statistically significant only at the time of outplanting. Paper birch seedlings grew much more rapidly than the yellow birch. An early August outplanting of red maple seedlings was added to the study. Growth and survival of the red maple was similar to that of the birches.

Planting northern hardwood seedlings presents some very difficult problems to the forest manager. The planting season is short, and the trees must be lifted from the nursery and outplanted while they are still dormant. Planting must be completed while soils are moist and temperatures are moderate. In many years, conditions are suitable for planting for only 3 or 4 weeks in the spring. Such a short season greatly limits the amount of planting that can be done. But even when the planting operations are accomplished, seedling survival is often poor (Bjorkbom 1968). When survival is adequate, the seedlings frequently grow slowly (Bjorkbom 1972) and are overtopped by faster-growing weed species (Rudolph et al. 1964).

One promising solution to this problem is planting container-grown seedlings (Davidson and Sowa 1974, Forbes and Barnett 1974, and White et al. 1970). We have tested this technique in New Hampshire with paper birch (*Betula papyrifera* Marsh.), yellow birch (*Betula alleghaniensis* Brit.), and red maple (*Acer rubrum* L.).

Figure 1.—Each cell in the styrofoam block contained a single seedling.

Figure 2.—After 16 weeks' growth, these yellow birch seedlings are ready for outplanting.

METHODS AND MATERIALS

The seedlings were grown in styrofoam blocks with planting cavities of two sizes: 40 and 125 cubic centimeters (2.45 and 7.63 cubic inches, respectively). The styrofoam blocks were filled with four different soil mixes as follows: Soil A: 50 percent shredded forest humus, 25 percent Jiffy-mix,[1] and 25 percent sandy loam; Soil B: 50 percent shredded forest humus and 50 percent sandy loam; Soil C: 50 percent Jiffy-mix and 50 percent sandy loam; Soil D: 100 percent Jiffy-mix.

In late March, a single germinated seed of yellow or paper birch was planted in each cell of the styrofoam blocks (Fig. 1). The plants were grown in a greenhouse, irrigated daily with an automatic misting system, and fertilized with a complete nutrient solution every 2 weeks.

At the end of the 16-week growth period in mid-July, the seedlings were outplanted in the White Mountain National Forest in New Hampshire (Fig. 2). The planting site had previously been forested with old growth beech, yellow birch and sugar maple. After logging, the site was prepared for planting by stump removal and scarification. Most of the litter and humus was removed during site preparation and the ground was bare or nearly so at the time of planting. The soil, a well-drained sandy loam podzol, was moist from a recent rain at the time of planting. The seedlings were planted by forcing a dibble into the ground; then removing the seedling from the container complete with soil and placing the root-bound soil cone into the hole. The soil was tamped around the newly planted seedling. First summer rainfall was normal with 30.94 cm (12.18 in) evenly distributed through the critical July-to-September growing period.

A randomized block design with sampling of plots was used in this study of two container sizes, two tree species and four soil combinations. Ten seedlings were randomly selected from each of the 16 treatment combinations. Total seedling height and diameter at the root collar were measured for each of these seedlings. The measured seedlings were marked so that they could be remeasured at the end of the first and second growing seasons. The treatment effects were tested for significance at the 1 percent level by analysis of variance.

An abbreviated planting test was made with red maple. Only the D soil, consisting of 100 percent Jiffy mix, was used for this species. The seed was collected from the current seed crop in early June and immediately sown in the 40 and 125 cubic-centimeter blocks. In early August, after 8 weeks of growth, the red maple seedlings were outplanted at the same location as the birches. Ten red maple seedlings from each container size were randomly selected and measured before planting. They were marked in the field so they could be remeasured at the end of the first and second growing season.

RESULTS AND DISCUSSION

Growth of the container seedlings was good. At the time of planting, the 16-week-old birches averaged 1.6 mm (.06 in) in diameter at the root collar and 12.5 cm (4.92 in) in height. After one growing season, average diameter was 2.9 mm (0.11 in) and average height was 14.5 cm (5.71 in). At the end of the second growing season, average diameter was 8.2 mm (.32 in) and the average height was 53.8 cm (21.18 in). The rapid growth represents a successful adaptation of the seedlings to the planting site.

At the end of the greenhouse growth period, the effect of the four soil mixtures on diameter and height growth was significant: soil mix D had the best growth, followed by C, then A, and finally B (Table 1). However, growth differences at the end of the first and second growing seasons in the field were not significant.

The 125-cubic-centimeter containers produced a larger seedling with height growth 31 percent greater and diameter growth 22 percent greater than those in the 40-cubic-centimeter containers (Table 2). This advantage in size diminished during the first and second growing seasons, being statistically significant only when first measured at the time of outplanting.

Paper birch grew faster than yellow birch. The differences between species were statistically significant in all measurements. At the end of the second growing season, the paper birch seedlings

[1] Trade name for a commercial product containing equal amounts of finely shredded sphagnum peat moss and horticultural vermiculite, plus nutrients. The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture or the Forest Service of any product or service to the exclusion of others that may be suitable.

Table 1.—Effect of soil mix on height and diameter growth of paper and yellow birch seedlings

Growth observation	Soil Mix							
	A		B		C		D	
	Height	Diameter	Height	Diameter	Height	Diameter	Height	Diameter
	cm	*mm*	*cm*	*mm*	*cm*	*mm*	*cm*	*mm*
Container—16 weeks	12.2	1.6	10.8	1.5	13.4	1.7	13.8	1.7
Field—1st year	16.0	3.1	12.5	2.7	14.7	3.1	14.8	2.8
Field—2nd year	56.6	8.7	57.9	8.9	51.3	8.5	49.5	7.1

Table 2.—Effect of container size on height and diameter growth of paper and yellow birch

Growth observation	Container Size			
	40 cm^3		125 cm^3	
	Height	Diameter	Height	Diameter
	cm	*mm*	*cm*	*mm*
Container—16 weeks	10.8	1.5	14.2	1.8
Field—1st year	13.0	2.9	16.0	3.0
Field—2nd year	51.4	8.0	56.2	8.5

Table 3.—Effect of species on height and diameter growth

Growth observation	Species			
	Paper birch		Yellow birch	
	Height	Diameter	Height	Diameter
	cm	*mm*	*cm*	*mm*
Container—16 weeks	13.2	1.7	11.8	1.6
Field—1st year	16.7	3.2	12.3	2.6
Field—2nd year	64.8	9.6	42.8	7.0

were 50 percent taller than the yellow birch. This rapid growth reflects the superior juvenile growth of paper birch and its better adaptation to the exposed planting site (Table 3).

At the end of the first season, the red maple seedlings averaged 2.2 mm (.09 in) in diameter at the root collar and 16 cm (6.30 in) in height. The seedlings which had been grown in the 125-cubic-centimeter containers were 22 percent larger in diameter and 25 percent taller than the seedlings grown in the small containers. After the second growing season, the red maple seedlings averaged 6.0 mm (.24 in) in diameter and 27 cm (10.63 in) in height.

The effects of container size (40 cm^3 vs. 125 cm^3) on diameter and height growth were relatively small, and by the end of the first growing season were not significant. The use of large containers for the birches and red maple does not seem justified under the conditions of this study. The large containers require more greenhouse space, and the resulting seedlings are heavier and more difficult to plant in the field. Larger seedlings might be desirable where intense plant competition is anticipated or on difficult sites.

Survival for the three species was extremely good. None of the marked seedlings died the first growing season. One paper birch and one yellow birch died during the second growing season.

It is unlikely that seedling mortality would be this low (1.2 percent) in a large-scale planting. But this result is an indication of the good survival that may be expected from container-grown seedlings. The seedlings were planted in July (the birches) and August (red maple), a time when conventional bare-root nursery stock could simply not be expected to survive. The implication of this excellent survival is that container-grown seedlings can greatly extend the planting season, allowing greater flexibility and more efficient scheduling of planting operations.

Neither seedling growth nor survival was strongly influenced by the choice of soil mix. At the time of outplanting, the soils with 50 percent or 100 percent Jiffy mix (soils C and D) produced the larger seedlings, but this effect was soon lost. By the end of the second year, seedlings grown in the A and B soil mixes with 50 and 25 percent forest humus, respectively, were slightly larger. With regular applications of a balanced nutrient solution and careful irrigation during the greenhouse growing period, any reasonable soil mix may be adequate. An ideal soil mix should be porous enough to ensure good aeration and drainage and yet hold an adequate moisture and nutrient supply. The addition of at least a small percentage of forest humus might be desirable to ensure inoculation with mycorrhizae (Zak 1975).

Paper birch, yellow birch, and red maple seem equally well adapted to the container method, and seedlings of these species have a good potential for survival and growth even when outplanted in midsummer.

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FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE, 370 REED ROAD, BROOMALL, PA. 19008

VACUUM TRANSFER SYSTEM INCREASES SUGAR MAPLE SAP YIELD

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Abstract. Yields of sugar maple sap collected from three plastic pipeline systems by gravity, vacuum pump, and a vacuum pump with a transfer tank were compared during 2 years in northern Vermont. The transfer system yielded 27 percent more sap one year and 17 percent more the next year. Higher vacuum levels at the tapholes were observed in the transfer system.

The yield of sugar maple sap collected with a plastic pipeline and vacuum pump can be as much as 385 percent greater than that collected from the same trees by gravity (Blum and Koelling 1968), and this system is being used in many sugarbushes (Walters 1975). However, sometimes the distance from the trees in the sugarbush to the location of the vacuum pump is great, and there is a substantial loss in vacuum due to friction. The vacuum-transfer system was devised to reduce such loss and consequently increase the volume of sap collected.

During two maple sap-flow seasons in northern Vermont, larger volumes of sap were collected from a pipeline with a vacuum-transfer tank than from a similar pipeline without a transfer tank. The pipeline with the transfer tank maintained higher vacuum levels at the tapholes.

THE STUDY

This study was conducted in a sugarbush in the town of Jericho, Vermont[1]. The stand is typical of a northern Vermont even-aged sugarbush. The trees ranged from 40 to 71 cm in dbh.

A total of 111 study trees were tapped in 1973, and in 1974 the number was increased to 135.

[1] This sugarbush is located within the boundaries of the Ethan Allen Test-Firing Range, and is available for forest research by permission of The Adjutant General, Vermont National Guard.

Three tapholes were drilled in each tree in late February of both years. The tapholes conformed to industry standards.

Each of the three tapholes per tree were connected at random to one of three parallel pipeline systems. The systems were as identical as possible in all respects except the method by which sap was collected from them: gravity, vacuum pump, or vacuum pump with a transfer tank. The plastic pipelines were installed according to recommended procedures (Smith and Snow 1972, Lancaster and Walters 1974, and Walters 1975) (Fig. 1).

In the gravity system, the sap flowed downhill through the pipeline to the collection tank where it could be measured. The second pipeline was connected to a 151.4-liter steel tank where vacuum was created by a compressor-type vacuum pump. This tank was emptied by a water pump that was controlled by a float switch inside the tank (Fig. 2). As the sap was pumped from the vacuum tank, it was measured by a water meter. The third system—the vacuum-transfer system (Fig. 3)—differed from the vacuum system only in that a second tank was placed in the sugarbush (Fig. 4). Conduit lines from this tank branched out to different parts of the sugarbush. This system was designed to place the source of the vacuum closer to the trees. In this study, the tank was approximately 160 m from the vacuum pump. The slope from the transfer tank to the vacuum pump averaged

Figure 1.—The sap collection networks were constructed of 5/16-inch plastic tubing as unvented, aerial-line systems with droplines at least 18 inches long. The small lateral lines were connected to 1/2-inch main lines.

Figure 2.—Schematic of a sap collection vacuum tank. The float switch inside the tank automatically controls the water pump for sap removal.

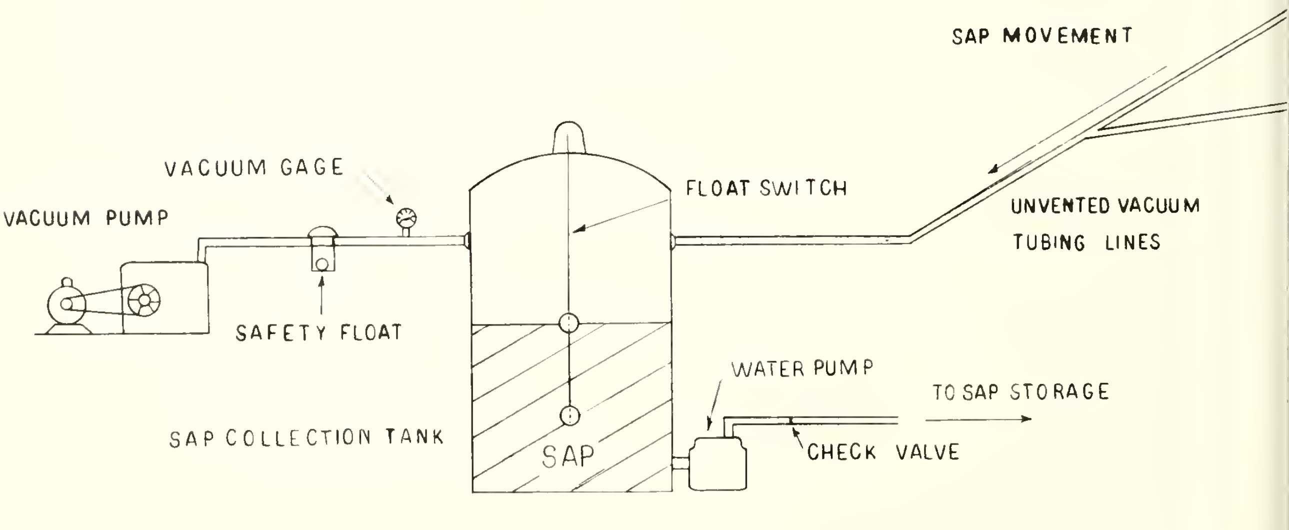
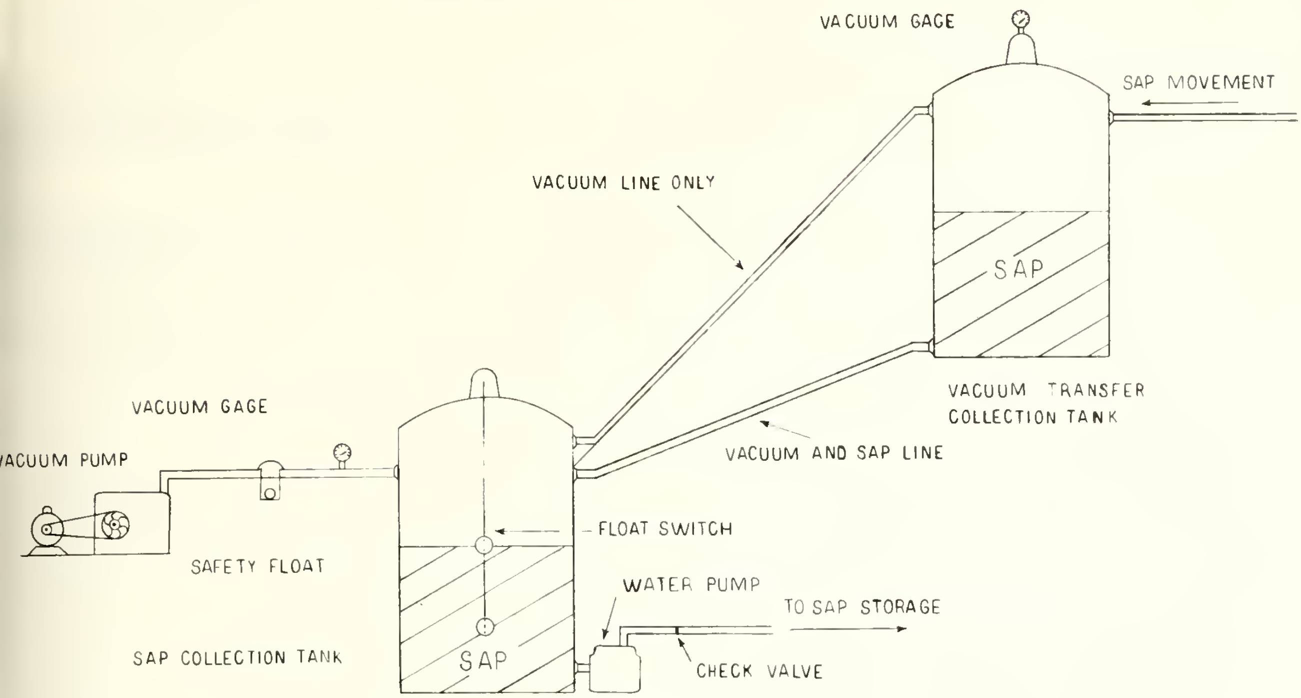


Figure 3.—Schematic illustrates how the vacuum-transfer tank is connected to the sap collection vacuum tank.



about 6 percent. Two pipelines connected the transfer tank to the vacuum tank: the pipe at the bottom carried sap, while the one at the top evacuated gases, which created a vacuum.

The vacuum levels between the two vacuum systems were equalized at the pumps so that one system was not favored. The pumps were controlled automatically by a thermostat set to turn on when the air temperature rose to about − 1.5 °C.

Vacuum gages were installed on each vacuum tank and on the transfer tank. Gages were also attached to each pipeline at the point farthest from the vacuum pump. The vacuum levels at these points were checked periodically.

The volume of sap for each sap flow was measured, and the average yield per taphole was determined. These data were subjected to an analysis of variance for randomized blocks. Each flow period was considered a block. The number of blocks was determined by the number of flow periods that occurred each year. Treatment means were compared by the Duncan Multiple Range Test (Duncan 1955).

RESULTS

The volume of sap per taphole collected by the vacuum-transfer system during each season was greater than that collected by the other two systems (Table 1). In 1973, the amount collected by vacuum transfer was 27 percent more than was collected by vacuum only, and 109 percent more than was collected by gravity. The amount collected by vacuum alone was 65 percent more than was collected by gravity. All of these differences were statistically significant. In 1974 the transfer system yielded 17 precent more sap than vacuum alone.

Table 1.—Average sap volume per taphole collected by three tubing systems, 1973 and 1974 (in liters)

Year	Vacuum transfer	Vacuum	Gravity flow
1973	43.3	34.1	20.7
1974	52.6	45.0	13.6

All pairs within the same year differ significantly (at $p<0.05$) except those underscored.

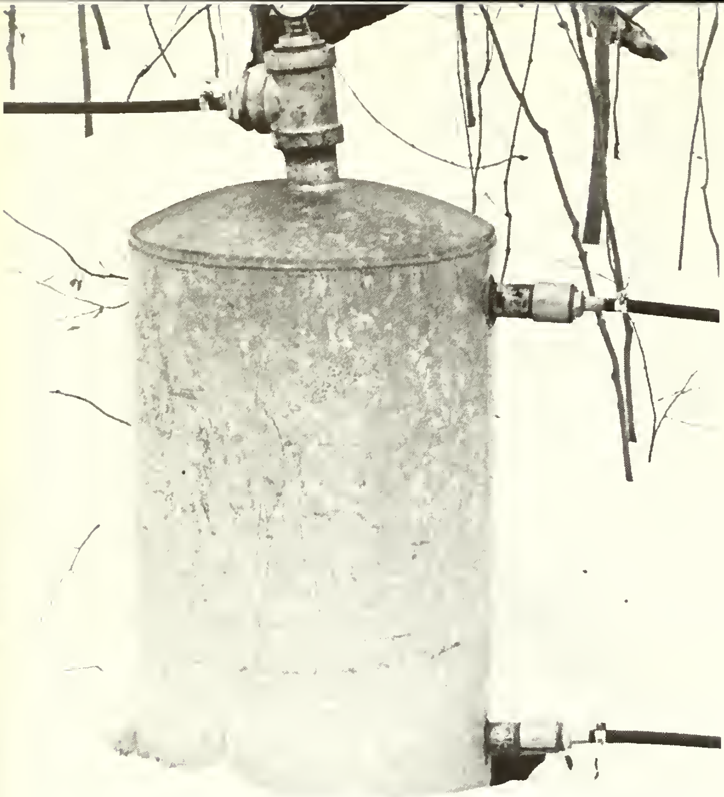


Figure 4.—The vacuum-transfer tank is in the sugarbush. Sap flows from the trees on the left into the tank. The upper pipe on the right removes air from the tank, creating a vacuum, and sap travels out through the lower pipe.

This difference was not significant. The transfer tank and vacuum systems produced 287 percent and 231 percent more sap, respectively, than the gravity system. These differences were highly significant.

The vacuum level created and maintained in the vacuum tanks by the pumps was very consistent, at about 565 mm of mercury (Hg). At the transfer tank, the vacuum level was generally somewhat less, about 450 mm of Hg. The readings at the tapholes farthest from the pumps during the sap flows averaged about 425 mm of Hg for the transfer tank and 350 for the vacuum system. The highest natural vacuum level that was recorded for the gravity system was 100 mm of Hg. However, quite often readings were 0, indicating no natural vacuum.

DISCUSSION

The major advantage of using a vacuum pump with sap collection pipelines is that vacuum can induce sap flow even when conditions are not quite right for a natural flow. Vacuum can also increase the sap-flow rate from the taphole during normal flow periods (Yawney 1977). In addition, applied vacuum helps sap to flow quickly through the pipelines; this reduces the possibility of back-pressure buildup caused by pipeline overload which inhibits the sap yield. Applied vacuum also empties the pipeline at the end of a sap run so that sap residue does not freeze and block the line.

In the vacuum-transfer system, the two separate pipes from the transfer tank to the sap collection tank evacuated air from the system more efficiently than the single pipe in the vacuum-only system—thus the vacuum level at the taphole in the transfer system was higher, usually by 75 mm. We were able to maintain vacuum levels well above the recommended minimum of 250 mm of Hg (Walters and Smith 1975).

If there had been more distance between the transfer tank and the pump, the vacuum advantage at the tapholes probably would be even greater. If the distance is not greater than 200 m, the advantage may be only slight. In a sugarbush where the trees are as much as twice that distance or more from the vacuum pump and the collection tank, the transfer-tank system would be more effective, and is recommended.

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TAPHOLES DRILLED INTO FROZEN SUGAR MAPLES CLOSE SLOWLY

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Abstract. Tapholes drilled into frozen maple tissues remain open longer than tapholes drilled into trees that have not frozen. Taphole closure was not affected by the speed of the tapper drill bit.

INTRODUCTION

Sugar maple (*Acer saccharum* Marsh.) sap is collected from tapholes drilled into the trees. It is necessary to drill new tapholes each spring. The cambial tissues adjacent to the taphole often dies, causing an elliptical wound (Fig. 1) much larger than the original taphole (Gibbs and Smith 1973). Possible causes of cambial damage are drilling tapholes and inserting sap spouts when the tree tissues are frozen, and using high-speed drills, such as a gasoline-powered chain saw equipped with a drill chuck.

My investigations show that tapholes drilled when the trees were frozen had adjacent areas of cambial dieback more frequently and closed more slowly than tapholes drilled in trees that were not frozen.

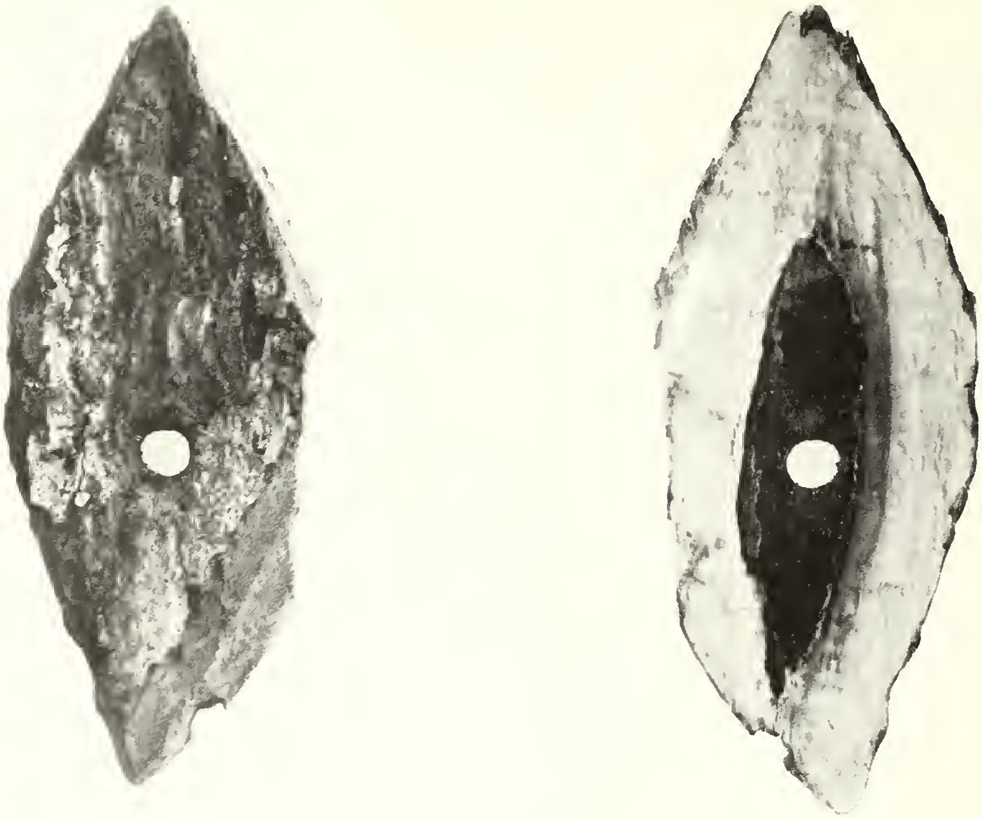
The study also demonstrates that the speed of power-driven drills did not affect the rate of taphole closure.

This information is useful to the maple syrup industry because it helps to explain why cambial dieback might develop adjacent to tapholes, and suggests methods to prevent it.

This study was conducted in a sugarbush located in Jericho, a town in northern Vermont.[1] Fifty trees, ranging in dbh from 42 to 73 cm, were used. Four taphole locations were selected on each tree; taphole treatments were then assigned at random. Two tapholes were drilled on a very cold day, and two more were drilled on a warmer day. Of the two tapholes drilled at the same time, a high-speed tapper was used on one; the other was drilled by hand, using a brace and bit. Extreme care was taken to make all tapholes the same size and conform to industry standards. A drill bit 1.11 cm in diameter was used; the holes were 6.5 cm deep; tapholes were spaced at least 15 cm apart, and, as nearly as possible, were on the

[1] The sugarbush is located within the boundaries of the Ethan Allen Test Firing Range, and is available for forestry research by permission of the Adjutant General, Vermont National Guard.

Figure 1.—Section of bark and wood removed from a sugar maple to reveal the dieback of cambium adjacent to a taphole. Left: the bark side. Right: the underside.



south side of the tree. A plastic sap spout was inserted in each taphole after it was drilled.

The gasoline-powered tapper was an ordinary, small chain saw with the guidebar and chain removed, and a special drill chuck was attached to the drive shaft. This type of saw required a left-hand twist drill bit; its speed was approximately 6,600 rpm. The brace and bit was a regular woodworking tool; its estimated speed was 120 rpm.

The tapholes in the first group sampled for this study were drilled on 5 February 1974. On that day, the average temperature was − 18 °C, and the temperatures for the preceding 4 days had not been higher than − 11 °C. The tree tissues were definitely frozen at the time of drilling. Tapholes in the second group were drilled on 7 March 1974, when the average tempoerature was 9 °C. That day was preceded by 3 days when temperatures did not go below freezing.

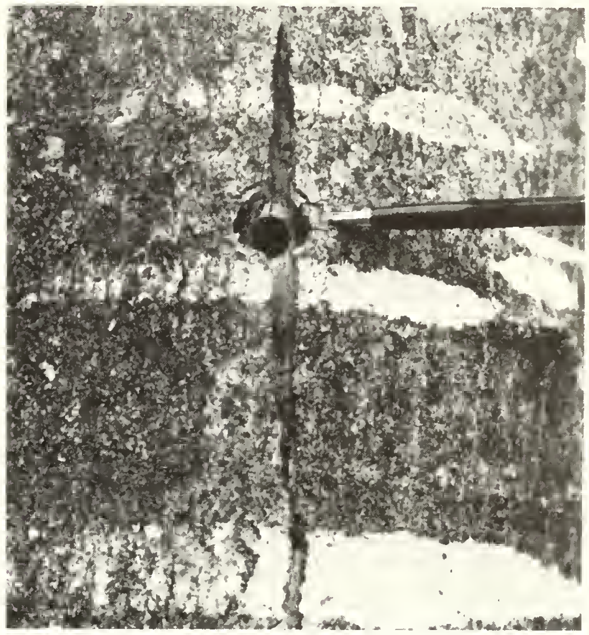
Following the end of the second and third growing seasons after tapping, each taphole was inspected for cambial dieback and classified as open or fully closed (Fig. 2). The data were analyzed, using the chi-square test of independence (Freese 1967).

Table 1.—Percentage of closed tapholes 2 and 3 years after tapping with a gasoline-powered tapper and by hand on a cold day and a warm day.

Drilled by	Temperature when taphole drilled	
	Low	High
	After 2 years	
Power	8	57
Hand	2	43
	After 3 years	
Power	31	80
Hand	20	82

Figure 2.—When cambium does not die back from a taphole as a result of tapping, callus tissue forms quickly, closing the taphole.

Figure 3.—Cambial dieback can be seen through the drill hole and crack in the bark.



RESULTS

Two years after drilling, half of the warm-day tapholes were fully closed with callus tissue. In contrast, only 5 percent of those drilled on the cold day had closed. This difference was highly significant (.01 level of probability). After 3 years, the number of closed warm-day tapholes had increased to 80 percent, and only about 25 percent of the cold-day tapholes had closed. Again, this difference was highly significant. The percentage of closed tapholes for each treatment combination 2 and 3 years after tapping is shown in Table 1.

It appeared that power-drilled tapholes closed sooner than hand-drilled tapholes, especially after the second year. However, in neither the second nor the third year was there a significant difference in closure between power- or hand-drilled tapholes.

DISCUSSION

This study shows that drilling tapholes and inserting plastic spouts in frozen trees usually result in slower taphole closure. A tapered spout driven into a taphole compresses the adjacent tissue. Frozen tissues are brittle, so this wedging action can rupture fragile cambium cells around the taphole, and will often cause the bark to split longitudinally above and below the taphole (Fig. 3).

Tapholes are closed over by successive layers of callus tissue that develop from live cambium on each side of the taphole. The smaller the area of dead cambium, or wound, the sooner closure is effected. When tapholes close rapidly, new layers of wood form over them, and the same area of the bole may be tapped again sooner. Rapid closure also tends to inhibit the advance of any aerobic decay organisms invading the taphole, and there is less chance for decay organisms to invade the tree's tissues (Shigo and Larson 1969).

In the past, tapholes were usually drilled by hand, using a brace and bit. Now, portable power-driven equipment is often used. This includes the gasoline-powered chain saw fitted with a drill chuck that revolves at a very high speed. It was thought that the vibration or the weight of the engine might cause the fast-revolving drill bit to hit the bark at the edge of the taphole and rupture the cambium cells. The results show that high- speed drilling did not affect taphole closure, and indicate that such equipment can be safely used for tapping maple trees. This conclusion is further supported by an earlier study (Smith and Lamore 1971) showing that high-speed drilling did not affect subsequent sap yield from a taphole.

Early tapping, which often means drilling tapholes in frozen trees, might be done to take advantage of that first sap flow. Tapping frozen maples can definitely cause tissue damage. However, we do not suggest that tapping be done only on very mild days, when temperatures are above freezing, or perhaps even waiting for the sap-flow season to start. Our experience indicates that tapping is successful when temperatures are about −5° or −4°C, or above. However, care should always be exercised in setting the spouts: driving spouts too hard into the taphole can severely damage the tree, even under mild weather conditions.

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THE TRAIL GUIDE SYSTEM AS A BACKCOUNTRY MANAGEMENT TOOL

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Abstract. A trail guide booklet containing a map, directional and distance data, and information about the natural and human history and management problems of a backcountry hiking trail was keyed to small, numbered, wooden markers along the trail. This system was evaluated on an 8-mile loop in the White Mountain National Forest in New Hampshire. The system may be useful for contacting backcountry recreationists, gaining their interest and their cooperation.

Introduction

Americans have placed tremendous demands on forest resources as a result of our society's increased mobility, affluence, and leisure time. Outdoor recreation is the dominant use of some forest areas and has equal status with timber, water, wildlife, and range in most forests. The outdoor recreation industry has continued to grow through bad times as well as good.

One element that has contributed toward this growth is the desire of many individuals for dispersed recreation. The National Forests in the Eastern Region reported that in 1975 about 69 percent of their visitors participated in dispersed-type recreation activities. Furthermore, the Forest Service's dispersed recreation program is based on an estimated 16 percent increase by 1980; 37 percent increase by 1990, and 52 percent increase by the year 2000 (U. S. Forest Service 1976). It would appear that America's interest in dispersed recreation and the problems associated with it are here to stay.

Historically, there has been very little recognition that dispersed recreation had much impact on the physical condition of forest resources. There was seldom more use than a site could biologically handle. Furthermore, the small number of backcountry recreationists probably had little or no negative impact on each other. However, during the past 10 to 15 years, we have recognized the tremendous pressure dispersed recreationists put on backcountry resources. There is now a genuine concern that sheer numbers may spoil the physical and social characteristics of some backcountry areas (Echelberger et al. 1974).

Managers have several options to cope with the increased pressure put on backcountry resources. They may impose use restrictions, they may harden the sites, they may use subtle techniques to shift use, or they may use a combination of these options. There is considerable research and experience with restricting use [1] (Echelberger et al. 1974; and Stankey and Baden 1977). But restricted use implies regulation, and regulation may detract significantly from the backcountry experience being sought. Managers also have considerable experience with hardening sites (Dunbar 1970; Herrington and Beardsley 1970; Homes et al. 1973; Proudman 1977). However, this may be expensive and it may detract from the attributes that contribute to a high-quality backcountry recreation experience. Furthermore, site hardening may be illegal in some locations.

Subtle means of shifting use pressure is another option, and managers may not be very familiar with its possibilities (Godin and Leonard 1976). Many dispersed recreationists are relatively well educated, fairly sophisticated, and young in spirit as well as body. Their behavior may be influenced by an explanation or a presentation of background reasoning behind management actions or use restrictions. In crowd management, managers seldom have the opportunity to explain the logic behind some of the things that visitors see.

The purpose of this report is to discuss one method that has been tried in the White Mountain National Forest of New Hampshire: the trail guide system. To decrease visitor impacts on fragile sites and improve the quality of the hiking experience, it uses an information and education approach. It can also be used to describe natural and human history, management problems, and use policies. It can also assist management in diverting pedestrian traffic to areas receiving little use or away from areas receiving excessive use.

Trail guidebooks have been in use for many years, either as an invitation to the "glories" of the mountains (Harrington 1926), or for straight trail directions and information (Larrabee 1932; Sadlier and Sadlier 1975; AMC 1976; GMC 1977). Most of the more recent guidebooks contain a brief section on backcountry etiquette and/or how to minimize man's impact on the resource. However, very few discuss man's unintentional and often detrimental impact on specific sites. The trail guide system described here combines the two types of information: Natural systems are briefly described, managerial actions pointed out, and policies discussed along the trail directions.

Evaluation of the guidebook system convinced us that it is a worthwhile tool to (a) decrease excessive user impacts; (b) increase area used by visitors (disperse use); and (c) sustain or even improve benefits derived from a backcountry recreation experience.

The Study

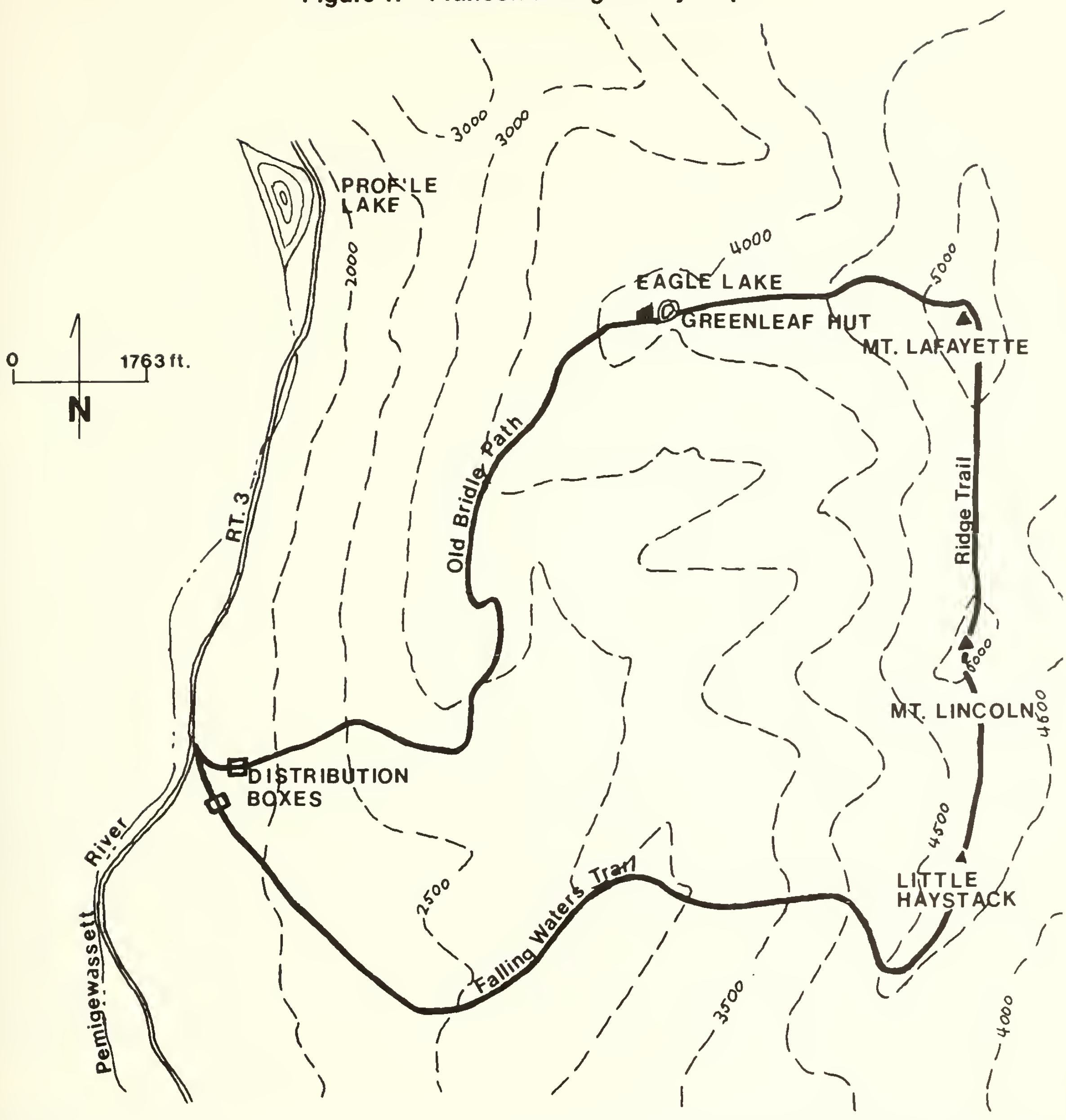
The booklet was made available to hikers on 11 days during July and August. On 6 days unobtrusive observers recorded the behavior of 155 groups (506 hikers). Ninety-two percent of the groups took booklets from the distribution boxes. Only 8 percent of these displayed neutral or negative reactions to the booklets.

The Franconia Ridge Trail Guide System was introduced to the Franconia Notch region of the White Mountains in the summer of 1976. Franconia Notch is a popular mountain pass between North Woodstock and Franconia, New Hampshire. Appalachian Mountain Club hut crew members estimated that about 15,000 hikers passed over the Franconia Ridge during the summer of 1975 (Hamblin 1977). Distribution boxes at the two trailheads of the Franconia Ridge 8-mile study loop (Fig. 1) contained guide booklets which included a topographic map, a mountain profile map, and a trail guide that discussed management problems such as fragile areas and trail erosion, and restricted use policies. Directional and distance information and information about the natural and human history of the area also were included. There were 15 numbered tags along the loop that pinpointed stations referred to in the guide booklet (Fig. 2).

Reaction category	*Percent of groups*	
	Observed	*Interviewed*
Strongly positive	41	41
Positive	51	35
Neutral	7	19
Negative	1	5
Total	100	100

[1] Rationing of Backcountry Use–Great Smoky Mountains National Park. Unpublished paper by R. Proudman on file with the Appalachian Mountain Club, Pinkham Notch, New Hampshire.

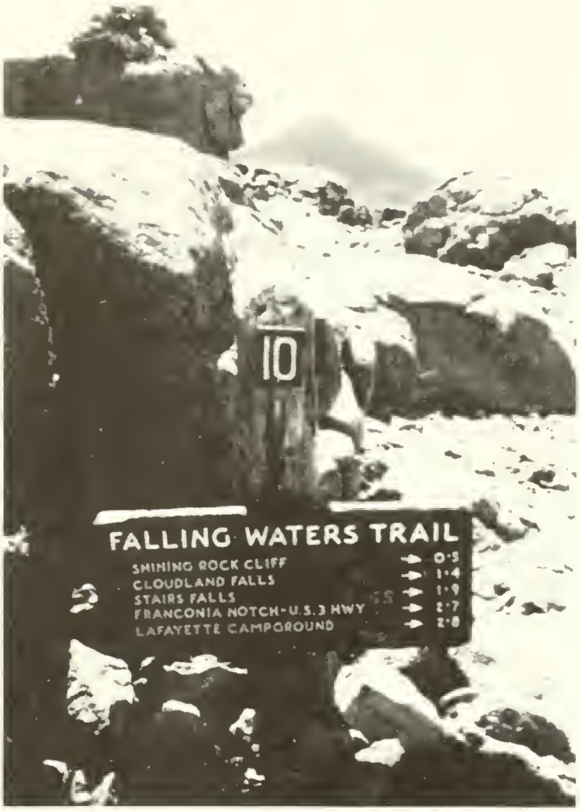
Figure 1.—Franconia Ridge study loop.



On 7 days, unstructured interviews were conducted with 96 groups (297 individuals). Of the groups interviewed, 76 percent responded positively to the booklets. This figure varied from 79 percent during good weather to 65 percent during inclement weather. Family groups were especially favorable toward the booklets. None of the 5 negative responses indicated more than a mild dislike; they just didn't think much of the system. The discrepancy between observed reactions and interviewed reactions is because 18 percent of the groups interviewed did not have booklets; they either had not picked one up at the trailhead or had reached the interview area by a different trail. These groups were recorded as neutral, even if they expressed interest in having a booklet.

Franconia Ridge backcountry hikers did not perceive the booklet as a threat to their hiking ex-

Figure 2.—Station 10 at Little Haystack. Note numbered tag on intersection post.



perience; instead, they were favorably impressed by it. Booklets were not found littering the trails, nor dropped off at the Greenleaf Hut on the trail loop. There was little or no vandalism of boxes or tags.

The booklet offered the hiker interesting explanations along with the regulations. It does say, "No", "This is fragile," and "Watch where you walk"; but most of the hikers found these admonitions palatable in that context.

Discussion

In spite of its limited scope, this study demonstrates that a trail guide system can be valuable for contacting backcountry recreationists and gaining their interest and cooperation. These findings agree with those of Hendee et al. (1968), who felt that most wilderness visitors in the Pacific Northwest would probably purchase and use a small booklet describing features along a trail, and Butterworth (1970), who proposed a Glacier Peak Wilderness guidebook that would be useful to visitors, contain information about the area's features, and assist in managing the resource.

There are still some questions to be answered. For example, was the system accepted mostly as a novelty? Would it be seen as favorably by visitors after a longer time? Are backcountry recreationists willing to alter their behavior as a result of new knowledge? Would they change trip itineraries and overnight sites after picking up a guidebook at a trailhead? There also is a need to determine the extent and durability of a positive change in attitude toward management objectives. The applicability of this system to other areas is also unknown.

The trail guide system must be carefully planned and articulated to give the manager a chance to explain his management problems and policies. It could encourage a more knowledgeable hiking public and could also reduce the proliferation of signs seen on some backcountry trails. An advantage of this system is that it can be used as heavily or as lightly as one wishes. If it were a fairly regular part of a backcountry management program, it could induce users to pick up maps which they do not always do now. A number of hikers become lost because they don't carry a trail map—they simply don't bother to pick one up. A trail map with a guidebook would make the trip more interesting, and might help managers by cutting search and rescue expenses.

Care must be taken to prevent a trail guide system from becoming a nature trail system: People interested in dispersed recreation often do not favor that type of development. A judicious blend of directional and management information is necessary for a successful trail guide.

Another advantage of the trail guide system is its flexability. It can be very expensive to change signs in the backcountry, but numbers can be removed and items blocked out of the guidebook at will. Another advantage is that the trail guide can provide more exact information about overnight facilities. A numbered tag and information in the booklet that this is the last water and that a good campsite is 1/2-mile farther on could be very much appreciated by the user.

This guidebook system would probably be most useful in areas where user density is moderate. Some hikers who use such areas are not proficient in reading topographic maps; a keyed informational map and booklet could be very helpful to them. In more remote areas, where users are widely dispersed, the trail guide system might not be cost effective; in crowded areas it probably would not reduce the need for signs.

The trail guide system, combined with user restrictions, site hardening, and other subtle techniques to shift use may be helpful to managers facing increased use pressure on backcountry resources. The combination of directional information, historical information, and information about man's impact on specific stretches of the trail seems to enhance the backcountry experience for most hikers and can enhance the usefulness of the resource.

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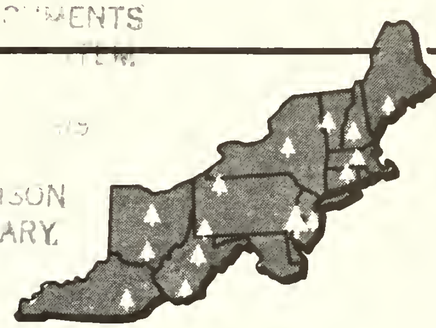

FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE, 370 REED ROAD, BROOMALL, PA. 19008

HYBRID POPLAR ON TWO ANTHRACITE COAL-MINE SPOILS: 10-YEAR RESULTS

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Abstract. Unrooted dormant cuttings of 28 hybrid poplar clones were planted on two graded anthracite coal-mine spoils derived from sandstone or from glacial till. Ten-year results show that the plantation survived very well (82 percent), but that growth was extremely varied. Spoil Characteristics and performance of individual clones are presented.

INTRODUCTION

There are about 50,000 ha of mine spoils in the anthracite coal region in northeastern Pennsylvania. Most of the waste area is devoid of vegetative cover, which is essential for stablizing the spoils and minimizing erosion.

Coal operators are now required by law to grade the strippings and revegetate the spoils with trees, shrubs, or grasses when mining is completed. A well-executed afforestation program is an effective way to correct severe environmental problems from strip mining.

Planting fast-growing hybrid poplar (*Populus* spp.) is an effective way to revegetate these harsh sites. It is essential, however, to use planting stock from clones that are best suited to these sites to achieve acceptable survival and growth rates.

In this paper I present 10-year results of the performance of 28 clones of hybrid poplar planted on anthracite coal-mine spoils in northeastern Pennsylvania.

STUDY

In the spring of 1964, 28 clones of hybrid poplar, with 32 cuttings from each clone, were planted in 16 blocks on graded strip-mine spoils. Between 1964 and 1973, 10 blocks were lost due to stripping-related activities, so complete 10-year data could be collected for only six blocks. In

Table 1.—Hybrid poplar clones, their parentages and performance, 10 years after planting

Clone	Parentage (Female X Male)	Sandstone						Glacial till		
		Block A			Block B + C			Block A + B + C		
		Height	Dbh	Trees	Height	Dbh	Trees	Height	Dbh	Trees
		m	*cm*	*No.*	*m*	*cm*	*No.*[a]	*m*	*cm*	*No.*[a]
NE-4	*P. nigra* X *P. laurifolia*	17.5	18.7	2	4.5	2.7	3/1	3.9	2.2	3/2
NE-9	*P. nigra* X *P. trichocarpa*	18.0	19.8	2	5.2	5.8	4	6.3	5.1	4
NE-11	*P. nigra* X *P. trichocarpa*	18.3	22.1	1	6.0	4.6	4	7.4	6.4	5
NE-17	*P.* cv. Charkoviensis X *P.* cv. Caudina	15.9	10.7	1	3.0	1.0	1/1	7.3	5.5	5
NE-29	*P.* cv. Charkoviensis X *P. trichocarpa*	15.9	17.3	1	5.5	4.3	4	6.7	5.3	4/2
NE-32	*P.* cv. Angulata X *P.* cv. Berolinensis	7.3	4.1	1	2.7	1.0	1	3.3	1.8	4/1
NE-35	*P.* cv. Angulata X *P.* cv. Plantierensis	13.9	14.2	2	4.3	3.0	4	6.5	5.2	3/2
NE-40	*P.* cv. Petrovskyana X *P.* cv. Caudina	8.1	5.6	2	2.9	1.4	4	3.6	2.1	5
NE-42	*P. maximowiczii* X *P. trichocarpa*	15.2	14.0	2	10.5	10.9	3	8.8	9.1	5
NE-44	*P. maximowiczii* X *P.* cv. Berolinensis	13.6	11.2	2	9.3	10.3	4	8.0	7.8	6
NE-50	*P. maximowiczii* X *P.* cv. Berolinensis	17.8	17.0	2	6.8	3.8	3	5.0	2.8	4
NE-51	*P. maximowiczii* X *P.* cv. Plantierensis	16.0	15.6	2	6.6	5.9	4	5.3	4.0	6
NE-52	*P. maximowiczii* X *P.* cv. Plantierensis	9.1	6.7	2	7.6	6.7	4	7.0	6.3	6
NE-53	*P. maximowiczii* X *P.* cv. Caudina	14.8	11.8	2	5.4	3.7	4	6.2	3.9	4/1
NE-207	*P. deltoides* X *P. trichocarpa*	14.0	16.8	2	10.4	11.2	4	6.8	6.6	5/1
NE-216	*P. deltoides* X *P. trichocarpa*	12.0	13.8	2	5.7	6.7	2/1	4.0	3.1	5/1
NE-241	*P. deltoides* X *P.* cv. Plantierensis	12.7	13.3	2	4.5	2.3	4	3.0	1.3	2
NE-253	*P.* cv. Angulata X *P. trichocarpa*	14.3	9.9	1	7.2	7.4	4	3.7	2.4	2
NE-258	*P.* cv. Angulata X *P. deltoides*	14.6	11.7	1	5.9	5.2	3/1	5.6	4.8	2/2
NE-273	*P. sargentii* X *P.* cv. Italica[b]	14.4	13.9	2	3.7	1.9	2/1	4.8	2.7	4/1
NE-278	*P. nigra* X *P.* cv. Eugenei	14.9	11.2	1	4.8	3.2	4	9.2	9.0	4
NE-279	*P. nigra* X *P. laurifolia*	14.3	16.5	1	7.9	7.2	4	8.3	8.4	4/2
NE-302	*P.* cv. Betulifolia X *P. trichocarpa*	15.5	14.1	2	7.2	4.8	2/2	3.4	1.5	5
NE-316	*P.* Charkoviensis X *P.* cv. Robusta	14.0	11.4	1	5.8	3.0	1	3.7	2.0	3
NE-327	*P.* cv. Candicans X *P.* cv. Berolinensis	13.4	12.7	2	5.6	4.0	3/1	3.0	1.6	4/1
NE-341	*P.* Rasumowskyana X *P.* cv. Plantierensis	16.5	14.7	1	5.8	3.6	2	7.5	5.8	3
NE-353	*P. deltoides* X *P.* cv. Caudina	15.7	14.1	2	2.9	1.2	3	7.4	5.7	3
NE-388	*P. maximowiczii* X *P. trichocarpa*	17.2	21.1	2	6.2	4.7	2/1	5.4	3.7	6
	Average	14.4	13.9	82%	6.1	5.1	86%	5.9	4.7	79%

[a] Numbers following slash represent trees less than 1.37 m in height.
[b] Trees were removed after 6th growing season. The data is interpreted from 5th year growth.

these blocks, 272 of the 336 trees planted survived (82 percent).

Sites. The study sites were located in the anthracite northern coal field, Luzerne County, Pennsylvania. Sites represented spoils of: (a) sandstone derived from upper carboniferous Pennsylvania age rocks, and (b) glacial till material of Quaternary age. The sandstone spoils contained an admixture of conglomerates and carbonaceous black shale fragments, and both spoil types contained weathered and eroded material. It was estimated that the spoils originated 20 to 25 years earlier, but 2 years before the study began, all areas were graded to slopes of about 10 to 20 percent. There was no vegetation on the sites when the study began.

Hybrid poplar. Dormant cuttings from the 28 hybrid poplar clones used in this study (Table 1) were about 1 to 2 cm in diameter at midpoint and 25 cm long. The cuttings were obtained from the Pennsylvania Department of Forest and Waters, West Virginia Pulp and Paper Company, and research plots of the Northeastern Forest Experiment Station, Beltsville, Maryland.

Plot layout. Plantings were arranged in randomized complete blocks; blocks were replicated three times on each of the two spoil types. Each block consisted of seven rows of cuttings, eight cuttings per row. Two cuttings from each clone were planted adjacent to each other in the same row. Spacing was at 1.8 m.

Data collection and analysis

Spoils. After planting, two 15-kg spoil samples were collected from the upper 30 cm on each block to determine the spoil's physical characteristics. Samples were air-dried and screened, and fragments larger than 5.1 cm in diameter were discarded. The fraction less than 2 mm in diameter was analyzed for sand, silt, and clay-size particles, by the hydrometer method.

In the fall of 1964, triplicate samples were taken to determine field capacity. Sampling was done when the amount of water in the soil approximated the field capacity (1 day after heavy rain). Each site was sampled two or three times. The 15-bar moisture content, determined by the pressure membrane procedure, was considered to equal permanent wilting point.

After five growing seasons, when differences in performance of individual clones on different spoil types and blocks were obvious, additional spoil samples were collected within 4 to 6 cm of each planted cutting to obtain data on chemical characteristics. Samples were analyzed for pH, N, P, exchangeable cations, and exchange acidity.

Trees. Data on survival and on total height of planted trees were obtained annually for 5 years and again after the 10th growing season. The diameter of all trees $\geq$ 1.5 m in height was measured in the 10th season after planting.

Because of large variability of tree growth within spoil types and a possible spoil type x clone interaction, it was not meaningful to rank collectively the performance of individual clones. Therefore results from blocks with similar growth patterns were combined and tabulated.

RESULTS AND DISCUSSION

The number of surviving trees and their height and diameter by clonal original and spoil type are given in Table 1. The performance of individual clones differed greatly among spoil types and blocks within the same spoil type.

Sandstone spoils

Block A. Among three blocks planted, Block A provided exceptionally favorable conditions for tree growth. Here, 82 percent of the planted cuttings survived; the average height was 14.4 m, and the mean diameter at breast height (dbh) was 13.9 cm. The clones NE-4, NE-9, NE-11, NE-50, and NE-388 (Fig. 1) attained a spectacular height of 17 m or higher, and the diameter of these clones ranged from 17 to 22 cm. Conversely, height growths of 10 m and less, and diameters ranging from 4 to 7 cm, were recorded for NE-32, NE-40, and NE-52 clones. The majority of clones (20) in Block A ranged from 10 to 17 m in height, and 10 to 17 cm in dbh.

Blocks B and C. Tree growth on these two blocks was satisfactory but less spectacular than that for Block A. Here, 86 percent of the trees survived, but overall mean height was only 6.1 m and mean dbh was only 5.1 cm. Only two clones, NE-42 and NE-207, exceeded a height of 10 m. Clones NE-44, NE-52, NE-253, NE-279, and NE-302 attained heights ranging from 7 to 10 m and diameters ranging from 5 to 10 cm. The remaining clones grew less than 7 m. Nine trees of 8 clones planted in Blocks B and C didn't reach a height to be measured for dbh.

The reasons for these striking differences in performance between Block A and Blocks B and C

Figure 1.—Fifteen-year-old hybrid poplar (NE-388) on spoil derived from sandstone; the spoil is located near Wilkes Barre, Pa.

cannot be easily explained. It is generally agreed that tree vigor, and particularly tree height at a certain age, is a function of many combined site factors—most frequently those related to the availability of water. Although all three sites had similar physical surface characteristics (Table 2), it is possible that subsurface characteristics in Block A were more favorable for tree growth than those of Blocks B and C.

The chemical characteristics showed small differences among the three blocks (Table 3). Nitrogen concentrations were low but comparable on all three blocks. However pH, P, Ca, Mg and percent base saturation were more favorable on Block A than on Blocks B and C. Perhaps a higher concentration of cations and P affected the more efficient use of N by trees planted on Block A.

Glacial till spoils

With the exception of a few trees that died back due to damage and root exposure from erosion, all clones planted on glacial till spoils survived and grew equally well in all three blocks. Thus growth data from individual blocks were averaged and presented as means of three blocks considered to be replicates.

Seventy-nine percent of the trees survived on glacial till spoil, which I consider good survival. However the plantation attained only 5.9 m in overall mean height and 4.7 cm in dbh. Only nine

Table 2.—Physical characteristics of planting sites.

Spoil	Texture				Db[b]	Water Retention[a]		
	>2.0 mm	Sand	Silt	Clay		FC	PWP	Available water
	- - - - - - %- - - - - - -				*g/cc*	- - %- -		*cm/30.0 cm*
Sandstone	57	28	11	4	1.5	10	2	3.6
Glacial till	43	34	13	10	1.8	8	4	2.2

[a] Determined in >2-mm fraction and adjusted to field conditions.
[b] Disturbed volume weight.

Table 3.—Chemical characteristics of planting sites.

Block	N	P	Ca^{++}	Mg^{++}	K^{+}	Exchange acidity	CEC	Base saturation	pH
	%	*ppm*	- - - - - -	- - -*meq/100g.*- - -		- - - - - -		%	
				SANDSTONE SPOILS					
A	.13	5.2	4.42	2.29	.21	4.05	10.99	63	5.6 5.2-6.0
B	.16	2.2	1.78	2.04	.22	5.98	10.04	40	4.9 4.3-5.4
C	.12	1.4	1.14	1.08	.22	4.81	7.26	34	4.8 3.6-5.2
Mean	.14	2.9	2.45	1.80	.22	4.95	9.43	46	5.1 4.4-5.5
				GLACIAL TILL SPOILS					
A	.11	33.1	3.08	1.82	.13	.76	5.81	87	6.8 6.0-8.4
B	.09	25.5	2.49	1.60	.12	1.06	5.29	80	6.6 5.3-7.8
C	.05	40.1	1.63	1.22	.06	.52	3.45	85	6.8 5.9-8.0
Mean	.08	32.9	2.40	1.55	.10	.78	4.85	84	6.7 5.7-8.1

clones, NE-11, NE-17, NE-42, NE-44, NE-52, NE-278, NE-279, NE-341, and NE-353, attained a height $\geq$ 7 m; diameter (dbh) ranged from 5.5 to 9.1 cm. Four clones, NE-32, NE-241, NE-302, and NE-327, performed poorly; their height growth was only 3 m. The remaining 15 clones ranged from 3 to 7 m in height and 2.0 to 6.6 cm in dbh, while 16 trees of 11 clones did not reach a height to be measured for dbh.

Although the trees planted on glacial till spoils survived well, their growth rates were below expectations. No one clone performed exceptionally well. The exact reasons are not known, but data on spoil characteristics allow certain assumptions. Favorable pH, percent base saturation, and P concentration are associated with good tree growth (Table 3). But total bases, CEC, and percent N became limiting factors for better performance.

Perhaps the very low amounts of available water during the growing season were major limiting factors to tree growth (Table 2).

CONCLUSIONS

On the basis of the limited results of this study, it is concluded that:

1. Hybrid poplars have good potential in afforestation of anthracite strip-mine spoils.
2. Sandstone-derived spoils provide somewhat more favorable growing sites than spoils derived from glacial till.
3. A number of clones planted on these two spoil types will achieve good survival and a growth range from remarkable to poor, depending on microsite of individual spoil.

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DECAY ASSOCIATED WITH BORER WOUNDS IN LIVING OAKS

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Abstract. Wood-borer wounds serve as entry courts for decay fungi in oak species in the central hardwood region. Thirteen species of fungi were isolated from decayed areas surrounding borer galleries. *Polyporus compactus* was the most frequently isolated fungus, accounting for about 1/3 of the total decay volume caused by identified fungi.

Wood-boring insects, including the red oak borer (*Enaphalodes rufulus* Hald.), the white oak borer (*Goes tigrinus* DeG.), and the carpenterworm (*Prionoxystus robiniae* Peck.), cause losses in both quality and quantity in oak species in the central hardwood region. Borer wounds are entry courts for decay fungi and sizeable amounts of decay are sometimes associated with borer galleries.

METHODS

This paper is based on a study of decay in upland oak stands in the central hardwood region. Scarlet (*Quercus coccinea* Muenchh.), black (*Q. velutina* Lam.), white (*Q. alba* L.), and northern red (*Q. rubra* L.) oaks on 150 sample plots 1/5-acre in size were felled and the amount and source of decay were determined. A total of 274 oaks—161 scarlet, 76 black, 20 white, and 17 northern red oaks—had decay associated with borer galleries. Cultures were prepared from decay samples to determine the fungi responsible for the decay. Sample blocks of decayed wood were split, and from the freshly-exposed faces of the infected wood, six cores of wood, approximately 4mm in diameter, were extracted with a sterilized increment hammer and placed in test tubes containing 2.5 percent Fleishman's diamalt syrup with 2 percent agar. If the decay organism was not isolated on the first attempt, a second attempt was made.

RESULTS AND DISCUSSION

In Kentucky, borer wounds were second only to fire scars as entry courts for decay fungi. Almost 16 percent of 490 infections developed through borer wounds, accounting for about 9 percent of the total decay volume.

In oak forests in Ohio, Indiana, Illinois, and Missouri, about 10 percent of 1,824 infections developed through borer wounds, or about 5 percent of the total decay volume.

Thirteen different species of fungi were successfully isolated from decayed areas surrounding borer galleries (Table 1). *Polyporus compactus* Overh. was the most commonly isolated fungus. It

Table 1.—Volume of decay caused by fungi associated with borer galleries in four oak species, in cubic feet.

Fungus species	Scarlet oak	Black oak	Northern red oak	White oak	Total
Polyporus compactus Overh.	8.09	5.48	0.49	0.12	14.18
Merulius tremellosus Schrad. ex Fr.	6.24	3.10	—	—	9.34
Stereum frustulatum (Pers. ex Fr.) Fckl.	4.47	—	—	—	4.47
Laetiporus sulphureus (Bull. ex Fr.) Bond & Sing.	3.78	—	—	—	3.78
Poria cocos (Schw.) Wolf	3.57	—	—	—	3.57
Inonotus andersonii (Ell. & Ev.) Černý	2.48	.74	.13	—	3.35
Phlebia chrysocrea (Berk. & Curt. in Berk.) Burds.	1.35	—	—	—	1.35
Hericium erinaceus (Bull. ex Fr.) Pers.	.44	.37	—	.34	1.15
Poria oleracea Davidson & Lombard	.72	—	—	—	.72
Poria mutans Pk.	.36	—	—	—	.36
Poria nigra (Berk.) Cke.	—	.24	—	—	.24
Stereum complicatum (Fr.) Fr.	—	—	—	.04	.04
Inonotus cuticularis (Bull. ex Fr.) Karst.	.04	—	—	—	.04
Total identified	31.54	9.93	0.62	0.50	42.59
Unidentified	24.00	11.24	2.95	0.96	39.15
TOTAL	55.54	21.17	3.57	1.46	81.74

was responsible for 14.18 ft^3 of decay, or about 1/3 of the total decay volume caused by identified fungi. It was the only fungus isolated from all four oak species. *Polyporus compactus* causes a white rot as do *Merulius tremellosus* Schrad. ex Fr. and *Stereum frustulatum* (Pers. ex Fr.) Fckl., which caused losses of 9.34 ft^3 and 4.47 ft^3, respectively. *Laetiporus sulphureus* (Bull. ex Fr.) Bond. & Sing. and *Poria cocos* (Schw.) Wolf, both brown rot fungi, ranked next as causes of decay. These five species accounted for 83 percent of the total decay volume caused by identified fungi associated with borer galleries.

Appreciable amounts of decay were associated wtih borer galleries in some of the trees. However, this volume loss represented a relatively small percentage of the gross volume of the 274 trees. In scarlet oak, decay averaged 2.2 percent of the gross volume of 161 trees. Black oak was next, with decay averaging 1.3 percent of the gross volume of 76 trees, followed by northern red oak and white oak with decay volume less than 1.0 percent of the gross volume of 20 and 17 trees, respectively.

SUMMARY

Borer wounds will continue to serve as entry courts for decay fungi until these insects are controlled. Research is now underway to develop methods to reduce borer population in oak forests, which would result in less decay associated with borer galleries.

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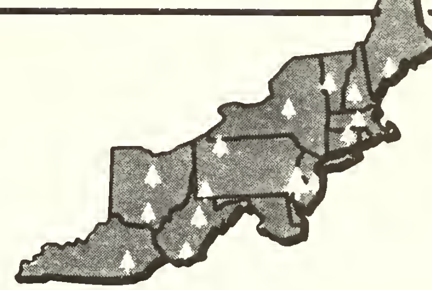

FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE, 370 REED ROAD, BROOMALL, PA. 19008

THE EFFECTS OF SOAK TEMPERATURE ON SUGAR MAPLE SEED GERMINATION

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Abstract. The temperature at which sugar maple seeds were soaked before stratification significantly influenced their germination. Maximal germination was obtained when seeds were soaked at 4°C, but if seeds were soaked at 25°C, germination decreased and the stratification requirement increased.

Introduction

Cold, moist stratification is the standard treatment for overcoming dormancy in sugar maple (*Acer saccharum* Marsh.) seeds.

A significant portion of the stratification period is required for water uptake (Webb and Dumbroff 1969, Janerette 1977).

When sugar maple seeds were soaked in water for periods up to 28 days before stratification, germination proceeded more rapidly, with 14 days being the optimum soak time (Janerette 1978b).

This study was conducted to determine the effects of soak temperature on germination.

Materials and Methods

Three lots of sugar maple fruits with a germination potential of at least 98 percent were collected from separate trees and dried to 10 percent moisture content. Filled fruits were separated from empty ones by floatation in pentane (Carl and Yawney 1969) and stored in sealed plastic bags at −10°C. All references to seeds refer to those enclosed in the fruit.

Three replicates of 50 seeds each were loosely placed in cheesecloth bundles and soaked for 14 days in distilled water at 4°C or 25°C.

After being soaked, the seeds were placed inside a moistened, folded, paper towel that was covered with aluminum foil (Janerette 1978a) and were stratified at 4 °C for periods up to 90 days.

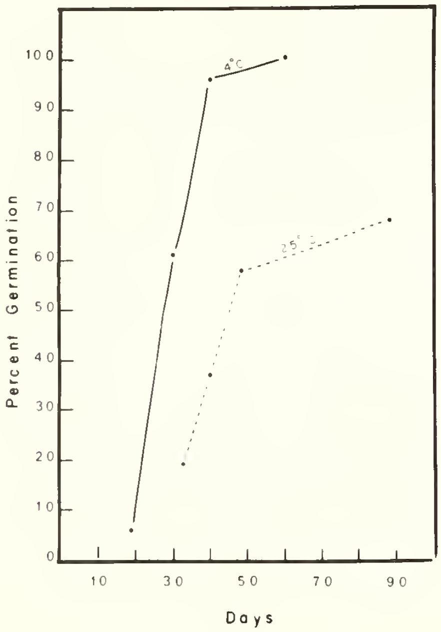
The emergence of the radicle through the pericarp was used as an indication of germination.

The experiment was repeated later, and the results of both trials were combined.

Results and Discussion

The temperature during imbitition significantly influenced germination. When seeds were presoaked at the higher temperature, their stratification requirement increased and the number of seeds that germinated decreased (Fig. 1). Seeds soaked at 25 °C were covered with fungal mycelia, and most of the ungerminated seeds were dead. High-temperature soaks appear to promote microbial growth, and, once stimulated, these organisms thrive even though the seeds are held at low temperatures after soaking.

Figure 1.—Germination profile of sugar maple seeds soaked in water at 4 °C or 25 °C and then stratified at 4 °C.



Hendricks and Taylorson (1976) associated the effects of high temperatures with changes in the permeability of seed membranes that result in a loss of material from the seed. When sugar maple seeds were soaked at 25 °C, there was a heavy precipitate in the soak water that was absent when seeds were soaked at 4 °C.

It seems likely that the detrimental effects of soaking sugar maple seeds at high temperatures can be attributed to a complex of factors including microbial destruction, permeability changes that cause leakage of cellular materials, and an effect on the metabolic mechanism that requires chilling.

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THE EFFECT OF DEER EXCLOSURES ON THE RECOVERY OF VEGETATION IN FAILED CLEARCUTS ON THE ALLEGHENY PLATEAU

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Abstract. In 6- to 10-year-old clearcuts that had failed to regenerate naturally, fencing was erected to protect seedlings from deer browsing. The fencing allowed the gradual recovery of the forest cover. Small seedlings that otherwise would have been browsed continued to grow, and ground cover species such as *Rubus,* which reduced ferns and grasses that sometimes interfere with seedling development, were reestablished. Fencing alone is likely to promote satisfactory restoration of forest cover only in failed clearcuts that contain adequate numbers of seedlings initially—few new seedlings became established after fencing.

REGENERATION FAILURES

Regeneration sometimes fails after harvest cutting on the Allegheny Plateau of Pennsylvania as a result of excessive deer browsing, (Marquis 1975a, Jordan 1967, Shafer and others 1961, Grisez 1957, Bennett 1957, Frontz 1930). Most such failures can be avoided by limiting cutting to stands that contain abundant advance seedlings, or by using shelterwood techniques (Marquis and others 1975). But regardless of the care used in prescribing cuts, there continue to be a few regeneration failures.

Once regeneration fails, ecological changes occur that make it increasingly difficult to establish tree seedlings. Any viable seed buried in the forest floor generally germinates during the first 3 or 4 years after cutting (Marquis 1975b). Thereafter, seed sources become limiting to further seedling establishment. Herbaceous vegetation often becomes established and some kinds of herbs can interfere with the growth and development of any seedlings present (Horsley 1977a, 1977b). Deer browsing also continues to restrict seedling growth, and artificial regeneration with hardwoods is not feasible unless the seedlings are also protected from browsing (Marquis 1977, Marquis and others 1976).

Recently clearcut areas will usually regenerate naturally if they are protected against browsing soon after cutting while there are still numerous seeds and seedlings present, and before herbaceous vegetation has become well established. To determine whether natural regeneration would develop in older failed clearcuts if protected, we studied the effect of fencing on the development of vegetation in areas that had failed to regenerate 6 to 10 years earlier.

METHODS

Four clearcuts that had failed to regenerate were selected in 1971. Two were about 6 years old; one was 8 years old, and the other 10 years old. Within each clearcut, eight pairs of 6-foot-radius (1/385-acre) plots were established, and one of each pair was fenced to exclude deer. Tree seedlings and sprouts were tallied on all plots by species and size class, and herbaceous vegetation was recorded as a percentage of the ground surface covered. Vegetation tallies were made when the study began and again in 1973, 1975, 1977. A test for paired plots was used to determine significant differences between fenced and unfenced plots. Relationships between regeneration stocking at the beginning and at the end of the study were examined with regression analysis.

RESULTS

Seedling development

There was a general decline in the number of seedlings throughout the 6-year study period. The decline in black and pin cherry was significantly greater on the unfenced than on the fenced plots. Differences were not significant for the other species, but the differences for the two cherries were large enough to result in a significantly smaller overall decrease on the fenced plots (Table 1).

Table 1.—Total number of seedlings per acre in fenced and unfenced plots in 6-year study

Species	1971	1973	1975	1977	Change, 1971 to 1977
Black cherry					
Fenced	2,000	2,350	1,750	2,025	+25
Unfenced	3,425	3,475	2,550	1,925	–1,5000*
Red maple					
Fenced	1,400	1,425	785	1,125	–275
Unfenced	1,225	3,725	2,300	1,075	–150
Birch					
Fenced	350	50	175	100	–250
Unfenced	175	250	650	125	–50
Beech					
Fenced	1,125	450	250	500	–625
Unfenced	650	375	275	450	–200
Pin cherry					
Fenced	700	175	150	375	–325
Unfenced	2,200	750	225	125	–2,075*
All desirable species[a]					
Fenced	3,400	3,775	3,125	3,175	–225
Unfenced	4,850	7,000	4,900	2,975	–1,875*
All commercial species[b]					
Fenced	5,050	4,450	3,625	3,775	–1,275
Unfenced	5,725	7,650	5,825	3,355	–2,370*
All stems					
Fenced	6,000	4,725	3,925	4,400	–1,600
Unfenced	6,650	8,750	6,625	2,782	–3,868*

[a] Black cherry, red maple, sugar maple, white ash, yellow-poplar, red oak, cucumber tree.
[b] Above species, plus beech, yellow birch, black birch, eastern hemlock.
* Statistically significant at 0.05 level.

Occasional new seedlings of several species were established each year. The most important such occurrence was the result of a bumper seed crop of red maple in 1973 in the stand adjacent to one of the four clearcuts. These red maple seedlings appeared most abundantly on the unfenced plots, apparently because the dense growth of *Rubus* spp. on the fenced plots precluded new seedlings there. But these increases were temporary and relatively unimportant compared to the overall decrease in seedlings.

Before fencing in 1971, there were comparatively few seedlings over 1 foot in height. Most were new, or slow-growing seedlings, or stems that had been repeatedly browsed. Over the 6-year period, the number of stems over 1 foot tall increased in both treatments, but the increase was considerably larger in the fenced plots (Table 2).

The proportion of plots stocked with at least one stem 1 foot tall, and the proportion stocked with at least one stem 3 feet tall were considerably higher for the fenced than the unfenced treatments by the end of the study in 1977 (Table 3).

The age of the clearcut seemed to have an impact on the regeneration. At the start of the study, 8- and 10-year-old clearcuts had fewer seedlings and fewer stems over 1 foot tall, and at the end of the study, they had fewer plots stocked with stems over 1 and 3 feet tall than the two 6-year-old clearcuts (Table 4). No statistical tests were run since there were only two clearcuts in each age group.

Fencing did not result in a dramatic recovery of tree vegetation in these failed clearcuts. With a few exceptions, the number of seedlings continued to decline in spite of the fencing, although protection from browsing reduced the rate of decline; more seedlings survived in fenced than in unfenced areas.

The major effect of fencing on seedling regeneration has been an increase in height growth of the surviving seedlings. In 6 years, 56 percent of the fenced plots contained a desirable stem over 3 feet tall, and 84 percent contained a desirable stem over 1 foot tall. Although these amounts of stocking would not be nearly adequate to develop satisfactory regeneration in unfenced areas, they may eventually permit these fenced areas to revert to forest cover. Some unfenced areas may also recover, but the process will be much slower, and the resulting stands less adequately stocked.

There was a definite relationship between the number of seedlings (or the stocking) before fenc-

Table 2.—Number of stems per acre over 1 foot tall in fenced and unfenced plots in 1971 and 1977

Species	Fenced		Unfenced	
	1971	1977	1971	1977
Black cherry	325	1,575	700	1,475
Red maple	25	450	25	75
All desirable species	400	2,150	725	1,550
All commercial species	825	2,600	975	1,725
All stems	900	3,075	1,175	1,875

Table 3.—Proportion of fenced and unfenced plots stocked with at least one stem 1 foot tall and one stem 3 feet tall in 1977 (in percent)

Treatment	Percent of plots with:			
	Black Cherry	Red Maple	All desirable species	All commercial species
	1+ FEET TALL			
Fenced	69	44	84	84
Unfenced	28	9	34	47
	3+ FEET TALL			
Fenced	50	22	56	66
Unfenced	16	0	16	25

Table 4.—Effect of age of clearcut on stocking of desirable stems in fenced and unfenced plots, by number of stems and percentage of plots

Treatment	Clearcut	
	6-year-old	8- to 10-year-old
	STEMS IN 1971	
Both	5,500	2,750
	STEMS 1+ FEET IN 1977	
Fenced	3,200	1,100
Unfenced	3,100	0
	PLOTS WITH STEM 1+ FEET IN 1977	
Fenced	88	75
Unfenced	69	0
	PLOTS WITH STEM 3+ FEET IN 1977	
Fenced	76	38
Unfenced	32	0

ing and the stocking 6 years after fencing. The more seedlings present initially, the better the chances for the reestablishment of a forest cover. Of numerous stocking criteria tested, the percentage of plots that contained at least four seedlings of desirable species per plot before fencing was more closely related than any other parameter to the percentage of plots stocked with at least one desirable stem over 3 feet tall 6 years later. An r^2 value of .82 was obtained for this regression.

Although only four stands were represented in this study, the above relationship can serve as a crude guide to the feasibility of fencing in a failed clearcut. If a regeneration survey indicates that 70 percent of the 6-foot-radius plots sampled contain at least four desirable seedlings, then one could expect the area to be at least 70 percent stocked with desirable stems over 3 feet tall 6 years later. If less than 70 percent of the plots are stocked with four stems initially, the chances of obtaining full stocking within a reasonably short time from fencing alone are less; artificial regeneration may be required in addition to fencing in such areas.

Since the number of seedlings declines over time, older clearcuts can be expected to have fewer seedlings—as did the four clearcuts studied here. An early identification of potential regeneration failure followed by the prompt erection of fences will therefore improve the chances of forest vegetation to recover.

Ground cover changes

Changes in the ground cover after fencing were far more dramatic than changes in seedling vegetation (Table 5). Before fencing, there was little *Rubus*[1] present; most plots were dominated by ferns or grasses. Within 2 years after fencing, *Rubus* seemed to dominate many plots, and continued to increase gradually. On plots where *Rubus* developed, the fern and grass declined.

Deer browsing obviously has a major impact on the ground cover in clearcut areas. Preferred species such as *Rubus* are virtually eliminated by browsing, and are soon replaced by ferns and grasses. These latter plants have been shown to reduce seedling growth and survival by release of toxic biochemicals (Horsley 1977a, 1977b). Thus, browsing has indirect effects on tree reproduction in addition to the direct damage to seedlings.

[1] Mainly blackberry (*Rubus allegheniensis*). Raspberry (*Rubus idaeus*) was also present on one area.

Table 5.—Percentage of plots with a particular dominant ground cover in 6-year study

Treatment	1971	1973	1975	1977	Change (1971-1977)
			GRASS		
Fenced	56	41	25	19	− 37
Unfenced	59	69	47	44	− 15
			FERN		
Fenced	38	6	10	13	− 25
Unfenced	38	20[a]	38	41	+ 3
			TALL HERBS		
Fenced	3	6	9	9	+ 6
Unfenced	0	3	9	13	+ 13
			RUBUS		
Fenced	0	41	50	59	+ 59
Unfenced	0	6	3	3	+ 3

[a] Some of the decline in ferns in 1973 is the result of a heavy June frost.

Fencing permits rapid recovery of *Rubus,* and, by reducing fern and grass, may eventually provide a more favorable environment for the recovery of tree species as well.

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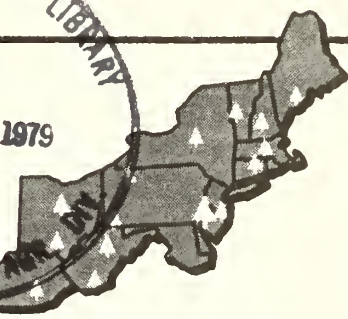

FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE, 370 REED ROAD, BROOMALL, PA. 19008

NORTHEASTERN FOREST SURVEY BOARD-FOOT VOLUME EQUATIONS

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Abstract. International 1/4-inch board-foot volume equations are presented for the 17 species groups used in the forest survey of the 14 northeastern states. The volume equations are nonlinear in form.

As a result of the ever-increasing use of automated data processing equipment, the demand for volume tables in equation form has risen. Some find it more efficient to compute a volume for a given species, diameter, and bole length than to store and access the tables. Others may simply find the equation form more convenient to use than the tables. The board-foot volume equations presented were chosen for convenience and accuracy.

BACKGROUND

The development of the board-foot volume tables parallels that of the companion cubic-foot volume tables, as described by Barnard et al. (1973). The original data used to develop the tables are not available; thus only the individual cell values (means) were utilized in the development of the board-foot volume equations. The goal of the analysis was to find an equation form that would predict the individual cell values accurately and avoid trends in the residual errors (actual minus predicted values).

The volume tables are divided into 17 species groups. The resulting 17 tables give the International 1/4-inch board-foot volume by 2-inch diameter class and half-log height class (assumes a 1-foot stump). The minimum top diameter outside bark is 9 inches for hardwoods and 7 inches for softwoods. Diameters ranged from 10 to 40 inches for softwoods (species groups 1 to 6) and 12 to 40 inches for hardwoods (species groups 7 to 17). The number of half-logs ranged from 1 to 10. Thus the bole lengths in the equations ranged from 8 to 80 feet. The tables are applicable to the 14 northeastern states surveyed by the Resources Evaluation Unit of the Northeastern Forest Experiment Station.

EQUATION DEVELOPMENT

The recent rapid development of computer technologies has been paralleled by rapid developments in standard statistical programs. These packages have made the linear and nonlinear analyses of the board-foot volume tables used in

Table 1—Board-foot volume equation statistics

(International 1/4-inch log rule)

General equation form: $V = b_o + b_1 D^{b2} + b_3 D^{b4} H^{b5}$

Where:

V = gross board-foot volume

D = Diameter at breast height (dbh) in inches

H = bole length in feet

Group	Species	b_o	b_1	b_2	b_3	b_4	b_5	No. of cells	Average square error	Average relative error (%)	>5% <10%	>10%
Softwoods												
1	White, red pine	−12.25	−0.02418	2.6865	0.0961	2.2281	0.4222	147	29.0	1.3	8	2
2	Red, white, black spruce	−13.03	−0.05197	2.5248	0.1200	2.1999	0.4227	145	6.8	0.9	6	2
3	Balsam fir	−12.29	−0.08212	2.5641	0.1416	2.2657	0.3744	147	207.1	3.1	32	12
4	Hemlock	−8.36	−0.01433	2.7878	0.0771	2.2593	0.4202	137	29.2	1.2	7	1
5	Hard pines, tamarack, Norway spruce	−6.78	−0.00841	2.7001	0.0645	2.1938	0.4713	142	62.2	1.8	18	2
6	Cedar species	−8.89	−0.07324	2.4556	0.1216	2.2382	0.3249	116	4.1	0.6	2	0
Hardwoods												
7	Sugar maple	3.73	−0.00182	3.3766	0.0262	2.4291	0.6139	138	127.1	2.4	16	5
8	Soft maple, yellow-poplar	2.84	−0.00557	3.1808	0.0296	2.4606	0.5771	138	477.7	4.5	33	25
9	Ash species, aspen species	9.20	0.00052	3.0	0.0193	2.2165	0.8043	138	207.9	2.9	22	11
10	Black cherry	1.58	−0.00151	3.3878	0.0287	2.3875	0.6356	138	79.5	1.6	6	3
11	Birch species	8.23	0.00039	3.0	0.0206	2.2116	0.8019	138	203.4	3.1	23	11
12	Beech	−0.84	−0.01207	3.0043	0.0419	2.3951	0.5912	138	461.7	3.6	31	15
13	Basswood	2.66	−0.00313	3.2780	0.0282	2.4416	0.5940	138	232.4	3.0	30	7
14	Red oaks, sweetgum, blackgum	1.01	−0.00192	3.3188	0.0246	2.4268	0.6000	138	75.8	1.9	6	4
15	Chestnut oak	4.46	−0.00061	3.5972	0.0182	2.4804	0.5922	138	74.4	2.1	15	5
16	Hickory	−1.24	−0.00385	3.1648	0.0312	2.3888	0.6067	138	65.5	1.3	5	1
17	Other hardwoods	0.03	−0.00196	3.3236	0.0263	2.4162	0.6012	138	62.2	1.5	6	2

this study possible at a relatively low cost. Several simple and multiple linear equations, weighted and unweighted, as well as some logarithmic transformations of nonlinear equations, were tried. Finally, equations that are strictly nonlinear in their parameters were tried; they more adequately estimated the table values.

Nonlinear regression techniques have only recently come into widespread use.[1] With nonlinear regression the standard linear statistical tests cannot be applied with known reliability. Thus the equation forms were chosen for lack of trends in the residuals and minimum average relative error. The percent relative error is the absolute value of the difference between each table cell value and its predicted value, divided by the cell value. The average relative error is simply the average percent relative error over all cells in the table.

On this basis the equation form chosen was:

$$V = b_o + b_1 D^{b2} + b_3 D^{b4} H^{b5}$$

where:

$b_o. . .b_5$ = parameters to be estimated

For species groups 9 and 11, the nonlinear regression failed to converge because of the presence of the $b_1 D^{b2}$ term. With b_2 set equal to 3.0, the regression converged. The 3.0 value was chosen on the basis of the other hardwood species group values and on dimensional considerations.

BOARD-FOOT VOLUME EQUATIONS

The values of the parameters ($b_o. . .b_5$) and the number of "observations" (cells) for each species group are given in Table 1. Also shown are the average squared error (mean square error) and the average relative error. The number of values with relative errors greater than 5 percent but less than 10 percent, and the number greater than 10 percent are also given.

To use the equations, three items must be recorded for each tree; (1) species; (2) dbh; and (3) bole length (in feet) to the minimum diameter. As stated earlier, the minimum top diameter (outside bark) is 7 inches for softwoods and 9 inches for hardwoods. For example, the board-foot volume of a 22-inch dbh white pine, with a bole length of 56 feet, is 407 board feet, according to the table.[2] Using the equation yields a value of:

$$\begin{aligned} V &= -12.25 - 0.02418(22)^{2.6865} \\ &\quad + 0.0961(22)^{2.2281}(56)^{0.4222} \\ &= 405.1 \text{ board feet} \end{aligned}$$

The error in estimation is 1.9 board feet, or 0.46 percent. This equation form may be tedious to compute on a hand calculator but is easy to use on a computer.

The volume equations presented could not be chosen by rigorous statistical testing, because only the table cell means were available. The equations were developed to predict cell means as closely as possible with as few terms in the equations as possible. The use of the equation form is not necessarily advocated; the equations were developed only for convenience and efficiency.

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[1] For a detailed treatment of the Gauss-Newton method of nonlinear regression, refer to sources such as Chapter 8 of Draper and Smith (1966).

[2] The board-foot volume tables used in the northeastern forest survey and in this study are available upon request from the Resources Evaluation Unit of the Northeastern Forest Experiment Station, 370 Reed Road, Broomall, PA. 19008.

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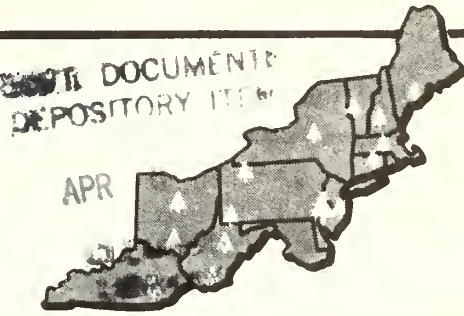

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SOLAR RADIATION AT PARSONS, WEST VIRGINIA

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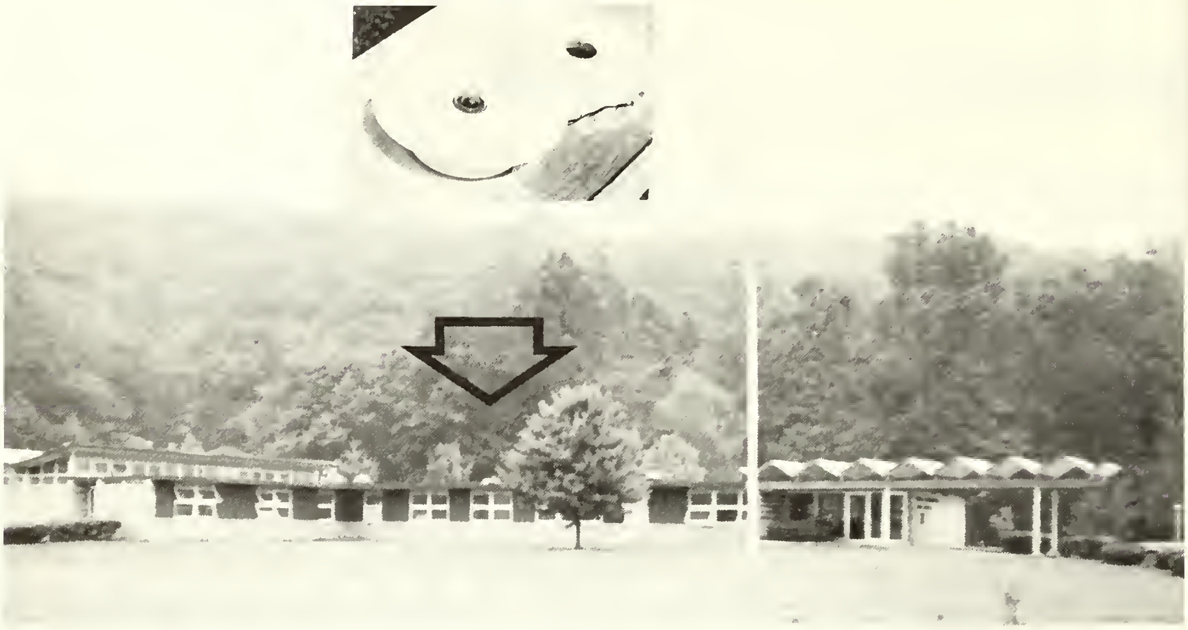
Abstract. Twelve years of solar radiation data, measured with a Kipp-Zonen pyranometer, were recorded near Parsons, West Virginia. The data agree well with calculated values of potential and average radiation for the vicinity and are applicable to the central Appalachian region.

Since 1965, incoming shortwave radiation has been measured at the Northeastern Forest Experiment Station's Timber and Watershed Laboratory near Parsons, West Virginia. We know of no similar long-term measurements in the central Appalachian region, within perhaps 150 miles from the Laboratory. A better understanding of solar radiation is needed to optimally manage forest resources. Moreover, the developing shortages of fossil fuel stimulate interest in solar radiation as a non-polluting source of fuel to help meet man's ever increasing energy needs.

The Kipp-Zonen pyranometer[1] was chosen for these measurements. It was considered

[1]The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture or the Forest Service of any product or service to the exclusion of others that may be suitable.

Figure 1.—The Kipp-Zonen pyranometer is located near the center of the roof of the Northeastern Forest Experiment Station's Timber and Watershed Laboratory near Parsons, W. Va. (lat. 39°06′N.; long. 79°40′W.).



more sensitive and less costly than competitive instruments, and satisfactorily shielded from reflected light. From the Laboratory roof, surrounding low ridges form a skyline to the pyranometer about 6° above horizontal (Fig. 1). Daily radiation is traced on strip charts by a Leeds & Northrop Speedomax H Recorder. An attached totalizer records langleys (calories/cm^2/min)[2] for 24-hour periods. Monthly and yearly totals have been compiled from these data. Pyranometer calibration has been checked 3 times since its installation, by a potentiometer with factory calibration or by a pyroheliometer calibrated at another laboratory.

During January 1978, daily totalizer data were checked against corresponding strip chart records. Anomolies were corrected by planimetering areas beneath the strip chart traces, then converting those areas to langleys per day. The verified records were transcribed to tape, then processed on an IBM model 5100 desktop computer. All of the following results were derived from data so processed.

[2]1 langley = 4.184×10^4 joules per square meter.

RESULTS

Mean daily radiation, with standard deviation, was calculated for each month. These data, with highest and lowest daily radiation observed for the month, are plotted in Figure 2. Note that all of these values peak during June, when amplitude also is greatest. Radiation values and their amplitude were, of course, least during December.

Mean monthly radiation, with standard deviation, also was calculated (Fig. 3). Note that standard deviation and extreme values of monthly radiation cluster more closely about the mean curve than the daily values in Figure 2. Here, too, amplitude was greatest in months with the most radiation.

Variation among annual data was even less; maximum (114,143 langleys) and minimum (102,427 langleys) values varied less than 8 percent from the 12-year mean annual radiation (105,475 langleys). This relative lack of variation illustrates the stability of solar radiation as an index of climate. Mean annual temperature, however, is the more widely used index because it more easily measured, and, therefore, data are far more abundant.

Figure 2.—The range of measured daily radiation at Parsons, W. Va. Mean daily values are plotted as a curve; about two-thirds of the daily values fall within limits around the mean as indicated by standard deviation. Minimum and maximum values plotted for each month are least and greatest daily radiation observed for that month during the 12-year period of record.

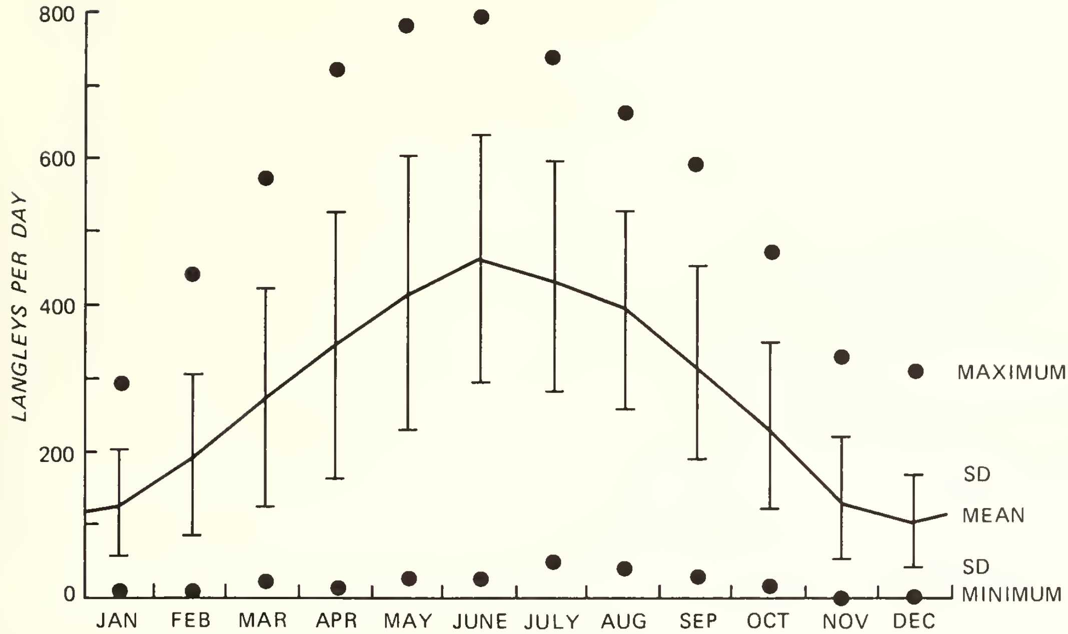


Figure 3.—The range of monthly radiation at Parsons, W. Va. Mean, standard deviation, and highest and lowest values observed are plotted as in Figure 2.

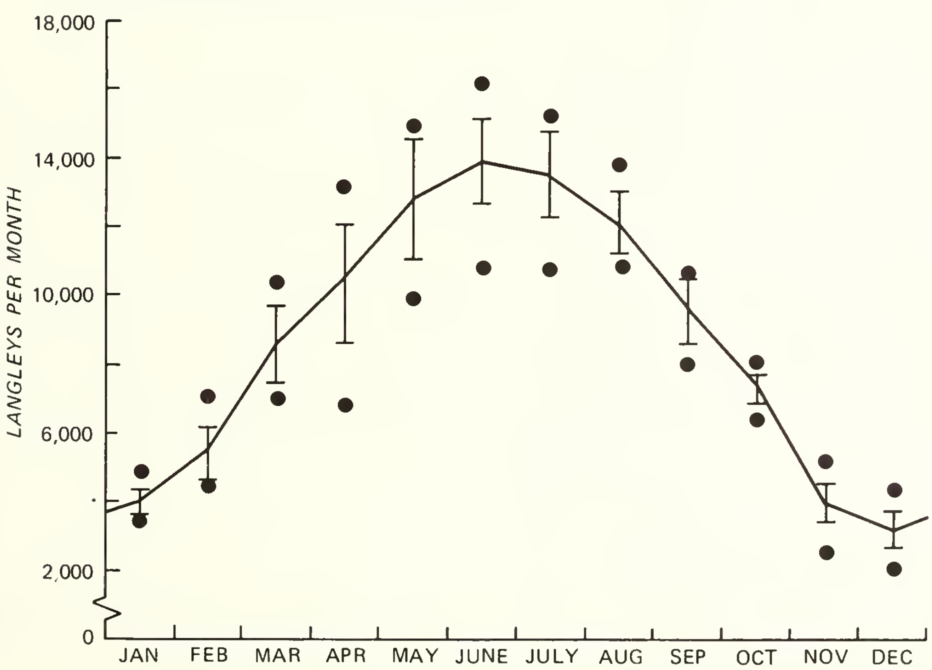
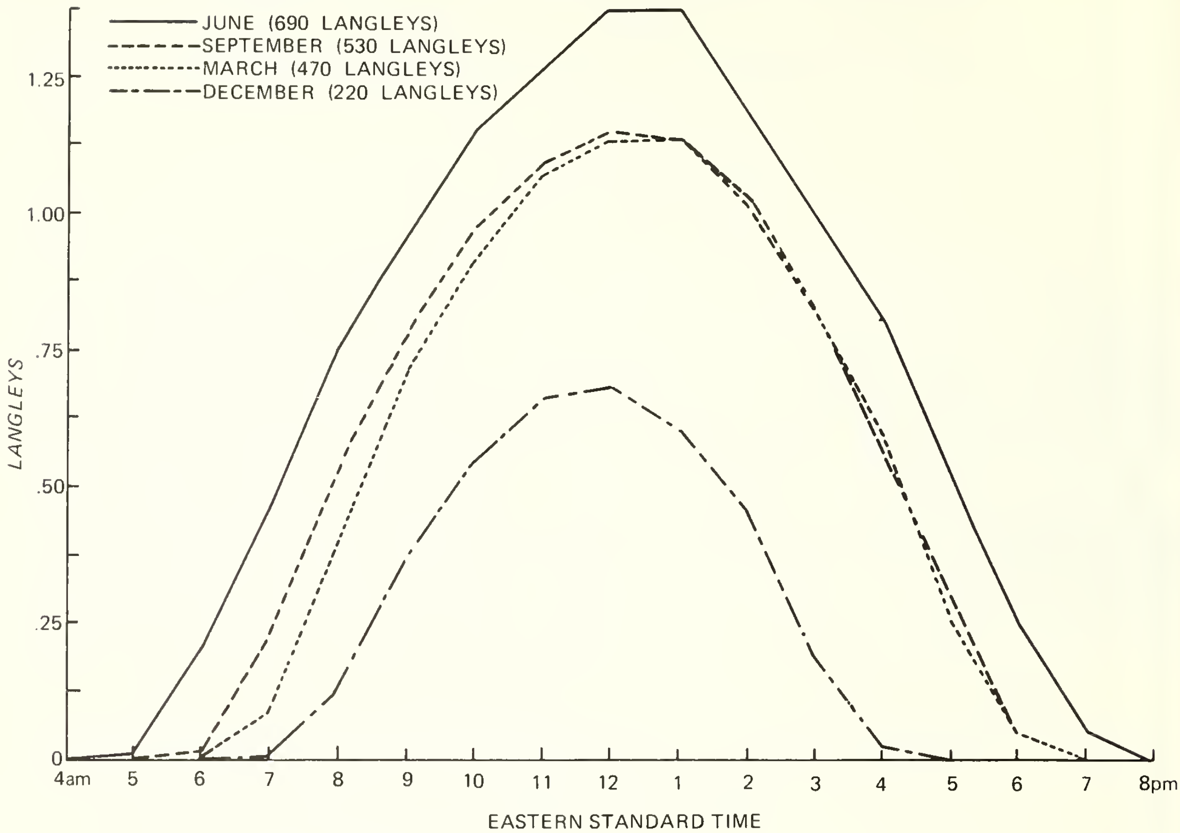


Figure 4.—These daily inputs of solar energy approach the upper limits likely at Parsons during solstice and equinox months.



Clear days (those with less than 1 hour of cloudiness after the usual morning fog) are relatively scarce at Parsons. On the average, there are 5 clear days in October, 3 each in April and May, 1 each in June and December, and 2 in each of the remaining months. In Figure 4, solar radiation was averaged for 10 clear days during June and December to illustrate maximum energy input likely at each solstice; solar radiation also was averaged for March and September to show the maximum likely at each equinox. The greater energy input during the September equinox probably reflects morning skies generally clearer than those of March.

The data in Table 1 provide a basis for probability statements about daily radiation during given months: (a) 700 or more langleys are likely on one day only, in May and June; (b) at least 100 langleys are probable every day in July and August; (c) radiation in excess of 300 langleys is unlikely November through January; (d) 500 or more langleys are likely for half of the days in June.

A Gunn-Bellani radiation integrator, placed in a forest opening about 2 miles east of the Timber and Watershed Laboratory, provided data for May through October from 1959 to 1965. Results with this instrument, measuring radiation on a spherical surface, differed somewhat from the results with the Kipp-Zonen instrument, by which radiation was measured on a horizontal surface. Pereira (1959) reported high linear correlation between these instruments. Results for both instruments were similar May through July but Gunn-Bellani data were higher August through October (Table 2). These comparisons must

Table 1.—Probable number of days per month in which solar radiation equals or exceeds the stated amounts.

Radiation (langleys)	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
	Days											
700					1	1						
650				1	3	3	2					
600				2	6	7	5	2				
550			1	5	9	11	8	5	1			
500			2	8	11	15	12	8	3			
450			5	11	14	18	16	12	6			
400		1	8	13	17	20	19	16	10	2		
350		3	11	16	19	23	21	19	15	6		
300		7	13	17	21	24	23	22	18	11		
250		2	15	19	23	26	25	25	20	16	3	1
200	8	15	19	22	25	27	27	27	23	19	8	4
150	12	18	20	24	27	28	28	28	25	21	13	9
100	17	21	25	26	28	29	30	30	28	24	17	14
50	23	26	29	29	30	30	30	30	30	28	24	22
0	30	30	30	30	30	30	30	30	30	30	30	30

be interpreted cautiously because they were obtained at different times and places.

How valid are Kipp-Zonen data? One kind of check concerns the greatest amounts of radiation possible per day at the latitude (39°06′N.) of Parsons (Table 3). Ideally, the observed maxima will not exceed computations of potential or clear sky values. These computed values, however, are only as valid as the assumptions built into them; for example, assumptions of atmospheric turbidity may or may not prove valid for all occasions. The observed maximum radiation for every month except February was close to or less than one of the computed values. We believe that the observed value for February (424 langleys) was real. The chart trace for that day (2/26/70) was exceptionally high and smooth, suggesting a bright and cloudless day. And the day length so late in February would considerably exceed the average day length for that month. The next highest value for February (383 langleys) was close to computed values.

Table 2.—Results of radiation measurements by two recorders

Month	Average radiation	
	Kipp-Zonen	Gunn-Bellani
	Langleys/day	
May	417	412
June	462	454
July	440	449
August	399	442
September	322	376
October	239	265

Table 3.—Measured versus computed daily maxima of radiation at Parsons, W. Va.

Month	Observed maximum	Potential direct beam[1]	Clear sky radiation[2]
		Langleys/day	
January	287	271	290
February	424	387	380
March	516	539	530
April	678	691	670
May	782	807	740
June	796	867	790
July	741	861	750
August	668	771	690
September	593	626	570
October	473	472	430
November	334	336	350
December	260	225	270

[1] Unpublished report on file at Timber and Watershed Laboratory, Parsons, per Fons (1961).
[2] From Chang et al. (1976), Table 2.

Table 4.—Measured versus computed daily average radiation at Parsons, W. Va.

Month	Measured at Parsons	Horizontal surface radiation[1]	Average for Northeast[2]
	Langleys/day		
January	130	160	125
February	195	220	225
March	275	320	300
April	348	430	350
May	417	510	450
June	462	560	525
July	440	540	525
August	399	480	450
September	322	400	350
October	239	290	250
November	134	210	125
December	107	150	125

[1] From Chang et al. (1976), Table 1.
[2] From Reifsnyder and Lull (1965).

A second kind of check, average daily radiation, also has been estimated for conditions of atmospheric turbidity characteristic of northern West Virginia. Two such estimates are compared with measured daily values for Parsons (Table 4). Measured amounts for every month except January are lower than computed values. As with clear sky radiation, there are large differences among computed values.

EVALUATION

There is no absolute check for evaluating the accuracy of this radiation record. There were consistent variations between autumn records for the instruments used, but they were exposed at different times and places (Table 2). Variations among computed values of daily maximum and average radiation often were of greater magnitude than variations between measured and computed radiation (Tables 3 and 4). On the basis of these checks, we conclude that the radiation data for Parsons are reasonably close to true values.

For how extensive a region are the Parsons radiation data representative? Climatic maps (USDA 1941) help identify the applicable region. They show that north-central West Virginia has some of the cloudiest, foggiest, least sunny weather in eastern United States. Our data seem most appropriate for the mountainous parts of West Virginia, western Maryland, and western Pennsylvania. They may be useful for all of West Virginia, western Pennsylvania, southern New York, parts of eastern Kentucky and Ohio, and parts of western Virginia and North Carolina. They are not representative of climate outside the more mountainous areas of the Appalachian region.

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1979

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FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE, 370 REED ROAD, BROOMALL, PA. 19008

FOREST STAND LOSSES TO GYPSY MOTH IN THE POCONOS

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Abstract. A Study of forest stand losses associated with the gypsy moth outbreak of the early 1970's in the Pocono Mountain Region of northeastern Pennsylvania, showed that while most of the stands incurred little or no loss, a few suffered heavy damage.

How much damage to trees and forests of a region will result from a gypsy moth outbreak? The answer depends on a number of interrelated factors such as the frequency and intensity of attack, the susceptibility and vulnerability of host trees, the size and effectiveness of insect control programs, and weather.

Since most of these factors are themselves difficult to predict, it is little wonder that we are unable to accurately forecast impacts of the pest. But, we can turn to recent experiences for some indication of what to expect. One is the outbreak that occurred during the early 1970's in the Pocono Mountains of northeastern Pennsylvania. Field-plot data have given us measures of tree and timber losses associated with that infestation.

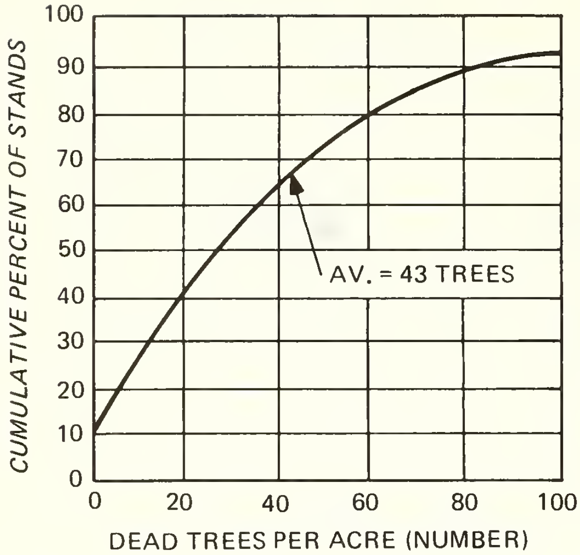
BACKGROUND

Forest stand losses were measured on 143 1/10-acre plots in Pike and Monroe Counties, Pennsylvania. This area was on the frontier of gypsy moth infestations in the early 1970's. The plots were established in 1971 in newly infested forest stands. Stand losses for trees 3 inches in diameter at breast height (dbh) and larger were measured each year for 5 years. The stands were not sprayed to control the gypsy moth during the study period.

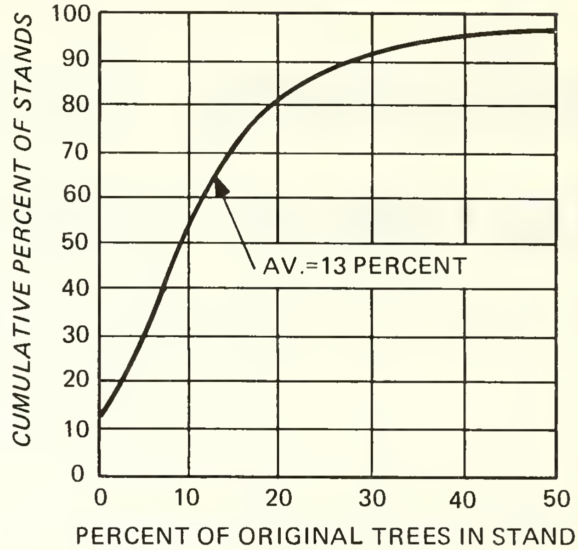
Severity and frequency of gypsy moth attacks varied from plot to plot. In general, the study area had moderate to heavy defoliation from 1971 through 1973. Insect populations all but collapsed in 1974 and 1975, and then built up again in 1976. Tree mortality reflected this pattern of infestation. Four-fifths

Figures 1a-4b.—Forest losses in gypsy moth infested stands in the Poconos, 1972-1976.

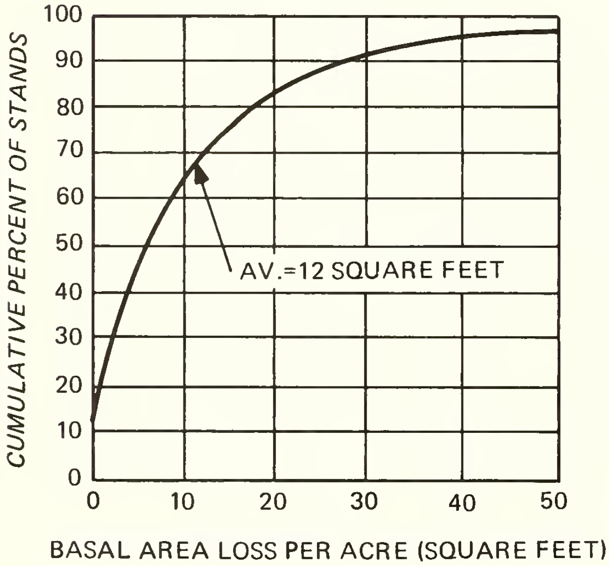
1a



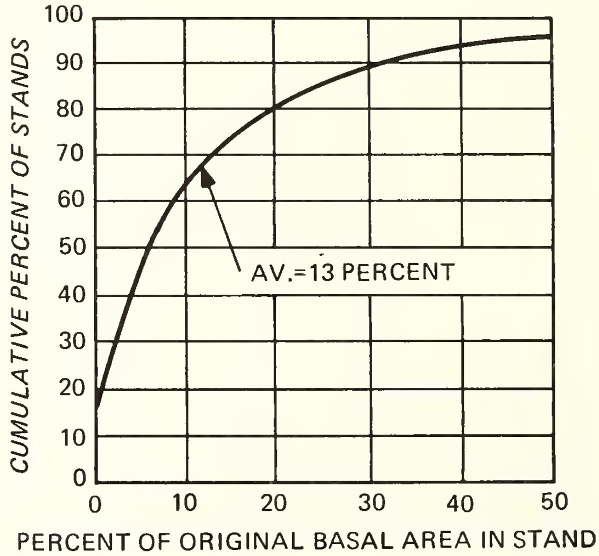
1b

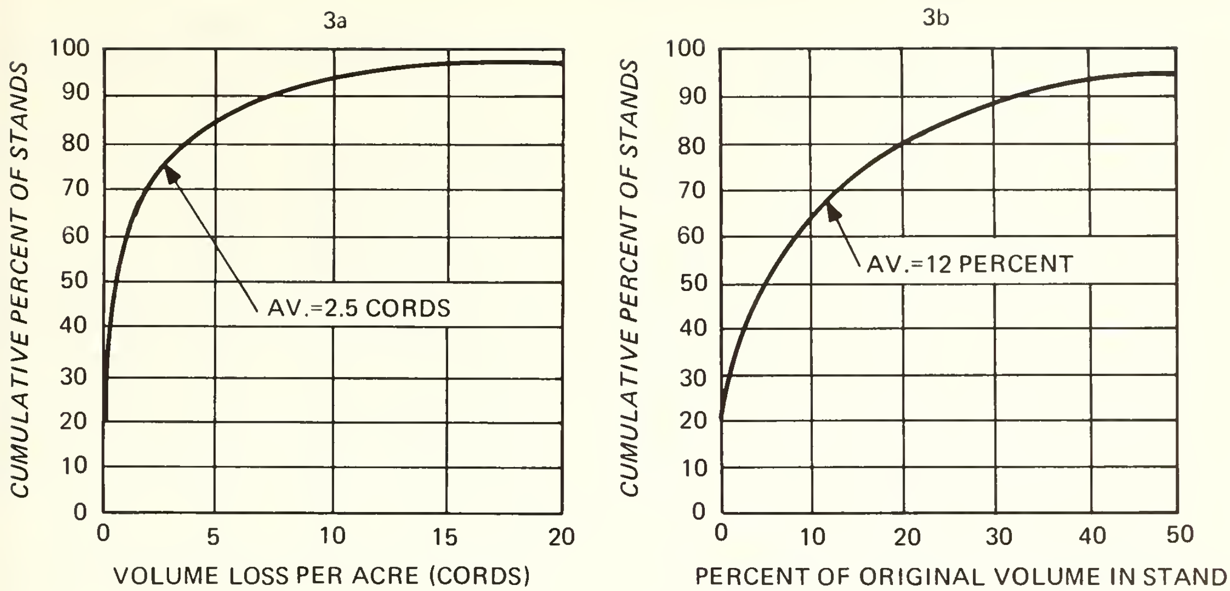


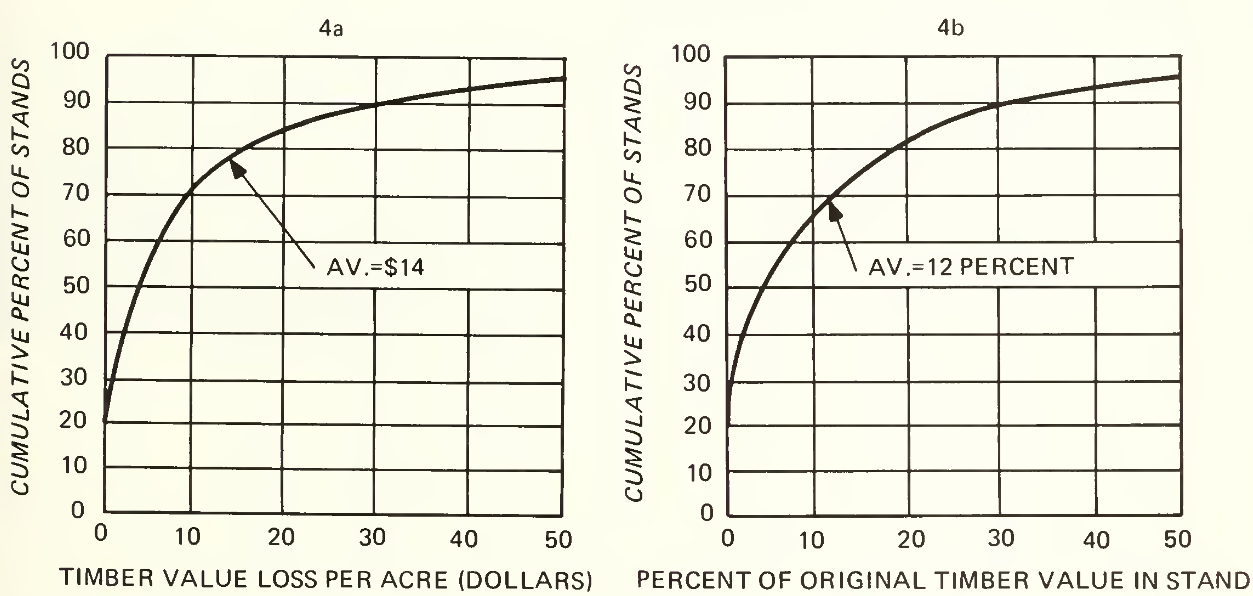
2a



2b




3a
CUMULATIVE PERCENT OF STANDS
100
90
80
70
60
50
40
30
20
10
0
0
5
10
15
20
AV.=2.5 CORDS
VOLUME LOSS PER ACRE (CORDS)
3b
CUMULATIVE PERCENT OF STANDS
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
AV.=12 PERCENT
PERCENT OF ORIGINAL VOLUME IN STAND


4a
CUMULATIVE PERCENT OF STANDS
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
AV.=$14
TIMBER VALUE LOSS PER ACRE (DOLLARS)
4b
CUMULATIVE PERCENT OF STANDS
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
AV.=12 PERCENT
PERCENT OF ORIGINAL TIMBER VALUE IN STAND

of the losses recorded through 1976 accumulated from 1972 through 1974.

Selected plot variables provide a general description of the infested stands in 1971:

	Mean	Range
Basal area per acre (ft^2)	95	35–180
Percent of basal area in oak	56	0–100
Average dbh (inch)	7.0	4.7–10.8
Stand age (yr)	68	25–105
Site index (ft, upland oaks)	59	30–80
Elevation (ft)	1190	620–1560
Standing timber value per acre ($)	132	20–840

Conversion standards developed by Mendel and his coworkers (1976) were used to estimate the value of timber lost on each plot. These value standards incorporate species, dbh, butt log grade, and merchantable height for each tree.

RESULTS

Forest stand losses were summarized by number of trees, basal area, timber volume, and value from 1972 through 1976 (Figs. 1a-4b). It is immediately obvious that losses, however expressed, were not uniformly distributed among the plots. A small percentage of the infested stands incurred major losses while a large percentage of the stands incurred minor losses (that is, the distribution is skewed). For example, volume losses over the 5-year period averaged 2.5 cords per acre (Fig. 3a). But 75 percent of the stands lost less than 2.5 cords per acre, 20 percent of the stands incurred no losses at all, and only 5 percent of the stands lost more than 10 cords per acre. Volume losses averaged 12 percent of total original stand volume (Fig. 3b). But 65 percent of the stands lost less than one-tenth of their volume and only 5 percent of the stands lost more than one-half of their volume.

The frequency distributions of stand losses are highly skewed. In a skewed distribution, the median (the value that divides the range of values into two equal parts) helps describe the "typical situation." Medians for the 5-year stand losses are:

30 trees per acre (10 percent of the original stand of trees)

6 ft^2 of basal area per acre (7 percent of the original basal area)

1 cord per acre (4 percent of the original volume)

$4 per acre (4 percent of the original value)

DISCUSSION

Knowing how much and what kind of damage to expect from gypsy moth outbreaks is a must for planners of cost-effective control programs. One 5-year case study of forest stand losses in the Poconos will not provide reliable and specific answers to all the questions about impacts of the insect. But it does give us fresh perspective on what, in general, to expect.

Only a small percentage of infested stands suffered major losses. This finding holds important implications for people whose job is to make cost-effective decisions about control. Suppose, for example, that effective gypsy moth control in infested stands required three successive annual treatments, each costing $10 per acre—that is, a total outlay of $30 per acre. Our analysis indicates that without treatment, 90 percent of the infested stands would suffer timber value losses of less than $30 per acre. So, from the standpoint of timber value saved, the cost of treatment would be justified on only 10 percent of the infested stands (Fig. 5).

Of course, decisions on gypsy moth control are based on more than the value of timber losses. Moreover, an operational decisionmaking model must be able to help us determine not only how many forest stands to protect, but also *which ones*. And it must be able to provide this information before an insect attack. From the Pocono data, techniques have been developed for predicting forest stand losses attributed to the gypsy moth (Gansner et al. 1978; Herrick et al. 1979). They can be used to estimate losses from easy-to-measure key characteristics of stand condition. We are working with the Northeastern Area State and Private Forestry's Forest Insect and Disease Management staff to install a system of field plots in Pennsylvania and adjacent states in advance of gypsy moth outbreaks. These plots will be used to monitor

Figure 5.—One of the big losers. Three-fourths of the timber volume in this stand was lost to gypsy moth.

the impacts of the insects as they spread to new frontiers of forest vegetation, and will also provide data needed to test and improve techniques for predicting and evaluating damages.

ACKNOWLEDGMENTS

Our thanks to personnel of "The Expanded Gypsy Moth Research and Development Program" and the Forest Insect and Disease Management staff, Northeastern Area State and Private Forestry, U.S. Department of Agriculture, Forest Service. Their support in collecting and analyzing data made this study possible.

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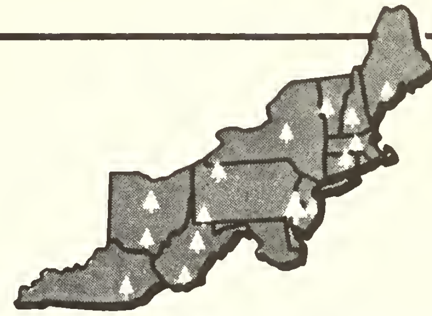

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GROWTH RESPONSE TO FERTILIZER IN A YOUNG ASPEN-BIRCH STAND

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Abstract

A thinned aspen-birch-red maple stand was fertilized with N, P, and N plus P, both with and without lime (L). Overall, treatments with N increased height growth by an average of 79 percent, and volume growth by 69 percent, over treatments without N. Lime tended to increase both average height and volume growth over each corresponding treatment without lime. The amount of growth response and the treatment that produced the greatest response differed among species. Bigtooth aspen and paper birch generally responded better than quaking aspen and red maple. Bigtooth aspen and paper birch responded strongly to N and combinations of N and P. Bigtooth aspen was the only species to respond significantly to P alone. Bigtooth aspen trees treated with NP and L grew nearly seven times as much in volume as the control trees. The volume growth of paper birch treated with NL was nearly twice that of the control. Depending on the duration of these growth responses, fertilizer treatment should substantially reduce the time required to produce merchantable size trees, particularly of bigtooth aspen and paper birch. The lesser response by quaking aspen and red maple suggests that fertilization of these species may not be practical.

INTRODUCTION

The study area is in Washington County, Maine in a young stand that originated after a fire that followed the harvest of a spruce-fir forest in 1952.

The area is gently rolling, and the soils are strongly acid Spodsols that developed from glacial till derived from granitic rocks. The soils are tentatively classified as sandy, mixed, frigid Typic Haplorthods on well-drained ridges and knolls, and as sandy, mixed, frigid Aquic Haplorthods on moderately well-drained depressions. The soils are marginal in fertility.

By 1973, the stand included a dense overstory of aspen (*Populus tremuloides* Michx. and *P. grandidentata* Michx.), paper birch (*Betula papyrifera* March.), gray birch (*B. populifolia* Marsh.), and red maple (*Acer rubrum* L.) along with an understory of widely spaced red spruce (*Picea rubens* Sarg.), balsam fir (*Abies balsamea* (L.) Mill.), and white pine (*Pinus strobus* L.). In the summer of 1973, the hardwood overstory was hand-thinned, which left a uniformly spaced stand of approximately 1,500 stems per ha of aspen and paper birch with an understory of spruce-fir. Stand characteristics after thinning are given in Table 1.

In 1974 we established a study to determine if the aspen-birch-red maple stand would respond to treatments with lime, nitrogen, and phosphorus applied singly and in combination. This paper reports the first 3-year growth response to the nutrient treatments.

THE STUDY

Twenty-four 20 by 20-m plots with 7-m wide isolation strips were established. Because of the nature of the landscape, some plots fell on well-drained soils, some on moderately well-drained soils, and some plots had both. Treatments were randomly assigned among plots.

The treatments were:

C = Control

L = Lime, 4,480 kg per ha; 100 percent $CaCO_3$ equivalent as ground limestone. It contained 1,749 kg Ca and 27 kg Mg per ha.

N = Nitrogen, 448 kg per ha of elemental N, as 46-0-0 urea.

P = Phosphorus, 112 kg per ha of elemental P as 0-20-0 triple superphosphate. (In addition to P, the fertilizer contained 12 percent Ca.)

And all combinations of L, N, and P for a total of eight treatments replicated three times.

Lime was broadcast by hand on the soil surface in the fall of 1974. Phosphorus and one-half of the nitrogen were broadcast in June 1975; the remaining nitrogen was added in August 1975.

Table 1. Characteristics of a 15-year old aspen-birch spruce-fir stand before fertilization (average of three replications)

Species	Stand characteristics							
	Trees/ha		Height	Dbh	Basal area/ha		Volume/ha	
	No.	*%*	*m*	*cm*	*m²*	*%*	*m³*	*%*
Bigtooth aspen	618	31	7.5	7.1	2.4	49	9.1	52
Quaking aspen	457	22	6.9	6.4	1.5	29	5.1	29
Paper birch	316	15	5.9	5.3	0.7	14	2.2	13
Red maple	121	6	6.6	5.6	0.3	6	0.9	5
Total or average	1,512	74[a]	6.7	6.4	4.9	98[a]	17.3	99[a]

[a] Balance in softwood species

Metric conversions: No./ha × .405 = No./acre; m × 3.28 = feet; cm × .394 = inches; m^2/ha × 4.4 = ft^2/acre; m^3/ha × 14.3 = ft^3/acre; m^3/ha × .2 = cord/acre

Tree measurements

All trees 1.3 cm in diameter at breast height and larger were numbered. Heights and dbh were measured and recorded for each of the species on each of the plots. The basal area and volume were calculated for each of the species on each of the plots before fertilization (1974) and annually from 1974 to 1977. Plot volume (M^3/ha) was one-half the average basal area times the average height for each species.

Statistical analyses

Height growth was analyzed as an incomplete factorial model with three factors: lime, fertilizer, and species. Even though the initial stocking varied among the species (Table 1), it was not a significant covariate with the height growth.

A preliminary analysis of volume growth showed significant effects of species, fertilizer, and fertilizer times species interaction. The species effects were due to differences in initial stocking. So initial stocking was used as a covariate with fertilizer, lime, and species as factors in an analysis of covariance, and the mean volume growth by species and treatment was adjusted to a common initial volume. The differences among adjusted mean volume growth of each treatment and the control were tested by least significant differences technique. Analysis of covariance showed that fertilizer effects and species times fertilizer interaction were highly significant.

RESULTS AND DISCUSSION

Height growth

N fertilizer significantly affected height growth. For every species except quaking aspen, height growth for at least one N treatment was significantly greater than for the control (Fig. 1). Bigtooth aspen showed the most consistent response to N. Every N treatment produced a greater response than every non-N treatment. Paper birch on plots treated with NL and NP grew more in height than it did on every non-N treated plot. The height growth response of red maple was less well defined, but the NL and NP treatments produced the greatest growth, as they did for paper birch (Fig. 1).

Height growth for all species combined followed the general pattern of the individual species, i.e., the growth of trees on N-treated plots was significantly greater than that of the trees on the non-N plots (Fig. 2). There was a consistent trend of increased height growth for each L treatment above the same non-L treatment: L>C; LP>P, NL>N, etc., but the main effect for L was not significant in the analysis of variance. Because of the slow availability of lime, its effect on height growth may increase over time, which could be determined by later measurements. The tendency of species to differ in response to lime also needs closer examination. Additional data, particularly of foliar levels of Ca and Mg, may reveal species differences in the use of the surface-applied lime.

Volume growth

Analysis of variance of volume growth showed a highly significant fertilizer treatment times species interaction. This indicates that the fertilizer and lime treatments did not effect the same volume growth response for each of the species. Bigtooth aspen and paper birch responded strongly, with several treatments resulting in faster growth than the control. Quaking aspen and red maple responded less, with growth for only one treatment for each species significantly greater than the control (Fig. 3).

Bigtooth aspen responded strongly to all fertilizer treatments. Every treatment except L applied singly resulted in significantly more growth than the control. When fertilized with NP and L, this species grew almost seven times as fast as the control trees—substantially more than any other species in all treatment combinations (Fig. 3). The average volume growth for all N treatments was nearly three times the average volume growth for non-N treatments. Volume growth of bigtooth aspen treated with P and P plus L was more than two times control—the only case where P alone significantly increased growth.

Paper birch was the second most responsive species. It clearly responded to N in volume growth (Fig. 3). The average growth for all N treatments was 71 percent greater than

Figure 1.—Three-year height growth by fertilizer-lime treatments and species. Solid bars are significantly greater than the control at .05 level or greater.

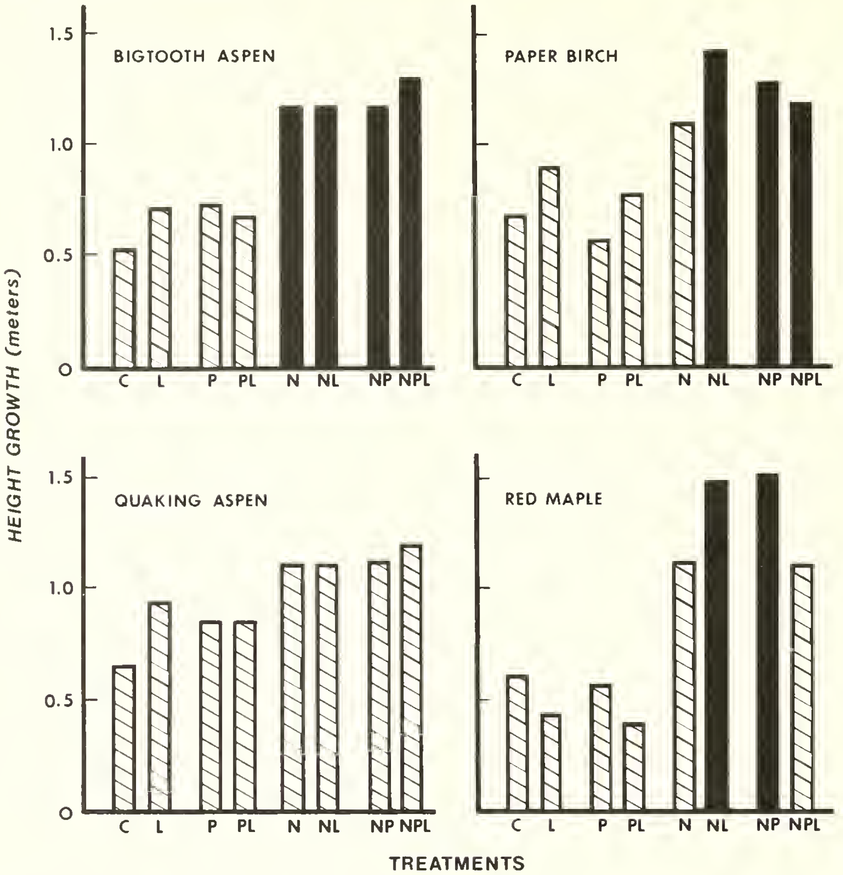
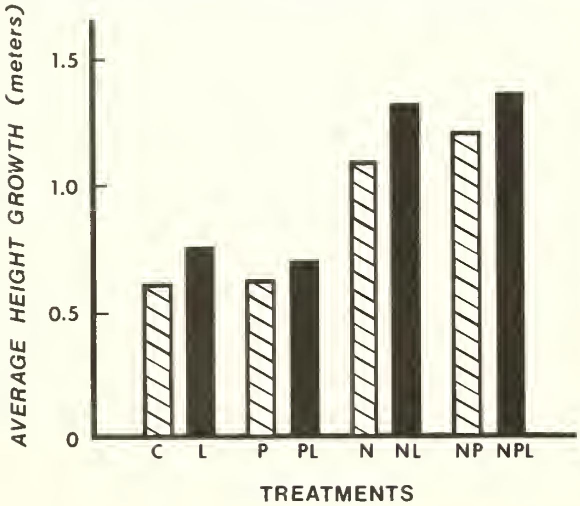


Figure 2.—Average 3-year height growth for all species, by fertilizer-lime treatments.

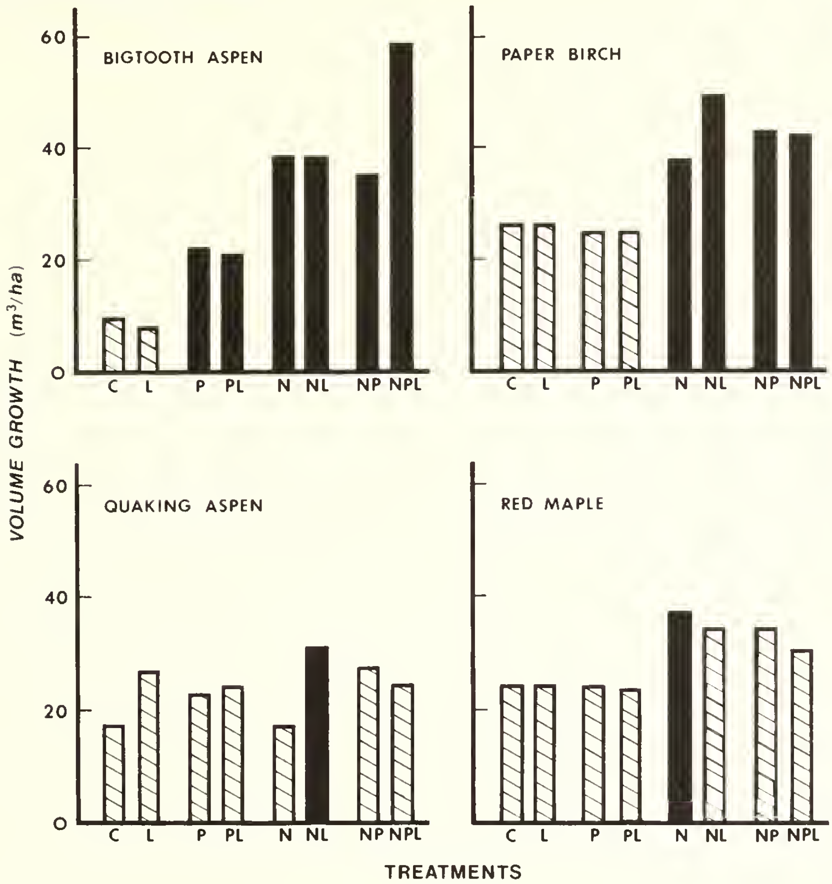


that for the non-N treatments. The best treatment, N plus L, resulted in nearly twice the growth of the control trees.

Red maple also generally responded to N rather than the non-N treatments, but L and P tended to depress growth so that the NL, NP, and NPL treatments were not significantly different from the control (Fig. 3). For this species, the lack of significant differences may result from high variation associated with the small amount of red-maple on the plots (Table 1).

Quaking aspen, which is often combined with bigtooth aspen in silvicultural considerations, responded the least consistently of any species to the fertilizer treatments (Fig. 3). The N plus L treatment was the only one that resulted in significantly greater volume

Figure 3.—Three-year volume growth by fertilizer-lime treatments and species. Solid bars are significantly greater than the control at .05 level or greater.

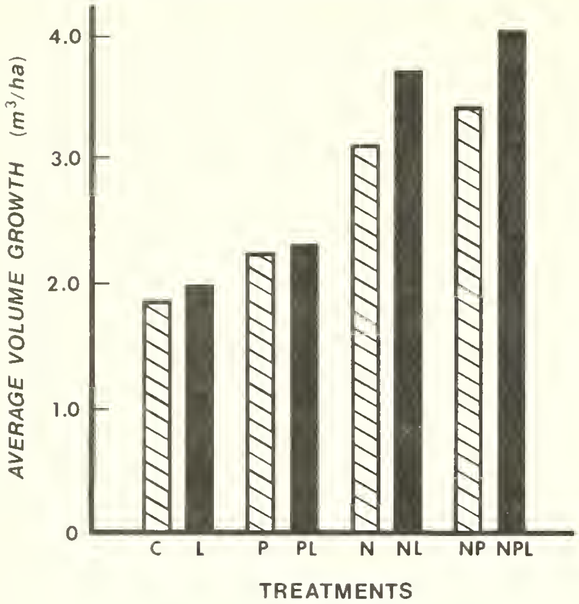


growth than the control. The average volume growth for all N treatments was only 15 percent greater than for non-N treatments—the smallest increase for any of the species. Quaking aspen did show the most consistent and greatest trend of increased volume growth in response to lime. This was the only case where L applied singly appeared to stimulate growth, and the average growth for all L treatments was 28 percent greater than the average for all non-L treatments. This result is consistent with the evidence that quaking aspen requires a high base status for good growth (Voigt et al. 1957), which might indicate that a higher base status is necessary for quaking aspen to take advantage of the supplemental N and P.

The average volume growth for all species reflected the same general trend as did height growth (Fig. 4). The main response was to N, but the response to each fertilizer treatment plus L tended to be greater than to the same treatment without L, and P>C, N>P, and NP>N. NPL, the best treatment, resulted in more than twice the volume growth of the control, which was the poorest treatment. The average volume growth for N-treated plots was 14.4 m^3/ha versus 8.5 m^3/ha for that of the non-N treatments, an increase in growth of almost 70 percent during the first 3 years after fertilization.

The apparent positive effect of lime probably results from the increased supply of bases that are critically low in these acid till soils (Hoyle 1969). Surface application does not realize the full potential of the lime, but as time passes, and as tree roots develop, the Ca and Mg from the lime will move deeper into the soil (Safford 1974). This deeper rooting and consequent increase in volume of the soil accessibly to the trees

Figure 4.—Average 3-year volume growth for all species, by fertilizer-lime treatments.



should also lead to additional supplies of moisture and nutrients.

The general response of this mixed stand to fertilizer in 3 years indicates a potential for substantially reducing rotation length by providing additional plant nutrients. Some species—bigtooth aspen and paper birch—clearly benefit from N and perhaps P and L as well. The case of quaking aspen and red maple is less well defined, but each of the species responded significantly to one of the treatments. It is obvious that we must observe the growth for a longer time to determine the duration of the growth response and whether additional effects of the surface-applied fertilizers will develop. It appears that stands of mostly quaking aspen or red maple would show less volume growth as a result of fertilization than the stands of bigtooth aspen. Fertilized stands of mostly paper birch should be intermediate in increased volume growth.

CONCLUSIONS

1. Three-year height growth of sapling northern hardwood species can be increased by N fertilizer.
2. Additional height growth may be attained with lime treatment.
3. Three-year volume growth of pioneer northern hardwoods differed among species and among fertilizer treatments within species.

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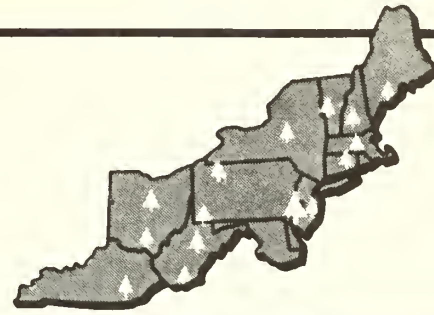

FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE, 370 REED ROAD, BROOMALL, PA. 19008

TREE GRADE DISTRIBUTION IN ALLEGHENY HARDWOODS

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Abstract. Estimates of the distribution of tree grades by diameter class were developed for six hardwood species on the Allegheny Plateau. These estimates can be used to calculate present and projected stand values when actual tree grade measurements are not available.

INTRODUCTION

From information developed as part of a series of financial maturity studies in northeastern hardwoods it is possible to calculate the value of a stand if one has data on the numbers of trees by species, diameter at breast height (dbh), merchantable height, and tree grade. (DeBald and Mendel 1976a; Mendel et al.; DeBald and Mendel 1976b; Grisez and Mendel 1972). Unfortunately, information on tree grade often is not included in data collected during stand inventories, or in data developed from yield tables or stand growth simulators.

However, if tree grade, which is an indicator of suitability for various wood products, can be correlated with size class for each species, estimates of stand quality and value can be made for typical stands where specific tree grade data is unavailable. We collected data to develop empirical tree grade distributions by dbh and species for typical cherry-maple stands on the Allegheny Plateau.

METHODS

Empirical grade distributions were derived from summaries of data on species, diameter, and tree grade. Two sources were used: timber sale cruise data from the four districts on the Allegheny National Forest, and data from complete inventories of seven sample stands.

The timber sale data consisted of information on species, dbh, and tree grade for about 12,500 trees, all of which were grade 3 or better; trees that were not at least grade 3 were not recorded. These data were from systematic samples of trees to be included in clearcutting sales over a 3-year period. We used grading rules described by Hanks (1971).

Because the first data set included only trees that were grade 3 or better, we used a second set so that we could calculate the probability of a tree of a given species and diameter being at least grade 3. This second data set was collected from complete inventories of seven additional cherry-maple stands. A total of 3,650 trees greater than 10 inches in dbh were recorded by species and dbh, and each tree was classified as grade 3 and better or less than grade 3. Thus, the two data sets provided a means of calculating—for each diameter class and species—the probability of a tree being grade 1 or 2 or 3.

Each of these probabilities were plotted separately as a function of diameter for each species. Species with similar distributions were grouped. These groups were: (1) black cherry and yellow-poplar; (2) sugar maple and red maple, (3) beech and birch.

Three regression equations were developed for each species group. Each equation related diameter to: (1) The proportion of trees grade 3 and better: (2) The proportion of grade 3 and better trees that were grade 1: and (3) The proportion of grade 3 and better trees that were grade 3. The proportion of grade 3 and better trees that were grade 2 was obtained by subtracting the values for equations 2 and 3 from equation 1.

Predicted values derived from these equations were tabulated and plotted for each species group.

RESULTS

The regression statistics for tree grade distribution and the diameter range over which these equations are valid are shown in Tables 1-3. The lower limit is the minimum dbh requirement for a particular grade. The upper

Table 1.—Regression statistics for dependent variable of percent of trees grade 3 or better.

Species	Regression Equation	R^2	Range in Diameter
			inches
Black cherry and yellow-poplar	$135.5 - 806.5D^{-1}$	73	10-22
Sugar maple and red maple	$140.9 - 1083.5D^{-1}$	84	10.22
Beech and birch	$111.9 - 980.2D^{-1}$	87	10-22

Table 2.—Regression statistics for dependent variable of percent of grade 3 or better trees in grade 1.

Species	Regression Equation	R^2	Range in Diameter
			inches
Black cherry and yellow-poplar	$127.8 - 839.7D^{-1}$	65	16-26
Sugar maple and red maple	$157.8 - 1777D^{-1}$	77	16-26
Beech and birch	$178.4 - 2408.3D^{-1}$	84	16-26

Table 3.—Regression statistics for the dependent variable of percent of grade 3 or better trees in grade 3.

Species	Regression Equation	R^2	Range in Diameter
			inches
Black cherry and yellow-poplar	$-17.4 + 431.6D^{-1}$	62	13-23
Sugar maple and red maple	$-31.8 + 755.9D^{-1}$	64	13-22
Beech and birch	$-42.5 + 896.6D^{-1}$	32	13-20

limit represents the upper limits of the data. Extrapolating beyond this upper limit gives unreasonable results; predictions beyond the upper limit are made by assuming the same value as that at the upper diameter limit.

Tree grade is dependent on two major factors: tree size (diameter), and the presence of grade stoppers such as limbs, knots, decay, sweep, and crook. Tree size alone is a major determinant of grade—a large percentage of the trees qualify for the next higher grade as soon as they reach the minimum diameter. For example, more than 60 percent of the black cherry and yellow-poplar trees that we examined qualified for grades 1, 2, or 3 when they reached the minimum diameter for those grades. This effect of diameter thresholds used in defining grade is evident in Figures 1 to 3.

However, species differed considerably in the extent to which diameter alone determines grade. Only 15 to 25 percent of the beech and birch qualified for the next higher grade when they reached the minimum diameter. Thus, grade stoppers are more common in the latter species and more often limit grade after minimum diameter has been attained.

The importance of grade stoppers in beech and birch also is evident in data for trees of large size—well beyond minimum diameter for grade 1 and at or near economic maturity. For example, less than half of the 23-inch beech and birch qualified for grade 1; but more than 90 percent of the black cherry and yellow-poplar qualified at that size.

The numbers of grade stoppers in individual stands may vary widely due to factors such as density, snow bending, ice breakage, insect or disease attack, and site conditions. So the grade distributions reported here represent average values that one might expect in typical stands—and the values may be in considerable error for an individual stand. Thus, these estimates of grade distribution are not intended to replace tree grading but are to be used as a management planning tool.

These data were collected, and will apply most accurately, in second-growth cherry-

Figure 1—Grade distribution for black cherry/yellow-poplar group.

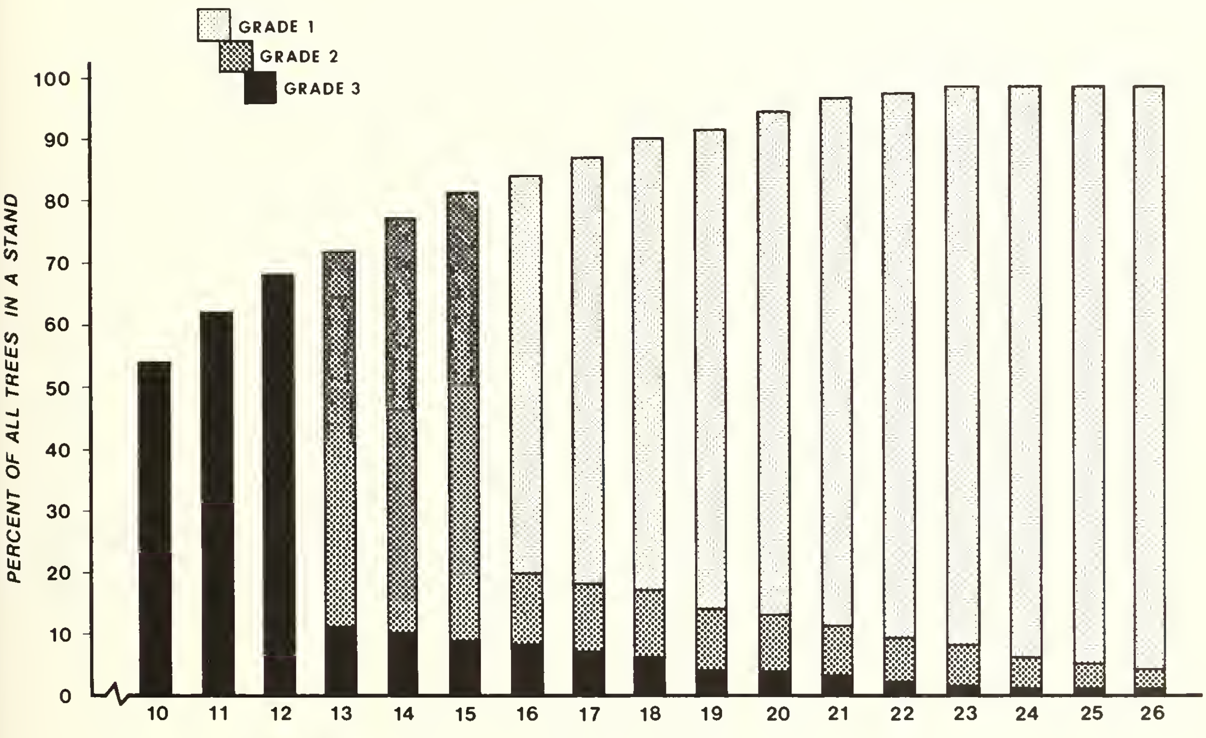


Figure 2—Grade distribution for red maple/sugar maple group.

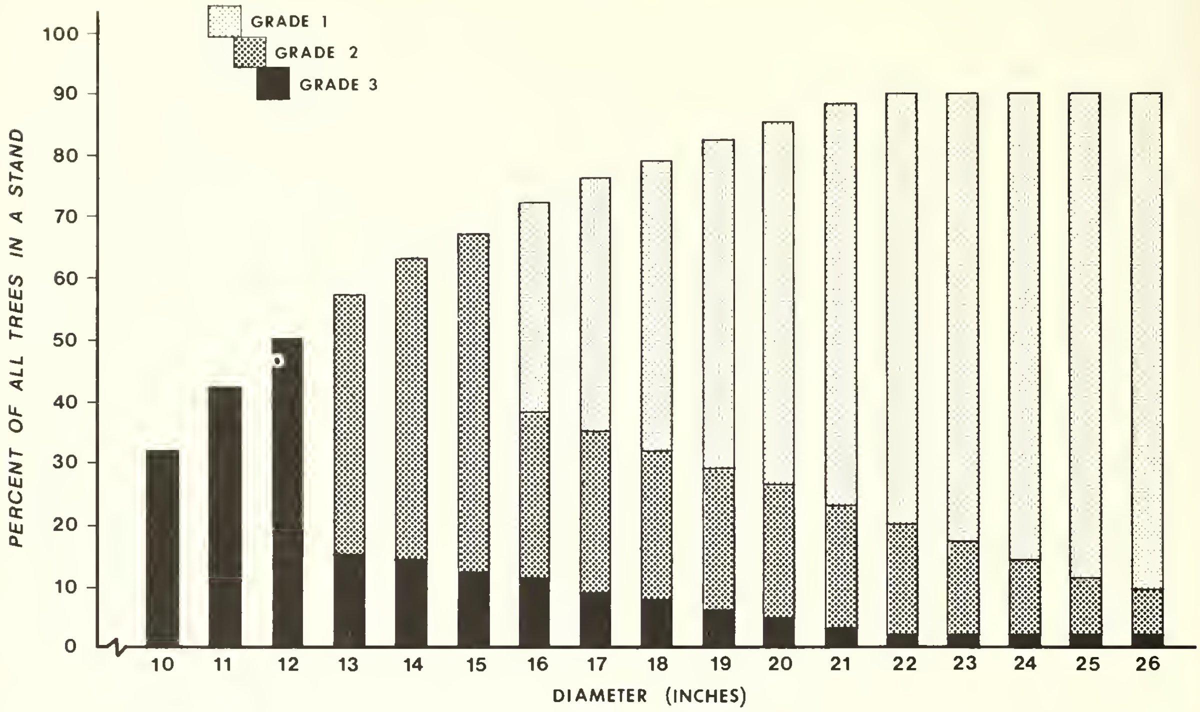
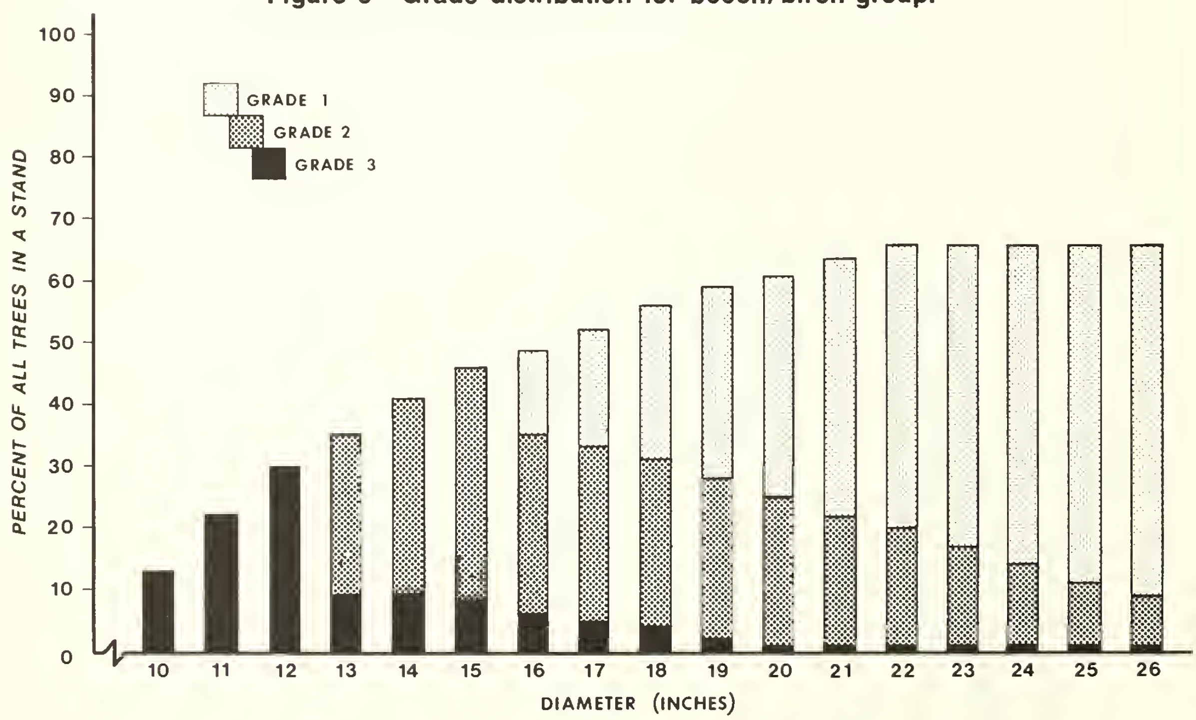


Figure 3—Grade distribution for beech/birch group.



maple stands on the Allegheny Plateau of northwestern Pennsylvania—stands that were uncut or had been thinned one time. Grade distribution is likely to be substantially different in stands that have been under intensive management over a long period, or that have been high-graded.

Despite these limitations, the data are useful for estimating stand value for typical stands where specific grade information is lacking. They can be used to estimate the financial maturity of typical stands or to evaluate short-term value changes that might be expected from several cutting strategies in typical stands.

Stand values may be calculated from stand table data by proportioning the trees in each species-dbh class into grades. Tree value conversion standards (Mendel et al. 1976) can then be applied to derive a value for the entire stand.

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FACTORS AFFECTING DISPERSION OF BACKCOUNTRY CAMPSITES

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Abstract. A study using observational and survey techniques found that no backcountry users fully complied with rules designed to promote campsite dispersion and to avoid recurrent use of particular sites. Users perceived hiking/camping in general, and movement away from established trails in particular, as involving an element of risk. They indicated that convenience was an important determinant of their site selections. Increased information about the rules did not decrease the use of previously used sites, but did increase the average distance of chosen campsites from established trails.

Our interest in backcountry campsite selection stems from a concern with the issue of camper dispersion in these areas. There appears to be a substantial contradiction between the frequently expressed desire of hikers for solitude and their selections of overnight camping sites. According to studies by Lucas (1964), Stankey (1973), and Lime (1975) wilderness users say they want an uncrowded camping experience, but they often select campsites that are very close to maintained trails or to other campers and which show signs of heavy previous use.

Use of such sites creates problems where human impact on the environment is to be kept to a minimum, as in fragile ecosystems or where management regimes are designed to maintain the pristine quality of the area and provide uncrowded backcountry experiences.

The objectives of this study were to (1) document the nature and the pattern of campsite use in a representative area where minimal human impact was a goal explicitly communicated to users; (2) investigate the role in campsite selection of the risks perceived in camping away from the trail, the sources and types of information received regarding site selection in the study area, and the physical characteristics of the selected area; and (3) assess the effects of disseminating supplementary information about what was expected of campers in backcountry areas. In addition, the use of a sign at a heavily impacted site to deter its continued use was examined.

STUDY AREA

The Great Gulf Wilderness Area in the White Mountain National Forest of northern New Hampshire is a 5500-acre tract, bounded on the south by the Mount Washington Auto Road, on the west and north by the northern Presidential Range, and on the east by the Osgood Trail. It is heavily used by backcountry recreationists during the summer.

Permits have been required of both day and overnight hikers in the Great Gulf since the summer of 1975. Day use is unlimited, but overnight camping is restricted to a maximum of 60 persons.

The area is managed to provide a wilderness experience. To disperse use and help prevent further deterioration of campsites, rules issued with all permits prohibit camping within 200 feet of trails and streams or within ¼-mile of any other camper and ask campers not to camp at sites that show clear signs of previous use.

A 1¼-mile section of one of the major trails in this wilderness area was selected for study because it provided opportunities for dispersal and had several sites that had been eroded and compacted as a result of excessive use (Fig. 1). The surrounding area was in many

Figure 1.—One of the overnight sites selected for study.

Figure 2.—Typical trail segment in the study area.

respects a typical Eastern glaciated mountain slope. The trail paralleled a stream and the general setting was moderately to heavily wooded with occasional rock outcroppings (Fig. 2). Terrain factors notwithstanding, sites that complied with the rules were plentiful, though perhaps not obvious to a neophyte camper.

METHOD

The most common techniques for surveying backcountry users on site have been to wait at an access point or roam at random through the study area to contact hikers or campers (Lucas and Oltman 1971). Mailed questionnaires have also been used to gather data. Each of these techniques, if carried out with appropriate care, should produce results unaffected by sampling error or artifact if the sample of users who are contacted is representative of the total population of users. Ensuring this is often difficult so this investigation sought to interview *all* persons found within the study area in the maximum use period of July and August 1976. To accomplish this, a "sweep" was made of the study area each late afternoon or early evening and all persons encountered were asked to answer the brief (25-item) questionnaire. Some users could have been missed, but the small size of the study area, the general topography, and morning checks for those who entered after dark minimized that possibility.

When an occupied campsite was found, a number of observations were made, including the number, sex, and estimated age of party members, and whether the site was one the party had prepared themselves, or was one of the several used sites that had been identified in the study area. Approximate distance from the trail was paced off and the location of any other nearby campers was recorded.

RESULTS

A total of 164 campers found in 73 different groups were interviewed. All persons and groups sighted during the study period were contacted and none refused to participate. The respondents, though young (60 percent were 15 to 25 years of age), were in general relatively experienced. Two-thirds of them had camped in the White Mountains before, and 42 percent indicated that they had previously spent a night on the trail under study. Fifty-six percent reported camping or hiking on five or more occasions per year. Only 5 percent of those contacted were camping alone, while 47 percent were in two-person groups, and 19 percent were in three-person groups. The persons encountered were found in primarily mixed-sex (51 percent), or all-male groups (44 percent).

The original intent of the research was to compare the characteristics of campers who did comply with the area rules by dispersing appropriately and by avoiding used sites with the attributes of those who did not comply. Unexpectedly, this was not possible because *none* of the campers encountered during the 2-month study period had established campsites that met all three criteria for a dispersed site: location 200 feet away from a trail or water source, and ¼-mile from other campers, and not showing obvious signs of prior use. Ninety-five percent of the sites selected showed clear signs of previous use, such as the absence of surface vegetation or normal groundcover, compacted and/or eroded soil, stone fire rings, and downed logs for seats or firewood. In fact, six of the most heavily impacted sites received 81 percent of the observed use during the study period (see Fig. 3). In addition, the average distance from a trail for all campsites studied was only 147 feet. Since we were not able to analyze differences between compliance groups, the data reported below represent summaries for the total sample.

Perceived risks

Ninety-five percent of the respondents said they believed that there is greater risk in camping and hiking off the trails than on or near them; 82 percent felt that fewer people would get lost in backcountry areas if only experienced campers ventured away from the established trails.

To give an indirect indication of the perceived degree of risk in entering the study area, several questions were asked about the preparations that had been made for this trip. Eighty-six percent of the respondents rated themselves as having done "much preparation," 94 percent indicated that they had first-aid materials with them, and 81 percent said that they had brought a full day's extra food supply. Although the issue of perceived risk is rather difficult to assess, the respondents' answers to these items seem to indicate that backcountry camping and hiking in general are felt to entail at least a moderate level of risk and that the level of risk is believed to increase as one moves away from an established trail system.

Convenience

Two-thirds of the respondents indicated that convenience was the main reason they had chosen their campsites. Another quarter mentioned that the information they had received had influenced their choice. The additional risk or danger that might have been perceived as being associated with the establishment of sites farther from the trail was not spontaneously mentioned.

Information

Another group of questions dealt with sources of information that might affect campsite selection. Slightly more than three-quarters of the individuals indicated that they *had* read the rule sheet that was given out with their permits. Half of the population had received additional information from acquaintances or from Forest Service personnel, either in the study area or when they got their permits.

Effects of added information

The influence that increased information might have on dispersion was also examined. During the second month of the study, campers applying for overnight permits were given, in addition to the standard rule sheet, a letter that reiterated where camping was and was not permitted, gave a brief rationale for these restrictions, and asked for cooperation in prac-

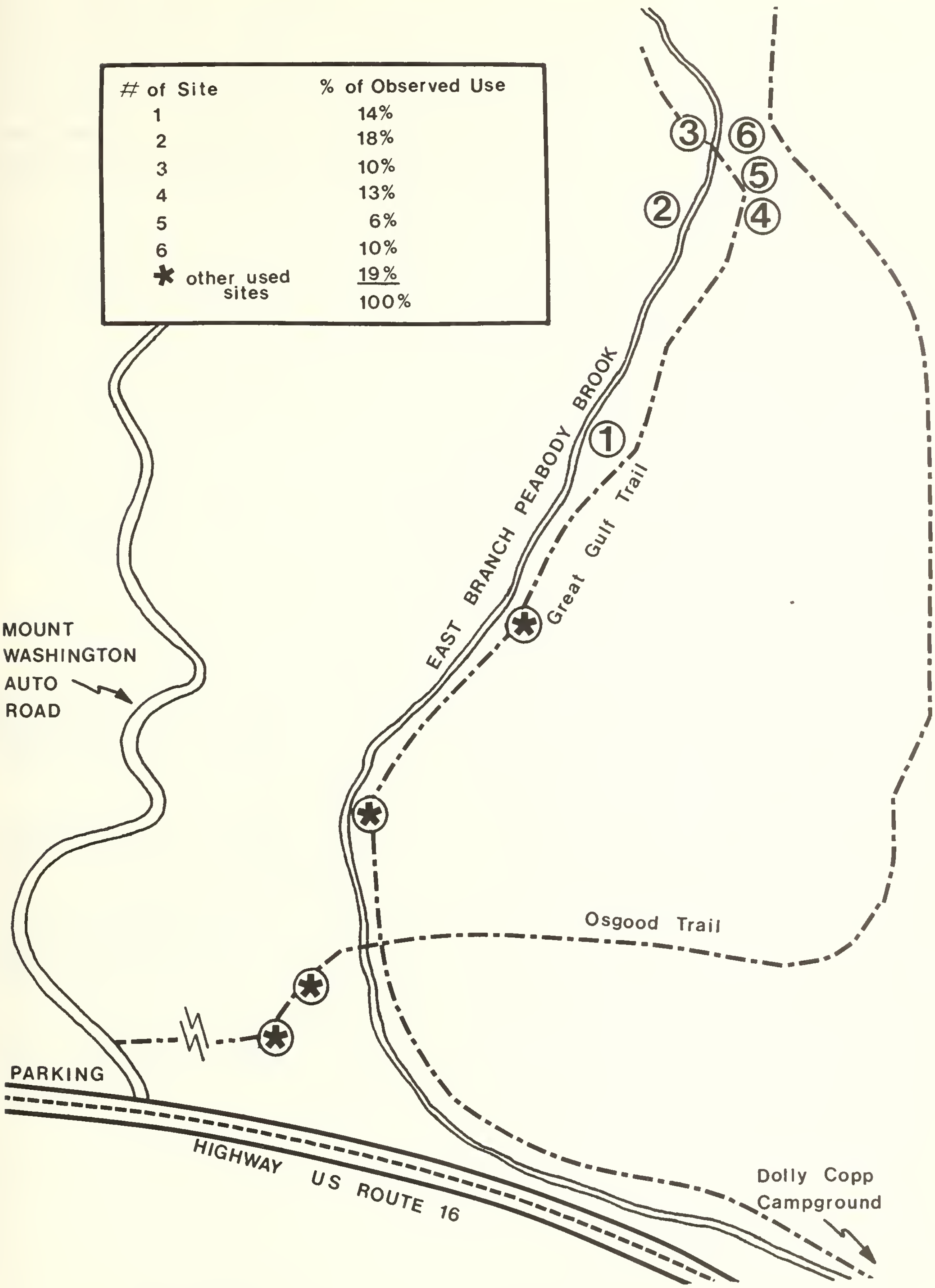

Figure 3.—Schematic map of study area and campsite locations.

ticing dispersed camping and in avoiding previously used sites. This additional information was associated with a substantial and statistically significant ($p<.01$) increase from 131 feet to 163 feet in the average distance of the campsites from the trail. However, campers continued to select *only* previously used sites, although they chose established sites farther from the trail.

A "no camping" sign was put on one site that had been used intensively during the first month of the study. This popular spot had been the location of a wooden shelter, which had been dismantled and packed out because it was inappropriate in this wilderness area. The cleared and leveled site that remained received fully 13 percent of the total use in the study area during the first month of the investigation. Once the sign was installed, however, no further use was observed, although people continued to camp in used sites nearby.

CONCLUSION

Clearly, the most dramatic outcome of this study is its documentation of the extremely strong attraction that previously used sites have for backcountry campers. Only 5 percent of the persons contacted during the 2-month study period had established new sites for themselves. Our evidence indicates that the convenience of sites with obvious signs of prior use and a strong preference for locations close to the trail promoted this behavior. Other responses from campers supported the inference that perceived risk in moving away from the trail may also have influenced site selection. The results do indicate that using a brochure to reinforce awareness of regulations and provide a rationale for them can encourage dispersion. It should be emphasized, however, that compliance with the rules regarding campsite distance from the trail appears to be only a secondary determinant of site selection. The specific effect of the added information was to induce campers to choose previously used sites farther from the trail than had been the case in the absence of such information. Campers persisted in selecting locations almost exclusively from the available *used* sites, however. Finally, signing specific sites does appear to deter campers from using them, at least where alternative sites are readily available.

It seems clear that the strong attraction previously used sites have for campers creates a problem for managers charged with dispersing campsites and maintaining areas in their natural state. This investigation suggests that most campers are unaccustomed to establishing appropriately dispersed new campsites and seldom avail themselves of opportunities to develop or practice skills in doing so. Simply publicizing rules that require them to use new, dispersed sites is unlikely to succeed. Signing specific sites and disseminating additional information on the reasons for the rules may help.

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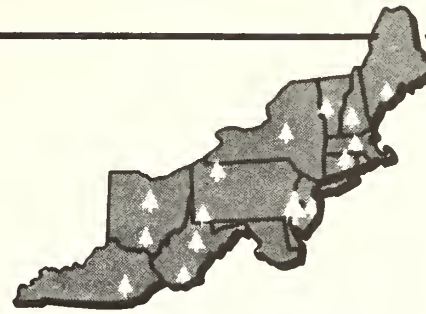

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WOOD CHIPS FOR DUST CONTROL ON SURFACE-MINE HAUL ROADS

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Abstract. On a coal haul spur road where water sprinkling was the primary method of dust control, the duration of control was increased tenfold by covering the road surface with a layer of wood chips. The chip blanket prevented existing dust-size particles from being kicked up and swept into plumes by passing traffic, insulated the road surface against evaporation and protected it from the pounding and abrasion of truck tires.

INTRODUCTION

Dust stirred up from the surface of haul roads serving coal surface mines in Appalachia has a number of disagreeable and hazardous impacts. This airborne dust is a readily visible detraction from what might otherwise be a model of mining and reclamation work. It is a hazard to health and safety. Inhalation of dust particles contributes to respiratory problems for persons who live and work near these roads. Dust plumes raised by passing vehicles often drastically reduce sight distances for drivers of approaching or following vehicles. At times, for periods of several seconds, visibility is so reduced that those drivers can hardly see beyond their own windshields. Both coal operators and regulatory agencies recognize that such conditions are undesirable and unsafe. Mine Safety and Health Administration (MSHA) regulations require that haul roads be treated to alleviate dusting conditions.

Coal haul roads may be separated into two basic groups; main routes and spur routes. Main routes generally serve several operations either simultaneously or consecutively; spur routes usually serve only one or two permits and their life is measured in weeks or months. The sub-base of both types consists of particulate materials derived from the native sandstone, siltstone, and shale strata traversed by the route. On main routes this may be topped with a base course of limestone gravel which also serves as the wearing surface. But the wearing surfaces of spur routes are particulate materials derived from whatever native strata the road penetrates. Often, substantial portions of spur routes consist of benches left by previous mine operations. In those cases mine spoil serves as the road surface material.

Dust and dust-related problems are endemic to roads in both groups. Controlling dust on coal haul roads requires continual attention, effort, and expense, and success varies widely from road to road and from hour to hour upon any given road.

The most common method of dealing with haul road dust problems is to wet the road surface from water trucks with sprinklers. Normally this method yields acceptable results. However, increases in vehicle traffic, temperature, and wind velocity, or decreases in humidity, can cause conditions to deteriorate quickly. When this happens, water trucks must make more frequent passes or apply more water with each pass. In either case, the number of miles of road that one truck can treat acceptably is reduced and more trucks are needed to properly treat the entire length of haul road. Adding to the problem is the fact that in many cases sources of water for sprinkling tend to dry up. Thus, both distance to supply and time required to take on a load of water increase, and the effective working time of a sprinkler truck is cut.

THE STUDY

In August 1978, we conducted a preliminary field investigation of the ability of wood chips to reduce airborne dust on a coal haul road. The results strongly suggest that the use of wood chips will allow a significant reduction in whatever day-to-day use of sprinkler trucks is required to control dust on surface-mine haul roads. The chip blanket acts to conserve moisture within the road surface by reducing evaporation rates. This reduces the volume of water required to be added by sprinkling. In dry periods when water supplies are low, this reduction alone might well make the difference between having and not having the ability to control dust.

But this is not the whole story. Even in periods when adequate water is available, the use of sprinkler trucks on a haul road system will be reduced, yielding greater flexibility in scheduling and an increased ability to sprinkle major haul roads where heavy, high-volume traffic may make it unwise to adulterate gravel surfaces with wood chips.

It was also noted that the chip blanket was somewhat disturbed by the partial vacuum created by fast moving coal trucks and by the pounding and abrasion of the truck tires. Where the blanket was not present, these forces were applied directly to the road surface. There, dust particles were easily swept into plumes and additional dust-size particles were developed from the road material. Where chips were present, they mitigated the formation of dust plumes and reduced the creation of new dust-size particles.

Methods and Materials

In this experiment, a segment of spur haul road in Breathitt County, Kentucky, was covered with wood chips. The road segment was approximately 100 meters long, averaged 8 meters wide, had a grade of from 0 to 3 percent, and incorporated a gentle"S" curve. The treated segment was located about 200 meters from the intersection of the spur route with the main haul road. It was bounded on each side by small berms thrown up during the grading and shaping of normal road maintenance (Fig. 1), and its surface was composed of particles derived from the siltstone, sandstone, and shale strata native to the site (Fig. 2).

The wood chips used were the result of processing whole trees—trunk, limbs, and leaves—recently cleared from a mine site. The trees were hardwoods—oaks, hickories, and gums—native to the area. They were chipped in the morning, hauled 50 miles (80.5 km) to the experimental site in a covered semi-trailer, and applied that same afternoon with a motor grader normally used in road maintenance (Fig. 3). Chips blanketed the treated road segment to a thickness of from 3 to 6 cm. Achievement of a more uniform thickness was prevented by variation in the size and shape of the chips and our desire to keep the chip layer free of contamination with scrapings from the road surface. In all, approximately 28.4 cubic meters of chips were used.

From 11:00 a.m. of the first day of observation until 12:00 noon of the second day

Figure 1.—Road segment before wood chip treatment: 11:00 a.m., first day.

Figure 2.—Material typical of road surface in and near treated segment: 11:00 a.m. on first day.

Figure 3.—Motor grader spreading wood chips into blanket covering road surface: 2:30 p.m. on first day.

a hygrothermograph continuously monitored ambient air temperature and humidity at the site. Measurements and photographs were made and samples of road surface materials and chips were taken for laboratory tests during two distinct periods: from 3:00 p.m. until 5:00 p.m. on the day the chips were applied, and from 8:00 a.m. until noon the following day.

Samples for laboratory testing, measurement, and analysis were taken at the beginning and end of each observation period. Field tests of the moisture content of the road surface material and of the chips were made at those same times, as well as at approximately 1-hour intervals during the observation periods.

Four samples of chips were randomly selected for measurement of chip length, width, and thickness. The length dimension ran with the grain of the wood. Width was the larger and thickness the smaller of the two remaining dimensions. Both width and thickness were measured at right angles to the run of the grain.

A count was made of vehicles traversing the experimental road segment during the two periods of observation. The vehicles were categorized as loaded coal trucks, empty coal trucks, or passenger/service vehicles. The speeds of coal trucks, both loaded and empty, were also measured.

Results

Moderate rain, (estimated at 0.7 cm), on the evening before the wood chips were applied and passage of the sprinkler truck 30 minutes before the chips were spread caused the moisture content of the road surface material to be relatively high at the time of chip application.

Ambient temperature and humidity at the site from 11:00 a.m. of the first day of observation until 12:00 noon of the second day are shown in Figure 4. Also shown are changes in the moisture content of the road surface material. Line A depicts temperature, line B depicts humidity, and lines C and D depict changes in road material moisture content for that portion of the road covered by chips and for adjacent sections not covered by chips respectively. Dotted portions of lines C and D depict estimated moisture content levels during the night hours when no measurements were made.

The slope of the moisture content curve (Fig. 4, line C) for the treated segment is much shallower and much less affected by ambient humidity than is the curve (Line D) that describes the moisture content of the untreated road surface. The overall moisture loss rate on untreated segments was 2.5 times that of the treated segment.

The particle size distribution of materials in the upper 40 mm of the road surface is plotted in Figure 5. Its liquid limit was 17 and its plastic limit was 11. According to the Unified Soil Classification System the road surface is a fine grained, clayey silt material of low plasticity (CL-ML).

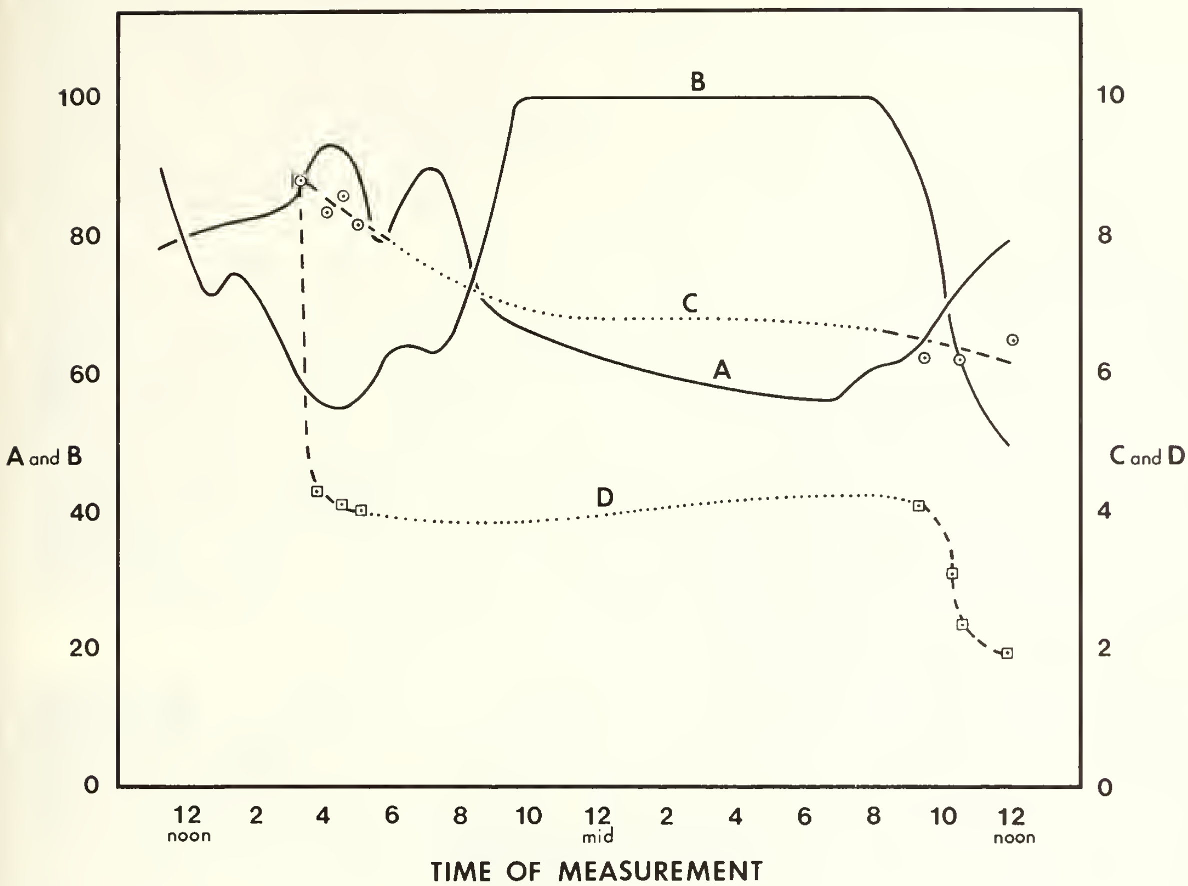
A summary of the laboratory-determined moisture contents and dimension measurements for the four chip samples is shown in Table 1.

Through both periods of observation a total of 57 loaded coal trucks, 53 empty coal trucks, and 33 passenger vehicles and service trucks traversed the experimental road segment. Average speeds of the trucks were 22 miles per hour (35 km/h), loaded and 27 miles per hour (43.5 km/h) empty.

Photographs of dust plumes stirred by passing coal trucks are shown chronologically in Figures 6 through 14 through the two observation periods. In each figure, photo A shows dust conditions on the road segment treated with wood chips and photo B depicts dust stirred up on the untreated segment. During this experiment it took 5 hours (Fig. 14, A) of traffic use and 21 hours elapsed time for dust plume density on the treated road segment to approach that which existed (Fig. 6, B) on the untreated segments after only ½ hour. When the photos in figure 14 were taken, the moisture content of the road surface on the treated segment was 6.2 percent, a level reached on untreated segments after less than half an hour.

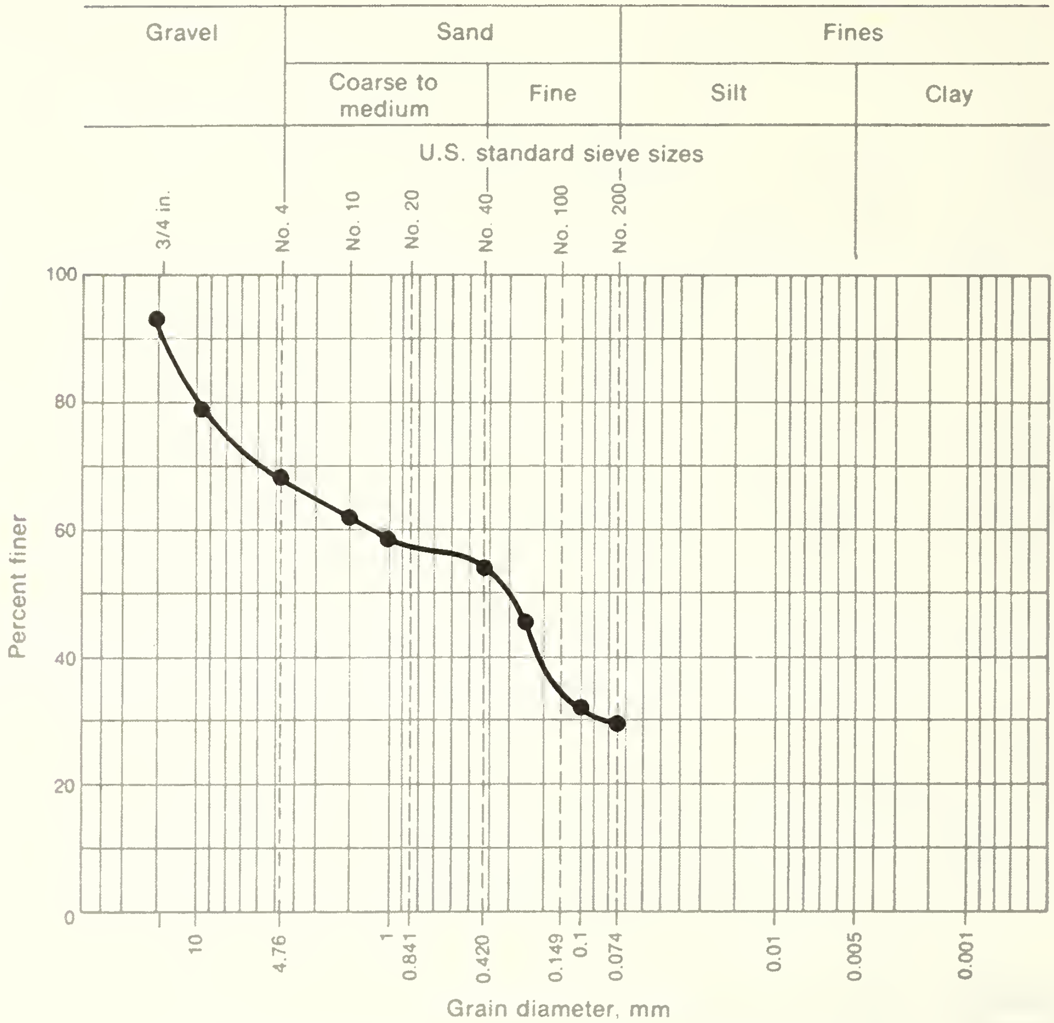
Text continued on page 16

Figure 4.—Ambient temperature and humidity and moisture content of road surface materials throughout experiment.



A—Ambient temperature (°F)
B—Ambient humidity (% saturation)
C—Moisture content of road surface beneath chips, as percent of dry weight
D—Moisture content of road surface not covered by chips, as percent of dry weight

Figure 5.—Particle size distribution of materials in the top 40 mm of road surface.



Liquid limit, 17; Plastic limit, 11; Plasticity index, 6.

Table 1. Mean (and standard deviation) of size and moisture content of wood chips

Sample taken	Length	Width	Thickness	Moisture content
		cm		%
1st day				
3:00 p.m.	2.48 (.358)	1.95 (.627)	1.01 (.136)	65.3
5:00 p.m.	2.77 (.864)	2.08 (.778)	1.02 (.212)	40.6
2nd day				
8:30 a.m.	2.60 (.864)	1.55 (.308)	0.99 (.113)	57.0
12:00 noon	2.40 (.405)	1.46 (.233)	0.97 (.105)	41.7

Figure 6.—Dust plumes at 3:30 p.m. on first day.

Figure 7.—Dust plumes at 4:00 p.m. on first day.

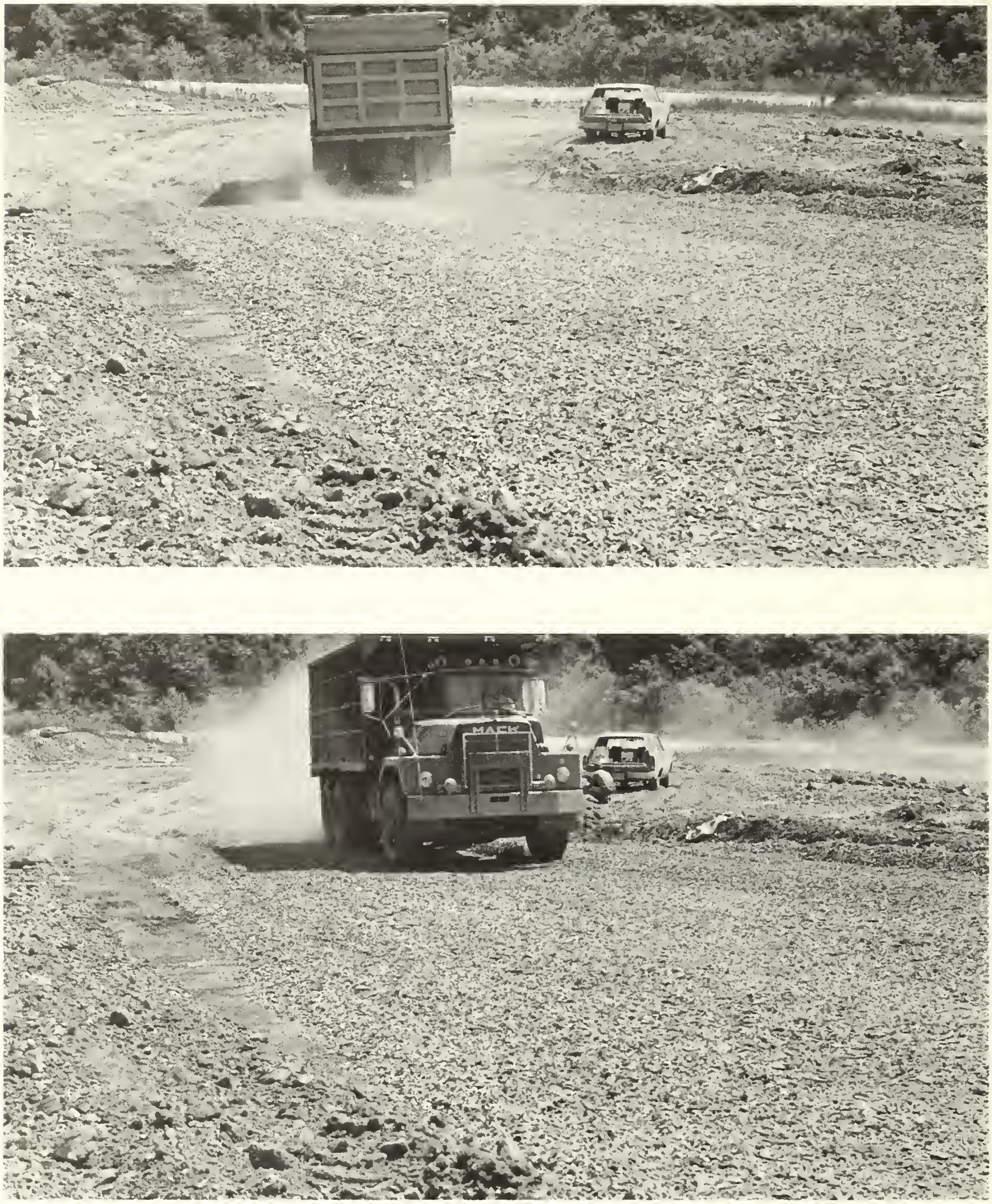


Figure 8.—Dust plumes at 4:30 p.m. on first day.

Figure 9.—Dust plumes at 9:00 a.m. on second day.

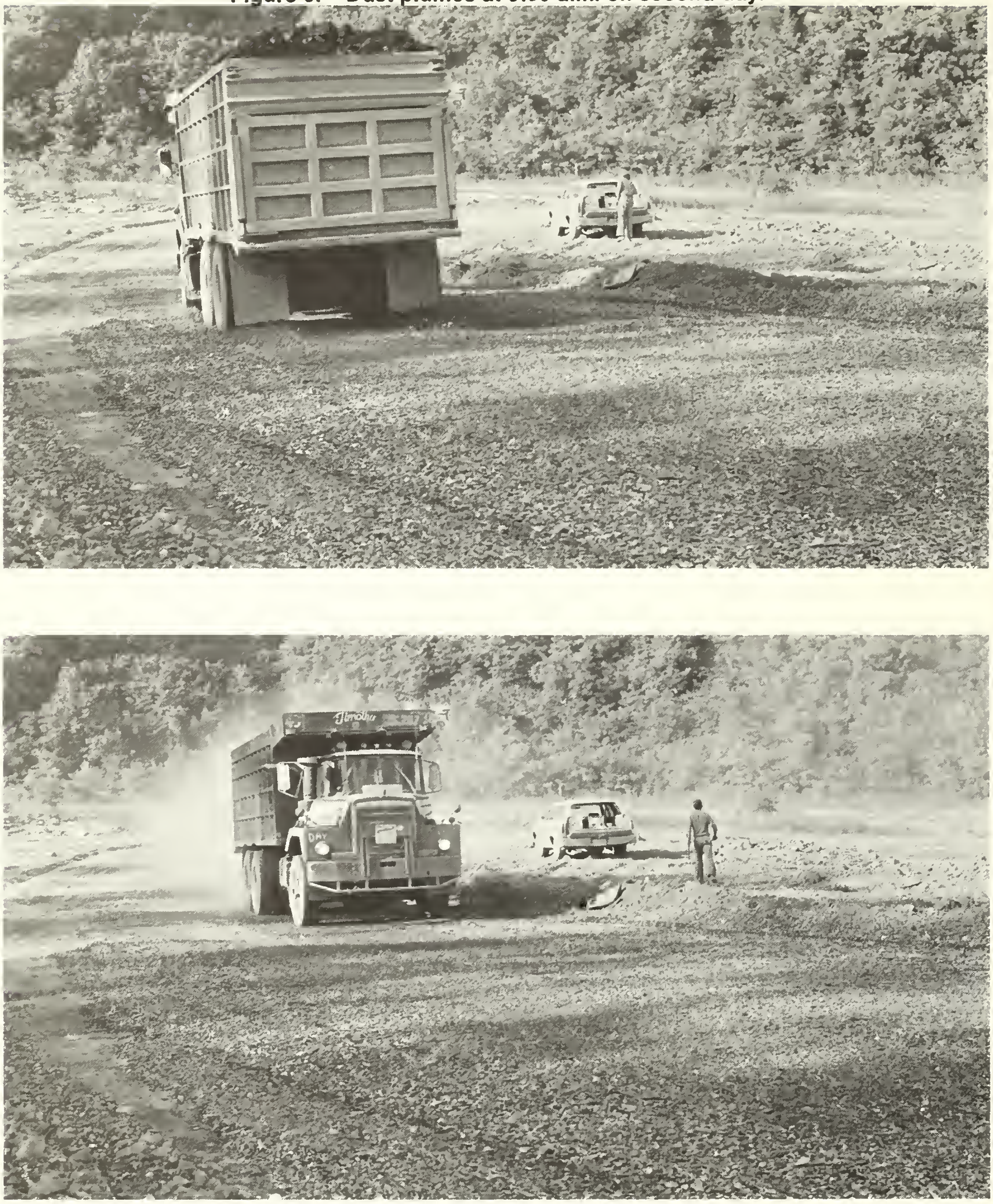


Figure 10.—Dust plumes at 9:30 a.m. on second day.

Figure 11.—Dust plumes at 10:00 a.m. on second day.

Figure 12.—Dust plumes at 10:30 a.m. on second day.

Figure 13.—Dust plumes at 11:00 a.m. on second day.

Figure 14.—Dust plumes at 11:30 a.m. on second day.

DISCUSSION

If working hours or hours of traffic use are taken as basis, it may be inferred that under traffic and weather stresses similar to those experienced here, the need to sprinkle for dust control is reduced tenfold by the use of wood chips. But this may not hold true over a medium or long range.

Even in the short time frame of this experiment there was noticeable deterioration in the chips themselves and in the continuity of the chip blanket. Table 1 shows that under 6 hours of traffic-imposed stress, the mean chip width decreased by 25 percent. Also, a slight tendency was noted for traffic to windrow the chips in berms paralleling the road alignment. Should this continue, portions of the treated segment would eventually be swept bare of chips.

Of course a motor grader could rework and respread the chip blanket to eliminate the berms and bare areas. But chip deterioration is permanent and further breakdown under traffic stress is to be expected. Moreover, each time the blanket is reworked and respread the chips will be adulterated with more dust and fine particles from the road surface. Therefore, over an extended period the day-to-day advantage of using wood chips is unlikely to be as great as the tenfold advantage noted during the limited period of this experiment.

But chip deterioration under traffic and contamination of the chip blanket with dust and road surface materials may well be blessings in disguise on the more temporary spur routes. Dudech, Swanson, Mielke, and Dedrick (1970) and Meyer, Johnson, and Foster (1972) found that wood chip mulches reduce erosion and can enhance the survival and growth of vegetative cover on construction slopes. Experience with wood chip mulches on surface mine spoils has indicated their chief potential drawback to be a tendency to deplete the already low nitrogen content of the spoil materials. But this is easily overcome by adequate application of fertilizers. When time comes to abandon, plow under, and revegetate a temporary haul road where wood chips were used to control dust, those same chips will provide a pulverized organic mass ready for use as mulch.

SUMMARY

The results of this preliminary experiment strongly suggest that use of wood chips will allow significant reductions in the day-to-day use of sprinkler trucks to control dust on surface-mine haul roads and that using chips will allow greater flexibility in the scheduling and use of available sprinkler trucks. Too, the protection of the road surface from direct encounter with the forces—draft, pounding, and abrasion—of moving vehicles tends both to forestall the creation of dust-size particles and to prevent those that are present from becoming airborne.

Thus, if converted to chips, the trees that currently are waste materials on a coal surface mine might find valuable use both during the mine operations and afterward when reclamation work is being done.

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FOLIAR NUTRIENT CONCENTRATIONS IN BALSAM FIR AS AFFECTED BY SOIL DRAINAGE AND METHODS OF SLASH DISPOSAL

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Abstract. Foliar nutrient concentrations in young balsam fir growing on strip clearcuts were assessed in relation to soil drainage and three methods of slash disposal. Concentrations of N, K, and Mn were higher for trees growing on well-drained soils than for trees growing on poorly drained soils. Mo concentrations were higher on poorly drained soils and all other measured nutrients were unaffected. Only foliar Fe was affected by the three methods of slash disposal.

Foliar analysis is a sensitive method of assessing tree nutrition and the ability of soils to supply nutrients for adequate tree growth. Although foliar nutrient levels have been reported for many species, little information is available for balsam fir (*Abies balsamea* (L.) Mill.) growing in Maine. In particular, little is known how soil drainage conditions and silvicultural practices might influence foliar nutrient levels. Hence, base-line levels of foliar nutrients are extremely limited for healthy balsam fir trees that are free of spruce budworm (*Choristoneura fumiferana* (Clem.)). In this study, foliar nutrient concentrations in young balsam fir were assessed in relation to two broad soil drainage groups and to three methods of slash disposal on clearcut strips 8 years after harvesting the mature stand.

THE STUDY

Area and plot layout

The study was made on the Penobscot Experimental Forest in Maine in conjunction with the earlier studies of the influence of strip-clearcutting and slash disposal methods on natural regeneration of spruce and fir and on site fertility. Detailed descriptions of the study area, the forest, soils, and plot layout are given by Czapowskyj et al. (1977).

Soils of the study area are complexes of well-drained to poorly drained soils on glacial till, and moderately well-drained to poorly drained soil of marine sediments. Soils on glacial till include Marlow, Peru, and Monarda; those on marine sediments include Elmwood, Buxton, and Scantic. Because of the intricate pattern of these soils on the landscape and the differential restriction of root penetration by a dense layer that impedes water movement, the soils were subdivided into two broad groups: Group A, which included very poorly and poorly-drained sites, and Group B, which included moderately well and well-drained sites.

The mature stand was harvested by strip-clearcutting in 1965 and the slash was either left in place, or removed, or burned.

Foliage sampling and analysis

In early October 1973, foliage samples were collected from 180 young balsam fir trees that ranged from 30 to 80 cm in height. Three trees randomly selected represented each of the 60 plots, evenly divided among the two soil drainage groups and three slash disposal methods. Consequently, each soil drainage group and slash disposal treatment were represented by 10 plots.

Twigs with current-year needles were collected from upper crown portions. Foliage from each of the three trees on each of the 60 plots was composited, making a total of 60 samples. Samples were dried at 70°C, ground to pass through a 20-mash screen, and prepared in duplicate for chemical analysis. Nitrogen was determined by Kjeldall digestion. The other nutrients were determined with an emission spectrograph after dry ashing (Carpenter 1964).

Analysis of variance was used to test differences among soil drainage groups and slash disposal treatment.

RESULTS AND DISCUSSION

Average foliar nutrient concentrations of young balsam fir are summarized in Table 1. The data are consistent with results reported by Young and Quinn (1966) and Henry (1973). Inconsistencies were noted only for Mo and Cu concentrations, and these are probably a function of the soils upon which the trees were growing. Comparisons between the present data and those reported by Timmer and Stone (1978) suggest that our balsam fir contained less N than is needed for optimum shoot growth.

Analysis of variance test for differences (Table 2) showed that foliar nutrient concentrations of one or more elements was affected by soil drainage or slash disposal treatment, or by their interactions.

Table 1.—Nutrient concentrations in balsam fir needles as affected by soil drainage and slash disposal[a]

Nutrient	Slash disposal treatment							
	Left on site		Removed		Burned		Mean	
	A[b]	B[c]	A	B	A	B	A	B
Nitrogen (%)	1.38	1.41	1.23	1.41	1.32	1.64	1.31	1.50
Phosphorus (%)	0.18	0.18	0.15	0.17	0.15	0.18	0.16	0.18
Calcium (%)	0.55	0.54	0.56	0.56	0.52	0.41	0.54	0.50
Magnesium (%)	0.12	0.12	0.12	0.12	0.19	0.11	0.14	0.12
Potassium (%)	0.49	0.52	0.45	0.49	0.43	0.52	0.46	0.51
Manganese (%)	0.07	0.11	0.09	0.11	0.08	0.10	0.08	0.11
Iron (ppm)	64	67	49	64	71	77	61	69
Zinc (ppm)	50	36	39	40	40	41	43	39
Copper (ppm)	6	21	19	11	8	17	11	16
Molybdenum (ppm)	0.36	0.41	0.42	0.39	0.43	0.32	0.40	0.37

[a]Each value is the average of 10 replications.
[b]A = very poorly and poorly drained soils.
[c]B = moderately well and well-drained soils.

Table 2.—F-values for comparisons of nutrient concentrations in balsam fir needles by soil drainage and slash disposal method

Source of variation	Nutrient									
	N	P	Ca	Mg	K	Mn	Fe	Zn	Mo	Cu
Soil drainage	13.33**	3.33†	1.44 NS	1.31 NS	6.00*	5.29*	3.66†	2.25 NS	6.13*	1.75 NS
Slash disposal	3.05†	2.78†	2.89†	0.71 NS	1.07 NS	0.59 NS	5.89**	0.81 NS	2.09 NS	0.14 NS
Soil drainage × slash disposal	1.63 NS	0.56 NS	1.21 NS	0.96 NS	0.64 NS	0.29 NS	0.80 NS	4.14*	12.91**	3.03†

NS = Not significant.

†Significant at $P \leq 0.10$.
$*P \leq 0.05$.
$**P \leq 0.01$.

Effects of soil drainage

Concentration of N, K, and Mn in the foliage of trees growing on moderately well and well-drained soils were higher than concentrations in trees growing on very poorly and poorly drained soils. The differences were significant for N ($P \leq 0.01$) and for K and Mn ($P \leq 0.05$). There was also a tendency for P to be higher in trees growing on well-drained soils ($P \leq 0.1$). Higher concentrations of Mo ($P \leq 0.05$) occurred on very poorly and poorly drained soils than on the better drained soils.

CONCLUSION

Based on results of this study the following generalizations can be made:

1. Eight years after clearcutting and subsequent slash disposal, it was found that the three slash treatments did not affect the nutrition of young balsam fir.
2. Soil drainage affected the uptake of N, K, and Mn with lower concentrations occurring on poorly drained soils than on well-drained soils.
3. Regardless of the soil drainage or slash disposal method, all sites were less than sufficient in available N for optimum growth.

Effects of slash disposal

Differences in foliar nutrient concentrations attributable to methods of slash disposal were of much lesser magnitude than those for soil drainage. Of 10 nutrients studied, only Fe concentrations were different ($P \leq 0.01$). On plots where slash was removed, the concentrations of Fe were consistently lower; where slash was burned, concentrations were consistently higher. Weak, insignificant trends are suggested by means for N, P and Ca, but data are inconsistent.

Soil drainage X slash disposal interactions

Only two micronutrients showed significant soil drainage X slash disposal interactions; Mo ($P \leq 0.01$) and Zn ($P \leq 0.05$). Considerably more Zn was found in trees growing on poorly drained soils than on well-drained soils where slash was left in place. For the other slash disposal X soil drainage combinations, Zn concentrations were about the same. The interaction for Mo had a different pattern. Where slash was left in place, less Mo was found in trees growing on the poorly drained soils than on better drained soils. The order of Mo concentrations is reversed for the other two slash disposal treatments.

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WOOD FUEL PLENTIFUL IN WEST VIRGINIA

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Abstract. Biomass estimators applied to West Virginia timber resource data indicate that 34 million tons of wood is potentially available for fuel each year. This tonnage is the annual forest growth in excess of that now harvested for roundwood products. One-half of this excess can supply more than all of the State's energy needs in the residential and commercial sectors, or 44 percent in the industrial sector.

A century ago, fuelwood was the primary source of energy in America; nearly 3 cords were consumed for each ton of coal mined (Reynolds and Pierson 1942). Now, as then, there is great interest in using wood for energy. Many rural and suburban dwellers are heating with wood to reduce the high cost of heating with oil, natural gas, and electricity. Numerous wood industries are finding that wood wastes are a low-cost alternative to coal, gas, and oil for generating steam and electric power. At least two municipal utilities now generate electricity from wood at a lower cost than that generated from other fuels. While cost reduction is a big factor in the switch to wood, so is the feeling of self-reliance and independence that comes from using a locally supplied fuel that can provide heat and power without interruption due to storms, strikes, and embargoes.

However advantageous the use of wood for energy may be, the increase in consumption of wood for fuel raises concern about the adequacy of wood supplies. Fortunately for residents of the Northeast and the Appalachian Region, forests and woodlots are abundant. West Virginia, for example, is 75 percent forested: these timberlands, if managed properly, have the potential to produce sustained crops of wood indefinitely. Nevertheless, potential wood fuel users, particularly, are concerned about wood supplies, and they question how much wood is available for energy, especially after allowing for that harvested for industrial products.

THE STUDY

Forest lands in the United States are inventoried periodically by the Forest Service in cooperation with the states. Timber volumes are reported in traditional units, the cubic foot and board foot. Reporting forest inventories as biomass (weight of complete trees including roots, stump, stem, limbs, branches, and leaves) is not yet a standard practice. However, this is expected to change as timber harvests are increased to meet users' needs for more wood for fiber products and for energy.

The heating value of wood, like coal, is more conveniently expressed in units of weight than in units of volume. Tree-weight data, therefore, allow us to assess the energy potential of forests and forest growth. Equations and tables by Wiant (1977), Wartluft (1977), Green and Grigal (1978), and Young et al. (1976) allow one to estimate tree weights for Appalachian hardwoods and softwoods 1 inch in diameter breast height (dbh) and larger. Estimates include weight of wood and bark of trunk, limbs, branches, and twigs, but exclude roots, a 6-inch stump, and leaves. For the purpose of estimating harvestable wood for energy, these estimators are quite practical.

In this study, I applied tree weight estimators to the latest forest inventory data for West Virginia (Bones 1978) to obtain tonnage of wood available for energy—over and above the tonnage now harvested for other products.

METHODS

The tonnage of wood potentially available for energy in West Virginia is defined as that portion of annual forest growth in excess of the amount harvested for wood products. In addition, trees killed by insects, fire, and disease, and the wastewood from logging operations and other removals are potentially available for energy. The total amount of wood for energy from West Virginia's forests can be expressed as: Energy wood = (Net growth − Timber cut) + (Mortality + Logging Residue and Other Removals).

Before this equation could be solved, it was necessary to convert inventory volume tables from cubic feet to tons. This was done for each component of the forest: growing-stock trees, saplings, and rough and rotten trees. Survey data[1] (Bones 1978) for these tree classes include numbers of trees by species and dbh class. These were combined by species group (Table 1), and appropriate tree-weight equations (Wiant 1977; Green and Grigal 1978), and tabular values (Wartluft 1977), or both, were applied to compute wood tonnages for species groups by dbh class. In this manner, inventory estimates in tons were obtained for growing-stock trees, saplings, and rough and rotten trees by species group (Table 1).

Net annual growth and mortality tonnages were calculated by applying growth and mortality rates from Bones (1978) to the inventory data (Table 2). Tonnages of harvested wood plus logging residues and other removals (as defined by Bones 1978) were determined by applying average cubic-foot weight factors (Timson 1975; U.S. Forest Service 1975) for wood and bark of hardwoods and softwoods (Table 3).

RESULTS AND DISCUSSION

The estimated weight, or biomass, of the aboveground portion of all forest trees on 11.5 million acres of commercial forest land in West Virginia is 981 million tons (Table 1). In 1974, this huge stock of hardwoods and softwoods produced a net increment of 32.9 million tons of wood and bark (Table 2). And these forests will continue to produce this growth year in and year out as long as the inventory of trees is maintained.

In 1974, 6.2 million tons of timber was removed from the forest through harvesting and other operations (Table 3). Another 5.3 million tons of timber was killed by insects, fire, and disease (Table 2). The net annual production in excess of timber removals was 26.7 million tons.

If we assume that all dead timber plus all logging residues and other removals (7.4 million tons) can be salvaged, then the total *annual* excess of wood and bark increases to 34.1 million tons. This quantity of forest biomass is potentially available for energy, chemical conversion, or wood and fiber products. Further, thinnings and improvement cuttings to capture part of the excess annual growth will result in faster growing, higher

[1]Personal communication from Joseph E. Barnard, U.S. Forest Service, Northeastern Forest Experiment Station, Broomall, PA.

Table 1.—Net aboveground biomass of the forest resource in West Virginia, by tree class and species group, 1975

Species group	All tree classes	Growing-stock trees (5.0 to 29.0+ dbh)	Saplings (1.0 to 4.9 dbh)	Rough and rotten trees (5.0 to 29.0+ dbh)
	Million tons, green weight			
Red oaks	—	159.0		
White oaks	—	155.4		
Hard hardwoods	—	247.1	78.2	180.8
Soft hardwoods	—	101.7		
All hardwoods	922.2	663.2	78.2	180.8
Softwoods	58.8	48.7	4.7	5.4
Total	981.0	711.9	82.9	186.2

Table 2.—Current annual net growth and mortality of whole trees on commercial forest land in West Virginia, by tree class and species group, 1974[a]

Species group	All tree classes		Saplings and growing-stock trees (1.0 to 29.0+ dbh)		Rough and rotten trees (5.0 to 29.0+ dbh)	
	Net growth	Mortality	Net growth	Mortality	Net growth	Mortality[b]
	Million tons, green weight					
Hardwoods	29.5	4.7	24.6	3.3	4.9	1.4
Softwoods	3.4	0.6	3.1	0.5	0.3	0.1
Total	32.9	5.3	27.7	3.8	5.2	1.5

[a]Based on trend between inventories.
[b]Mortality rate of rotten trees assumed to be three times the rate of that for sound trees.

Table 3.—Timber removals from commercial forest land, by species group and item, West Virginia, 1974

Species group	Roundwood products[a]	Logging residues and other removals	Total
	Million tons, green weight		
Hardwoods @ 55 lb/ft^3 [b]	3.8	2.0	5.8
Softwoods @ 51 lb/ft^3 [b]	0.3	0.1	0.4
Total	4.1	2.1	6.2

[a]Includes products harvested from growing stock and rough, rotten, and salvable dead trees.
[b]Weight per cubic foot of wood and bark.

quality timber suitable for high-value veneers, lumber, and cooperage.

It would be simplistic to say that all of the 34.1 million tons of excess *annual* wood production is truly available for immediate use. There are too many environmental, social, and economic factors that limit or prevent the harvest of West Virginia timber on many ownerships. We might allow for these factors by halving the potential *annual* excess to 17 million tons.[2] At 8.6 million Btu per ton, 17

[2]This quantity is midrange of the *available* timber volumes estimated for West Virginia by Birch and Kingsley (1978). Readers are referred to Birch and Kingsley's paper for a full discussion of the topic: How much timber *is* available in West Virginia?

Table 4.—Energy consumption in West Virginia, by consuming sector and fuel, 1975[a]

Consuming sector	Coal	Natural gas	Petroleum	Hydro-power	Total fuel inputs	Electricity purchased	Total energy consumed (three sectors)
	Trillion Btu						
Industrial	215.99	68.87	15.07	—	299.93	31.24	331.17
Residential and commercial	4.80	78.51	13.92	—	97.23	26.60	123.83
Transportation	0	14.51	121.90	—	136.41	0	136.41
Electric utilities	611.15	0.37	4.12	4.85	620.49		
Total fuel inputs	831.94	162.26	155.01	4.85	1,154.06		

[a]U.S. Department of Energy 1978.

million tons will yield about 146 trillion Btu of available wood energy—the equivalent of 24.8 million barrels of home heating oil annually.

One hundred and forty-six trillion Btu is equivalent to about one-eighth of the total fuel consumed in 1975 by all sectors of the West Virginia economy (Table 4). In that year, two-thirds of the fuel input was consumed for electric power generation and transportation, sectors where wood is not likely to have a significant impact. But in the residential and commercial sectors where wood fuels can be used, 146 trillion Btu could supply more than all of the energy consumed. In the industrial sector, where many plants can be converted to wood fuels, 146 trillion Btu could supply 44 percent of the energy needed.

Additional sources of wood fuel in West Virginia include sawmill and woodworking plant wastes, trees growing on nonforest lands, and salvable urban wood wastes. These sources are significant in volume, and often are more available to urban users than wood in the forest.

In conclusion, West Virginia has a huge unused supply of wood suitable for fuel. On the basis of energy use in 1975, enough wood fuel is available annually to supply about one-eighth of the State's needs: and this without depleting the forest capital.

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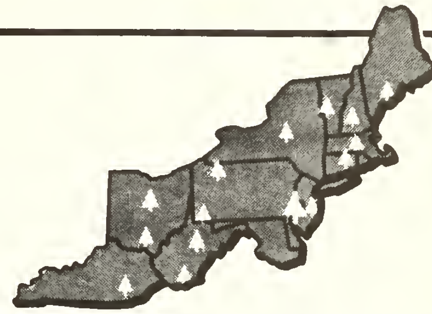

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EFFECTS OF DISBUDDING ON SHOOT MORTALITY AND STEM DEFORMITY IN BLACK CHERRY

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Abstract.—Insect damage was simulated by the removal of buds from black cherry trees to determine the effects on stem mortality and tree form. Black cherry was very sensitive to disbudding. All degrees of disbudding caused terminal deformities and stem deformity nearly always occurred after the terminal bud was destroyed. Shoot mortality usually occurred after half or more of the buds on the terminal branch were removed. The types of deformities are illustrated.

Keywords: *Prunus serotina*, disbudding, mortality, deformity

Insects destroy the buds on black cherry, *Prunus serotina* Ehrh., in early spring. Destruction of the buds by insects is suspected of causing dead or deformed terminals and reduction in shoot growth. However, there are few reliable data to support this suspicion, because the variability of insect feeding makes such observations and measurements difficult. Therefore, various levels of insect damage were simulated by several levels of bud removal from black cherry trees and the effects recorded.

METHODS AND MATERIALS

Insect damage was simulated by the removal of some to all of the buds from a series of branches on 5- to 10-foot-tall trees, and from the entire tree on 3- to 5-foot-tall trees near Bartow, West Virginia on April 7, 1976.

Four uniform branches in the lower third of the crown were marked on each of eight black cherry trees 5 to 10 feet tall. Four intensities of disbudding, replicated eight times, were randomly assigned to the branches. Each tree received one set of four treatments—one treatment for each branch.

The treatments were:

- Removal of all terminal buds.
- Removal of all terminal buds and half of the lateral buds on the terminal shoots.
- Removal of all buds.
- No buds removed (control).

Forty small (3- to 5-feet tall) black cherry trees were also marked. All buds were removed from 30 trees and no buds removed from 10 trees.

The buds were about three times winter size and turgid when removed. They were readily snapped off at the base by a thumbnail with no damage to the twigs.

The tree branches were cut March 16, 1977, 12 months after treatment, and brought to the laboratory for examination and measurement. The length and diameter of the terminal shoots were measured and the number of viable buds on the 1976 growth was recorded. The number of dead and living branches on each tree was also recorded and the form of each tree and branch classified. Examples of the resulting damage are illustrated.

RESULTS AND DISCUSSION

Black cherry is very sensitive to disbudding. Although disbudding did not kill the trees, each level of disbudding caused terminal deformities (Tables 1 and 2). Stems almost always became deformed after the terminal bud was destroyed.

Descriptive data on the mortality of the terminal shoots and recovery of the terminal function are shown in Tables 1 and 2. It was easy to determine whether axillary or adventitious buds developed shoots that assumed the terminal function after disbudding. Generally, terminals developed from shoots arising from axillary buds, even after the complete disbudding treatment. However, terminal function was often assumed by shoots developing lower than the apex of the original terminal (Fig. 2). Although decisions about terminal function were subjective, the inevitable result of disbudding was a deformed tree or branch (Figs. 1, 2, and 3). A normal branch is shown for comparison (Fig. 4).

The effects of disbudding on shoot growth and diameter growth and the production of buds were so variable that it was impossible to detect any significant differences between

Table 1.—Dieback of terminal shoots, recovery of terminal function and stem deformity of black cherry branches after disbudding.

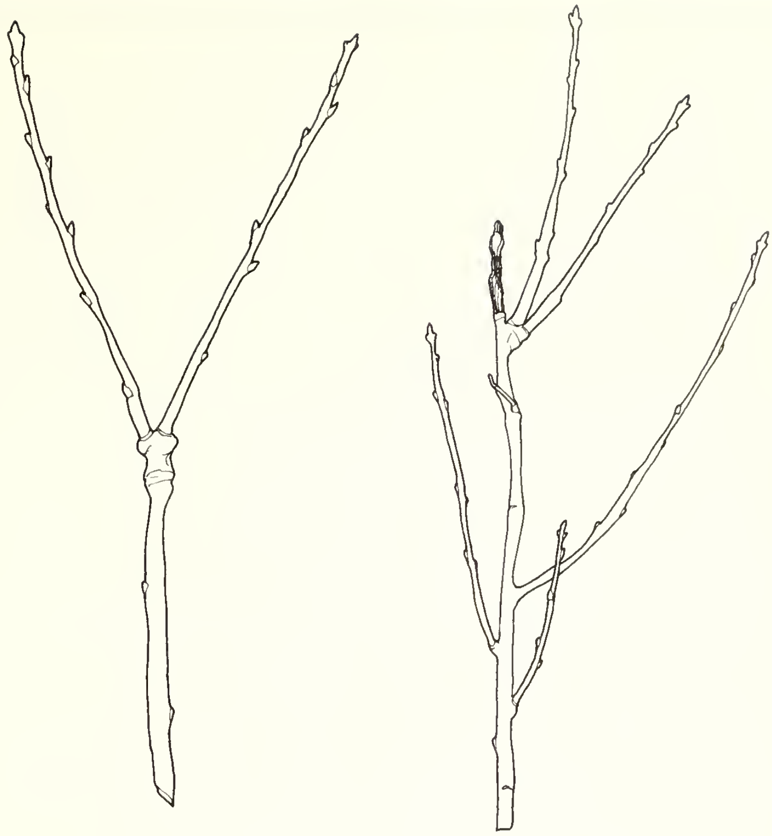
Treatment	Number of branches treated	Percentage of 1975 terminals with dieback	Assumption of terminal function by axillary buds	Percentage of leaders damaged, by type			
				Forked	Multiple	Straight with crook	Normal
Terminal bud	8	12	8 of 8	63	13	12	12
Terminal and half of laterals	8	75	8 of 8	63	25	12	—
Terminal and all laterals	8	100	8 of 8	12	25	63	—
None	8	12	8 of 8	—	—	13	87

Table 2.—Death of terminal shoots, recovery of terminal function and stem deformity of 3- to 5-foot black cherry trees after disbudding.

Treatment	Number of trees treated	Percentage of 1975 terminals dead	Assumption of terminal function by axillary buds	Percentage of leaders damaged, by type			
				Forked	Multiple	Straight with crook	Normal
All buds removed	30	90	30 of 30	17	57	26	—
None	10	80[a]	10 of 10	40	30	10	20

[a]Killed by a freeze on May 8, 1976.

Figure 1.—Forked leaders—typical of damage when terminal bud or terminal bud and half of lateral buds are destroyed.



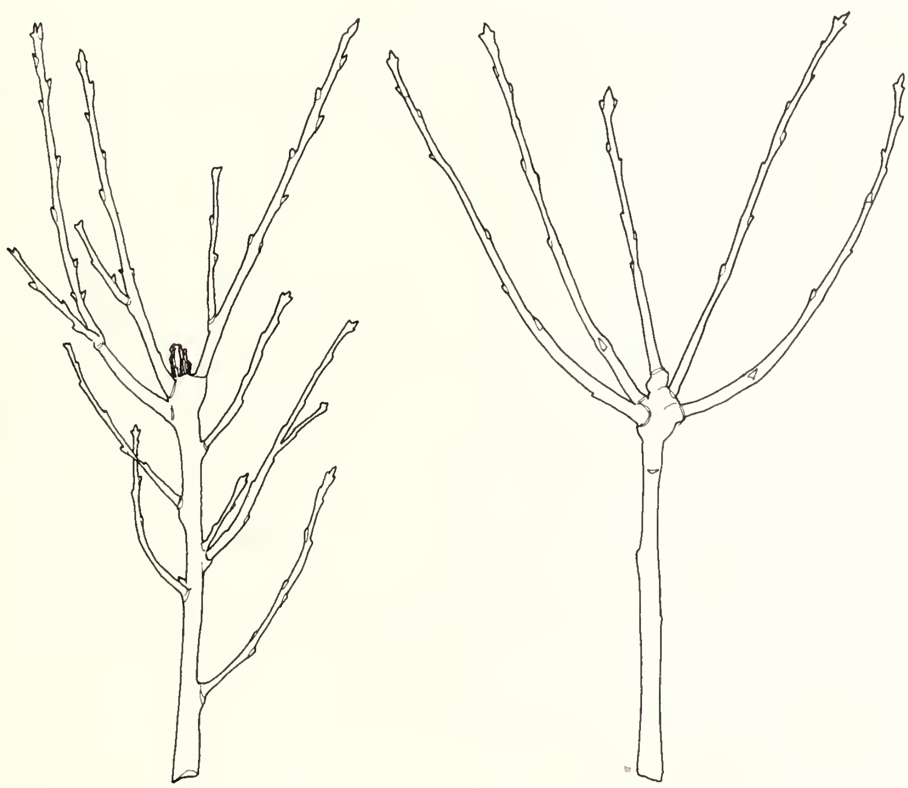


Figure 2.—Multiple leaders—typical of damage when all buds are destroyed or terminal killed by frost.

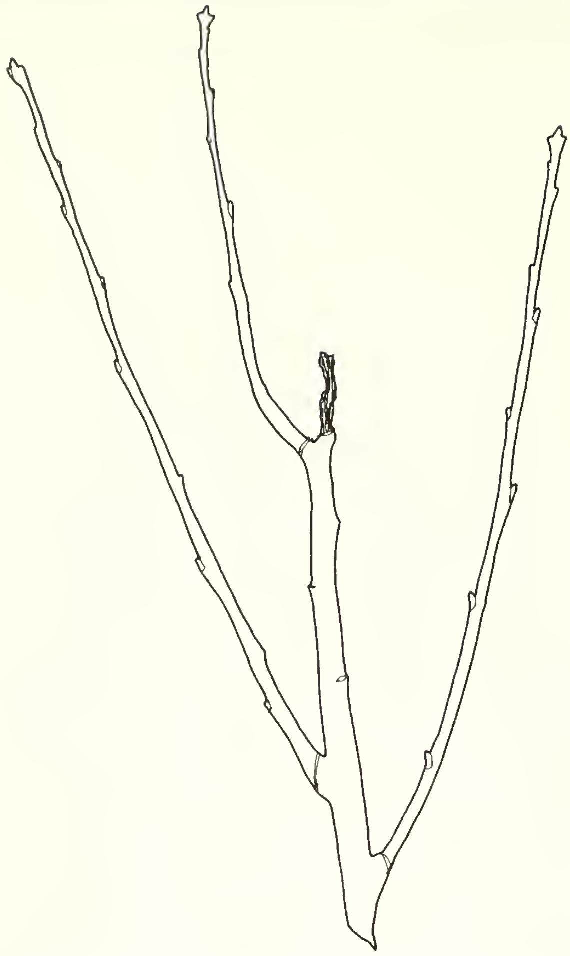


Figure 3.—Single leader with crook—common when all buds are destroyed or terminal killed.

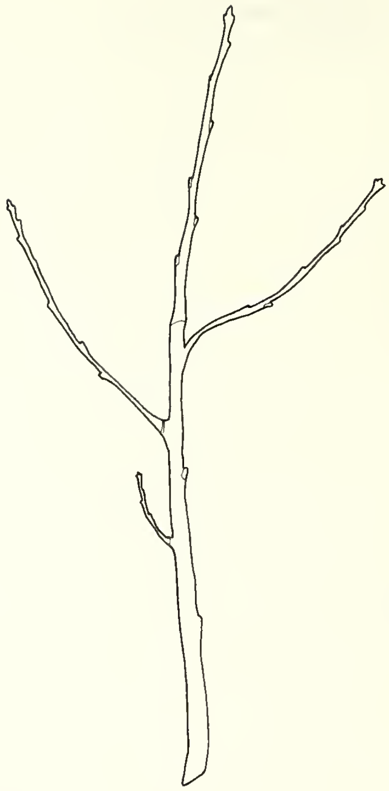


Figure 4.—Normal leader—no damage.

treatments. However, when all of the buds were removed, the effect was almost always a one-year loss of height growth—the 1975 growth died after the buds were removed in April 1976.

There have been many disbudding experiments with hardwood trees for the study of auxins and growth impact (Kulman 1971), but practically no studies of the effects of disbudding on tree quality, especially with black cherry. Since management of black cherry has intensified with emphasis on better quality through the selection and breeding of better stock, insect-caused deformities on young trees have become a serious problem.

Results of this study give us some insight into how bud destruction affects the form of young black cherry trees. The next question to be answered is, "How long do such deformities persist or affect the quality of the trees?"

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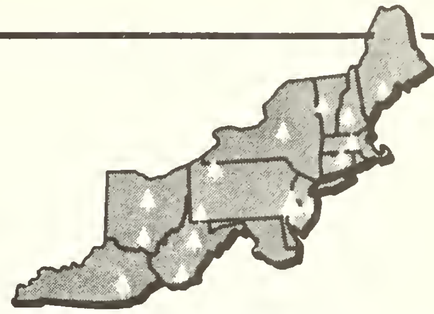

FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE, 370 REED ROAD, BROOMALL, PA. 19008

A SIMPLE TECHNIQUE FOR COLLECTING CHYLE FROM THE GYPSY MOTH, *Lymantria dispar* L.

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Abstract. A procedure for rapidly obtaining significant quantities of chyle is described. The amount and composition of chyle collected from larvae of the gypsy moth, *Lymantria dispar* (L.), varied according to the instar examined and the age within the instar.

In our studies on the effect of gypsy moth (*Lymantria dispar* L.) chyle (digestive juices) on the nucleopolyhedrosis virus, several techniques commonly used to obtain the chyle from insects were unsatisfactory. Such techniques, including dissection and maceration of the midgut of the insect (Turunen and Chippendale 1977; Baker 1976; Ahmad et al. 1976), and electroshock (Aizawa 1962; Euguchi and Iwamoto 1976) have inherent drawbacks. When using the midgut dissection procedures, no differentiation is made between intracellular and extracellular material collected. The electroshock method works well but it is time consuming. We resolved this problem by developing a simple procedure for quickly obtaining sizeable quantities of chyle free of cellular debris from various instars and larval sizes.

MATERIALS AND METHODS

Gypsy moth larvae were reared on an artificial diet (ODell and Rollinson 1966) and maintained in an environmental chamber at 26 to 27°C with a 12:12 DL photoperiod. The larvae were reared in 0.47-liter (pint) cardboard containers with plastic lids. Ten larvae were reared in each container, and diet was supplied every 48 h.

Chyle was obtained by grasping each larva with a pair of forceps at approximately the third segment from the posterior end, and turning the larva so that it lay dorsally along the length of the forceps. The larva was forced to regurgitate after gentle pressure was applied with the side of a micropipette along the ventral side of the insect. The drop of chyle accumulating at the mouth was then

Figure 1.—Chyle collection from a 5th-instar larva.

collected with the micropipette (Fig. 1). Occasionally too much pressure was applied and gut wall cells were regurgitated with the chyle; those chyle samples and the larvae were discarded. The chyle was pooled in small 5-ml test tubes chilled in an ice bath. A few crystals of phenyl thiourea (PTU) were added to prevent melanization. The chyle was then frozen at −20°C until needed.

The pH of the pooled chyle was estimated with narrow range pH paper (Micro Essential Laboratory, Brooklyn, N.Y.).[1] Protein determinations were made by the Lowry procedure (Lowry et al. 1951), using bovine serum albumin as a standard.

RESULTS AND CONCLUSION

Table 1 summarizes the chemical and physical characteristics of chyle obtained from three instars by our technique. The average pH and color of the chyle did not differ appreciably from instar to instar. However, there was a significant difference in the amount of chyle obtained from each instar examined. Noteworthy was the observation that the protein concentration decreased with the increasing age of the larvae. As expected, the largest volume of chyle was collected from the large 5th-instar larvae. Within each instar, the

[1]The use of trade, firm or corporation names in this paper is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture or the Forest Service of any product or service to the exclusion of others that may be suitable.

Table 1.—Characteristics of the chyle obtained from various instars of the gypsy moth

Instar examined	Number larvae pooled	Average volume of[a] chyle/larva	Average weight of larvae	Estimated chyle pH	Protein concentration in chyle	Description of chyle	Particulat matter present
		(ul)	(mg)		(ug/ul)		
3rd instar							
Day 0	10	1.05	22.28	9.3-9.5	89.50	faint brown	−
Day 2	10	0.15	45.47	9.2-9.3	400.00	cloudy brown	+ +
Day 4	10	0.55	82.17	9.2-9.4	143.01	light brown	+
4th instar							
Day 0	8	2.50	55.25	9.3-9.4	43.27	faint brown	−
Day 2	10	2.15	153.25	9.0-9.2	65.15	yellowish brown	+ +
Day 4	10	0.95	260.60	8.2-8.3	175.25	dark brown	+ +
5th instar							
Day 0	7	13.6	238.91	9.0-9.5	28.67	faint brown	−
Day 2	10	1.7	391.20	8.9-9.0	68.32	turbid yellow	+ +
Day 4	10	2.0	624.11	8.1-8.4	66.66	yellowish brown	+ +

[a]Refers to the amount of digestive fluid regurgitated by the larvae and is not an indication of the tot amount of digestive fluid present in each larvae.

[b]− = clear; + = slight amount; + + = heavy amount.

largest collection was obtained right after the larva molted and just before feeding resumed. The chyle collected during this stage of instar development was always free of contaminating particulate matter (usually partially digested food) compared with chyle collected at other times within the same instar.

For gypsy moth larvae, the time at which the chyle is taken is critical. Our technique facilitates the acquisition of large quantities of chyle with minimal expenditure of time and effort. Though the larvae used in this study was forced to regurgitate only once, we found that in using this technique, larvae could be forced to regurgitate every 3 or 4 days without apparent ill effects. However, more frequent forced regurgitations often resulted in reduced feeding and death.

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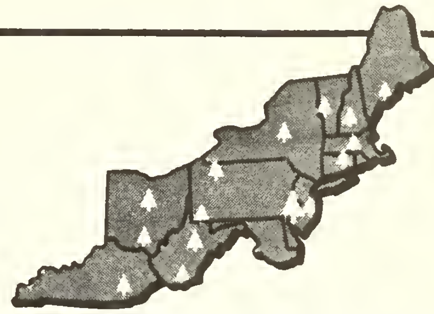

FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE, 370 REED ROAD, BROOMALL, PA. 19008

HYBRID POPLAR PULPWOOD AND LUMBER FROM A RECLAIMED STRIP-MINE

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Abstract. A 2-acre hybrid poplar planting on a reclaimed strip-mine was harvested at age 16. The commercial clearcut yielded 90 tons of pulpwood and 9,400 board feet of lumber. This is equal to a growth rate of approximately 2 cords per acre per year. Selected physical properties of the hybrid poplars were compared with those of other commercial eastern species.

THE PLANTATION

In the spring of 1962, W. G. Jones, conservationist and contract planter, established hybrid poplars on a reclaimed strip-mine in Clearfield County, Pennsylvania, using greenwood cuttings supplied by the Ohio Reclamation Association. There is no record of the clones he used. The planting site was on the outslope of a spoil bank which had not been severely compacted by heavy equipment. Drainage was good and root penetration was not restricted. The spoil was moderately acid but not enough to restrict tree growth.

Because it was not known how well hybrid poplars would perform on Pennsylvania strip-mine spoils, a mixture of hybrid poplar, white spruce, and Scotch pine was planted. The planting pattern was one row of hybrid poplar adjacent to either one or two rows of conifers at 6- x 6-foot spacing. Initial survival of all species was excellent, averaging 80 percent or higher. However, the slow-growing conifers were quickly overtopped by the hybrid poplars and many died from suppression. The end result was a hybrid poplar plantation with a conifer understory. During the first 6 years in the life of the plantation, the region was under the influence of drought; rainfall was approximately three-fourths of normal and growth of the hybrid poplars was probably reduced.

THE HARVEST

After 16 growing seasons the hybrid poplars were harvested (Davidson and Riddle 1978). They averaged 10 inches in diameter and 65 feet in height. Approximately 600 trees were harvested from the 2-acre plantation. Most of the wood was used for pulp; the logs were cut into 5-foot bolts to a top diameter of 5 inches. A few butt logs and second logs were sawn into lumber. Total yield from the harvest was 90 tons of pulpwood bolts and 9,400 board feet of lumber. Cord volume of the harvested pulpwood was not determined, but on the basis of preharvest samples, it is estimated at about 33 cords per acre. This equals a growth rate of about 2 cords per acre per

Table 1.—Selected physical properties of hybrid poplar compared with those of other species.

Property	Hybrid poplar[a]	Bigtooth aspen[b]	Eastern white pine	Northern red oak
Specific gravity	—	0.39	0.35	0.63
Modulus of rupture (lb/in^2)	8,047 (718)	9,100	8,600	14,300
Modulus of elasticity million lb/in^2)	0.91 (.14)	1.43	1.24	1.82
Compression parallel to grain—maximum crushing strength (lb/in^2)	3,604 (377)	5,300	4,800	6,760
Compression perpendicular to grain—fiber stress at proportional limit (lb/in^2)	886 (115)	450	440	1,010

[a]Standard deviation (in parentheses) of samples tested.

[b]Values for other species from U.S. Department of Agriculture. 1974. Wood handbook: wood as an engineering material. U.S. Dep. Agric., Agric. Handb. 72. Values adjusted for wood with 12 percent moisture content.

year. Compared to a rate of 0.7 cords per acre per year for yellow-poplar on site index 100 (Beck and Della-Bianca 1970), the hybrid poplars have performed exceptionally well on this site.

Logs from two of the hybrid poplar trees were taken to the Pennsylvania State University for testing. The logs were sawn into small blocks, 1 x 1 x 12 inches, and the blocks were kiln dried for physical testing. Results of these tests indicate that some properties of the hybrid poplar wood are similar to other commercial eastern species.[1] As Table 1 shows, the hybrid poplar is nearly equal to eastern white pine in rupture strength and stronger than both white pine and bigtooth aspen in compression strength perpendicular to the grain. It has lower elastic strength than any of the three species to which it was compared and will crush more easily under pressure applied parallel to the grain.

DISCUSSION

The harvest of commercial-size pulp and sawlogs from a reclaimed strip-mine is good indication that previously mined lands can be returned to productive use. Hybrid poplars have shown potential for rapid growth on spoils, in spite of drought and harsh site factors. The slow growth of the conifers enabled the hybrid poplars to develop rapidly without competition or the need for thinning. A previous study showed that hybrid poplars planted at 6- x 6-foot spacing needed to be thinned at age 5 (Davidson and Davis 1972). It is doubtful that the pines or spruces will now develop into usable trees because they were so badly suppressed.

[1]Personal communication from Dr. Wayne Murphy, School of Forest Resources, The Pennsylvania State University, September 27, 1977.

In future plantings of hybrid poplar it would probably be better to use alternate rows of a shrub species rather than conifers. This type of planting would be of greater benefit to wildlife and should still eliminate the need for early thinning. Especially beneficial to the poplars would be a nitrogen-fixing shrub such as autumn olive.

The physical properties of hybrid poplar measured in this study indicate that the wood can be used for more valuable products such as construction lumber, interior woodwork, core stock for veneers, and others, as well as pulp.

Additional field testing of hybrid poplars has identified several clones that are adapted to planting on strip-mine spoils. Mixtures of selected clones for reclamation planting are available from the Pennsylvania State Forest Nurseries and should be used if hybrid poplars are a part of a reclamation plan.

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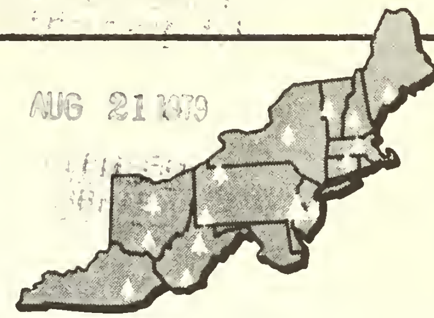

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CUBIC-FOOT TREE VOLUMES AND PRODUCT RECOVERIES FOR EASTERN REDCEDAR IN THE OZARKS

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Abstract. Tree volume tables and equations for eastern redcedar are presented for gross volume, cant volume, and volume of sawmill residue. These volumes, when multiplied by the average value per cubic foot of cants and residue, provide a way to estimate tree value.

Eastern redcedar, though not a major component of Missouri's forests, is a commercial species (Spencer and Essex 1976). The USDA Forest Service appraises redcedar during timber sales, and many small sawmills purchase the timber for the production of cants, which are later resawn into lumber.

This report contains gross volume and product recoveries for eastern redcedar. These can be used to appraise the value of a stand of cedar.

FIELD PROCEDURE

Ninety-one forest grown trees, ranging from 5 to 12 inches in diameter at breast height (dbh), were selected in the Ozark Mountains of Missouri. The trees were felled and the diameter outside bark (dob) was measured at 4-foot intervals from the stump to a 3-inch top. Height to a 3-inch top ranged from 11 to 42 feet.

Inside bark diameters were estimated by applying appropriate bark factors. Volume of each 4-foot section was calculated as a frustrum of a cone, and these volumes were summed to obtain gross tree volume.

The trees were bucked into blocks (3 ft. 7 inches) or logs (7 ft. 2 inches) that were sawn into cants. The cants were measured, and total cant volume was determined for each tree. The cants ranged from 8⅛ x 6½ inches down to 3⅜ x 3⅜ inches. Seven trees contained no cants.

VOLUME PREDICTION EQUATIONS

Gross volume model

Gross tree volume (V_t) is the cubic-foot volume inside bark from the stump to a 3-inch top, dob. The following equation was derived by multiple regression techniques.

$$V_t = -0.531 + 0.02143\ (dbh^2) + 0.05828\ (h) + 0.0018519\ (dbh^2 \times h),$$

where h = distance from the top of a 6-inch-high stump to a 3-inch top, dob.

$R^2 = 0.98$

$SE = 0.39\ ft^3$

Cant volume model

Cant volume (V_c) is the cubic-foot volume of merchantable cants sawn from the blocks and logs. Cull sections were removed from many of the trees. Therefore, it was necessary to include cull length (c) in the model. I tried a model with $dbh^2 \times h$ and $dbh^2 \times c$, but found that the residuals were correlated with the dependent variable. Adding dbh^2 and height to the model resulted in independent residuals.

$$V_c = -2.1075 + 0.074167\ (h) + 0.0006007\ (dbh^2 \times h) - 0.0031305\ (dbh^2 \times c) + 0.026377\ (dbh^2)$$

where c = length of cull section, in feet.

$R^2 = 0.89$

$SE = 0.44\ ft^3$

Table 1.—Predicted gross volumes for eastern redcedar trees, in cubic feet

Height—stump to 3 inches dob (feet)	Dbh (inches)								
	5	6	7	8	9	10	11	12	13
8	0.8	1.2	1.7	2.2	2.9	—	—	—	—
9	0.9	1.4	1.9	2.4	3.1	—	—	—	—
10	1.0	1.5	2.0	2.6	3.3	—	—	—	—
11	1.2	1.6	2.1	2.8	3.5	—	—	—	—
12	1.3	1.7	2.3	3.0	3.7	—	—	—	—
13	1.4	1.9	2.4	3.1	3.9	—	—	—	—
14	1.5	2.0	2.6	3.3	4.1	—	—	—	—
15	1.6	2.1	2.7	3.5	4.3	5.2	—	—	—
16	1.7	2.2	2.9	3.7	4.5	5.5	—	—	—
17	1.8	2.4	3.0	3.8	4.7	5.7	—	—	—
18	1.9	2.5	3.2	4.0	4.9	6.0	—	—	—
19	2.0	2.6	3.3	4.2	5.1	6.2	—	—	—
20	2.1	2.7	3.5	4.4	5.4	6.5	—	—	—
21	2.2	2.9	3.6	4.5	5.6	6.7	8.0	—	—
22	2.3	3.0	3.8	4.7	5.8	6.9	8.3	—	—
23	2.4	3.1	3.9	4.9	6.0	7.2	8.5	—	—
24	2.5	3.2	4.1	5.1	6.2	7.4	8.8	—	—
25	2.6	3.4	4.2	5.2	6.4	7.7	9.1	—	—
26	2.7	3.5	4.4	5.4	6.6	7.9	9.4	11.0	—
27	2.8	3.6	4.5	5.6	6.8	8.2	9.7	11.3	—
28	2.9	3.7	4.7	5.8	7.0	8.4	9.9	11.6	13.5
29	3.0	3.9	4.8	6.0	7.2	8.7	10.2	12.0	13.8
30	3.1	4.0	5.0	6.1	7.4	8.9	10.5	12.3	14.2
31	3.2	4.1	5.1	6.3	7.6	9.1	10.8	12.6	14.6
32	3.3	4.2	5.3	6.5	7.9	9.4	11.1	12.9	14.9
33	3.5	4.4	5.4	6.7	8.1	9.6	11.4	13.3	15.3
34	3.6	4.5	5.6	6.8	8.3	9.9	11.6	13.6	15.7
35	—	4.6	5.7	7.0	8.5	10.1	11.9	13.9	16.1
36	—	4.7	5.9	7.2	8.7	10.4	12.2	14.2	16.4
37	—	—	—	7.4	8.9	10.6	12.5	14.6	16.8
38	—	—	—	7.5	9.1	10.8	12.8	14.9	17.2
39	—	—	—	—	9.3	11.1	13.1	15.2	17.5
40	—	—	—	—	9.5	11.3	13.3	15.5	17.9
41	—	—	—	—	9.7	11.6	13.6	15.9	18.3
42	—	—	—	—	9.9	11.8	13.9	16.2	18.7

Note: The figures inside the boxed areas indicate the tree sizes that were sampled in the study.

Table 2.—Predicted cant volumes for eastern redcedar trees, in cubic feet[a]

Height—stump to 3 inches dob (feet)	Dbh (inches)								
	5	6	7	8	9	10	11	12	13
13	0.0	0.1	0.5	1.0	1.6	—	—	—	—
14	0.0	0.2	0.6	1.2	1.7	—	—	—	—
15	0.0	0.3	0.7	1.3	1.9	2.5	—	—	—
16	0.0	0.4	0.8	1.4	2.0	2.7	—	—	—
17	0.1	0.5	0.9	1.5	2.1	2.8	—	—	—
18	0.2	0.6	1.0	1.6	2.2	2.9	—	—	—
19	0.2	0.7	1.2	1.7	2.4	3.1	—	—	—
20	0.3	0.8	1.3	1.8	2.5	3.2	—	—	—
21	0.4	0.9	1.4	1.9	2.6	3.3	4.2	—	—
22	0.5	0.9	1.5	2.1	2.7	3.5	4.3	—	—
23	0.6	1.0	1.6	2.2	2.9	3.6	4.5	—	—
24	0.7	1.1	1.7	2.3	3.0	3.8	4.6	—	—
25	0.8	1.2	1.8	2.4	3.1	3.9	4.8	—	—
26	0.9	1.3	1.9	2.5	3.2	4.0	4.9	5.9	—
27	1.0	1.4	2.0	2.6	3.3	4.2	5.0	6.0	—
28	1.0	1.5	2.1	2.7	3.5	4.3	5.2	6.2	7.3
29	1.1	1.6	2.2	2.8	3.6	4.4	5.3	6.4	7.4
30	1.2	1.7	2.3	3.0	3.7	4.6	5.5	6.5	7.6
31	1.3	1.8	2.4	3.1	3.8	4.7	5.6	6.7	7.8
32	1.4	1.9	2.5	3.2	4.0	4.8	5.8	6.8	8.0
33	1.5	2.0	2.6	3.3	4.1	5.0	5.9	7.0	8.1
34	1.6	2.1	2.7	3.4	4.2	5.1	6.1	7.2	8.3
35	—	2.2	2.8	3.5	4.3	5.2	6.2	7.3	8.5
36	—	2.3	2.9	3.6	4.5	5.4	6.4	7.5	8.7
37	—	—	—	3.7	4.6	5.5	6.5	7.6	8.9
38	—	—	—	3.9	4.7	5.6	6.7	7.8	9.0
39	—	—	—	—	4.8	5.8	6.8	8.0	9.2
40	—	—	—	—	4.9	5.9	7.0	8.1	9.4
41	—	—	—	—	5.1	6.0	7.1	8.3	9.6
42	—	—	—	—	5.2	6.2	7.3	8.4	9.7

[a]Cull length = 0.
Note: The figures inside the boxed areas indicate the tree sizes that were sampled in the study.

Sawmill residue volume model

Sawmill residue volume (V_r) is the cubic-foot volume of wood that reaches the mill in merchantable sections but is not converted into cants. It represents slabs, end trim, and sawdust.

I selected the same model for predicting this variable that was selected for predicting cant volume. The prediction equation is:

$$V_r = -1.2183 + 0.003358\ (h) + 0.0002382\ (dbh^2 \times h) - 0.0023042\ (dbh^2 \times c) + 0.024052\ (dbh^2)$$

$R^2 = 0.76$

$SE = 0.42\ ft^3$

VOLUME TABLES

The three volume equations were solved for combinations of dbh and height for trees with no cull length. Predicted volumes are presented in Tables 1 to 3. For trees with cull lengths, the equations should be used.

The difference between gross tree volume and the sum of cant volume plus sawmill residue volume represents roundwood volume between the last cant and the 3-inch top.

APPLICATION

The boxed areas in Tables 1 to 3 indicate the tree sizes sampled in the study. Volumes for some size classes beyond the boxes are shown. You are cautioned against using the

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Table 3.—Predicted volumes of sawmill residue for eastern redcedar trees, in cubic feet[a]

Height—stump to 3 inches dob (feet)	Dbh (inches)								
	5	6	7	8	9	10	11	12	13
13	0.0	0.2	0.5	1.0	1.4	—	—	—	—
14	0.0	0.2	0.6	1.0	1.5	—	—	—	—
15	0.0	0.3	0.6	1.1	1.5	2.0	—	—	—
16	0.0	0.3	0.7	1.1	1.6	2.1	—	—	—
17	0.1	0.4	0.7	1.2	1.6	2.2	—	—	—
18	0.1	0.4	0.8	1.2	1.7	2.2	—	—	—
19	0.1	0.4	0.8	1.2	1.7	2.3	—	—	—
20	0.2	0.5	0.9	1.3	1.8	2.3	—	—	—
21	0.2	0.5	0.9	1.3	1.8	2.4	3.0	—	—
22	0.3	0.6	1.0	1.4	1.9	2.4	3.1	—	—
23	0.3	0.6	1.0	1.4	1.9	2.5	3.1	—	—
24	0.3	0.7	1.0	1.5	2.0	2.6	3.2	—	—
25	0.4	0.7	1.1	1.5	2.1	2.6	3.3	—	—
26	0.4	0.7	1.1	1.6	2.1	2.7	3.3	4.0	—
27	0.5	0.8	1.2	1.6	2.2	2.7	3.4	4.1	—
28	0.5	0.8	1.2	1.7	2.2	2.8	3.4	4.1	4.9
29	0.5	0.9	1.3	1.7	2.3	2.9	3.5	4.2	5.0
30	0.6	0.9	1.3	1.8	2.3	2.9	3.6	4.3	5.1
31	0.6	1.0	1.4	1.8	2.4	3.0	3.6	4.3	5.1
32	0.6	1.0	1.4	1.9	2.4	3.0	3.7	4.4	5.2
33	0.7	1.0	1.5	1.9	2.5	3.1	3.8	4.5	5.3
34	0.7	1.1	1.5	2.0	2.5	3.1	3.8	4.6	5.4
35	—	1.1	1.5	2.0	2.6	3.2	3.9	4.6	5.4
36	—	1.2	1.6	2.1	2.6	3.3	3.9	4.7	5.5
37	—	—	—	2.1	2.7	3.3	4.0	4.8	5.6
38	—	—	—	2.2	2.7	3.4	4.1	4.8	5.7
39	—	—	—	—	2.8	3.4	4.1	4.9	5.7
40	—	—	—	—	2.8	3.5	4.2	5.0	5.8
41	—	—	—	—	2.9	3.5	4.3	5.0	5.9
42	—	—	—	—	3.0	3.6	4.3	5.1	5.9

[a]Cull length = 0.

Note: The figures inside the boxed areas indicate the tree sizes that were sampled in the study.

equations to compute volumes for size classes that are not included in the tables.

Use of the equations or tables to predict gross tree volume requires measurements of dbh and height to a 3-inch top. To estimate cant volume or sawmill residue volume, you must also determine cull length. Nearly all cull in redcedar is confined to the butt section and is related to fire damage. The base of each tree should be inspected for indicators of fire damage.

If you want to predict the value of redcedar trees, you must know the value per cubic foot of cants and sawmill residue.

Tree value can be estimated by multiplying product value per cubic foot by product volume. This value should be reduced by appropriate costs to arrive at stumpage value.

Cant volumes in board feet can be obtained by multiplying by 12 the cubic-foot volumes in Table 2. Board-foot estimates will be useful for estimating tree value if cant value per board foot is known rather than cant value per cubic foot.

The redcedar sampled in this study did not include glade cedar, a name given to open grown trees in the Ozarks. We applied the equations to nine glade cedar trees and found that actual gross tree volume for the nine trees was 5.5 percent less than predicted. Actual cant volume was 3.9 percent less than predicted cant volume. If glade cedar is absent or represents a small part of the total number of trees being considered, we suggest using the equations presented here.

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FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE, 370 REED ROAD, BROOMALL, PA. 19008

PRELIMINARY TEST OF BOOBY-TRAPPING FOR CONTROL OF TWO CERAMBYCIDS

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Abstract. Small aluminum "boats" containing cotton saturated with lindane were glued to elytra of female red oak borers and locust borers and the beetles released into cages or onto trees. Males attempting to mate with booby-trapped females contacted the insecticide and died. However, females also became contaminated in mating attempts and soon died.

Keywords: red oak borer, locust borer, insecticide

INTRODUCTION

The idea of using "booby-trapping" for insect control was proposed by Smith (1963), Whitten and Norris (1967), and Morgan (1967). Masner et al. (1968) proposed a similar technique. The idea of booby-trapping is to release females or males that carry insecticide or chemosterilant and thus kill or sterilize potential mates of the released insects.

For insecticide treatment, it is necessary to have an insecticide-resistant strain of insects so that the treatment does not kill those carrying the booby-traps. Developing resistant strains can usually be accomplished within a few generations; however, the task is time consuming with insects that have long life cycles.

The red oak borer, *Enaphalodes rufulus* (Haldeman) and locust borer *Megacyllene robiniae* (Forster), both primary borers, have long life cycles. The red oak borer has a 2-year life cycle with an economically important generation only in odd years throughout most of the beetles' range (Hay 1974). The locust borer has a 1-year life cycle. While both of these species can be reared artificially, a generation requires 7 to 8 months for the red oak borer (Galford 1974) and about 3 months for the locust borer (Wollerman 1969).

However, both cerambycids have potential for control by booby-trapping, because peak male emergence occurs 1 to 2 weeks before peak female emergence.

The red oak borer is a prime candidate for booby-trapping because adults occur only in odd-numbered years. Adult activity lasts only about 6 weeks and average populations are 12 to 24 beetles per acre. Also, the adults are large and easily handled for affixing booby-traps.

This paper reports on preliminary studies with female beetles carrying insecticide-treated booby-traps.

MATERIALS AND METHODS

The red oak borers used in this study were artificially reared (Galford 1974). The locust borers were collected in late September from goldenrod flowers, *Solidago* spp.,. Female beetles were cooled in a refrigerator to facilitate their handling. Small pieces of cotton wadding were cut to fit inside small aluminum combustion boats (#29-410, Coleman Instruments Corp. Maywood, IL).[1] The cotton was glued inside the boats with contact cement. Next, the bottoms of the boats were dipped in contact cement and they were laid on their sides to dry until the cement became tacky.

The beetles were removed from the refrigerator and the boats were glued onto the elytra just behind the thorax. The beetles were then released in well-ventilated containers until the glue dried.

An eye dropper was used to saturate the cotton with 0.1 ml of a 20 percent lindane solution. Ten female red oak borers and six female locust borers were prepared. The red oak borers were tested as follows: Each female red oak borer was released singly in 1-liter plastic bucket, the sides and bottom of which were lined with filter paper to enable the beetles to crawl around without falling. Three male beetles were introduced into each bucket and a perforated lid was placed on top. After 24 hours beetle mortality was recorded.

Treated female locust borers were released singly on trees in a black locust plantation. Small trees were selected so that the treated females could be easily observed and any males contacting them could be collected. Any male beetles that made contact with or attempted to mate with treated females were collected and placed in individual jars. After 24 hours male mortality was recorded.

RESULTS AND DISCUSSION

All 30 of the male red oak borers were dead or near death after 24 hours; however, so were the females. The aluminum boats were intended to prevent the insecticide from contacting the females. However, male beetles attempting to mate contaminated the booby-trapped females with insecticide. Not all the locust borer males attempted to mate with the females they encountered. When their antennae contacted the boats before the body of the female, they were apparently repelled by the odor of the insecticide and moved away. The boats were apparently too large for the locust borer females and greatly reduced the body area a male could contact. This is important because males recognize females by touch.

Eleven male locust borers that made contact with the six released females were collected. Nine of the 11 males died within 24 hours. The other two males appeared unaffected. Three other males made contact with the females but escaped. All six treated females fell from the trees within 30 minutes and soon died.

While the test results show that females can be successfully booby-trapped, it also demonstrates the necessity of using insecticide-resistant strains. If effective chemosterilants for cerambycids could be found, they would greatly enhance control by booby-trapping.

[1]The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture or the Forest Service of any product or service to the exclusion of others that may be suitable.

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RESULTS OF TREE AND SHRUB PLANTINGS ON LOW pH STRIP-MINE BANKS

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Abstract. Test plantings were established to evaluate the survival and growth of trees and shrubs on 10 acid strip mines in the bituminous region of Pennsylvania. Included in the test were five species of European alder, four birch species, black locust, sycamore, Scotch pine, autumn olive, sawtooth oak, bristly locust, and Japanese fleeceflower. After 11 years, data showed that two of the birches had highest rate of survival and best growth overall. On a few plots, European alder from a German seed source performed well. Scotch pine also performed well on a few plots. In general, survival and growth of all species was poor on spoils where the pH was less than 3.5.

Revegetation of low pH strip-mine banks has been a problem since reclamation of strip mines was first attempted. New legislation has reduced this problem on current mining operations. Pennsylvania strip-mine operators are now required to bury acid-producing overburden and spread topsoil on affected areas. Nevertheless, many acres of partially vegetated and unvegetated (orphan) banks remain from old mining operations. Low pH, less than 4.0, is often cited as the reason why revegetation has failed. Federal legislation has provided funds to reclaim orphan banks. Some coal mining companies and private landowners are attempting to reclaim orphan banks without Federal assistance. However, recommendations for tree and shrub species to plant on low pH spoil banks are limited.

A study to test the performance of tree and shrub species on low pH spoil banks was established in 1964. The study was limited to low pH spoils created by the surface mining of bituminous coal in Pennsylvania; 11-year results of the study are presented in this report.

THE STUDY

In the 1964 study in Pennsylvania, test plantings were established on 10 strip-mine areas in the bituminous region. Study sites were selected on the basis of low pH and failure of the original reclamation plantings. All areas had been backfilled, graded, and planted according to the 1945 Pennsylvania reclamation legislation. Five of the areas were overburden from mining the Clarion coal seam; two were from the Brookville, two from the Lower Kittanning, and one from the Middle Kittanning. Average pH values on these sites ranged from 3.1 to 3.6.

Sixteen species of trees and shrubs were used in this study (Appendix). In addition, three of the European alder species were represented by two or more seed sources. Study plots were designed to contain one row of 25 seedlings of each species. Seedlings were planted at a spacing of 2 feet within rows and with 6 feet between rows. At the time of planting, there were not enough seedlings of some species to conform to the planting design. Seedlings in short number were distributed among the study areas to have representation on each site. Test plantings were replicated twice on six sites, four times on three sites, and eight times on one site. Altogether, 14,205 seedlings were planted.

Individual test plots had a wide range of pH values; the value for soil samples collected from the 32 replicates ranged from 2.6 to 4.7, and 70 percent of the samples had a pH of 3.5 or lower.

Table 1.—Average survival of species planted on 10 low pH strip-mine banks in the bituminous region of Pennsylvania

Species	Number planted	Survival			
		1 yr	3 yr	5 yr	11 yr
		percent			
Alnus incana (France)	800	13	5	4	3
Alnus incana (Germany)	800	21	9	7	6
Alnus viridis (Corsica)	650	10	4	4	4
Alnus viridis (France)	800	10	2	2	2
Alnus japonica arguta (Japan)	170	27	13	5	4
Alnus ihokumae (Japan)	800	6	2	2	2
Alnus glutinosa (1495, Germany)	800	34	16	15	11
Alnus glutinosa (1489, Germany)	800	33	19	16	15
Alnus glutinosa (1793, Germany)	800	26	13	10	8
Alnus glutinosa (SCS)	80	30	15	13	2
Betula lenta (Pa.)	800	19	14	13	12
Betula populifolia (Pa.)	800	49	46	45	42
Betula humilis (Germany)	50	22	22	22	10
Betula pendula (Germany)	775	44	43	43	40
Robinia pseudoacacia	800	32	17	15	13
Platanus occidentalis	800	8	3	2	1
Pinus sylvestris	800	41	33	31	24
Elaeagnus umbellata	800	28	6	5	5
Quercus acutissima	800	52	13	13	12
Robinia fertilis	800	33	23	21	18
Polygonum cuspidatum	480	28	8	8	8

RESULTS

On the average, plant losses were quite high the first year; mortality by species ranged from 48 to 94 percent. On some sites, survival and growth seemed directly related to spoil pH. However, on other sites, there was little or no relationship between plant performance and pH. This suggests that other soil chemical and physical characteristics must be considered when selecting species for planting on low pH spoils.

The average survival rates (Table 1) show —except for birch—that most of the mortality occurs in the first 3 years. After the third year there was little additional mortality for most species but others continued to decline through the entire 11-year test period.

Average 11-year survival rates and height data are given by site in Table 2 for six of the species with the highest average survival. These data illustrate the variability in plant performance on different sites. Survival of all species was poor on the site with the lowest pH (3.1). As spoil pH increased, survival generally increased, but the relationship between average height and spoil pH was erratic. In the following discussion, planting recommendations for the various species are based on their performance at each of the planting sites. In this study, an average survival rate of 50 percent or greater was considered acceptable after 11 growing seasons.

Alders. In general, overall performance of the alders was poor. Eleven-year survival of one or more species exceeded 50 percent on only four plots on the 10 sites. All plots on which the survival rate was better than 50 percent had a pH of 3.5 or higher. After 11 years, 64 percent of the surviving alders were *Alnus glutinosa* from German seed sources.

It is recommended that *Alnus glutinosa* from German seed sources be planted on spoils that have a pH of 3.5 or higher.

Birches. Two species of birch (*Betula populifolia* and *B. pendula*) had the highest survival rates and best growth of all the species tested. These species had 50 percent or better survival on test plots at eight of the sites. The data suggest that the acid limit for these two species is about pH 3.3.

Table 2.—Eleven-year survival and average height of selected species planted on low pH strip-mine banks

Planting site[a]	Spoil pH	European alder[b]		Gray birch		European white birch		Scotch pine		Bristly locust		Sawtooth oak	
		Survival	Height	Survival	Height	Survival	Height	Survival	Height	Survival	Height	Survival	Height
		(%)	*(ft)*	*(%)*	*(ft)*	*(%)*	*(ft)*	*(%)*	*(ft)*	*(%)*	*(ft)*	*(%)*	*(ft)*
Lower Kittanning I[c]	3.1	1	8	2	9	3	4	0	—	0	—	1	5
Middle Kittanning	3.1	1	6	13	20	11	21	5	10	1	1	2	8
Clarion I	3.3	5	6	75	16	62	15	44	8	27	2	15	4
Clarion II	3.3	3	4	42	19	52	21	16	8	14	2	6	10
Brookville I	3.4	17	11	38	17	54	17	24	7	28	10	12	10
Lower Kittanning II	3.4	38	18	79	18	66	17	42	7	10	8	3	5
Clarion III	3.4	3	4	68	15	48	18	42	9	12	1	16	6
Clarion IV	3.5	2	4	32	18	40	24	44	10	48	3	58	9
Brookville II	3.5	15	8	62	19	64	20	16	16	24	5	12	9
Clarion V	3.6	26	19	56	20	50	23	52	11	64	4	42	5

[a]Planting sites are named according to the coal seam that was mined.
[b]Data for European alder are based on survival and height of the three German sources of *A. glutinosa* combined.
[c]One replication on this site had a pH of 4.7; data from that replication are not included in the table.

Only 50 European white birch (*B. humilis*) were planted; after 11 years, 5 were alive. This number is too small to provide a good estimate of performance for this species.

Black birch (*B. lenta*) was heavily browsed by deer, a factor which greatly reduced survival. This species should not be planted if deer browsing poses a problem.

A recent study has shown that paper birch (*B. papyrifera*) performs as well as European white birch on problem spoils (1).

It is recommended that gray birch, European white birch, and paper birch be planted on spoils where the pH is 3.3 or higher.

Scotch pine. Performance of Scotch pine was highly variable. On four plots (pH 3.4 to 3.8), survival rates were among the highest observed in the study. Best height growth also occurred on plots in this pH range. On other plots in the same pH range, Scotch pine did not survive or grow well.

It is recommended that Scotch pine be planted on spoils where the pH is 3.5 or higher.

Bristly locust. Initial mortality was high. However, on plots where seedlings survived, the bristly locust is now spreading profusely by underground runners. On one plot, only a single seedling lived; but after 11 years, this plant has spread to cover an area of more than 300 square feet. On plots with living plants, sprouts are common at distances of 15 feet or more from the parent plants. Often, these sprouts are intermingled with other species in adjacent tree rows. Competition does not seem a problem and the additional nitrogen made available by the bristly locust probably benefits adjacent plants.

Survival after 11 years is more than 50 percent only on three plots (pH 3.4, 3.5, and 3.7). However, there were live plants on all plots (except one) that had a pH of 3.3 or higher.

It is recommended that bristly locust be planted on spoils with a pH of 3.3 or higher.

Sawtooth oak. Mortality of sawtooth oak was very high and performance was highly variable. Best results were obtained on spoils with a pH of 3.4, 3.5, and 3.7.

Sawtooth oak is not recommended for problem spoil plantings.

Black locust. Survival of black locust was quite variable. Only three plots (pH 3.6, 3.8, and 4.5) had survival of 50 percent or better. Height growth was also poor. Average height on the three best sites was 10.3 feet.

Black locust should not be planted on spoils with a pH below 3.5.

Sycamore. This species performed very poorly on all sites. Only 10 seedlings survived after 11 years.

Sycamore is not recommended for low pH spoils.

Autumn olive. This species performed poorly. Only one plot (pH 4.5) had a survival rate greater than 50 percent.

Autumn olive is not recommended for planting on highly acid sites.

Japanese fleeceflower. Survival of this species was poor. However, on some sites (pH between 3.0 and 3.5) where one or more fleeceflower survived, the plants have spread by natural seeding. Observations have shown that the spread of fleeceflower is confined to open spoils. None has been observed in woodlands or grass areas adjacent to spoils.[1]

Fleeceflower is recommended only for spoils with a pH less than 4.0. On less acid spoils, more valuable species are available for reclamation planting.

SUMMARY

Average survival for all species in the study was low. Some species performed better than others and can be recommended for planting on acid spoils, pH 3.5 and higher. Survival of the more acid tolerant species was unpredictable on sites with a pH lower than 3.5.

Birches performed better than other species tested. Gray birch and European birch (*B. pendula*) were the best. Deer and rabbit browsing posed a problem on the black (sweet) birch. Thus, gray birch and European birch (*B. pendula*) are recommended for Pennsylvania bituminous spoils with a pH of

[1]Balogh, Richard. 1978. An investigation of Japanese fleeceflower (*Polygonum cuspidatum*) planted on two bituminous strip-mine spoils in Pennsylvania. Unpublished Master's thesis, Clarion State College, Clarion, Pa.

3.5 or higher. At a lower pH these species may be acceptable if other spoil characteristics are not limiting. If pH or other spoil characteristics are limiting, then the application of ameliorating amendments is necessary to establish suitable planting sites.

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APPENDIX

Species Tested on Low pH Strip-mine Banks

European alder (*Alnus incana*), French seed source
European alder (*Alnus incana*), German seed source
European alder (*Alnus viridis*), Corsica seed source
European alder (*Alnus viridis*), French seed source
European alder (*Alnus japonica arguta*)
European alder (*Alnus ihokumae*)
European alder (*Alnus glutinosa*), German seed source #1495
European alder (*Alnus glutinosa*), German seed source #1489
European alder (*Alnus glutinosa*), German seed source #1793
European alder (*Alnus glutinosa*), SCS seed
Black (sweet) birch (*Betula lenta*)
Gray birch (*Betula populifolia*)
European white birch (*Betula humilis*)
European white birch (*Betula pendula*)
Black locust (*Robinia pseudoacacia*)
Sycamore (*Platanus occidentalis*)
Scotch pine (*Pinus sylvestris*)
Autumn olive (*Elaeagnus umbellata*)
Sawtooth oak (*Quercus acutissima*)
Bristly locust (*Robinia fertilis*)
Japanese fleeceflower (*Polygonum cuspidatum*)

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MANAGEMENT GUIDELINES FOR MONITORING USE ON BACKCOUNTRY TRAILS

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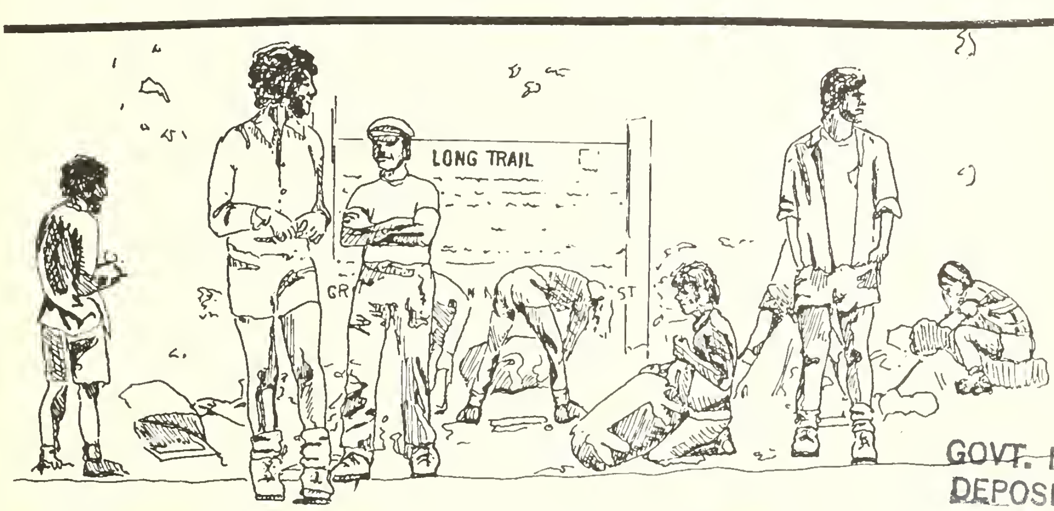
Abstract. This state-of-the-art management guideline describes the importance of knowing backcountry use patterns and the questions that should be asked before embarking on a use-monitoring program. It summarizes information about six techniques for monitoring use of backcountry trails and provides practical information about site suitabilities, installation and maintenance requirements, equipment costs, and data analysis considerations of each monitoring system.



A NOTE TO THE READER

These guidelines have been prepared under the direction of the Backcountry Research Program, USDA Forest Service, Northeastern Forest Experiment Station, Durham, N.H. in cooperation with other groups and individuals as mentioned. Their purpose is to present up-to-date, practical information on a number of subjects concerning backcountry management. The guidelines are not meant as policies, regulations, or rules, but simply a summary of the "state of the art."

Because these documents are contemporary, they will be updated in future years, as additional information becomes available. Therefore, if you have comments or suggestions please send them along to the Backcountry Project. Guidelines will be revised as time and funds permit. Appropriate credit will always be given.

Also, if you have suggestions for areas of major interest that might deserve treatment in a guideline, please send them along, too.

R. E. LEONARD
Project Leader

PREFACE

This guideline has been prepared to collect diverse and scattered information on methods of monitoring backcountry trail use. It is intended to give managers of public and private backcountry recreation lands a comparative view of the techniques that have been used for counting trail users and sampling their characteristics.

Some of the monitoring systems only count trail traffic; others provide additional information about trail users. Some of the systems are technologically sophisticated; some are labor-intensive. Descriptive information about each system is presented in the text of the guidelines. Practical information about site suitabilities, installation and maintenance requirements, equipment costs, and data analysis considerations of each monitoring system is presented in the appendix. It is hoped that this information will help managers select and manage use-monitoring systems that will suit their needs and budgets.

Information in this report has been developed for the guidance of the employees of the Forest Service, U.S. Department of Agriculture, its contractors, and its cooperating Federal and State agencies. The Department of Agriculture assumes no responsibility for the interpretation or use of this information by other than its own employees.

The use of trade, firm, or corporation names is for the information and convenience of the reader. Such does not constitute an official evaluation, conclusion, recommendation, or approval of any product or service to the exclusion of others which may be suitable.

TABLE OF CONTENTS

MANUSCRIPT RECEIVED FOR PUBLICATION 21 AUGUST 1979

PART I. MONITORING VISITOR USE

Importance of knowing backcountry use patterns

In the early 1960's, public forest managers and leaders of private trail organizations became aware of a substantial increase in recreational use of backcountry. This increase led to more active management of backcountry recreational areas to protect the trail environment and at the same time preserve the intangible, but much sought, "backcountry experience."

To manage a backcountry trail system, an inventory of site conditions and use patterns is essential. The former can be assessed readily enough by a competent site survey. Because of the diffuse nature of dispersed forest recreation, use patterns are more difficult to determine. Nevertheless, with the right monitoring system or combination of systems much useful information can be obtained.

This information is important in backcountry management to:

- Develop and assign priorities to maintenance programs for specific areas
- Determine long- and short-term use trends
- Make requests for financial support commensurate with actual use levels
- Plan and implement long-term facility development and educational programs
- Determine correlations between site impacts and use levels in specific areas
- Set up systems models to help manage use patterns in heavily used areas.

The early 'double-sampling' or 'cordon-sampling' method of estimating total dispersed use of a large area of forest land relied on the determination of a relationship between some indicator count, such as a vehicle count, and the desired statistic, such as the number of site visits. Visitors had to be interviewed at a roadblock near the forest land (Cushwa 1963; James 1967). This system posed practical limitations for forest lands accessed by several major highways and for Federal agencies needing questionnaire/interview approval. The 'double-sampling' method is, however, readily applicable to developed roadside campgrounds and picnic areas where traffic funnels through one access road.

Several site-specific backcountry monitoring systems are now available that can provide much useful information without the need for roadblocks. Some are quite simple; others are complex. Before any system can be used effectively, however, monitoring goals and costs must be determined.

Determining monitoring goals and costs at the outset

Trail use should not be monitored without a specific reason or plan. Because even the simplest system requires a substantial investment of time and money, care should be taken in choosing and administering a counting system. A number of questions might be asked to help with this process:

1. *Is a monitoring system needed?*

Some backcountry areas receive relatively little use. Physical impacts and facility needs may be negligible. Under such conditions, the time and effort involved in running a monitoring system might better be spent on other projects.

However, a trail system in which the physical impacts of recreationists are evident requires active management. Decisions to improve, expand, or close overnight sites and trails should be made in recognition of existing or accepted visitor use levels. For example, at physically damaged sites that receive frequent and heavy use, site maintenance facilities and management could be increased to accommodate the heavy use. If this is not possible because management funds or time are limited, the site could be closed for rehabilitation or put under stringent use restrictions. At sites designed to handle heavy use, but where use is found to be low, managers could either encourage more visitors to use the site, or reduce the management attention given to it. Site durability and use levels should be matched with management procedures to prevent site degradation. Without information on use levels, management decisions are difficult to make.

2. *If a monitoring system is needed, exactly what information is desired?*

Managers must determine what information they need and whether and how it can be obtained. Some monitoring systems can be used for more than counting trail traffic. Information obtainable by one or more of the various systems includes:

Use levels
- Number of individual users
- Number of one-way trips
- Date of use

Details of use
- Number of groups
- Size of groups
- Mode of travel (hiking, horseback, etc.)
- Direction of travel
- Trails used
- Duration of trip

Details of users
- Name
- Address
- Age
- Occupation and/or similar information
- Main purpose of trip (hiking, hunting, fishing, etc.).

Basically, use-monitoring systems fall into two major categories: those that provide use numbers only (pressure plate and photoelectric counters), and those that provide information on both use and users (permits, self-registrations, time-lapse photography). A decision should be made initially as to which type of system will better serve management purposes.

Some management questions may require knowledge of more than simple numbers of users. Information about visitors' residences can indicate where to direct information and education ("I&E") efforts. A percentage breakdown of group sizes can help to determine overnight facility needs, e.g., size and spatial distribution of shelters or tent platforms at some overnight sites. A temporal and geographic distribution of dispersed recreationists can indicate when and where to station backcountry patrols or where to upgrade the facilities (Plumley et al. 1978). Visitor information may also be used to aid in search-and-rescue operations and, in the case of mandatory permits, to control use levels in restricted use areas.

3. *Is the management value of the desired information equal to the cost of getting it?*

Monitoring systems differ greatly in complexity and precision. When the sort of information and level of precision desired have been determined, the simplest, least expensive system that satisfies the basic data requirements can be selected.

All monitoring systems require regular maintenance and at the outset these costs, including vehicle expense, travel time, and wages, should be evaluated along with the cost of setting up a system initially. Some visitor information may need to be collected over more than one season, or at several sites, to be of value for management decisions. The length of time and expense of data collection should be considered in the cost also. With some of the monitoring systems now available, a wide variety of information on users can be obtained. Much of it, however, is of questionable management value and may border on an invasion of privacy, e.g., sex or race of users, income or education, etc. Questions that simply satisfy management's curiosity should be omitted. The cost of acquiring visitor use data should be weighed against the "cost" of making a wrong management decision. For example, overuse of an alpine site results in very high rehabilitation costs.

The importance of determining monitoring goals before choosing a system cannot be overemphasized. After the three questions listed above have been reviewed, an appropriate system should be chosen with full recognition of its shortcomings and maintenance requirements.

PART II. THE MONITORING SYSTEMS

A variety of use-monitoring systems is available. Several are sophisticated electronic systems that are likely to be refined and improved rapidly.

Comparing systems is difficult because many variables are involved, e.g., site conditions, use levels, available funding, and competence of maintenance personnel. An attempt has been made here to describe each system briefly and discuss its advantages, disadvantages, and applications. A chart in the last section of this guideline summarizes some of these points. Detailed operational information for each system may be found in the appendix.

Field sampling

1. *The system.* Until the development of mechanical counters in the late 1960's, random field-sampling of visitors was often used to estimate use levels in backcountry areas. The usual procedure is to station people on selected trails to observe or interview users.

Simple observations provide information on numbers, direction of travel, and other clearly observable characteristics; interviews may be as detailed as desired. "Cordon sampling"—interviewing users as they leave or enter an area at checkpoints on every access road or trail—has been used in some studies.

2. *Advantages and disadvantages.* Experience has shown that backcountry use, and particularly day use, is profoundly affected by time of year, day of week, weather, and many other variables (Bowley 1977). In order to obtain use estimates of high accuracy (e.g., ± 2 parties per day with 95 percent confidence), quite a few sampling times must be chosen (see Appendix A). On trails where use does not fluctuate by more than ± 2 parties per day, the random sampling method can be quite practical, as the amount of sampling time required for an accurate estimate is low.

Sampling, particularly interviewing, may be perceived by many users as obtrusive and inappropriate. Federal regulations require a rationale for every question and a strict review and approval procedure for studies by Federal agencies. This provides some degree of protection against invasion of privacy.

3. *Application.* Where information about users and/or their opinions is needed, random sampling can be very useful. Occasional sampling in conjunction with other monitoring systems can help to improve the reliability of such systems.

Voluntary self-registration

1. *The system.* For many years backcountry use estimates have been based largely on information from sign-in registration stations. Visitors simply register and provide the requested information. The trailside stations have consisted of (1) coffee cans nailed to trees, (2) drop-leaf wooden register boxes with register sheets or books (Fig. 1), or (3) individual register cards that are deposited in slot-style boxes. The latter style provides confidentiality between hiking parties. The former styles provide space for parties to communicate with other parties by leaving messages.

The format of the registration sheet or card depends on what agency is seeking the information. Private hiking clubs have designed their own sheets to obtain the information they want at the time. The U.S. Forest Service has used a standard form for registering visitors to western wilderness areas. Its format is very similar to the "Wilderness Permit" used by the Forest Service in eastern wilderness areas. Standardization of registration forms allows forest managers to collect comparable information so that nationwide statistics can be compiled. Within one management unit, standardization can also provide more

Figure 1.—Register boxes usually contain reg sheets, pencils, and some educational informa

useful (comparable) information on hiker use patterns.

2. *Advantages and disadvantages.* Voluntary self-registration systems have a number of advantages. Both initial costs and maintenance costs are low because of the simplicity and durability of the system. The register boxes are portable and easy to install. Vandalism has been rare in backcountry studies (Wenger 1964), although damage by animals may be a problem in some areas.

Registration stations can serve secondary functions. Maps and educational information can be put in them, and the register information can be of some value in search-and-rescue operations. Self-registration systems normally provide information on date, name, address, and number in group. Many forms also request information on duration of visits, direction of travel, destination, etc. An effort should be made to avoid requesting too much information, as lengthy or complex forms are more likely to be left uncompleted.

The greatest shortcoming of voluntary self-registration systems is the lack of followup procedures to determine visitor sign-in rates. Although studies have shown that a compliance rate of between 60 percent and 80 percent is likely (Wenger 1964; James and Schreuder 1971; Lucas, Schreuder and James 1971), some studies have shown rates as high as 89 percent (James and Schreuder 1972) and as low as 28 percent (Lucas 1975). Because of this variability, managers should avoid the temptation to apply a conjectural compliance rate to the figures they gather from the boxes.

In order to estimate trail use, the registration sign-in rate must be determined for each station, unless very similar characteristics and users are found at different stations. The accuracy with which this rate should be determined depends on the manager's need for accurate trail-use numbers. A sampling scheme for validating registration box sign-ins is presented in Appendix B. The validation procedure involves stationing someone in the vicinity of the register box to count the number of hikers and compare that number with the number of those who have signed in. Eventually, a compliance rate for that particular station can be derived. Because this procedure does not require special training, it is possible for volunteers (e.g., trail club members or Scouts) to do this work, thereby reducing costs considerably.

Researchers who want to study hiker characteristics or attitudes from mailed questionnaires can obtain hiker addresses from the registration station. However, the sample may be biased if registrations are the only source of addresses. Studies have shown lower-than-average compliance rates among solo hikers, day-users, and local people, and substantially lower compliance among horseback riders, fishermen, and hunters (Lucas and Oltman 1971). Therefore, registers on a trail with substantial non-hiker use may bias the final user profile. In addition, most register forms ask only one person from each party to sign in. Other party members, especially if they live at different addresses, will not be surveyed.

If greater accuracy is needed, the register system can be supplemented by random interviews combined with the validation process. In some cases, a separate compliance rate can be developed for readily observable user groups such as horseback riders.

3. *Applications.* Despite the shortcomings discussed above, self-registration systems have many applications, especially where funds are low and volunteers can be used for validation. Wherever names, addresses, and other hiker characteristics are desired, self-registration provides an unobtrusive and inexpensive way to collect this information. Additional information about use of trail registers can be found in Wenger and Gregerson (1964).

Mandatory permit system

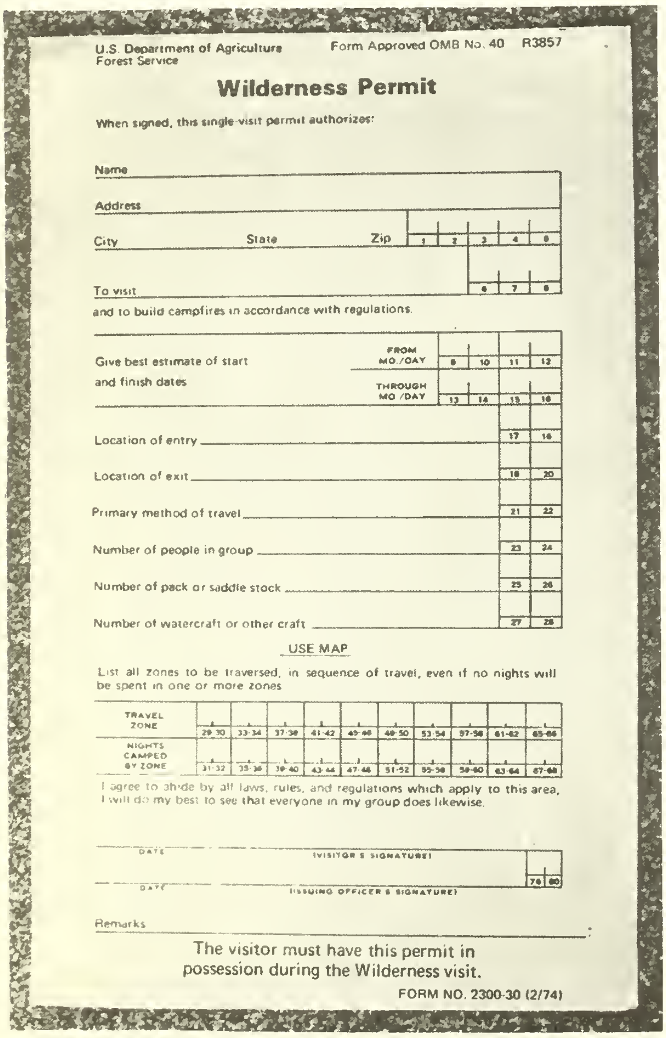
1. *The system.* Mandatory use permits or reservations have been used where daily or overnight use limits have been imposed to keep visitor levels from exceeding site capacities. Permits are issued to persons stopping at local agency offices, or by mail or a first-come, first-served basis (see Appendix C).

Some of the nation's designated wilderness areas use a mandatory permit system. This should not be confused with the voluntary permit system (registration system) used by many Federal wilderness areas in the West.

The current standard Federal wilderness permit requires information on name, address, area to be visited, estimated start and finish dates, locations of entry and exit, primary method of travel, number of people in group, and "travel zones" to be traversed (see Fig. 2). Permit information is currently fed into a nationwide computer so that each national forest can receive a quick tabulation of user characteristics.

As with any system that requires personal registrations, the compliance rate is rarely 100 percent. In areas with mandatory permits, rangers or backcountry patrols travel through the area to enforce the permit requirement as well as assist visitors with other needs. Failure to have a permit may result in a legal citation and fine, but often the hiking party is simply issued a permit by the patrol and advised of the importance of obtaining a permit on the next trip.

Figure 2.—Wilderness permits supply managers with useful information in addition to being an effective means of limiting use in an area.



U.S. Department of Agriculture
Forest Service

Form Approved OMB No. 40 R3857

Wilderness Permit

When signed, this single-visit permit authorizes:

Name
Address
City State Zip 1 2 3 4 5
To visit 6 7 8
and to build campfires in accordance with regulations.

Give best estimate of start and finish dates
FROM MO./DAY 9 10 11 12
THROUGH MO./DAY 13 14 15 16

Location of entry 17 18
Location of exit 19 20
Primary method of travel 21 22
Number of people in group 23 24
Number of pack or saddle stock 25 26
Number of watercraft or other craft 27 28

USE MAP

List all zones to be traversed, in sequence of travel, even if no nights will be spent in one or more zones

TRAVEL ZONE	29-30	33-34	37-38	41-42	45-46	49-50	53-54	57-58	61-62	65-66
NIGHTS CAMPED BY ZONE	31-32	35-36	39-40	43-44	47-48	51-52	55-56	59-60	63-64	67-68

I agree to abide by all laws, rules, and regulations which apply to this area. I will do my best to see that everyone in my group does likewise.

DATE (VISITOR'S SIGNATURE)
DATE (ISSUING OFFICER'S SIGNATURE) 79 80

Remarks

The visitor must have this permit in possession during the Wilderness visit.

FORM NO. 2300-30 (2/74)

2. *Advantages and disadvantages.* Mandatory use permits have a number of significant attributes. Because they are compulsory, permits can be used to limit or control access to heavily used or fragile areas. They are also valuable information and education tools because they provide direct contact with users. In addition, they can be used to help find lost or injured persons.

As use-monitoring tools, however, mandatory permits have some significant disadvantages. The cost to administer the system is quite high. The permit system incurs printing and distribution costs, clerical time to issue the permits to hikers, and daily patrolling time to enforce the system. In fiscal years 1976 and 1977, the cost per permit in the Federal wildernesses of New England was estimated at $5.84, not including printing, processing, and analysis costs (Guldin 1978).

Reliance on permit data for estimating use of an area, or determining patterns of use, can lead to erroneous conclusions. While some hiking parties fail to obtain permits, others apply for permits and never use them. Permit compliance among actual users in one New England wilderness was found to be about 60 percent for day users and 80 to 90 percent for overnight users. A higher average compliance rate, 78 percent, was calculated when all permits issued (used or not) were included in the figures. Total use of an area would be inflated if all issued permits were counted. In addition to the difficulty of estimating total use, the patterns of use that can be derived from the permit information are not completely dependable or accurate. The activities and travel routes listed on the permits are anticipatory, so the information supplied by the hiking party does not always reflect the actual trip itinerary (Leonard, Echelberger, and Schnitzer 1978). As with the self-registration system, the permit compliance rates and information must be validated.

3. *Applications.* Mandatory permits are valuable in areas where day or overnight use must be limited, such as fragile alpine or subalpine campsites. As a use-monitoring system,

the permit system requires validation and enforcement to yield reliable information. The self-registration system provides comparable information at much lower cost; however, in areas with a multitude of access points or a complex trail network, permit systems may be easier to administer and easier to estimate total use of the area from than a system of trail-specific counting devices. Further information about mandatory permits can be found in Behan (1974), Godin and Leonard (1977), Hendee and Lucas (1973), Lime and Lorence (1974) and Lime and Buchman (1974).

Pressure plate electric counters

1. *The system.* Pressure plate counters were developed in the mid-1960's, using components from a variety of commercial sources. Despite the popularity of the system in some areas, no prepackaged pressure plate counter is available.

The components consist of a flat 18 x 24-inch plastic-covered mat switch, which is placed in a sandwich of plywood, masonite, or other material. Mat switches are common, and often used to ring bells in stores. The sandwich is designed to protect the mat switch from sharp rocks and to distribute the weight of a hiker's foot evenly over it. The sandwich is wrapped in a plastic trash bag, which in turn is wrapped in burlap, and buried a couple of inches below the surface of the trail. The plastic bag serves to waterproof the system and the burlap provides a rough surface to which the soil will cling.

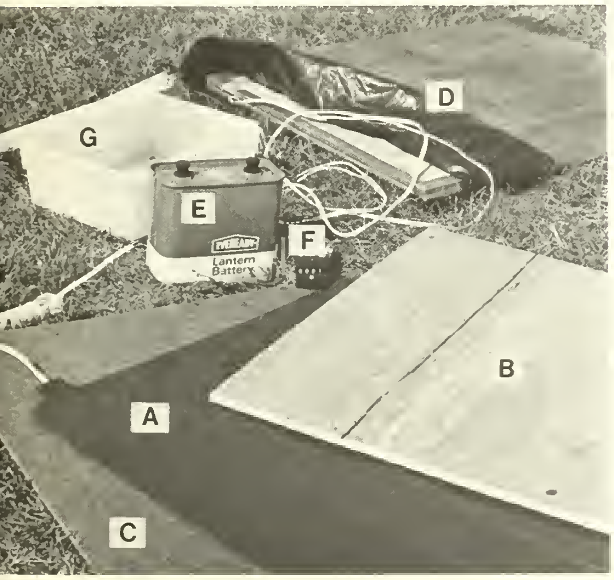
From the buried mat, leads run to a 6-volt lantern battery and a small digital counter stored in a buried, watertight container about 6 feet away from the trail. When a hiker walks on the buried mat, the switch is closed; as the person's foot is lifted from the mat, the switch is opened and the counter advances one digit (see Fig. 3).

2. *Advantages and disadvantages.* Pressure plate counters have a number of significant advantages. Component costs are relatively low (from $40 to $70, depending on materials), and operating costs are also low. The 6-volt lantern battery usually lasts from 14 to 20 weeks. The components are good for at least four seasons, and even longer if carefully protected from moisture. The components are portable, so maintenance is relatively straightforward because infrequent malfunctions can be repaired easily in the field by simply replacing defective parts. Should a malfunction occur, however, or the batteries become exhausted, there is no way of establishing the date or time of the breakdown. Therefore, the counters should be checked regularly. We suggest biweekly checks.

Placement and installation are critical. Ideally, the trail should be nearly as narrow as the plate. On wider trails it may be possible to funnel traffic over the plate by discreetly placing rocks or dead branches on the trail edges. Sections of trail that are extremely wide, not flat, or have poorly drained soil or soil of high stone/gravel content, will not be suitable for pressure plate counters.

Like any counting system, pressure plate counters do not record traffic perfectly—some people may walk around or step over the plate and large animals (over about 40 pounds) will be counted. Careful placement and installation will alleviate many of these problems, but any counter should be observed during

Figure 3.—The pressure plate (A), sandwiches between plywood (B), and masonite (C), protected with a layer of plastic and burlap (D), is buried several inches below the trail surface. A 6-volt battery (E) and counting mechanism (F) are housed in a plastic container (G), wired to the pressure plate and hidden near the trail.



periods of use to be sure it is working properly (see Appendix D).

3. *Applications.* The pressure plate counter is an economical and reliable tool to measure total trail use. At present the pressure plate counter cannot distinguish direction of travel and so counts use in both directions.

The counter may be used alone or in conjunction with another system to count hikers. Where additional information on hiker characteristics is desired, or where trail conditions are not suitable for the pressure plate installation, an alternative system should be used.

Photoelectric traffic counters

1. *The system.* A photoelectric trail traffic counter was developed in the late 1960's by the Equipment Development Center of the USDA Forest Service at Missoula, Montana. The system consists of a scanner that emits a beam of pulsed infrared light, a reflector that returns the beam to the scanner, and a battery box containing one 6-volt and two 12-volt lantern batteries. The scanner is mounted on a tree and directed toward the reflector affixed to another tree up to 75 feet away (see Fig. 4). When an object passes on the trail and interrupts the beam, the counter on the scanner advances one digit.

2. *Advantages and disadvantages.* The photoelectric counter, like the pressure plate counter, estimates total trail use. Its advantages are that it may be used over any trail surface and does not require a flat or nonsloping trail. The counter may be used to monitor a variety of backcountry users, from horseback riders to cross-country skiers. A narrow trail tread at the counting site is still recommended to funnel trail users by the scanner in single file.

When trail counts are desired at sites above treeline or in sparsely forested areas, the light beam counter is not suitable. The scanner and reflector need to be mounted inconspicuously to prevent vandalism (see Appendix E). In addition, these elements should be protected from direct sunlight and precipitation.

Although the infrared scanner is an ingenious application of sophisticated electronics to the problem of measuring trail use, reports from the field on the counter's reliability and

Figure 4.—The photoelectric counter (A) is inconspicuously mounted on a tree directly opposite a reflector (B), also affixed to a tree across the trail. The counter is wired to a battery in a box (C), buried nearby.

accuracy have been mixed, according to a telephone conversation with Loren Delan of the Equipment Development Center in July, 1978. A number of studies (James and Schreuder 1971; James and Schreuder 1972; Lucas, Schreuder, and James 1971; and Bowley 1977) indicate that overcounting is a problem. Incorrect installation is usually blamed for these problems. Ten of 19 counters field-checked by the Equipment Development Center on various national forests had been improperly installed (Tietz 1973). Scientific Dimensions, Inc., the manufacturer of the counters, suggests that faulty components in some of the early models made the scanners unduly sensitive to fog and rain. Scientific Dimensions recommends reducing the distance between scanner and reflector by 30 to 50 percent of the specified maximum range in areas likely to have dense fog.

3. *Applications.* The photoelectric counter is moderately expensive but because it does not require foot pressure, it may be used to count hikers where pressure plates cannot be installed. It can also monitor winter use by cross-country skiers or snowshoers. One model of scanner will count objects moving as fast as 40 miles per hour, such as snowmobiles and trail bikes. Further information about photoelectric trail counters can be found in DeLand 1976.

Time-lapse photography

1. *The system.* In the early 1970's, some interest developed in the use of photography for monitoring recreational use and particularly for counting boaters on remote lakes and rivers. Systems considered included video tape, closed-circuit television, and aerial photography. Costs of these systems were deemed prohibitive under most circumstances, but a related system using a super-8 movie camera and time-lapse photography may be practical for some applications.

The time-lapse photography system is still being developed and refined, but to date it has usually used a Kodak "Analyst" or other movie camera that can be set to expose frames at various intervals. The camera is mounted as inconspicuously as possible at a favorable angle to the trail or waterway to be monitored. With the camera is a battery pack and usually a timer to shut it off at night to save film and batteries (see Fig. 5). Very recently, the Equipment Development Center has developed a system using a Canon 814-XL camera that can expose a single frame when triggered by an infrared or other electrical impulse counter. This system greatly conserves film and batteries, and requires much less field maintenance than the more primitive system.

The super-8 films are processed and reviewed with a projector especially designed for time-lapse work (see Fig. 6). Some systems include timed light-emitting diodes to provide an hourly time reference.

2. *Advantages and disadvantages.* The most obvious advantage of time-lapse photography is that it approximates having a person at the site counting people. When properly installed and operating, it should provide nearly 100-percent accuracy. Whether this theoretical perfection can reasonably be achieved in the field, or is worth the extra cost, are separate, but important, considerations.

Time-lapse photography is expensive, although not so much so as might be expected. Two major studies (Marnell 1975, Bowley 1977) found an average cost of about $1.50 per hour of surveillance. In each case, at least two-thirds of this cost was attributed to vehicle operation and field maintenance salaries. These relatively high labor costs reflect the need to replace batteries and film at short intervals. A refined design would drastically reduce these expenses.

Information available from the time-lapse system includes mode of travel, direction of travel, and number of users. Group size and day or overnight users are possible to discern in many cases. However, infomation on names and addresses is, of course, not possible. Some legal questions are involved in photographic surveillance, and managers should check with legal counsel before embarking on a time-lapse project. Restrictions placed on one study, for example, included an assurance that individuals could not be recognized and that the film would be destroyed at the end of the study (Marnell 1975).

3. *Applications.* Time-lapse photography is applicable wherever more informative counts are needed and sufficient funds are available. It may be especially useful for periodic vali-

Figure 5.—The movie camera (A) is housed in a weather- and sound-proof box (B) and fixed in the required monitoring position. The system includes a battery-operated automatic timing device (C) which turns the camera off at night and on in the morning, or, when AC power is available, an AC-DC converter and automatic timing device (D) that serves the same function.

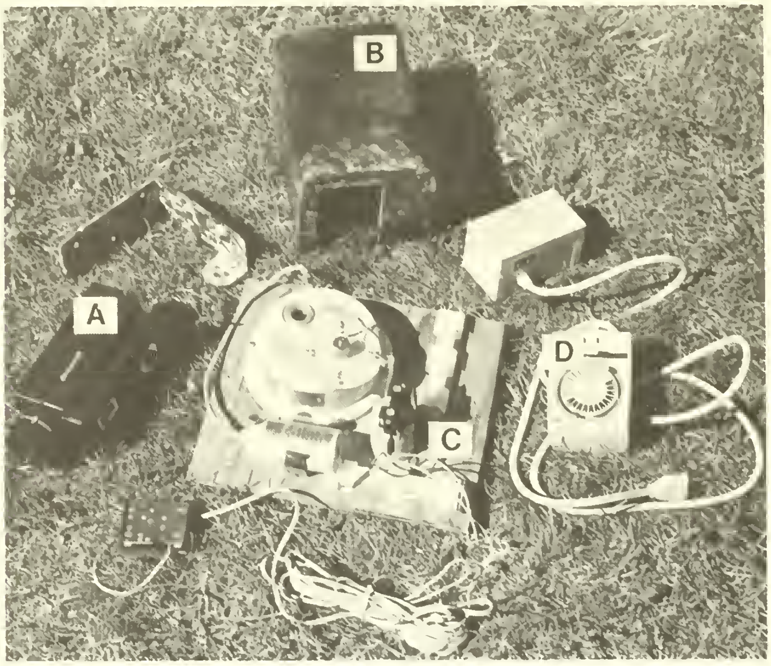


Figure 6.—Editing machine for 8-mm movie film is used to view and analyze film taken by the automatic monitoring camera.

dation of the performance of other use-monitoring systems.

Detailed information on setting up two different types of time-lapse systems is found in Bowley 1977, Gasvoda 1978, and Marnell 1975.

PART III. SUMMARY

Studies and field experience in the Northeast have shown that when only total trail use numbers are desired, pressure plate electric counters are likely to provide the least expensive, most reliable system. Where more information on users is desired, e.g., name and address, date, or group size, the sign-in register box with regular validation may prove to be the best system.

Special applications may require random sampling, photoelectric counters, or time-lapse photography. Special management units, such as Federal wildernesses, may require mandatory permits to control use. These systems may be used alone or in combination to get the desired results.

Each of these systems has advantages, limitations, and shortcomings (Table 1). Improperly used, they can produce expensive, misleading information. But carefully planned and managed, each can produce valuable information at reasonable cost to aid backcountry management.

Table 1.—Comparison of use-monitoring systems

Data yielded	Field sampling	Voluntary self-reg.	Mandatory permits	Pressure plates	Photoelectric counter	Time-lapse photography
Number of passes across trail	C	C	C	X	X	X
Number of individual users	C	C	C			S
Number of groups	C	C	C			S
Group size	X	X	X			S
Name	X	X	X			
Address	X	X	X			
Date	X	X	X			S
Mode of travel	X	X	X			X
Direction of travel	X	X	X			X
Duration of trip	X	X	X			
Other capabilities						
Information and education distribution	X	X	X			
Public relations potential	X	X	X			
Aid in search and rescue		X	X			
Potential to limit use of an area or specific site			X			
Other characteristics						
Initial equipment and assembly cost (per unit)		$20 to $35		$50 to $85	$300	$250 to $750+
Average battery life				16 wks	8 wks	variable
Time to install unit on site		0.5 h		1 h	1 h	1 h
Time to check and maintain hardware		10 min every 2 wks		$\frac{1}{4}$-$\frac{1}{2}$ h every 2 wks	$\frac{1}{4}$-$\frac{1}{2}$ h every 2 wks	1 h per film roll
Time to validate or sample trail use	Time depends on accuracy desired See App. A.	Time depends on accuracy desired & trail traffic volume. See App. B.	Personnel required to check permit compliance, e.g., 1 person 8 h/day/20 mi of trail. This job can include additional duties.			

Symbols: X = Available
C = Calculated from sample
S = Sometimes available
(Blank) = Not available

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APPENDIX A

Field Sampling by Personnel

A sampling scheme can be established to determine an average visitor use per time period, such as 4 hours or 1 day. The sample size required (n), which in this case is the number of observation periods, can be calculated by statistical methods. The sample size to be selected depends on (1) the maximum error of estimate about the mean desired (E); (2) the confidence level desired in the estimate (associated with a value of t that can be found from a table); and (3) the variance of visitor use per observation period (S^2). This last factor must be computed from previous or preliminary trail observations, either by field personnel or from a self-registration box. Many pocket calculators will compute variance. It indicates the degree of variation in number of visitors per observation period. Total trail use volume, however, does not affect the amount of time required for sampling. The formula for calculating a sample size from these variables is:

$$n = \frac{t^2 s^2}{E^2}$$

This method is described in Avery (1975) and in most survey sampling textbooks. Observations for n periods will provide an estimate of the average number of visitors per period, $\pm$ E visitors, at a confidence level of t, such as at 95 percent confidence. (At 95 percent confidence, $t = 1.96$ and at 90 percent confidence, $t = 1.645$.) If one desires an estimate of the number of parties per period, then E must be specified in number of parties, not number of persons.

For example, if after 5 days of observations the number of parties per day were found to be 8, 10, 8, 5 and 1, the variance would be computed to be 12.3 and the number of sampling days required to estimate use at ± 1 party per day at a confidence level of 90 percent would be 33 days. Likewise, with the same variance and confidence level, four sampling days would be required to estimate use within ± 3 parties per day.

As the variance in trail use increases, the number of sample periods increases rapidly. To reduce the number of sample periods, the sampling scheme may be "stratified" between two or more types of periods or days that are known to have vastly different use patterns, e.g., weekdays versus weekend days. Also, longer observation times, e.g., all day rather than 2 hours, can reduce the observed variance. If sampling is stratified, sample sizes must be computed separately for each selected condition.

To select periods for observation, once sample size has been determined, a table of random numbers may be used. All the potential observation periods for each stratum should be sequentially numbered, and the ones used whose numbers are given by the table of random numbers. Wagar (1969) provides a detailed description of this process.

The field sampling technique may be used to obtain more information than simple hiker numbers. Surveys of hiker attitudes or characteristics may be obtained during the sampling periods. If a Federal agency is administering the survey, however, it must comply with Federal regulations governing public surveys.

APPENDIX B

Managing a Voluntary Self-Registration System

The effectiveness and reliability of register box data is highly dependent on the care with which the system is organized and maintained. The following suggestions are based on field experience:

A. *Design*

1. *Station design.* Over the years, many different station designs have been used. Field experience indicates that the dropped or notebook type wooden register box mounted on a tree or post is quite serviceable. The slot-type station in which individual registration cards are inserted into a locked slotted box have also been used successfully.

The registration station is a good place to put maps or other pertinent trail information. A small calendar is important to assure accurate dating of entries. A pencil holder helps to encourage the return of the pencil(s).

2. *Sign design.* Signs requesting people to register have varied from a simple "Please

Register" on the box itself to large signs telling users they "must" register. Studies have shown that a firm but not demanding sign is slightly more effective than other signs. Clarity and brevity are probably equally important.

3. *Register sheet/card design.* Register forms should appear straightforward and uncluttered. The more complicated the form the greater the likelihood of incomplete registration.

The register form should clearly state whether *one* member from each party or *all* members of each party should sign in. In addition, the form should state whether the party is to sign both in and out or only in. Experience has shown that hikers are confused by "in and out" registration (Wenger 1964). Requesting hiking parties to sign in once before entering the area may help.

B. *Register placement*

Placement and installation of register boxes is of critical importance. Generally, registers should be:

1. A reasonable distance (usually at least 0.3 miles) from the nearest road or trailhead to avoid tampering by nonrecreationists. Remote locations (i.e., more than 3 miles from the nearest access point) should be avoided because of the time required for maintenance and validation.

2. At a natural momentary resting point in the trail, e.g., stream crossing, ridgetop vista. Areas likely to be used for overnight camping should be avoided.

3. Located far enough from side trails to avoid confusion in validation.

4. Mounted low enough for young hikers to sign in—usually about 3½ feet above the ground. If posts are used, they must be firmly anchored, because hikers tend to lean on the boxes while signing in. Likewise, drop-door register boxes require fastenings strong enough that the door won't pull off when hikers lean on it. In areas of heavy snow accumulation, the boxes should be raised late in the fall if an attempt to monitor winter use is planned.

5. Mounted so they are equally obvious from either direction on the trail.

C. *Maintenance and validation*

Regular maintenance of a self-registration system is essential. A register box without sheets or pencils not only fails to produce data, but it also hurts the credibility of more carefully maintained registers elsewhere. Regular validations, normally combined with routine maintenance visits, provide information for calculating the compliance rate for that particular station. The validator should avoid revealing the purpose of his/her presence on the trail.

Validators should always carry extra pencils, register sheets, pocket calendars, and any other materials used at the register. In some cases, it may be advisable to carry tools and spare parts in the car in case the register box has been vandalized or destroyed by animals.

D. *Determining sample size for validation*

To determine a compliance rate for a register box, a certain number of hiking parties must be observed. Observing more parties increases the accuracy and confidence in the findings. Trail managers should select an accuracy level and confidence level that they feel is just necessary to make the kinds of management decisions they need to make. Accuracy beyond that point will be of little additional utility and will waste effort.

The required sample size can be calculated from a statistical formula used for estimating the proportion of a population that possesses a specified characteristic. The sample size required depends on (1) the estimated *probability* that a hiking party will sign in; (2) the level of confidence desired; and (3) maximum error desired in the compliance rate.

The formula to compute sample size is:

$$n = p(1-p)\ (t/E)^2$$

where p = probability of a hiking party signing in, expressed as a percent

t = value from a statistical table of t-values associated with the percent confidence desired. (For 90 percent confidence, $t = 1.645$. For 95 percent confidence, $t = 1.96$.)

E = the maximum error desired in the compliance rate, expressed as a decimal, e.g., $E = .10$ for a compliance rate ± 10 percent.

Where there is no idea about the probability value, $p = .50$ is used (i.e., for a 50 percent probability that a hiking party will sign in).

A discussion of this statistical method can be found in Mendenhall (1971) or most survey sampling textbooks.

As it is necessary to observe n hiking parties, the relative trail use will affect the amount of time that a validator must spend on a trail. For very low-use trails, it would probably not be worthwhile to spend the time required to obtain very accurate sign-in rates.

For example, if the probability of a party signing in is 50 percent and an estimate within 10 percent is desired at a confidence level of 95 percent, the validator will need to observe 96 parties. If trail use averages 20 parties per day, this will take 5 days; at 10 parties per day it will take 10 days, and at 3 parties per day it will take 32 days.

To estimate the compliance rate within 5 percent under the same conditions would require observing 384 parties, which could take 128 days on a trail used by an average of 3 parties per day.

Validation (or sampling) times should be selected randomly in the same manner described for field sampling in Appendix A.

In some cases, volunteers may be available to do validations. Scout troops or clubs can have a number of members share the responsibility for making the validations, thereby reducing the burden on any one person. Volunteers must understand the importance of following the procedure, so that they do the validations properly. They should be provided with forms to make the data-gathering easier. Because the enthusiasm of volunteer validators tends to lag in the course of the season, it is a good idea to provide some incentive for completing the project, and also to have a paid backup validator available.

Preliminary field experience in Vermont with volunteer validators who were given little guidance was not very satisfactory. Four volunteer validators were found in 1976 and 1977 to validate four register boxes in the Green Mountains. The volunteers were told to validate the boxes about twice a week, or whenever they found the time. Total validation time during a summer season for each volunteer was between 4 and 17 hours. For a comparison, four Green Mountain Club employees responsible for shelter caretaking were also told to validate register boxes whenever they had time. Total validation time for each of them was 7 to 44 hours. It was more convenient for these field personnel to validate boxes as they were already near the register sites. In addition, they were directly involved with site management and therefore more highly motivated to validate trail registers.

E. *Interpreting the register sheets*

The most frequent problem in interpreting register sheets is overregistration—several individuals signing in separately from the same group or a group signing both in and out during a round trip. Usually, this duplication can be detected by the repetition of date, group size, and residence, but the person doing the tabulations must be alert to it. Overregistration should be struck out and gratuitous entries should be ignored.

Disappearance, or theft, of the pencils may occur from time to time, and can usually be determined by the beginning of entries in a variety of inks and leads. Since many users don't carry pens or pencils and are therefore unable to sign in, registrations may be lower than normal while pencils are missing.

Estimating overall use of a trail at the register station involves simply taking the total number of registrants and dividing by the compliance rate derived from the validations, e.g., 500 registrants, 75 percent compliance rate: $500 \div 0.75 = 667$ users.

APPENDIX C

Administration of Mandatory Permits

Use permits have been made mandatory on some private lands as well as on some publicly owned lands where restrictions on use are considered necessary. The federal manager does not have much administrative flexibility because the permit system has been standardized for national or regional use. States and private land-owning organizations can set up more flexible permit programs. In establishing such programs, several points should be kept in mind:

1. The permit requirement should be well publicized in areas from which users are known to come.

2. If a fee is required or a use restriction exists, these aspects should be well publicized.

3. It should be made clear whether permits are required for day or overnight use, or both.

4. Permits should be fairly short and to the point. They should be organized to facilitate data tabulation.

5. Getting a permit should be made as easy as possible to ensure high compliance. Independent issuers of permits (e.g., stores), however, should be well versed in the importance of carefully filling out the form.

6. Information and education ("I&E") material should be prepared for distribution with the permits.

7. Field personnel are needed at least periodically to check for permits and determine compliance rates.

8. Names and addresses should be saved if followup correspondence is deemed likely (e.g., for unit planning material, opinion survey).

APPENDIX D

Managing a Pressure Plate Counter System

A. *The components:*

1. Mat switch: "Tapeswitch Signal Mat" model CVP-1723
Tapeswitch Corporation of America
100 Schmitt Blvd.
Farmingdale, NY 11735

2. Sandwich: ⅜" plywood
⅛" tempered hardboard
2" wide duct tape
5 mil plastic trash bag
burlap bag

3. Counter: Sodeco TCeZ4E (made in Switzerland)
Landis & Gyr
4 Westchester Plaza
Elmsford, NY 10523

4. Battery: Standard 6-volt lantern-type battery
Eveready #731

5. Plastic container: 3-qt plastic storage container with well-fitted lid to store battery and counter below ground surface.

(Addresses given are for national distributors; local retailers can be determined by writing to these addresses.)

The mat switch is simply sandwiched between the plywood and hardboard and the edges of the sandwich sealed with duct tape. The sandwich is then placed in the trash bag to protect it from moisture and covered with the burlap to provide a rough surface which will hold soil and forest litter.

B. *Placement:*

1. *Trail width.* Ideally, pressure plates should be located on trails that are little wider than 18 inches, the width of the mat. Heavily used trails are rarely that narrow, so obstructions must be used to funnel users single-file over the plate. They should be large enough to divert hikers, e.g., large rocks, large dead trees or limbs, and so placed to conceal their purpose.

2. *Slope.* Because paces and strides vary greatly on steep pitches, extreme slopes should be avoided. A flat or nearly flat stretch of trail assures even, steady foot pressure.

3. *Drainage.* Although the plastic bag should make the sandwich watertight, poorly drained places should be avoided. Mucky organic soil does not transmit foot pressure as well or as consistently as better drained mineral soils. The organic soil can also retain much water and become heavy. Rocky or stoney soils may be too heavy for the pressure plate, and keep the mat switch closed continuously.

Proper placement of the counter is critical. It may be well worth the time to walk the entire stretch of trail to be monitored before placing the counter, to locate an area that will meet as many of the site requirements as possible.

C. *Installation:*

Once a site has been selected, installation can begin. It is usually best to install counters at off-peak times to minimize the chance of discovery by users.

1. Excavate to a 4- or 5-inch depth an area slightly larger than the pressure plate. Care should be taken to smooth the bottom of the excavation and remove protruding rocks and roots.

2. Place the plate in the excavation and run the leads, with splices, to a point selected for burying the battery and counter.

3. Bury the leads at least 4 inches deep.

4. Attach the leads to the counter and battery. Polarity is not important. Running the leads through a small hole beneath the lip of the plastic container lid will help to keep moisture out of the container.

5. Bury the container and cover the top with a flat rock or twigs and leaves.

6. Cover the plate with soil and forest litter—sift out rocks and other debris. Test the buried counter by stepping lightly and then firmly over the entire plate area. If too little soil is over the plate, it may double-count. If too much soil is over the plate, it may miss counts.

7. Once any adjustments are made for plate cover, restore the site to as near a natural appearance as possible.

8. If possible, wait to observe a number of hikers as they pass over the plate. Some unanticipated problems may be observed.

D. *Maintenance:*

A maximum recommended maintenance interval is 2 or 3 weeks. The more frequently the counter is checked, of course, the more reliable the data will be.

Maintenance should include:

1. Recording the number on the counter.

2. Walking over the trail a number of times at different paces and strides to be sure the system is functioning properly.

3. Either zeroing the counter or recording the new figure so that test counts won't get confused with actual use counts.

4. Checking the battery strength with a voltmeter. Weak batteries may cause miscounts.

5. Checking the site to be sure there are no tell-tale signs of the plate, wires, or battery container.

E. *Troubleshooting:*

In making field checks, maintainers should always carry extra components and a tool kit (folding shovel, pliers, knife, etc.). This troubleshooting chart is based on the most common malfunctions, and their remedies, in order of likelihood:

1. Counter does not work at all:
   a. Dead battery.
   b. Bad connection.
   c. Bad splice.
   d. Soil too heavy over plate (frequently sodden after rain).
   e. Malfunctioning mat switch.
   f. Malfunctioning counter.
2. Counter double-counts periodically:
   a. Too little soil over the plate.
   b. Rocky soil over the plate.
   c. Warped or twisted plate.
3. Counter misses counts intermittently:
   a. Battery weak.
   b. Bad connections or splices.
   c. Too much soil over plate.
   d. Soil compacted over plate; dig up plate and replace in same spot with looser soil on it.
   e. Malfunctioning mat switch or counter.

APPENDIX E

Setting Up a Photoelectric Counter System

A. *Installation*

Installation of infrared counters is of critical importance. Most of the reported problems with the counters appear to be related to improper installation. The instruction book prepared by Scientific Dimensions, Inc., which accompanies each counter, should be followed closely, with special attention to:

- Selecting trees for scanner and reflector which will not move substantially in the wind.
- Selecting a site where hikers will pass by in single file and where there is little temptation for hikers to stop to view the scenery or wait for friends.
- Aiming the beam at waist level (about 3½ feet).
- Centering the reflector in the scanner beam and not separating the two by more than 75 feet (for standard scanner). The manufacturer recommends reducing that distance

by 30 percent to 50 percent in areas expected to be in dense fog periodically (52 feet or 37½ feet, respectively).

- Clearing branches and underbrush which might be blown in front of the scanner.
- Burying the battery box to protect it from extremes in temperature.
- Checking the beam alignment a few days after the installation to be sure the components have not settled.

Installation may be easier with the following suggestions:

- Have two people set up the counter rather than one.
- Use a string attached to the scanner to help locate the proper position of the reflector and/or attach several reflectors to a stick to minimize the amount of time spent groping about for the infrared beam.

The potential for vandalism or theft can be reduced by:

- Making the installation at "off-peak" use times.
- Affixing the scanner to the tree so a minimum of it shows.
- Camouflaging the reflectors by placing them on birch trees or the butt ends of sawed logs, or "decorating" the edge of the reflector with plant and leaf trimmings.
- Using a variety of paths when maintaining the scanner, none of which leads directly from the trail being monitored.

B. *Maintenance*

Replacement batteries and reflectors, as well as a tool kit, should always be carried. A pocket voltmeter will help anticipate miscounting due to weak batteries. The manufacturer recommends replacing the batteries when voltages have dropped 20 percent.

Because the digital impulse counter on the scanner cannot be zeroed, maintainers must be careful to record the reading at the beginning and end of each field check. The difference between the two figures should not be included in the traffic counts because they are simply a result of maintenance activity.

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)REST SERVICE RESEARCH NOTE NE-287
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Northeastern Forest Experiment Station

FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE, 370 REED ROAD, BROOMALL, PA. 19008

TECHNIQUE FOR ESTIMATING YIELD OF FURNITURE SQUARES AND FLAT STOCK FROM FLITCHES

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Abstract. A grading technique developed to predict the yield of furniture squares and random-width stock from flitches is presented.

INTRODUCTION

There is increasing pressure on the processor of forest products to make better use of the portion that he is able to procure. The reason, quite obviously, is that the cost of the raw product has risen substantially along with a greater demand for it. Therefore the producer must correctly allocate his share of the raw material to the most profitable end use if he is to remain competitive.

In the use of bolts, if flitch production is an intermediate step, then the allocation for the flitch as well as for the log and bolt is critical in the profit picture. This note describes a method to predict the yield of furniture squares or random-width flat stock to be processed from flitches.

DATA AND PROCEDURE

The flitches used were part of a cooperative study in southwestern New York. Eighty northern red oak logs were sawed into 210 bolts of 37-, 43-, 48-, and 60-inch lengths ranging in diameter from 8 to 19 inches. The bolts were then processed into 1,619 flitches.

Rather than diagraming each flitch, three to four flitches at a time were positioned against a large grid marked off in 3- by 3-inch squares and photographed (Fig. 1). The side of the flitch with the most defects faced the camera and defects from the reverse side were marked on the poorer face with a lumber-marking crayon. A log-bolt-flitch number was marked on each flitch.

After the flitches were kiln dried, a

Figure 1.—Photographic grid system for measuring flitch and defect size.

randomly determined sample of 69 bolts was selected. The sample consisted of 36 bolts processed into 189 flitches (8/4-inch thick) and 33 bolts processed into 264 flitches (6/4-inch thick). The flitches were then cut into square stock or random-width flat stock, according to the dimensions listed in Table 1. The tally for the squares was a piece count by length, and for the random width, actual measurements by length were made.

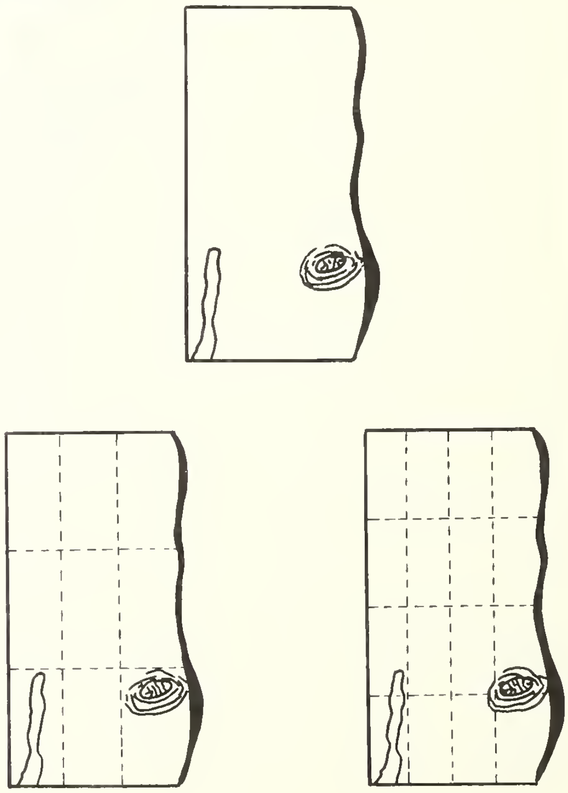
DEVELOPMENT OF SPECIFICATIONS

A random selection of 50 flitches from the selected sample was used to develop a grading system to predict the yield of square and flat stock. Our primary goals for the system were accuracy and ease and speed of application. Of most systems tried, such as defect count, clear area, and number of cuttings, only one of the two objectives—speed or accuracy—could be achieved. The system selected predicts yield of squares or flat stock by reducing total possible yield (100 percent) by the percentage of defect determined by the number of "affected" compartments on the flitch. The compartments are areas that constitute either 1/9 or 1/16 of the total area of the flitch face.

Table 1.—Square and flat stock dimension sizes, by thickness

Square length		Random-width length	
8/4	6/4	8/4	6/4
inches			
37	37	28	20
33	35	25	18½
30	32	22	17½
28	15	18	15
25	14	17	14
22		15	
18			
17			
15			

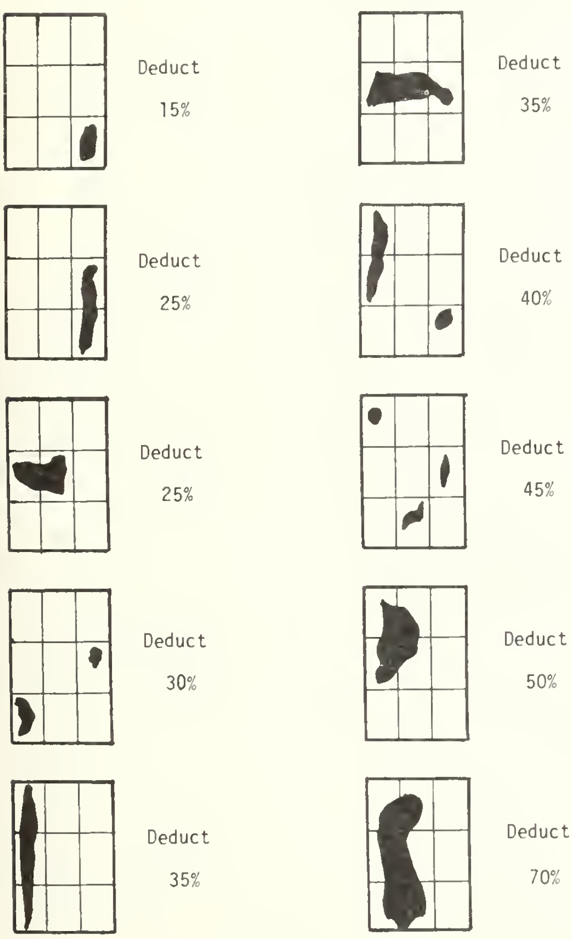
Figure 2.—Compartmentalization of defects by thirds (1/9 of area) or by quarters (1/16 of area).



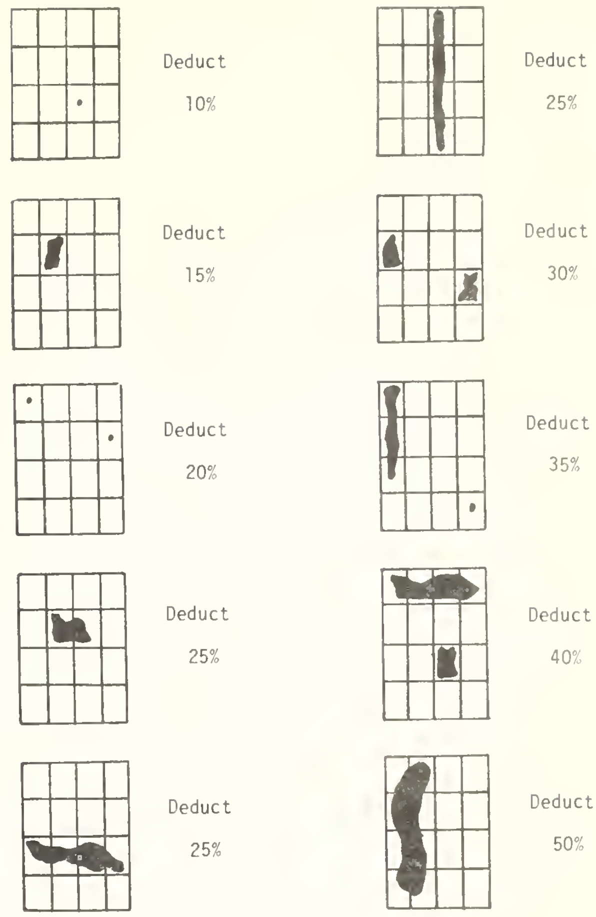
To select the best compartmentalization grid, simply visualize a grid divided in thirds or in quarters superimposed over the flitch, and select the one with the least number of affected compartments (Fig. 2). For flitches that are divided in thirds both lengthwise and horizontally (3 × 3) the minimum defect deduction is 15 percent. For those divided in quarters (4 × 4), the minimum deduction is 10 percent for small defects (pin knots, single grub hole, bark pocket, etc.; that is, defects small in relation to the size of the compartment in which it is contained) and 15 percent for other defects.

This system is easy to apply and can be done quickly. The following grids depict affected compartments and give the percentage that should be deducted accordingly:

1) For the 3 × 3 compartments:



2) For the 4 × 4 compartments:



3) Deductions for cutting and kerf:
If the defect deduction is 15 percent or less, deduct an additional 5 percent from total.

No deduction for cuttings and kerf is made if the total deduction is 20 percent or greater because our data show that the higher defect deduction rounded to an even 5 percent compensates for this additional reduction.

EVALUATION

As a test, the yield for each of the remaining flitches was estimated by this system and compared to the actual yield of cut up squares and flat stock. The results show that for the 8/4 flitches, 83 percent of the estimated yields were within ±5 percent of the actual yields, and for the 6/4 flitches, the figure was 81 percent.

We are not saying that this system is the only method or the best, but it does give a fast, fairly accurate estimate of yield of flitches to be cut up for furniture squares and random-width flat stock used at this study location. More data at other locations are needed to further test and refine this system, but we feel that plants that wish to segregate flitches by different levels of yield can use this technique in its present form or make modifications to fit their specific needs.

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1980

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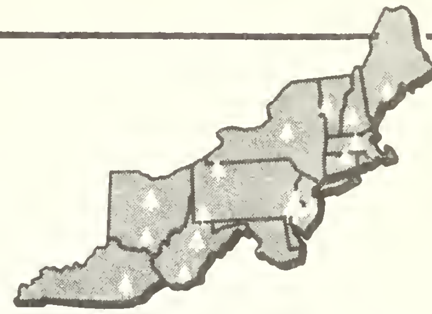

FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE, 370 REED ROAD, BROOMALL, PA. 19008

TIME SERIES ANALYSIS OF MONTHLY PULPWOOD USE IN THE NORTHEAST

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Abstract. Time series analysis was used to develop a model that depicts pulpwood use in the Northeast. The model is useful in forecasting future pulpwood requirements (short term) or monitoring pulpwood-use activity in relation to past use patterns. The model predicted a downturn in use during 1980.

In many decisionmaking situations, past values may be the best variables to use when forecasting future values. Developing stochastic models can be both a necessary and difficult endeavor. Such models are necessary in an industrial society because we live in a world of increasing population and limited natural resources and raw materials. For example, to satisfy regional requirements for paper and allied products, adequate supplies of pulpwood and woodpulp must be forthcoming, or substitute materials must be found. With forecasts of expected pulpwood demand, industrial decisionmakers can devise strategies for obtaining the pulptimber resources that will be needed.

The difficult aspect of developing a predictive model is that variables that are currently known to be highly related to pulpwood use are assumed to be important prognosticators of future use. In addition to the forecaster's inability to incorporate technological and other change into his predictive model, he is also vulnerable to the mathematical constraints of his model. Simple time series models may only be able to predict broad trends within the current data base, while other types of models with more parameters may account for every aberration. When these models are used to project as many as ten periods into the future, the simple model often proves to be the most helpful because the decisionmaker understands its limitations and is able to allow for possible errors. Although the time series model may predict actual future values closely, it can only forecast future points if the past trends and cycles are repeated. This fact points to another important use of time series analysis; the technique allows the analyst to determine whether the system he is studying is operating normally. By using his model as a standard for comparison, he can identify abnormal periods.

DATA BASE

For many years the American Pulpwood Association has collected monthly statistics on pulpwood use and ending inventory from all member company pulpmills in the United States and has published monthly summaries by geographic regions (American Pulpwood Assoc. 1977). Pulpwood-use statistics for nine states of the Northeast region[1] between January 1967 and August 1979 were used for developing a time series model.

A plot of the regional pulpwood-use statistics revealed that there is a predictable seasonal pattern (Fig. 1). The normal sequence of use in the Northeast has been to start the year with low-use levels. Pulpwood use proceeds to build until peaks are reached in the spring. These peaks are followed by a drop in use as pulpmill workers go on their summer vacations and major mill maintenance is done. If the demand for woodpulp remains high, low pulpwood use in July is followed by a resurgence in use that extends into the fall. As winter approaches and inclement weather hampers pulpmill operations, pulpwood use once more declines.

[1]Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont.

METHODS

A number of quantitative forecasting techniques are available for making predictions based on historical analysis; regression (Neter and Wasserman 1974), the U.S. Census Seasonal Adjustment Program (X-11) (U.S. Bureau of Census 1967), and exponential smoothing (Brown 1959) are only a few. Recently Box and Jenkins (1970) proposed a structured approach to time series model building by unifying material and techniques that have been available for a long time. In general, their analysis technique accounts for four components of a series, namely, long-term trends, cyclical effects, seasonal effects, and random variation. The first three components are referred to as the "signal" and the random variation is called "noise." A model is developed which, to the greatest extent possible, eliminates the signal so that only the noise remains. The relative

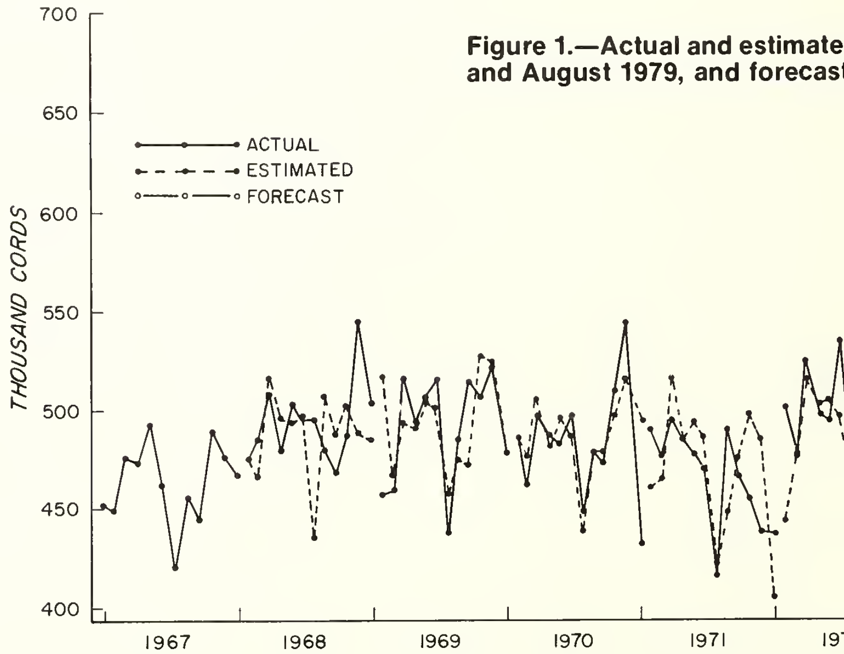


Figure 1.—Actual and estimate
and August 1979, and forecast

contribution of the noise is determined by the autocorrelation function. Based on standard tests such as Bartlett's (1946) approximation or the Q statistic (Box and Pierce 1970), if the model fits the observed data except for random variation, then it is deemed acceptable. A time series model, however, can only be validated when forecasts are compared with actual future values.

The autoregressive integrated moving average process (ARIMA) developed by Box and Jenkins is a powerful tool for modeling time series. Contrary to other model-building techniques, the analyst does not pick a specific model, but instead eliminates inappropriate models until he is left with the most suitable one. MINITAB II (Ryan 1978), a general-purpose statistical computing system, has recently added a computer algorithm for time series analysis based on ARIMA. The user can generate a series of models by specifying the number and kind of parameters. The program provides sample estimates of the model parameters with their standard errors, plots of autocorrelation functions and partial autocorrelation functions, and forecasts of future observations and their 95 percent confidence intervals.

The preferred model is the one which best represents the data with the fewest number of parameters that are consistant with the stochastic structure. Parameters should be statistically significant and the residuals should not be serially correlated.

RESULTS

The model that best depicts monthly pulpwood use in the Northeast is:

$$(1-B^{12})(1-\theta_1 B-\theta_2 B^2)Z_t = (1-\theta_{12} B^{12})a_t$$

where:

B^m = backward shift operator ($B^m Z_t = Z_{t-m}$)

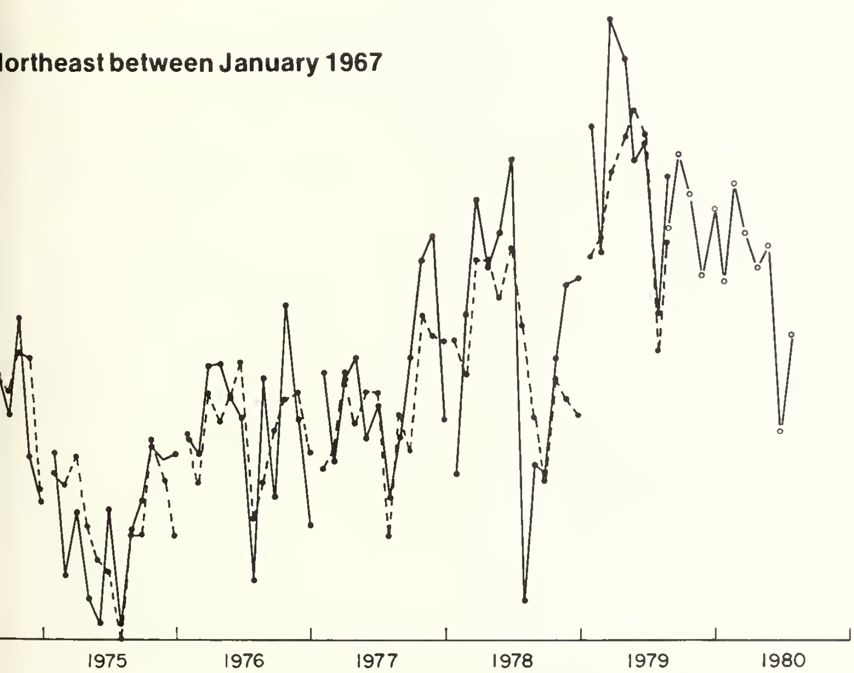
Z_t = observation at time (t)

a_t = random error at time (t)

The model[2] has two autoregressive parameters (θ_1 and θ_2) and one seasonal moving-

[2]For detailed explanation, see Box and Jenkins 1970, p. 8.

lortheast between January 1967



average term (θ_{12}). Differencing was required for the seasonal portion of the model. The estimate of parameters and their standard errors are:

Parameter	*Estimated value*	*Standard error*
ϕ_1	0.6085	0.0835
ϕ_2	0.2617	0.0853
θ_{12}	0.8210	0.0750

The pulpwood-use model was judged satisfactory in that all of the parameter estimates were statistically significant, and none of the sample autocorrelations were statistically significant so that the residuals were not autocorrelated.

Based on this model, Figure 1 shows a comparison of the actual pulpwood-use statistics and the predicted values for the Northeast between January 1968 and August 1979. In addition, pulpwood use is forecast to August 1980. During the 11-year period, all of the predicted values were within ±13 percent of the actual values, except in July 1978 when actual pulpwood use dropped 25 percent below predicted use. This illustrates how the model can be used as a means of identifying abnormal levels of use.

DISCUSSION

By using the ARIMA technique, a time series can be fitted with a mathematical model that is optimal in the sense that it assigns smaller errors to history than any other model. The type of model is identified and the parameters are then estimated. This statistical routine is currently considered to be one of the most accurate portrayals of time series for short-term forecasting. Although forecasts are used by resource and raw material planners to estimate future requirements, they are also used by economists to gauge market supplies and demands relative to the norm. Calendar year 1975 was an atypical year for pulpwood use in the Northeast. Forecasts based on time series analysis data between 1967 and 1974 tracked monthly use of between 450 and 550 thousand cords. Actual monthly use, however, dropped to between 400 and 450 thousand cords during 1975. As a result, there were pulpwood inventory build-ups in many northeastern woodyards. Additional wood inventories tie up working capital and increase the risk of wood deterioration during the longer holding period.

Our time series model forecasts that 7.0 million cords of pulpwood will be required in the Northeast between August 1979 and August 1980. This figure represents a 1.0 percent decrease in use from the same period in 1978-1979.

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USE OF A PHEROMONE TO CAUSE COPULATION BETWEEN TWO SPECIES OF CERAMBYCIDS

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Abstract. The painted hickory borer, *Megacyllene caryae* (Gahan) and the locust borer *Megacyllene robiniae* (Forster) will not attempt to interbreed in the laboratory. However, male locust borers copulated with painted hickory borer females painted with an alcohol extract of female locust borers. No eggs were laid by treated or untreated beetles, though females were full of eggs. A bacillus disease may have prevented egg deposition.

Recent interest in the potential of sterile hybrids for pest control (LaChance and Ruud 1979; Pal and Whitten 1974) prompted me to try interbreeding the locust borer, *Megacyllene robiniae* (Forster), and the painted hickory borer, *Megacyllene caryae* (Gahan). The painted hickory borer and the locust borer are cerambycids that are hardly distinguishable in the adult stage. In nature, hickory borers emerge in spring and locust borers in late summer.

A few years ago, when artificially rearing the locust borer and painted hickory borer (Galford 1969), I attempted interbreeding the two species by confining the opposite sexes. However, the beetles made no attempt to mate. Subsequently I found that the locust borer female has a pheromone (Galford 1977) that she deposits on the host tree, alerting incoming males of her presence and causing them to search that tree. The painted hickory borer female also produces a pheromone that functions the same way (unpublished).

Heintz (1925) stated that males of some species of Lepturini recognized females only when they touched them with their antennae. Laboratory observations of the sexual behavior of several species of cerambycids led me to believe that males can immediately sense whether they have touched a male or female. These observations plus knowledge of the locust borer and painted hickory borer pheromones prompted a different approach to interbreed the painted hickory borer and locust borer.

MATERIALS AND METHODS

The painted hickory borers were reared on an artificial medium (Galford 1969). Locust borers were collected in September from goldenrod flowers at Delaware, Ohio.

Thirty female locust borers were washed in 30 ml of 190 proof ethanol ca 5 minutes to obtain the pheromone. The extract was heated and held at 70°C until the volume was reduced to 2 ml or 15 female equivalents per ml. A small artist brush was used to paint the locust borer extract onto the bodies of six painted hickory borer females. All parts of the body and appendages were painted.

Treated female hickory borers were placed singly in 4-liter jars along with hickory bolts, *Carya* spp., wrapped with cotton bias tape to provide oviposition sites. The bolts were dabbed with some of the locust borer extract. Three male locust borers were then introduced into each jar. Three additional jars with the untreated female and male hickory borers were used as checks. The activity of the beetles was observed and recorded. After 5 days the bias tape was removed from the bolts to check for eggs.

RESULTS AND DISCUSSION

Locust borer males immediately detected the pheromone dabbed on the bolts of wood and began searching for females. Some of the treated painted hickory borer females copulated with locust borer males within a few minutes while others did not copulate for almost an hour. In some instances, males did not react to a female when they initially touched a part of her body. Apparently the extract was heavier on some body parts than others. However, all the treated females copulated eventually. The females made no attempt to fight off males, so the two species were sexually compatible. The untreated females and males readily copulated.

No eggs were laid by treated or untreated females. Unfortunately, it is not known what the results might have been, because the beetles were infected with a bacillus disease which may have prevented them from laying eggs. Stock laboratory cultures of painted hickory borers and another cerambycid species died out completely due to the disease. Although females were full of eggs and mated, they failed to lay any eggs before they died.

The use of pheromones to cause interbreeding among insects could lead to many useful studies in genetics and control.

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FOREST-LAND CLEARING AND WOOD RECOVERY IN MARYLAND

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Abstract. Changing land use often results in removal of the existing forest cover. During a resurvey of Maryland's timber resources, a study was conducted to measure the losses of wood fiber attributable to forest-land clearing. An estimated 107 million cubic feet of growing stock were destroyed on 164,000 acres of commercial forest land cleared between 1961 and 1972. For fuel purposes, this represents a gross energy loss of 24.1 trillion Btus. Much of the recovered industrial wood came from forest lands cleared in rural areas, and much of the recovered firewood came from forest lands cleared in urban-suburban areas.

Forest-land clearing in the Eastern United States is an important potential source of industrial and fireplace wood. Until recently little attention had been paid to providing for the orderly harvest and utilization of this material because there were no formal markets. Rising solid-wood product prices and skyrocketing fuel costs have enhanced the possibilities of wood recovery at a profit and stimulated requests for statistics about the magnitude and composition of this underutilized raw material. In addition to determining the land area and volume of timber removed, this research attempted to identify those key factors that were related to timber recovery and use.

THE STUDY

During the Northeastern Station's second inventory of Maryland's timber resources, the land area had been divided on aerial photographs into two major classes—forest and nonforest—and the classification was confirmed in the field in 1961. Forest land was defined as at least 1 acre in size and at least 16.7 percent stocked by forest trees of any size, or land that formerly had such tree cover and was not currently developed for a non-forest use. Of 6,509 photo points so classified, 3,406 were forested.

During Maryland's third inventory, the forested point locations were transferred to a second set of aerial photographs taken in 1972. Comparisons showed that 186 points had changed from forested to nonforested. These nonforest points were further divided into eight current land use classes: agriculture, rights-of-way, single family housing, tract housing, mining or waste disposal, industrial-commercial, public use and recreation, and water. The photo interpretation was verified by checking the classification on the ground. If correct (that is, if the forest cover there in 1961 had been removed), the field man determined when the cover was removed and whether all or a portion of the trees were used for industry wood products such as sawlogs, pulpwood, and piling, or for firewood. This information and data from the 1976 inventory field plots were used to calculate acreages cleared and volume of timber loss.

RESULTS

About 164,000 acres of commercial forest land[1] in Maryland were cleared between 1961 and 1972 (Table 1). This area is equal to 6.5 percent of the total commercial forest-land acreage in Maryland in 1976. Some of this loss, however, has since been offset by reversion of nonforested areas to tree cover. According to the forest resources report (Powell and Kingsley 1980) that resulted from Maryland's third inventory, the gross change[2] in commercial forest-land acreage was a decline of 13 percent from 1964. Gross commercial forest-land acreage dropped by 22 percent between 1964 and 1976 in the Central Survey Unit, but acreage increased by 5 percent in the Western Unit where marginally productive farmlands were reverting to tree cover at a faster rate than commercial forest lands were being cleared. Although the findings of our study cannot be compared directly with this report, they are compatible.

The greatest use of cleared forest land—nearly 75,000 acres—was for residential construction (Table 2). About two-thirds of the commercial forest-land clearing took place in the Central Unit, especially in Prince Georges, Anne Arundel, and Montgomery Counties where outward migration of government support workers from Washington, D.C. to the surrounding suburbs took place on a grand scale. The Southern and Lower Eastern Shore Units experienced another type of land-use change. Much of the commercial forest-land clearing in these units were for agricultural purposes. In the Western Unit, the forest land acreage cleared was low—913 acres annually—and according to the forest resources report, the loss was offset by farmlands that reverted to tree cover. Besides residential construction, forest clearing in preparation for mining operations was an important cause of forest land conversion.

Between 1961 and 1972, nearly 107 million cubic feet of growing stock—including 205 million board feet of sawtimber—were burned, buried, or otherwise destroyed in clearing commercial forest land in Maryland (Table 3). This loss of wood fiber represents enough volume to satisfy twice the entire industrial roundwood requirement for the forest-product industries in Maryland at 1975 operating levels; or as a fuel, this material has a gross energy value of 24.1 trillion Btus. Hardwood trees accounted for 81 percent of the growing-stock volume loss. Forest-land clearing in Prince Georges County alone accounted for 40 percent of the total growing stock and 49 percent of the total sawtimber volume that was destroyed.

Wood Recovery

Timber recovery for industrial purposes depended on such factors as location and amount of timber, intended land use, and year of clearing. In rural areas of the Southern and Lower Eastern Shore Units, industrial wood was recovered during agricultural land clearing whenever extensive areas were cleared and sawtimber-size trees were present. In many cases, however, if a farmer was extending a small field or if pole-size trees predominated, the trees were simply windrowed and burned (Fig. 1). Rural Allegany and Garrett Counties also experienced high industrial wood-recovery rates when the timberlands were cleared in preparation for coal mining operations.

[1] Land capable of producing industrial wood and not withdrawn from harvesting by law or regulation.

[2] Gross change represents the combined effect of administrative withdrawals, land reclassification, and land-use change.

Table 2.—Area of commercial forest land cleared between 1961 and 1972 by units and counties and current land use, Maryland

County	Current land use								
	Agriculture	Rights-of way	Housing		Mining and waste disposal	Industrial-commercial	Public use and recreation	Water	Total all uses
			Single family	Tract					
	(Thousand acres)								
Central Unit:									
Anne Arundel	—	1.6	3.3	8.1	—	—	1.6	—	14.6
Baltimore	—	—	—	4.1	—	2.1	2.1	—	8.3
Caroline	3.2	—	—	—	—	—	—	1.6	4.8
Carroll	1.9	—	1.9	—	—	—	—	—	3.8
Cecil	—	2.2	2.2	—	—	—	—	—	4.4
Frederick	—	1.3	—	—	—	—	—	—	1.3
Harford	—	2.2	2.2	6.5	—	—	—	—	10.9
Howard	—	1.7	3.4	—	—	—	—	—	5.1
Kent	—	—	1.3	—	—	—	—	—	1.3
Montgomery	1.9	1.9	5.6	1.9	—	—	—	—	11.3
Prince Georges	—	7.4	1.9	18.6	1.9	1.9	5.6	—	37.3
Queen Annes	2.6	—	—	—	—	—	—	—	2.6
Talbot	3.9	—	—	—	—	—	—	—	3.9
Washington	1.3	—	—	—	—	—	—	—	1.3
Unit total	14.8	18.3	21.8	39.2	1.9	4.0	9.3	1.6	110.9
Southern Unit:									
Calvert	5.8	1.9	—	—	—	—	—	1.9	9.6
Charles	1.5	2.9	—	2.9	1.5	—	—	—	8.8
St. Marys	1.3	1.3	—	—	—	—	—	—	2.6
Unit total	8.6	6.1	—	2.9	1.5	—	—	1.9	21.0
Lower Eastern Shore Unit:									
Dorchester	3.6	—	—	—	—	—	—	—	3.6
Somerset	—	—	—	—	—	—	—	—	—
Wicomico	7.8	—	—	—	1.6	—	—	—	9.4
Worcester	1.7.	—	3.5	—	—	—	—	—	5.2
Unit total	13.1	—	3.5	—	1.6	—	—	—	18.2
Western Unit:									
Allegany	—	1.6	—	—	3.1	—	—	—	4.7
Garrett	—	—	5.4	1.8	1.8	—	—	—	9.0
Unit total	—	1.6	5.4	1.8	4.9	—	—	—	13.7
State total	36.5	26.0	30.7	43.9	9.9	4.0	9.3	3.5	163.8

Table 1.—Area of commercial forest land in 1976 and area cleared between 1961 and 1972, by units and counties, Maryland

County	Area of commercial forest land—1976	Area of commercial forest land cleared, 1961-1972		
		Total	Percent of 1976 area	Sampling error[a]
	(Thousand acres)	*(Thousand acres)*	*(Percent)*	*(Percent)*
Central unit:				
Anne Arundel	114.9	14.6	12.7	
Baltimore	113.5	8.3	7.3	
Caroline	70.8	4.8	6.8	
Carroll	62.8	3.8	6.1	
Cecil	75.5	4.4	5.8	
Frederick	117.9	1.3	1.1	
Harford	86.0	10.9	12.7	
Howard	47.6	5.1	10.7	
Kent	43.5	1.3	2.9	
Montgomery	70.8	11.3	16.0	
Prince Georges	110.6	37.3	33.7	
Queen Annes	56.2	2.6	4.6	
Talbot	40.0	3.9	9.8	
Washington	95.4	1.3	13.6	
Unit total	1,105.5	110.9	10.0	5.3
Southern Unit:				
Calvert	74.6	9.6	12.9	
Charles	178.8	8.8	4.9	
St. Marys	122.7	2.6	2.1	
Unit total	376.1	21.0	5.6	11.8
Lower Eastern Shore Unit:				
Dorchester	150.7	3.6	2.4	
Somerset	98.8	—	—	
Wicomico	113.9	9.4	8.2	
Worcester	159.6	5.2	3.3	
Unit total	523.0	18.2	3.5	10.5
Western Unit:				
Allegany	207.6	4.7	2.3	
Garrett	310.5	9.0	2.9	
Unit total	518.1	13.7	2.6	15.7
State total	2,528.7	163.8	6.5	4.2

[a]Sampling error of commercial forest-land area cleared for individual counties is 25 percent or more.

Figure 1.—In agricultural areas in southern Maryland, when fields are extended, the existing vegetation often is windrowed and burned.

In urban-surburban fringe areas where access roads were being extended and new homes constructed, little industrial wood was recovered, but significant quantities of firewood were cut. During the 1960's it was common for contractors to pile and burn the trees and other unwanted vegetation. By the 1970's, open burning was discouraged for environmental reasons, forcing the contractor to consider other means of debris disposal. Today, when sawtimber-size stands are cleared, the sawlogs and pulpwood are recovered for industry use and firewood is recovered by residents or fireplace wood cutters. Thus, only the stumps and fine branches are left for disposal. Often, this material is chipped and trucked to landfills or used onsite as a landscape mulch. As corroborated by recent research in the Southeast (Welch 1978), heavy current demand for domestic and industrial fuelwood has made it possible to use those species and tree sizes, and that quality of material, that only yesterday were considered a cost item when clearing and developing forested lands.

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Table 3.—Net volume of growing stock and sawtimber destroyed during land clearing in Maryland between 1961 and 1972, by species group

County	Growing stock		Sawtimber	
	Softwood	Hardwood	Softwood	Hardwood
	(Million cubic feet)		(Million board feet)[a]	
Central Unit:				
Anne Arundel	1.6	6.9	2.1	16.6
Baltimore	.7	5.4	1.2	14.6
Caroline	.5	2.6	.6	5.4
Carroll	.1	.7	—	—
Cecil	.4	2.8	.7	7.6
Frederick	(*)	.4	—	—
Harford	.1	1.6	—	—
Howard	.1	.6	—	—
Kent	.2	1.7	.4	4.6
Montgomery	.6	7.0	.8	14.0
Prince Georges	8.7	33.5	13.6	86.4
Queen Annes	—	—	—	—
Talbot	.6	2.3	1.1	6.0
Washington	.3	1.5	.5	4.1
Unit total	13.9	67.0	21.0	159.3
Western Unit:				
Allegany	.1	.5	—	—
Garrett	(*)	.7	—	—
Unit total	.1	1.2	—	—
Southern Unit:				
Calvert	1.7	6.7	3.1	4.7
Charles	.9	7.5	.9	3.4
St. Marys	.3	.8	—	—
Unit total	2.9	15.0	4.0	8.1
Lower Eastern Shore Unit:				
Dorchester	1.3	1.5	3.1	3.0
Somerset	—	—	—	—
Wicomico	1.3	1.5	3.3	3.1
Worcester	.3	.7	—	—
Unit total	2.9	3.7	6.4	6.1
State total	19.8	86.9	31.4	173.5

[a]International 1/4-inch rule.
(*) Less than 50,000 cubic feet.

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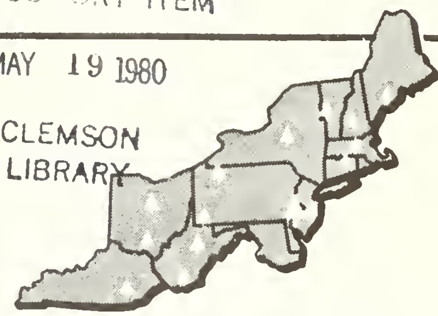

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OAK SITE INDEX AND BIOMASS YIELD IN UPLAND OAK AND COVE HARDWOOD TIMBER TYPES IN WEST VIRGINIA

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Abstract.—More biomass was present in 46-year-old cove hardwood than upland oak types on the West Virginia University Forest near Morgantown. Oak site index was a poor predictor of biomass yields.

Site index is commonly used as an index to the productivity of sites. However, that productivity has usually been measured in board feet or cubic feet and limited to merchantable minimum diameters. Because of the current interest in utilization of the whole aboveground woody biomass, we investigated the utility of site index as a predictor of biomass yield.

PROCEDURE

The study was established on the 8000-acre West Virginia University Forest near Morgantown. The 46-year-old forest is even aged with a few scattered residuals, and is fully stocked. Approximately 62 percent of the forest area is in the upland oak type, dominated by white, chestnut, scarlet, northern red, or black oaks. The remainder of the forest is of the cove hardwood type, dominated by yellow-poplar, black cherry, and northern red oak.

One hundred point samples (BAF = 10) were randomly located on the forest, 67 falling in the upland oak type and 33 in the cove hardwood type. Total height and age of at least three dominant or codominant oak trees were determined at each location, and site index was calculated using Wiant's (1975) prediction equations for Schnur's (1937) site index curves at each location.

The dbh and species of each in-tree were recorded; and the weights of the total tree (excluding stump, roots, and leaves) and of the bark, stem (more than 4 inches diameter

Table 1.—Statistics for regression of biomass components (in pounds per acre) on site index

Tree component, weight	Intercept	Slope	Correlation
Total tree, green	31, 319	3,032	0.493**
Total tree, dry	28,192	1,582	0.456**
Total bark, dry	8,894	153	0.329**
Stem to 4-inch top, green	-9,483	2,756	0.514**
Stem to 4-inch top, dry	-4,567	1,551	0.504**
Bark to 4-inch top, dry	3,393	147	0.394**
Branches, green	36,170	245	0.493**
Branches, dry	23,928	94	0.105 NS
Branch bark, dry	5,459	-1	-0.007 NS

** = Significant at the .01 level of probability
NS = Not significant at the .05 level of probability
Degrees of freedom = 98

outside bark), and branches were estimated using formulae developed by Wiant and others (1977). The linear regressions of per-acre biomass estimates on site index for the two timber types were compared by analysis of covariance.

RESULTS

The estimated total dry weight biomass averaged 78 tons per acre for the cove hardwood type and 66 tons per acre for the upland oak type, and the difference was statistically significant. However, the average site index was also higher for the cove hardwood type (81) than for the upland oak type (66).

The analysis of covariance showed that regressions of biomass on site index were not significantly different for the two forest types. Therefore, the data were pooled and common regressions were computed for the components of biomass (Table 1). The correlation coefficients were highly significant in most cases, but they were too low (.30 to .50) for the regressions to have much predictive value.

CONCLUSIONS

The cove hardwood type had more biomass per acre than the upland oak type relating to the higher average site index of the cove hardwood type. But at a given site index, there was no significant difference in biomass yield between the types. Oak site index by itself was a poor predictor of the aboveground biomass; it accounted for only 25 percent of the variation in total tree biomass.

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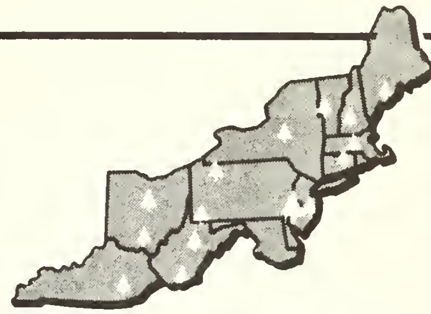

FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE, 370 REED ROAD, BROOMALL, PA. 19008

TRAIL DETERIORATION AS AN INDICATOR OF TRAIL USE IN AN URBAN FOREST RECREATION AREA

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Abstract. The average width of a trail was used to predict trail use in an urban forest recreation area. Results show that width indicates use only very generally at best. Consequently, simply inspecting the physical condition of a trail may lead to erroneous conclusions about its use. Managers requiring more than a simple light use/heavy use classification should adopt more elaborate schemes to determine use levels.

Managers of recreation areas are often faced with the difficult job of making decisions about the carrying capacity of an area. As a concept, carrying capacity is multi-faceted—a final decision reflects many factors. Among the most important are total use and use distribution; it is essential to know what use a particular trail or site is receiving before one decides what use level is optimal.

Total use can be estimated in a variety of ways. Observers can be used to simply count the number of visitors, or there are a number of ingenious devices available to accomplish this mechanically. Over the years, however, perhaps the most common method of determining the amount of use a trail or site receives has been the simple visual inspection of physical condition. Physical condition is assumed to be directly correlated with use—the greater the use, the more physically deteriorated a site is liable to be.

Conversely, so the reasoning goes, we should be able to estimate use levels from physical condition. For trails, use should be reflected in the width of a trail—heavily used trails should be wider than lightly used ones due to greater trampling of vegetation.

Yet just how reliable is physical condition as an indicator of use? Several studies have examined this relationship explicitly. In Montana, Dale and Weaver (1974) found that trail width increases linearly with logarithmic increases in the number of users; that is, widths approximately doubled with a tenfold increase in the number of users between 1,000 and 10,000. Helgath (1975) found trail use in the Selway-Bitteroot Wilderness to be less consistently related to trail deterioration (including both width and depth of erosion) than expected. Weaver and Dale (1978) found trail width varied with type of use; it was greatest on horse trails, moderate on motorcycle trails, and lowest on trails used only by hikers. In this paper, I examine the width/use relationship for a system of trails in a day-use, urban forest recreation facility.

METHODS

To assess the relationship between use and trail width, 27 pressure-plate trail traffic counters (Leonard et al. 1979) were buried in trails at Pleasant Valley Wildlife Sanctuary, a day-use urban forest area operated by the Massachusetts Audubon Society in Lenox, Massachusetts. This 650-acre area offers 7.5 miles of interconnected trails covering a variety of terrain and vegetative types common to eastern hardwood forests. The area was opened in 1929 and the trail system is well established. The trails consist of footpaths through the woods; they have not been widened or surfaced artificially. Hiking is the only form of use permitted.

Trail use was monitored with the counters from July 1, 1976, to October 31, 1976. The counters consist of mat switches buried in the trail. Each time a person steps on the switch, a connection is formed, tripping a counter buried along the side of the trail. The total number of users of each trail during this period was entered in the analysis.

Trail width data were obtained at the end of August, 1976. Bayfield (1973) noted that three trampling zones usually can be identified along trail corridors: bare ground, heavy trampling, and light trampling. In this study, width was considered the length of bare ground only. Width was measured at 100-foot intervals with a steel tape. For each trail or segment of trail on which a counter was located, the width measurements were averaged to obtain an overall mean width for use in the analysis.

The data were analyzed using simple linear regression to predict use (Y) from width (X), and one-way analysis of variance.

RESULTS AND DISCUSSION

As in many recreation areas, the use of these trails was unevenly distributed, ranging from a high of 4,777 users to a low of 64. Mean trail widths also varied widely, ranging from more than 7.6 feet to less than 1.8 feet (Table 1). As might be expected, the

Table 1.—Trail conditions and use at Pleasant Valley Wildlife Sanctuary

Variable	N	Minimum value	Maximum value	Range	Mean	Standard deviation
Number of users on each trail	27	64	4777	4713	1352	1339.2
Mean trail width	27	1.76	7.68	5.9	3.8	1.6

regression analysis indicated a significant positive relationship between use and width ($p < 0.001$, $r^2 = 0.28$)—as the mean trail width increases, so does trail use (Fig. 1), though this does not imply a causal relationship.

From a predictive standpoint, however, the relationship is none too strong, with mean trail width accounting for only 28 percent of the variance in use. The actual equation for predicting the use of a trail from its average width is:

Number of users of trail i =
-292 + 437 (mean width of trail i)

The standard error of regression ($s_{y \cdot x}$) is 1158 users. Thus, estimates of trail use from trail width are likely to be very imprecise.

Part of the reason for this imprecision seems to be the greater variability in the use that the wider trails receive. It may be, for instance, that as increasing numbers of people use a trail, it begins to widen. At some point, however, the trail is sufficiently wide to accommodate additional users with no further change. To test this, I divided total range of use into thirds and compared the mean widths of high, moderate, and lightly used trails using a one-way analysis of variance (Tables 2 and 3). The results indicated that the moderately used trails were significantly wider than lightly used trails ($p < 0.001$), but there was virtually no difference in width between moderate and heavily used trails. This tends to confirm the hypothesis that width is a good indicator of trail use only very generally at best.

Figure 1.—Relationship between trail width and number of users.

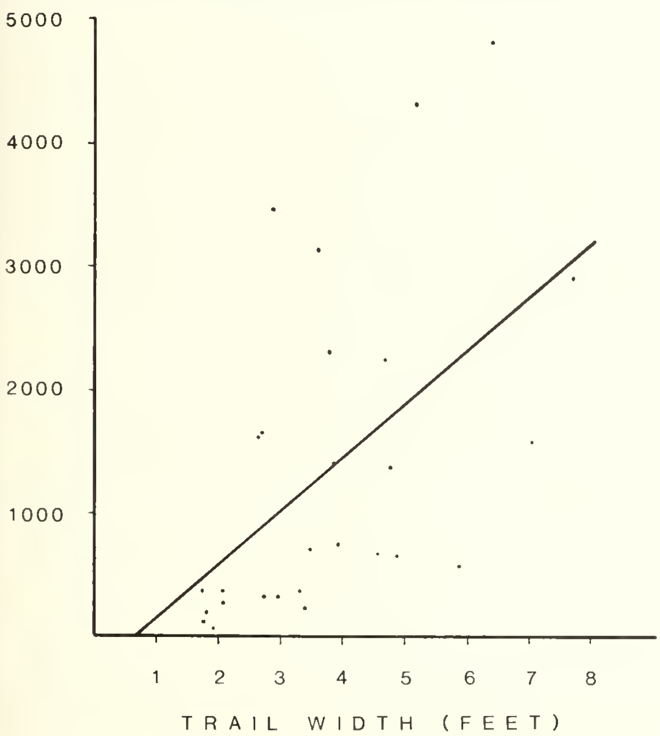

Table 2.—A comparison of mean widths for light, moderate, and heavy use trails

Use category	N	Mean Width
light (64 to 1635 users)	10	2.4
moderate (1636 to 3207 users)	7	4.5**
heavy (3208 to 4777 users)	10	4.6
All categories	27	3.8

**The difference in width between light and moderate use trails is significant ($p < 0.001$). The difference in width between moderate and heavy use trails is not significant.

Actually, the width of a trail is influenced by a number of site factors other than use. Slope, for instance, is positively related to width (Helgath 1975, Weaver and Dale 1978) because hikers may wander across a trail in search of footing, or may zigzag during descents to slow down. Slope may also interact with soil type to influence the roughness of the trail tread because of erosion, prompting hikers to form a new trail alongside the original. Wetness, too, makes a difference as hikers spread out to avoid muddy conditions (Bayfield 1973). In general, it may be that a well-located trail receiving heavy use may actually show less wear than a poorly located trail receiving light or moderate use.

Table 3.—Analysis of variance table for mean trail widths under different levels of use.

Source	Sum of squares	Degrees of freedom	Mean squares	F	P
Treatment	29.942	2	14.971	9.270	0.001
Error	38.759	24	1.615		
Total	68.701	26			

How good, then, is trail width as an indicator of trail use? More generally, how possible is it to make judgments about the amount of use a site receives from simply examining the physical condition? The answer is mixed and depends on management objectives and the information needed to fulfill them. For example, if only very general information is required, a simple visual inspection of physical conditions might well be sufficient to divide trails or sites into categories of light and heavy use. This is especially true for trails and sites at the extreme ends of the range; one will probably make some mistakes classifying those in the middle of the range. Where more detailed information is needed, managers should adopt one of the more elaborate methods of measuring use mentioned previously. The persistent belief that one can make fine judgments about use on the basis of casual nonsystematic observation may lead to incorrect conclusions.

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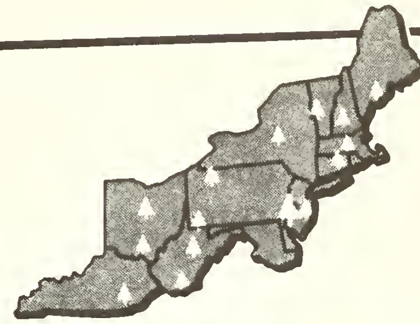

FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE, 370 REED ROAD, BROOMALL, PA. 19008

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BAIT BUCKET TRAPPING FOR RED OAK BORERS (Coleoptera: Cerambycidae)

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Abstract. Forty baits were tested in buckets to attract the red oak borer, *Enaphalodes rufulus* (Haldeman). Only six beetles were caught. A low beetle population and above normal rainfall may have reduced the catch. However, many other cerambycids were trapped.

Fermenting bait traps yield many species of insects not commonly collected by other methods (Champlain and Kirk 1926) and have proved especially good for attracting cerambycids (Champlain and Knull 1932). However, the above authors did not report capturing red oak borers, *Enaphalodes rufulus* (Haldeman). This cerambycid is a serious pest of living oak, *Quercus* spp., and causes millions of dollars worth of damage annually—primarily in the form of degraded lumber sawed from infested trees. Hay (1969) reported that red oak borers emerge in odd-numbered years.

Previous bait trapping studies in even years, not conducted in forest situations, and in which only brown sugar or molasses and water were used for bait, were unsuccessful in capturing red oak borers. Therefore, I decided to test many kinds of substances for baits in a forest during an odd-numbered year (1979) to learn if red oak borers could be attracted and trapped.

MATERIALS AND METHODS

The traps or buckets used were ten 14-liter black plastic buckets, twenty 5-liter red plastic buckets, and ten 4-liter sheet metal buckets.

Forty different baits were tested: honeys: clover, cranberry, orange blossom, avocado, eucalyptus, tupelo, alfalfa, buckwheat, linden, sourwood, and safflower; fresh fruits. . . . . apples, cantaloup, watermelon, bananas, pears, and peaches; canned juices: orange, pineapple, grapefruit, grape, apple and Hawaiian

Punch;[1] soft drinks: Vernors ginger ale, Pepsi, Mr. Pibb, Barrelhead root beer, and Mellow yellow; food flavorings: coconut, red raspberry, rum, vanilla, anise, and almond; others: molasses, blackberry wine, beer, maple syrup, malt extract, and fresh, black oak wood chips and brown sugar.

About 250 ml of a liquid bait, 20 ml of a food flavoring, 1 lb of crushed fruit, or about 1 liter of fresh black oak chips and 1 lb of brown sugar were added to about 3 liters of water in a bucket. One lb of sucrose was added to each bucket except for those containing honey, molasses, or maple syrup. Baker's yeast was sprinkled into each bucket to start fermentation.

The buckets were hung on nails driven into live black *(Quercus velutina)* and scarlet *(Q. coccinea)* oaks growing along forest roads in Vinton County, Ohio. The buckets were spaced 15 m or more apart along about 5 km of roads. The buckets were checked daily except for weekends and a large tea strainer was used to remove trapped insects. Trapping dates were June 18 to August 17.

RESULTS AND DISCUSSION

Only two "wild" red oak borers, 1 male and 1 female, were trapped in 8 weeks and these were captured the last week in June and first week of July. The female was caught with tupelo honey and the male with molasses bait. Four artificially reared red oak borers that escaped from a cage being used in a pheromone study were captured, the same night they escaped, in a bucket with molasses bait.

Many species of cerambycids were caught (see listing), some in large numbers. Since the primary purpose of the study was to trap red oak borers, exact numbers of other species caught were not recorded but representative species were kept and recorded.

The best baits for cerambycids were malt extract, watermelon, and bananas. The soft drinks and food flavorings, with the exception of rum, were very poor.

Two possible reasons for the poor red oak borer catch were a very low population of beetles and above normal rainfall in Southern Ohio during July and August. The two wild and four escaped artificially reared beetles were caught during the only dry period of the season. Had not so much moisture been available to the beetles they might have been attracted to the liquid baits in the buckets. Either the beetles were not strongly attracted to any of the baits tested or bait buckets are not good traps for red oak borers.

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Species Trapped in Study

Anoplodera proxima (Say)
Asemum striatum (L.)
Cyrtophorus verrucosus (Olivier)
Derancistrus taslei (Buquet)
Distenia undata (Fab.)
**Eburia quadrigeminata* (Say)
Elaphidionoides incertus (Newman)
Elaphidionoides parallelus (Newman)
**Elaphidionoides villosus* (Fab.)
Enderces picipes (Fab.)
Graphisurus fasciatus (Degeer)
**Leptura emarginata* (Fab.)
**Leptura vittata* (Germar)
Neoclytus acuminatus (Fab.)
Neoclytus scutellaris (Olivier)
**Orthosoma brunneum* (Forster)
Parandra brunnea (Fab.)
Purpuricenus axillaris (Haldeman)
Purpuricenus humeralis (Fab.)
**Strangalina luteicornis* (Fab.)
Tylonotus bimaculatus (Haldeman)
**Typocerus velutinus* (Olivier)
**Xylotrechus colonus* (Fab.)

*25 or more specimens trapped

[1] Mention of a particular product or trade name does not imply endorsement by the U.S. Department of Agriculture or the Forest Service.

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GROWTH TRENDS IN PRUNED RED SPRUCE TREES

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Abstract. The diameter growth of red spruce with 1/6, 1/3, and 1/2 crown removed was compared with that of unpruned trees for 18 growing seasons. Although removal of 1/6 of the live crown did not adversely affect annual radial growth, compared with that of the controls, removal of 1/3 and 1/2 had a significant effect on the cumulative radial growth for 2 and 9 growing seasons, respectively.

Pruning of softwood trees is generally to improve wood quality by increasing the production of knot-free wood. In the case of a relatively slow-growing species like red spruce, pruning may be practical only on the fastest growing individuals on better sites where a usable shell of clear wood can be produced in a reasonable time. Any adverse effect that pruning might have on growth is, therefore, a major concern. This concern prompted researchers at the Northeastern Forest Experiment Station unit at Orono, Maine, to investigate the effect of pruning on the radial growth of red spruce.

METHODS

During the fall of 1958, 40 forest-grown red spruce trees (*Picea rubens* Sarg.) on the Penobscot Experimental Forest in Bradley, Maine, were chosen for study. Treatments consisted of no pruning and removal of 1/6, 1/3, and 1/2 of the live crown. Each treatment was randomly assigned to 10 of the 40 trees. Sample trees were vigorous codominants with at least 60 percent of their total height in live crown (crown length ratio = 0.60).

Initial measurements were diameter at breast height (dbh) and bark thickness to the nearest 0.1 inch, total height to the nearest foot, height to live crown before and after pruning to the nearest foot, and diameter at 17 feet. These data were later converted to metric units (Table 1).

The trees were remeasured in 1976, 18 growing seasons after pruning. Annual radial growth was determined to the nearest .01 mm from increment cores taken at breast height. Thirty-two trees remained in 1976; 8 control trees; 7 with 1/6 crown removed; 9 with 1/3 crown removed; and 8 with 1/2 crown removed.

RESULTS AND DISCUSSION

The differences among the four pruning treatments were found not to be significant by analysis of variance on the total 18-year radial growth measured at breast height. This result was unexpected, as the data indicated initial differences in growth, and cumulative differences were expected to be reasonably long-lasting (Fig. 1). Therefore, cumulative radial growth data were analyzed on an annual basis through the 1976 growing season to determine in what year cumulative growth differences first occurred.

Differences in cumulative radial growth were significant through the first 9 years following treatment (Table 2). There were no significant differences among treatments in cumulative growth from the 1968 through 1976 growing seasons. This trend in cumulative growth among treatments led to the speculation that as the trees increased in height, the effect of crown removal on annual radial growth was reduced. This was probably due to crown development of the pruned trees, as indicated by the relative equality of the average crown length ratio of all but the most severely pruned trees in 1976 (Table 1). The crown length ratios for the control trees and those with 1/6 of their crowns pruned decreased somewhat, while those for the other treatments increased.

To explore this further, the mean annual growth differences among the pruning treat-

Table 1.—Average characteristics of sample trees in 1958 (after pruning) and in 1976

Characteristic	Treatment			
	Control	1/6 crown removed	1/3 crown removed	1/2 crown removed
Number of trees				
1958	10	10	10	10
1976	8	7	9	8
dbh (cm)				
1958	18.5	17.8	15.7	15.0
1976	23.9	21.3	20.6	18.3
Average annual growth in dbh outside bark	.3	.2	.3	.2
Height (m)				
1958	13.7	12.8	11.3	10.0
1976	18.0	16.8	15.2	13.7
Average annual growth in height	.24	.23	.22	.21
Crown length (m)				
1958	7.9	6.7	4.6	3.1
1976	8.8	8.2	7.3	5.8
Crown length ratio				
1958	.58	.52	.41	.30
1976	.49	.49	.48	.42

ments were analyzed and plotted in Fig. 2A. Differences among treatments were found for the years 1959 through 1963 (Table 3), and there is some evidence of an initial shock effect due to treatment, particularly with more severely pruned trees. No significant differences were found among treatments for the remaining years to 1976, and in no case did comparisons among treatments indicate a significant difference between the control trees and those with 1/6 of their crowns removed. In fact, from about 1966 on, those trees with 1/3 of their crowns removed grew the fastest. Also, significant differences between the controls and the trees with 1/3 of their crowns removed were present only the first two growing seasons after pruning, 1959 and 1960.

It appeared from the plots in Figure 2A that the radial growth of the control trees and those with the lighter pruning treatment (1/6 crown removed) was reduced, relative to the more severe treatments, during the growing seasons of the mid-1960's (ca. 1965-66), which may account for the lack of cumulative growth differences at the end of the study in 1976. During this period the radial growth of all but the most severe treatment (1/2 crown removal) was about at its lowest point. Rainfall data (Fig. 2B) indicate that a drying trend reached a low point in 1965.

Possibly the greater foliage area on the lightly pruned and control trees, resulting in greater transpirational capacity, may have produced moisture stress in these trees that adversely affected radial growth to a greater degree than in the more heavily pruned trees. Although soil moisture was not measured in this study, the interaction of rainfall, soil moisture, and foliage area in creating water deficiency in trees has been established (Kramer 1962).

CONCLUSIONS

These results indicate that the annual radial growth was adversely affected by removing more than 1/6 of the live crown, although the data indicate that the removal of up to 1/3 of

Table 3.—Mean annual growth of pruned trees by treatment (mm)

Year	Crown removed				Within-treatment MS	F
	None (control)	1/6	1/3	1/2		
1959	1.86	1.49	0.96	1.01	0.318	4.80**
1960	1.67	1.52	1.05	0.64	0.269	7.11**
1961	1.55	1.38	1.14	0.57	0.283	5.55**
1962	1.28	1.45	0.98	0.57	0.400	3.32*
1963	1.57	1.72	1.20	0.76	0.457	3.61*
1964	1.45	1.49	1.17	0.91	0.778	0.85
1965	1.06	0.94	0.85	0.73	0.157	1.06
1966	0.95	0.91	0.98	0.75	0.194	0.48
1967	1.00	1.05	1.08	0.94	0.284	0.14
1968	0.95	1.17	1.21	0.94	0.326	0.64
1969	1.37	1.32	1.64	1.09	0.658	0.68
1970	1.34	1.13	1.62	0.95	0.648	1.16
1971	1.41	1.29	1.61	1.20	0.737	0.38
1972	1.32	1.24	1.55	0.96	0.506	1.00
1973	1.34	1.01	1.30	0.93	0.388	0.90
1974	1.44	1.24	1.44	1.13	0.507	0.41
1975	1.09	1.21	1.49	1.19	0.431	0.61
1976	1.04	0.98	1.25	0.82	0.407	0.66

**Significant at 0.01 level
*Significant at 0.05 level

Figure 2.—(A) Mean annual radial growth by treatment; (B) Total periodic rainfall, Old Town, Maine.

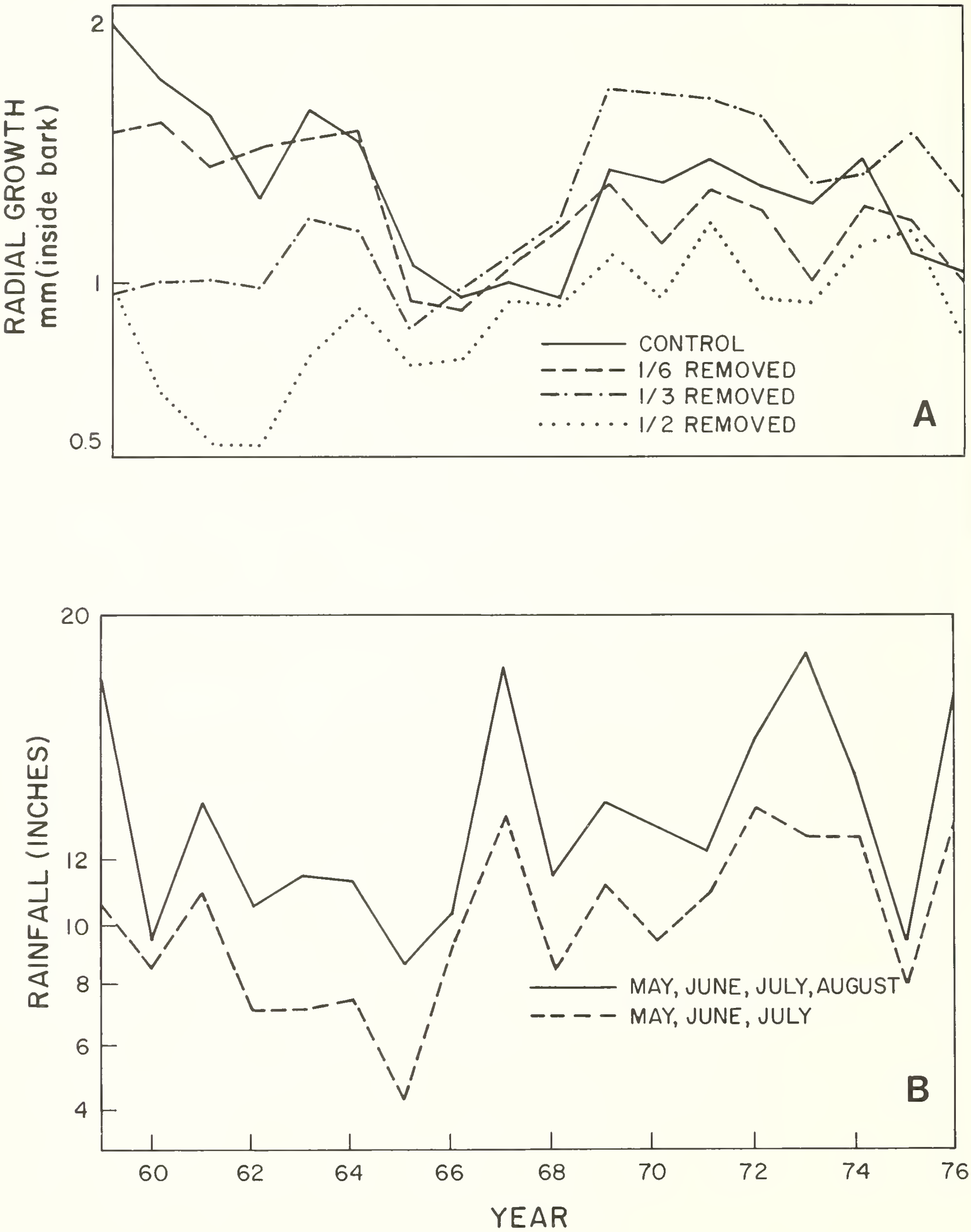

Figure 1.—Cumulative radial growth, by treatment.

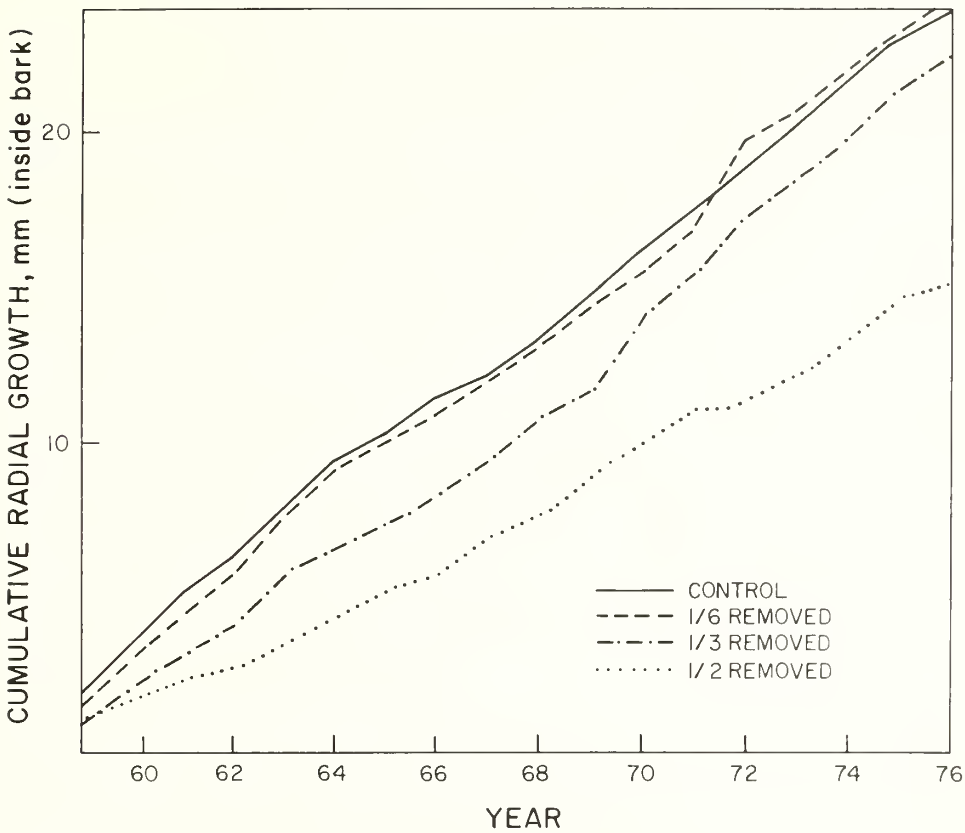

Table 2.—Cumulative growth by treatment and year (mm)

Year	Crown removed				Within-treatment MS	F
	None (control)	1/6	1/3	1/2		
1959	1.86	1.49	.96	1.01	1.52	4.76**
1960	3.49	3.01	2.01	1.65	6.29	6.64**
1961	5.07	4.39	3.15	2.21	13.99	7.10**
1962	6.35	5.84	4.13	2.79	23.03	5.97**
1963	7.92	7.59	5.76	3.65	32.87	4.73**
1964	9.38	9.05	6.50	4.45	46.93	4.50**
1965	10.43	9.99	7.35	5.18	52.43	4.13*
1966	11.39	10.90	8.32	5.92	55.76	3.71*
1967	12.39	11.95	9.41	6.87	57.12	3.07*
1968	13.34	13.12	10.62	7.77	59.59	2.64
1969	14.75	14.44	10.75	8.86	64.63	2.19
1970	16.26	15.57	13.87	9.95	69.94	1.88
1971	17.47	16.87	15.48	11.01	74.87	1.61
1972	18.79	19.68	17.03	11.28	111.06	2.21
1973	20.14	20.69	18.33	12.21	118.27	2.06
1974	21.59	21.93	19.78	13.34	125.20	1.88
1975	22.68	23.14	21.27	14.53	125.56	1.68
1976	23.72	24.11	22.53	15.35	133.08	1.60

**Significant at 0.01 level
*Significant at 0.05 level

the live crown affected growth for only two growing seasons after pruning. Cumulative growth differences became nonsignificant the ninth growing season after pruning. At the end of the study period, crown length ratios had become practically equal for trees in all treatments.

The effect of pruning on growth is only one of many variables that enter into a decision to invest time and money in pruning red spruce trees. While in general our growth rates following pruning are somewhat lower than those reported by Davis (1958), in our opinion the differences in growth among the two lightest pruning treatments and the control are not sufficient to affect a decision to prune or not.

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PREDICTED CUBIC-FOOT YIELDS OF SAWMILL PRODUCTS FOR BLACK CHERRY TREES

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Abstract. Equations and tables for estimating the cubic-foot volumes of lumber, sawdust, and sawmill residue for black cherry trees are presented. Also included are cubic-foot and board-foot predictions for the sawlog portion of the trees.

The cubic foot is now the accepted unit of measure for U.S. Forest Service timber appraisals, and it is one of the primary units of measure used by forest industries. The cubic-foot unit can be used to measure not only lumber yields but other product yields as well. In a previous study I developed predicted cubic-foot yields of lumber, sawdust, and sawmill residue for 10 hardwood species (Hanks 1977). Cubic-foot volumes of the sawlog portion of these tree species also were presented. Comparable information for black cherry is now available for sawmills with either band or circular headsaws. I have also included board-foot volumes, lumber recovery factors (LRF), and lumber recovery ratios (LRR).

METHODS

A total of 192 black cherry trees from three locations were selected for this study. Diameter at breast height (dbh) and merchantable height were recorded prior to bucking. Merchantable height begins at the top of a 1-foot stump and ends where local-use material stops.[1]

[1] A local-use class log must scale at least 8 inches in diameter, inside bark (dib), by 8 feet long and it must be one-third sound.

The felled trees were bucked and log lengths ranged from 8 to 16 feet. Log length and both end diameters were recorded and later used to determine the cubic-foot volume of the bucked sections. The butt log was divided at breast height and treated as two sections. All sections were considered to be conoid in shape and volume was computed using the following equation:

Sectional cubic-foot volume = .001818 $(D^2 + Dd + d^2)L$
D = inside bark diameter of large end
d = inside bark diameter of small end
L = log length

Sectional volumes were summed to obtain the cubic-foot volume for the sawlog portion of each tree (gross tree volume).

Logs from 69 trees were sawed at a band mill, and logs from the remaining 123 trees were sawed at two circular mills. Nominal length, width, and thickness of each board were recorded and adjusted to industry averages developed in the previous study. The adjusted lumber dimensions were used to compute the cubic-foot volume of each board, and board volumes were summed by tree.

For each tree, we computed the cubic-foot volume of solid wood that was converted to sawdust. Saw kerfs of 10/64 and 17/64 were used for band and circular mills, respectively.

Sawmill residue volume—slabs, edgings, and end trims—was obtained for each tree by subtracting the volumes of lumber and sawdust from the volume of sawlogs.

During the sawing process a board-foot tally was maintained, and this provided actual total board-foot volume by tree.

RESULTS

Prediction equations

Standard regression procedures were used to calculate prediction equations of the following form:

volume = a + b $(dbh)^2$ + c (merchantable height) + d (dbh^2 x merchantable height)

Dependent variables include cubic-foot volume of lumber, sawdust, sawmill residue, and the gross tree, and board-foot volume of lumber.

Regression coefficients and related data are presented in Table 1. Gross tree volume was not related to mill type. All other dependent variables were, however, and this is a reflection of saw kerf and perhaps sawing procedures. Therefore, except for gross tree volume, separate equations are presented for band and circular mills.

Cubic-foot yields

Table 2 contains the predicted cubic-foot volumes of lumber, sawdust, sawmill residue, and the gross tree for black cherry trees measured to the nearest 1/2 log. For greater accuracy, measure the trees to the nearest foot and use the equations in Table 1. The boxed areas indicate the size classes included in the tree sample. These volumes were obtained by solving the regression equations for various tree sizes.

Board-foot yields, LRF, LRR

Solutions to the board-foot equations are presented in Table 3 along with lumber recovery factors (LRF), and lumber recovery ratios (LRR). The terms LRF and LRR have become familiar in recent years. LRF represents the board feet of lumber recovered per cubic foot of logs sawed and has been described by Fahey and Woodfin (1976) as a substitute for overrun. LRR equals the cubic volume of lumber recovered per cubic volume of logs sawed.

The product of LRF and cubic-foot volume of logs represents the predicted board-foot volume of lumber. The cubic-foot volume of logs may be obtained from Table 2 by summing the volumes of lumber, sawdust, and sawmill residue. A tree's log volume differs from its gross tree volume and must be obtained by summation. Gross tree volume includes the volume of cull sections bucked from the sawlog portion of a tree and left in the woods. Therefore, we expect gross tree volume to be greater than the summed volume of lumber, sawdust, and sawmill residue.

Text continued on page 8

Table 1.—Regression coefficients and related statistics

Volume of:	Unit of measure	Independent variable: Constant	Dbh^2	Merchantable height	Dbh^2 x merchantable height	Number of trees	SE[a]	R^2	Means: Dbh (inches)	Merchantable height (feet)	Volume
Gross tree	cubic foot	0.5967	0.032981	-0.0065	0.002695	192	3.7	0.97	17.4	35.7	42.3
Lumber											
band	cubic foot	-.1569	.029332	-.0895	.001867	69	3.1	.97	17.0	37.5	28.1
circular	cubic foot	2.0629	.016514	-.1650	.001881	123	2.7	.95	17.6	34.7	23.3
band	board foot	-5.4792	.320763	-.9044	.019239	69	31.7	.97	17.0	37.5	290.5
circular	board foot	20.8308	.177764	-1.7420	.019574	123	29.6	.94	17.6	34.7	242.5
Sawdust											
band	cubic foot	-.4561	.005474	.0187	.000209	69	.5	.95	17.0	37.5	4.4
circular	cubic foot	1.3147	.001420	-.0530	.000584	123	.7	.95	17.6	34.7	6.6
Sawmill residue											
band	cubic foot	-.7673	.006312	.1133	.000374	69	2.2	.80	17.0	37.5	9.9
circular	cubic foot	-2.6851	.017791	.2183	.000089	123	2.6	.67	17.6	34.7	11.7

[a]Standard error of the estimate.

Table 2.—Predicted yields of sawmill products from black cherry trees, in cubic feet

Dbh (inches)	Product	Merchantable height (feet)											
		16	24	32	40	48	56	16	24	32	40	48	56
		BAND MILL						CIRCULAR MILL					
10	Lumber	4.3	5.1	5.9	6.7	7.4	8.2	4.1	4.3	4.5	4.6	4.8	5.0
	Sawdust	.7	1.0	1.4	1.7	2.0	2.3	1.5	1.6	1.6	1.7	1.7	1.8
	Residue	2.3	3.5	4.7	5.9	7.1	8.3	2.7	4.5	6.4	8.2	10.0	11.8
	Gross tree	8.1	10.2	12.3	14.4	16.5	18.6	8.1	10.2	12.3	14.4	16.5	18.6
11	Lumber	5.6	6.7	7.8	8.8	9.9	11.0	5.1	5.6	6.1	6.6	7.1	7.6
	Sawdust	.9	1.3	1.6	2.0	2.3	2.7	1.8	1.9	2.1	2.2	2.3	2.5
	Residue	2.5	3.8	5.1	6.3	7.6	8.9	3.1	5.0	6.8	8.6	10.5	12.3
	Gross tree	9.7	12.3	14.8	17.4	19.9	22.5	9.7	12.3	14.8	17.4	19.9	22.5
12	Lumber	6.9	8.4	9.8	11.2	12.7	14.1	6.1	7.0	7.8	8.7	9.5	10.5
	Sawdust	1.1	1.5	1.9	2.3	2.7	3.1	2.0	2.3	2.5	2.8	3.0	3.3
	Residue	2.8	4.2	5.5	6.8	8.2	9.5	3.6	5.4	7.3	9.1	11.0	12.8
	Gross tree	11.5	14.5	17.6	20.6	23.7	26.7	11.5	14.5	17.6	20.6	23.7	26.7
13	Lumber	8.4	10.2	12.0	13.8	15.6	17.5	7.3	8.5	9.7	11.0	12.2	13.4
	Sawdust	1.3	1.8	2.2	2.6	3.1	3.5	2.3	2.7	3.0	3.4	3.7	4.1
	Residue	3.1	4.5	5.9	7.4	8.8	10.2	4.1	5.9	7.8	9.7	11.5	13.4
	Gross tree	13.4	16.9	20.5	24.1	27.7	31.3	13.4	16.9	20.5	24.1	27.7	31.3
14	Lumber	10.0	12.2	14.4	16.6	18.9	21.1	8.6	10.2	11.8	13.4	15.1	16.7
	Sawdust	1.6	2.0	2.5	3.0	3.5	4.0	2.6	3.1	3.6	4.1	4.5	5.0
	Residue	3.5	4.9	6.4	7.9	9.4	10.9	4.6	6.5	8.3	10.2	12.1	14.0
	Gross tree	15.4	19.6	23.8	27.9	32.1	36.3	15.4	19.6	23.8	27.9	32.1	36.3
15	Lumber	11.7	14.4	17.0	19.7	22.3	25.0	9.9	12.0	14.0	16.1	18.2	20.2
	Sawdust	1.8	2.4	2.9	3.4	3.9	4.5	2.9	3.5	4.1	4.8	5.4	6.0
	Residue	3.8	5.4	7.0	8.6	10.1	11.7	5.1	7.0	8.9	10.9	12.8	14.7
	Gross tree	17.6	22.4	27.2	32.0	36.8	41.6	17.6	22.4	27.2	32.0	36.8	41.6
16	Lumber	13.6	16.7	19.8	22.9	26.0	29.1	11.4	13.9	16.4	19.0	21.5	24.0
	Sawdust	2.1	2.7	3.3	3.8	4.4	5.0	3.2	4.0	4.8	5.5	6.3	7.1
	Residue	4.2	5.9	7.5	9.2	10.9	12.6	5.7	7.7	9.6	11.5	13.4	15.4
	Gross tree	20.0	25.4	30.9	36.7	41.8	47.3	20.0	25.4	30.9	36.7	41.8	47.3
17	Lumber	15.5	19.1	22.7	26.3	29.9	33.5	12.9	15.9	19.0	22.0	25.0	28.0
	Sawdust	2.4	3.0	3.7	4.3	4.9	5.6	3.6	4.5	5.4	6.4	7.3	8.2
	Residue	4.6	6.4	8.1	9.9	11.7	13.5	6.4	8.3	10.3	12.2	14.2	16.1
	Gross tree	22.5	28.7	34.8	41.0	47.2	53.4	22.5	28.7	34.8	41.0	47.0	53.4

18	Lumber	17.6	21.7	25.8	30.0	34.1	38.2	14.5	18.1	21.6	25.2	28.7	32.3
	Sawdust	2.7	3.4	4.1	4.8	5.5	6.2	4.0	5.0	6.1	7.2	8.3	9.4
	Residue	5.0	6.9	8.8	10.7	12.5	14.4	7.0	9.0	11.0	13.0	14.9	16.9
	Gross tree	25.1	32.1	39.0	45.9	52.9	59.8	25.1	32.1	39.0	45.9	52.9	59.8
19	Lumber	19.8	24.5	29.1	33.8	38.5	43.2	16.2	20.4	24.5	28.6	32.7	36.8
	Sawdust	3.0	3.8	4.5	5.3	6.0	6.8	4.4	5.6	6.9	8.1	9.4	10.7
	Residue	5.5	7.5	9.5	11.4	13.4	15.4	7.7	9.7	11.8	13.8	15.8	17.8
	Gross tree	28.0	35.7	43.4	51.2	58.9	66.6	28.0	35.7	43.4	51.2	58.9	66.6
20	Lumber	22.1	27.4	32.6	37.9	43.1	48.4	18.1	22.8	27.5	32.2	36.9	41.6
	Sawdust	3.4	4.2	5.0	5.8	6.6	7.5	4.8	6.2	7.7	9.1	10.6	12.0
	Residue	6.0	8.1	10.2	12.3	14.4	16.5	8.5	10.5	12.6	14.6	16.6	18.6
	Gross tree	30.9	39.5	48.1	56.6	65.2	73.8	30.9	39.5	48.1	56.6	65.2	73.8
21	Lumber	24.5	30.4	36.3	42.1	48.0	53.9	20.0	25.3	30.6	35.9	41.2	46.6
	Sawdust	3.7	4.6	5.5	6.4	7.3	8.2	5.2	6.8	8.5	10.1	11.8	13.4
	Residue	6.5	8.7	10.9	13.1	15.4	17.6	9.3	11.3	13.4	15.5	17.5	19.6
	Gross tree	34.1	43.5	53.0	62.4	71.9	81.3	34.1	43.5	53.0	62.4	71.9	81.3
22	Lumber	27.1	33.6	40.1	46.6	53.1	59.6	22.0	27.9	33.9	39.9	45.8	51.8
	Sawdust	4.1	5.1	6.0	7.0	7.9	8.9	5.7	7.5	9.4	11.2	13.0	14.9
	Residue	7.0	9.4	11.7	14.1	16.4	18.8	10.1	12.2	14.3	16.4	18.5	20.6
	Gross tree	37.3	47.7	58.1	68.5	78.9	89.2	37.3	47.7	58.1	68.5	78.9	89.2
23	Lumber	29.7	36.9	44.1	51.3	58.5	65.7	24.1	30.7	37.4	44.0	50.6	57.3
	Sawdust	4.5	5.5	6.6	7.6	8.6	9.7	6.2	8.2	10.3	12.3	14.4	16.4
	Residue	7.6	10.0	12.5	15.0	17.5	20.0	11.0	13.1	15.2	17.3	19.5	21.6
	Gross tree	40.8	52.1	63.5	74.8	86.2	97.5	40.8	52.1	63.5	74.8	86.2	97.5
24	Lumber	32.5	40.4	48.3	56.2	64.1	71.9	26.3	33.6	41.0	48.3	55.7	63.0
	Sawdust	4.9	6.0	7.1	8.3	9.4	10.5	6.7	8.9	11.2	13.5	15.7	18.0
	Residue	8.1	10.8	13.4	16.0	18.6	21.3	11.9	14.0	16.2	18.3	20.5	22.7
	Gross tree	44.3	56.7	69.1	81.4	93.8	106.2	44.3	56.7	69.1	81.4	93.8	106.2

Table 3.—Predicted lumber yields, in board feet, and lumber recovery factors (LRF) and ratios (LRR)

Dbh (inches)	Item	Merchantable height (feet)											
		16	24	32	40	48	56	16	24	32	40	48	56
		BAND MILL						CIRCULAR MILL					
10	Lumber	43	51	59	67	76	84	42	44	46	47	49	51
	LRF	5.9	5.3	4.9	4.7	4.6	4.5	5.1	4.2	3.7	3.2	3.0	2.7
	LRR	.59	.53	.49	.47	.45	.44	.49	.41	.36	.32	.29	.27
11	Lumber	56	67	79	90	102	113	52	57	62	67	72	77
	LRF	6.2	5.7	5.4	5.3	5.2	5.0	5.2	4.6	4.1	3.9	3.6	3.4
	LRR	.62	.57	.54	.51	.50	.49	.51	.45	.41	.38	.36	.34
12	Lumber	71	85	100	115	130	145	64	72	81	89	98	107
	LRF	6.6	6.0	5.8	5.7	5.5	5.4	5.5	4.9	4.6	4.3	4.2	4.0
	LRR	.64	.60	.57	.55	.54	.53	.52	.48	.44	.42	.40	.39
13	Lumber	86	105	124	143	161	180	76	88	101	114	126	139
	LRF	6.7	6.4	6.2	6.0	5.9	5.8	5.5	5.1	4.9	4.7	4.6	4.5
	LRR	.66	.62	.60	.58	.57	.56	.53	.50	.47	.46	.45	.43
14	Lumber	103	126	149	172	195	218	89	106	123	139	156	173
	LRF	6.8	6.6	6.4	6.3	6.1	6.1	5.6	5.4	5.2	5.0	4.9	4.8
	LRR	.66	.14	.62	.60	.59	.59	.54	.52	.50	.48	.48	.47
15	Lumber	121	149	176	204	231	258	103	125	146	167	189	210
	LRF	7.0	6.7	6.5	6.4	6.4	6.3	5.8	5.6	5.4	5.3	5.2	5.1
	LRR	.68	.65	.63	.62	.61	.61	.55	.53	.52	.51	.50	.49
16	Lumber	141	173	205	237	270	302	119	145	171	197	223	249
	LRF	7.1	6.8	6.7	6.6	6.5	6.5	5.9	5.7	5.6	5.5	5.4	5.4
	LRR	.68	.66	.65	.64	.63	.62	.56	.54	.53	.53	.52	.52

17	Lumber	162	199	236	273	311	348	135	166	197	229	260	291
	LRF	7.2	7.0	6.8	6.7	6.7	6.6	5.9	5.8	5.7	5.6	5.6	5.6
	LRR	.69	.67	.66	.65	.64	.64	.56	.55	.55	.54	.54	.54
18	Lumber	184	226	269	312	354	397	152	189	226	262	299	336
	LRF	7.3	7.1	7.0	6.9	6.8	6.8	6.0	5.9	5.8	5.8	5.8	5.7
	LRR	.70	.68	.67	.66	.65	.65	.57	.56	.56	.56	.55	.55
19	Lumber	207	255	304	352	400	449	170	213	255	298	341	383
	LRF	7.3	7.1	7.1	7.0	6.9	6.9	6.0	6.0	5.9	5.9	5.9	5.9
	LRR	.70	.68	.68	.67	.66	.66	.57	.57	.57	.57	.56	.56
20	Lumber	231	286	340	394	449	503	189	238	287	335	384	433
	LRF	7.3	7.2	7.1	7.0	7.0	6.9	6.0	6.0	6.0	6.0	6.0	6.0
	LRR	.70	.69	.68	.68	.67	.67	.58	.58	.58	.58	.58	.58
21	Lumber	257	318	379	439	500	560	209	265	320	375	430	485
	LRF	7.4	7.3	7.2	7.1	7.1	7.0	6.1	6.1	6.1	6.1	6.1	6.1
	LRR	.71	.70	.69	.68	.68	.68	.58	.58	.58	.58	.58	.59
22	Lumber	284	352	419	486	553	621	231	292	354	416	478	540
	LRF	7.4	7.3	7.2	7.2	7.1	7.1	6.1	6.1	6.1	6.2	6.2	6.2
	LRR	.71	.70	.69	.69	.69	.68	.58	.59	.59	.59	.59	.59
23	Lumber	313	387	461	535	609	683	253	322	390	459	528	597
	LRF	7.5	7.4	7.3	7.3	7.2	7.2	6.1	6.2	6.2	6.2	6.2	6.3
	LRR	.71	.70	.70	.69	.69	.69	.58	.59	.59	.60	.60	.60
24	Lumber	342	424	505	586	668	749	276	352	428	505	581	657
	LRF	7.5	7.4	7.3	7.3	7.3	7.2	6.1	6.2	6.3	6.3	6.3	6.3
	LRR	.71	.71	.70	.70	.70	.69	.59	.59	.60	.60	.61	.61

Gross tree volume is less than the summed log volume for several dbh and height classes in Table 2. This occurred because of small differences between the actual gross tree volumes of the trees sawed at the band mill and those sawed at the circular mills.

Note that LRF and LRR differ by a factor of about 10. This indicates that about 10 board feet of lumber were sawed from each cubic foot of actual lumber.

DISCUSSION

Sawtimber has traditionally been sold using the board-foot measure. At first look, this is logical because most sawlogs have been converted to lumber which has been and still is measured and sold in board-foot units. The Forest Service is in the process of converting all timber sales to cubic feet from board feet. Cubic-foot measure is more consistent than board-foot measure for relating volume of round material to volume of end products.

In the earlier report (Hanks 1977), I found that the volume of sawmill residue was unaffected by type of headsaw. However, the circular mills selected to saw the black cherry logs produced more sawmill residue than the band mills. Therefore, separate equations were developed for predicting sawmill residue. Possible reasons for differences in the amount of sawmill residue can only be hypothesized, and they include the following:

- The saw kerf at the band mill was less than 10/64-inch.
- The saw kerf at the circular mills was greater than 17/64-inch.
- The band mill was more efficient.

Two circular mills were used and both were chosen because they demonstrated good practices. The band mill represented here was more efficient than the circular mills and should be considered "better than average."

In the future it may be possible to predict yields of sawmill products for various combinations of saw kerf, lumber thickness, log size, and taper. Until more work is completed, we believe that these tables provide a reasonable estimate of yields from band and circular mills.

Results of field trials indicate that real differences between the predicted and actual volumes will occur (Hanks 1980). However, if lumber is sized and edged properly, actual lumber volume will equal or exceed predicted volume and sawmill residue volume will be minimized.

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RAPID ECONOMIC ANALYSIS OF NORTHERN HARDWOOD STAND IMPROVEMENT OPTIONS

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Abstract. Data and methodology are provided for projecting basal area, diameter, volumes, and values by product for northern hardwood stands, and for determining the rate of return on stand improvement investments. The method is rapid, requires a minimum amount of information, and should prove useful for on-the-ground economic analyses.

Economic analysis of silvicultural options must be based on two types of information: stand responses to various treatments, and price and cost data. Although both types of information are available for northern hardwoods in New England, we lack a system for analyzing investment possibilities that can be used readily by consultants, county foresters, and industrial foresters—those who make rapid, on-the-ground economic evaluations.

Efforts have been made to assemble growth response information for northern hardwoods and related types in the form of computerized systems or fairly complex tabulations (Alimi and Barrett 1977; Solomon 1977a). Such systems are not always suited to the needs of field foresters who may need to make economic evaluations on the ground. Available economic studies provide general guidelines on the feasibility of certain practices (Manthy 1970; McCauley and Marquis 1972), but do not account for specific stand conditions or economic factors applicable to a given property.

The purpose of this paper is to provide some growth factors for essentially even-aged northern hardwood stands and a method for using them to make rapid economic analyses of silvicultural investments. The approach is applicable to those owners who are already committed to managing their forests and are considering fairly small investments in timber stand improvement.

APPROACH

Three main steps are suggested for evaluating stand improvement options:

1. Inventory current stand conditions.
2. Project stand composition by products if it is treated and if it is not treated.
3. Evaluate future volume and value added by the treatment in terms of rate of return on the treatment cost.

As an example, let's assume that a consultant is faced with evaluating the economics of a precommercial thinning and stand improvement operation in a 25-year-old stand of paper birch, red maple, oak, and aspen. We'll not discuss measurement or estimation techniques in detail, but we suggest taking a few prism plots to estimate the mean diameter of the main stand and the basal areas (and percentages) of species and potential products. A few increment borings to estimate current diameter growth would also be helpful. Procedures would be similar to those outlined in most silvicultural guides (e.g. Leak et al. 1969).

Stand Inventory

Measure or estimate basal area per acre (100 ft^2 in this example) and mean stand diameter (3 inches) of the main stand (main crown canopy), and record them on a tally sheet (Fig. 1) on lines 1 and 3 for the untreated stand at year 0. Measure or estimate the potential product composition of the stand and record on lines 5 through 10. This is a very critical step in the analysis. Because of large differences in product utilities and values, northern hardwood stands require a very careful analysis of the product mix to assess their economic possibilities. In the example given, we'll assume that 40 percent of the stand basal area is paper birch of potential boltwood quality, and that 20 percent of the basal area is accounted for by each of the following:

Figure 1.—Economic evaluation sheet.

Stand Location__________ Age______ Date________

	If stand is untreated		If stand is treated	
	Year 0	Year 20	Year 0	Year 20
1. Basal area (ft^2)	100	132	60	120
2. Prospective basal area growth (ft^2)	1.6		3	
3. Mean dbh (inches)	3	5.1	3	6.6
4. Prospective mean dbh growth (inches)	.105		.18	
Potential Products (%):				
5. Pulpwood	40	40		
6. Fuelwood	20	20	33	33
7. Boltwood	40	40	67	67
8. Softwood logs				
9. Hardwood logs				
10. ______				
11. Future basal area from Line 1:	132		120	

VOLUME AND VALUE AT YEAR 20
(in 1980 dollars)

	Percent	Basal Area (ft^2)	Volume (ft^3 or fbm)	Price ($)	Value ($)	Percent	Basal Area (ft^2)	Volume (ft^3 or fbm)	Price ($)	Value ($)
12. Pulpwood	40	53	795 ft^3	.035	28					
13. Fuelwood	20	26	390 ft^3	.118	46	33	40	720 ft^3	.118	85
14. Boltwood	40	53	795 ft^3	.353	281	67	80	1440 ft^3	.353	508
15. Softwood logs										
16. Hardwood logs										
17. ______										

Untreated Value (UV) = $355 Treated Value (TV) = $593 conversions should be multiplied by a factor equal to actual site index divided by 60. For example, for a stand of site index 80, multiply the values in Table 4 by 80/60 or 1.333.

Future prices (columns 4 and 9 of lines 12 through 17) should be estimated as stumpage value in current (e.g. 1980) dollars—ignoring inflation. Market experience and published market information (Engalichev and Sloan 1979) are useful aids in developing appropriate price information. Price expectations can be incorporated into the future price figures, as well as owner preferences. For example, some owners who cut their own fuelwood may value this material at higher than the usual stumpage price. We'll use prices of \$3.00, \$10.00, and \$30.00 per cord for pulp, fuel, and boltwood respectively, converting these to prices per cubic foot by dividing by 85. Multiplying volume times price gives value per product for both the untreated and the treated stand (columns 5 and 10 in lines 12 through 17). When summed, these provide future stand values for the untreated (UV) and treated (TV) stand.

The formula for the compound interest ratio (found in compound interest tables) is

$$(TV - UV)/C$$

where TV is the prospective value of the stand if treated, UV is its prospective value if untreated, and C is the cost of treatment. This cost should be estimated as the actual cost to the landowner, plus any fees (including consultant's fees or inventory costs) and minus any amounts received as incentive payments or from sale of the removed material. In this example, and assigning a treatment cost of \$50, the compound interest ratio is

$$(593 - 355)/50 = 4.76$$

If n is the number of years, the nth root of the value of this equation will be 1 + p, where p is the compound interest rate of return. It can be computed easily on many hand calculators. In this example

$$\sqrt[20]{4.76} = 1.081$$

and the rate of return is 8.1 percent over a 20-year period.

This rate of return can be compared with those of other treatment options and with the owner's preference. In comparing rates of return with returns from nontimber investments, remember that these computations were all in constant 1980 dollars, whereas a monetary investment pays back in inflated dollars, so its real rate of return is the stated rate minus inflation. A real rate of return of 8 percent compares favorably with the returns of bonds, savings certificates, etc. but timber investments are subject to risks of fire, insect damage, disease, and market fluctuations.

If there is some return from the proposed treatment, it can be subtracted from the initial cost (thus reducing the cost) and the analysis can proceed as described above. However, if the initial return exceeds the cost (i.e., if there is a net gain), the best approach is to project future volumes and values of the treated and untreated stand as described above, then discount these future values to their present values by dividing them by the appropriate compound interest ratio. These ratios for various interest rates and time periods are shown in Table 5. The chosen interest rate should reflect the owner's minimum acceptable rate of return in constant dollars. Then, add the initial net

Table 5.—Values of treatment gain (treated stand value minus untreated stand value) divided by treatment cost for various compound interest rates and time periods

Compound interest rate %	Time period 10 years	20 years	30 years
3	1.34	1.81	2.43
4	1.48	2.19	3.24
5	1.63	2.65	4.32
6	1.79	3.21	5.74
7	1.97	3.87	7.61
8	2.16	4.66	10.06
9	2.37	5.60	13.27
10	2.59	6.73	17.45
12	3.11	9.65	29.96
14	3.71	13.74	50.95
16	4.41	19.46	85.85
18	5.23	27.39	143.37
20	6.19	38.34	237.38

Table 2.—Annual diameter growth (in inches)[a] by species, stand age, and residual basal area. Site index 55 to 65

Species	25-Year stand Residual basal area (ft^2)			50-Year stand[b] Residual basal area (ft^2)			70-Year stand Residual basal area (ft^2)			
	100	72	56	100	75	60	100	80	60	40
Beech	.04	.07	.11	.06	.08	.12	.08	.10	.12	.14
Yellow birch	.06	.08	.12	.06	.07	.10	.05	.05	.08	.16
Sugar maple	.06	.09	.12	.05	.07	.10	.04	.04	.07	.13
Red maple	.10	.15	.19	.08	.13	.16	.07	.11	.13	.17
Paper birch	.11	.16	.17	.08	.12	.13	.06	.07	.09	.07
White ash	.18	.20	.20	.14	.17	.18	.11	.14	—	.21
Hemlock	—	—	—	—	—	—	.16	.18	.24	.30

[a] From additional measurements on Marquis' (1969) study and from Solomon (1977b).
[b] Values for the 50-year stand are approximate averages of the 25- and 70-year-old stand figures.

basal area ratios are quite consistent. The board foot/basal area ratios tend to be variable for small mean stand diameters since they change with small variations in diameter distribution. These conversions are for stands on average sites of about 55 to 65 feet site index. On much better or poorer sites, the

Table 3.—Annual basal area and diameter growth of white pine; site index 60. (Alimi and Barrett 1977; Gevorkiantz and Zon 1930)

Stand age	Residual[a] stocking	Annual basal area growth	Annual dbh growth
		ft^2/acre	*inches*
20	Full	2.3	0.18
	Thinned	4.5	—
40	Full	1.5	.13
	Thinned	3.5	—
60	Full	1.2	.09
	Thinned	3.0	—
80	Full	1.0	.08
	Thinned	2.6	—

[a] "Full" and "thinned" refer to A-line and B-line stocking respectively, as defined in the standard stocking guides.

Table 4.—Ratios of cubic feet and board feet per square foot of basal area by mean stand dbh

Mean dbh (inches)	Cubic feet per square foot	Cubic feet per square foot	
		Hardwoods	Softwoods
5.0	15	—	—
6.0	17	—	—
7.0	19	17	32
8.0	21	37	46
9.0	24	50	65
10.0	25	75	80
11.0	27	90	95
12.0	28	105	109
13.0	29	120	122
14.0	30	122	135

From basal area and yield figures in Leak et al. 1969, Leak et al. 1970, and Dale 1972, revised using additional information from volume tables and local plot information. Cubic feet to a 3.0-inch dib; board feet to a dib of 6.0 inches for softwoods and 8.0 inches for hardwoods.

limby oak (fuelwood), red maple sprouts (pulpwood, or perhaps home-owner fuelwood), and aspen (pulpwood).

Stand Projection

The first step in stand projection is to characterize the treated stand—or several treated stands if several treatment options are to be compared. One possibility is to remove the potential pulpwood-quality material and to concentrate growth on the boltwood and fuelwood. Under this option, the basal area of the treated stand would be 60 ft^2 (line 1), and the mean dbh (line 3) would be carried as 3 inches. Sometimes, the initial mean diameter of the treated stand should be increased or decreased to reflect the immediate effect of the treatment: for example, a thinning from above of overtopping aspen would immediately reduce the initial mean diameter of the treated stand.

Prospective basal area growth (line 2) of the treated and untreated stand can be estimated from the growth factors in Table 1;

Table 1.—Basal area growth[a] of northern hardwoods related to initial stand age and residual basal area

Initial stand age	Residual basal area	Basal area growth
years	*ft^2*	*ft^2*
25	100	1.6
	72	2.6
	56	3.0
50[b]	100	1.2
	75	2.0
	60	2.4
70	100	.9
	80	1.4
	60	1.7
	40	1.2

[a] For the 25-year-old stand, basal area growth consists of 16-year net change in basal area of the potential crop trees in the stand (app. 400 per acre); (data from additional measurements on a thinning study reported by Marquis 1969). In the 70-year-old stand, growth consists of 10-year accretion minus mortality, thus excluding ingrowth into the 5-inch class (based on the 45 percent sawtimber treatment reported by Solomon 1977b).

[b] The values for the 50-year stand are approximate averages of the figures for the 25- and 70-year-old stand.

actual growth data seldom are available for specific stands. We'll use 1.6 and 3.0 ft^2 for the untreated and treated stand, and we'll project for a 20-year period (line 1). This projection period should (1) meet the planning horizon of the owner, (2) not greatly exceed the duration of the available growth data, and (3) be long enough to provide an opportunity for the proposed treatment effects to be expressed. Twenty or thirty years probably is the longest period we can safely use.

Changes in stand diameter can be estimated from the growth factors in Table 2. Increment borings can be used to estimate current diameter growth of the stand; however, factors such as those in Table 2 will be needed to project the response of the treated stand. Since the stand has a high proportion of paper birch and red maple, we'll use prospective growths of .105 and .18 for the untreated and treated stand (line 4), and project for the 20-year period (line 3).

Table 3 provides some additional growth data for white pine stands. Diameter responses of thinned white pine stands are not well documented, but we do know that thinned young stands can double or triple in diameter growth rate. Tables 1 through 3 do not provide a complete range of data; I suggest that they be used simply as a guide to developing estimates on the ground.

Potential product percentages (lines 5 through 10) for the untreated stand are kept constant for the 20-year period. For the treated stand, product percentages are recalculated to reflect the removal of the pulpwood-quality stems. This would leave 60 ft^2 of basal area, 1/3 in fuelwood and 2/3 in boltwood.

Future Volume and Value

Future basal area and product percentages are recorded in lines 11 and 12 through 17. These two types of entry are then used directly to calculate basal areas by products in the second and seventh columns of lines 12 through 17 for both the treated and the untreated stand. To convert basal areas to volumes (third and eighth columns of lines 12 through 17), I'll suggest using the conversion factors in Table 4. The cubic foot/

return to the discounted value of the treated stand. The treatment or nontreatment option that produces the highest present value is the most profitable one to adopt.

DISCUSSION

Once the user gains some familiarity with the system, and the basic inventory information is obtained, an economic evaluation can be made in just a few minutes with a hand calculator. The results appear to be reasonably accurate. McCauley and Marquis (1972) analyzed in detail the costs and returns from thinning a 25-year-old northern hardwood stand on the Bartlett Experimental Forest, and calculated a 9.9 percent return on investment from a light thinning. Using the same price and cost assumptions, I calculated a 9.5 percent return on investment for the light thinning by following the procedure described here. Note that the growth information in Tables 1 and 2 is derived from the same study analyzed by McCauley and Marquis. So this comparison indicates that by using average growth factors and the volume conversions in Table 4, we can fairly well duplicate the results of a more detailed analysis.

When the procedure outlined in this paper is applied to other stands, additional uncertainties arise. First, the stand response information is not complete, and best applies to average sites with site indexes of 55 to 65 feet. More response information should be added to the data base as it becomes available. Conversions to volume also are approximate; not nearly as accurate as can be made with computer systems that project diameter distribution and height.

The economic analysis deals with the simple alternative of treating or not treating a given stand, where the only variable input is treatment cost. This system does not consider alternatives such as selling or leasing timber land, nor does it consider the influence of a timber stand improvement decision upon the owner's entire financial situation. The approach should be useful in assigning limited funds among alternative stands and treatment options.

The advantages of this approach are rapidity, simplicity, and adaptability to given stand conditions and economic situations. The method can be understood and applied by field foresters, and demonstrated step by step to owners interested in the economic evaluation of their silvicultural options.

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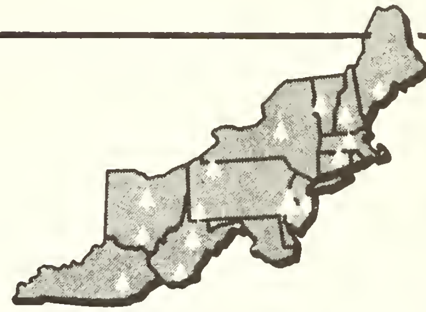

FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE, 370 REED ROAD, BROOMALL, PA. 19008

TRENDS IN TIMBER USE AND PRODUCT RECOVERY IN PENNSYLVANIA, 1966-1977

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Abstract. Repeated timber utilization studies in Pennsylvania suggest that the recovery of growing-stock timber has improved over the years. Currently 95 percent of the inventory growing stock volume is being recovered from harvested trees. There are many opportunities to recover additional amounts of biomass from nongrowing-stock trees and logging residues. Until recently, these operations were regarded as unprofitable.

INTRODUCTION

High demand for a variety of timber products from Pennsylvania forests has stimulated increased timber utilization and product recovery. Timber growers, harvesters, and processors are finding that the most direct way to stretch the current roundwood timber supply is to use more of each tree that is harvested. In the past, trees of a certain species, size, and straightness were selected in the woods, with a specific product in mind. Often, only a small segment of the tree bole was removed; it was not economical to recover the remainder (Staebler 1979).

Although timber managers have encouraged better harvesting practices for years, it was not until the development of whole-tree harvesting systems and the advent of skyrocketing energy costs that greater product recovery could be achieved at a profit. In addition to increasing wood recovery from harvested trees, there are many opportunities to recover biomass from poorly formed and defective trees. As in the Southern United States, these trees often account for much of the logging residue, especially where hardwood stands are harvested (Chappell and Beltz 1973).

The Resources Evaluation Unit at the Northeastern Forest Experiment Station has inventoried the forest resources of Pennsylvania three times. On each occasion, information concerning timber utilization has been gathered. The most recent utilization work was conducted in 1977. Field measurement data were gathered for more than 1,000 trees that were harvested on 30 widely dispersed logging operations throughout the State. To ensure a representative sample, we selected operations with probability proportional to production. Enough measurements were taken to enable us to compute volume, in cubic feet (ft^3) and board feet, based on both inventory specifications and how the tree was actually harvested. In addition to conventional volume estimation, fresh weight of the above-ground portion of the tree (excluding foliage) was calculated (Fig. 1).

Inventory specifications (as defined in the National Forest Survey Handbook) dictate that cubic volume be measured from a 1-foot stump to a minimum top diameter of 4 inches for growing stock, and that board-foot volume be measured to a top diameter of 7 inches for softwood sawtimber and 9 inches for hardwood sawtimber. Recoverable volume was determined by the timber harvester; it represented his assessment of the usable volume contained in each tree.

TRENDS IN PRODUCT RECOVERY

The volume of timber that is left after the removal of merchantable stemwood represents a considerable untapped resource. Improved recovery can be accomplished through (1) better use of unmerchantable tops and branches that are severed and left at the harvesting site, and (2) recovery of nongrowing-stock trees that are either too small, too rotten, or too poorly formed to be used for conventional wood products. The biomass from these sources could be recovered and used for energy production, channeled into reconstituted board products or small dimension stock, or converted into chemical derivatives and paper products. As shown in Figure 2, the amount of nongrowing stock available for recovery is a function of present levels of timber use.

Conventional methods

Both single product and multiproduct harvesting are common in Pennsylvania. In multiproduct harvesting the operator usually

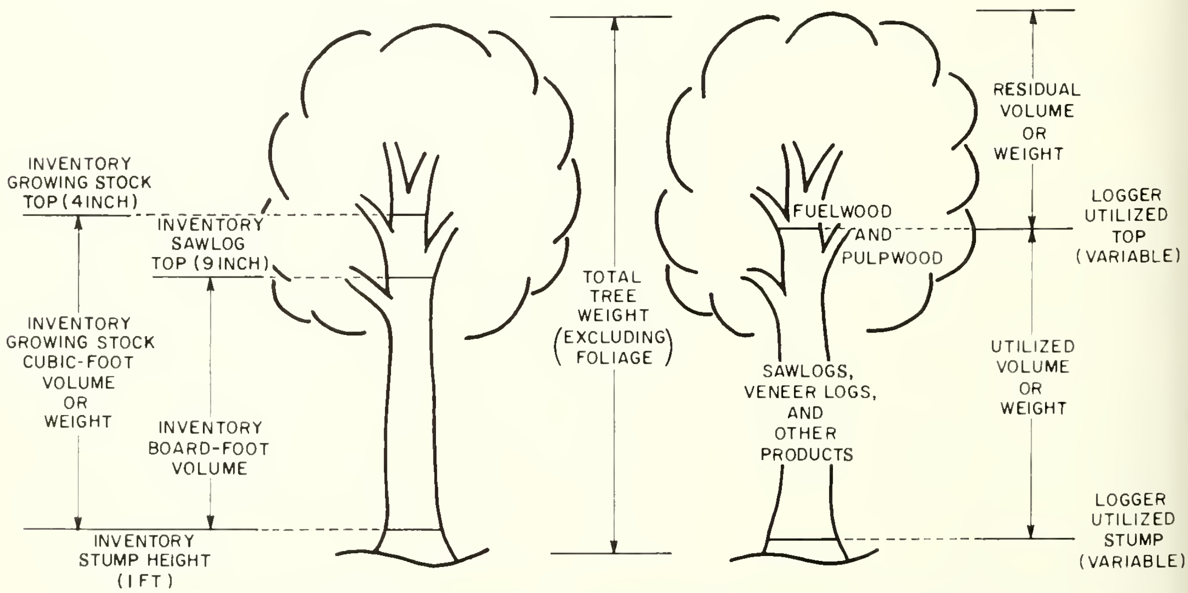

Figure 1.—Product alternatives from different portions of hardwoods upon which volume and weight relationships are based.

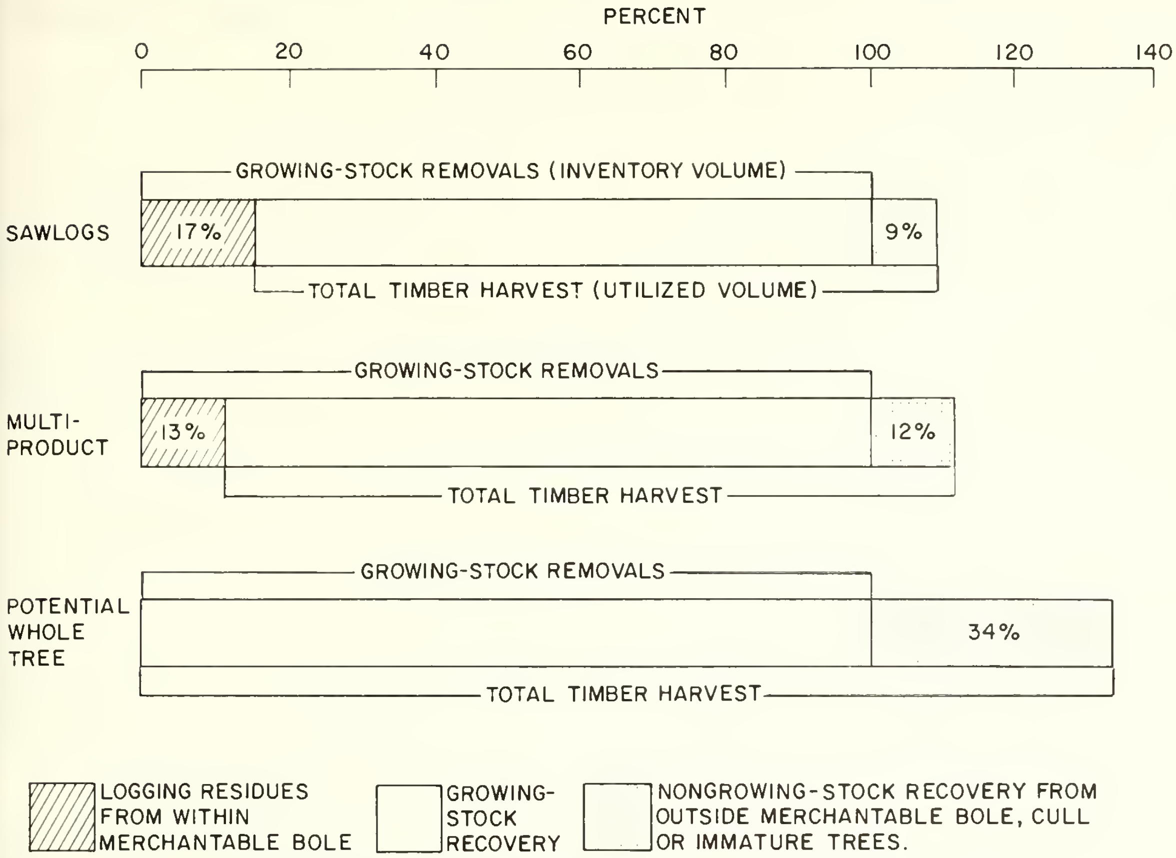

Figure 2.—Relationship of inventory to utilized hardwood volume for three product alternatives in Pennsylvania, 1977.

recovers a greater portion of the tree stem by using the bole to a smaller top diameter in addition to harvesting smaller diameter trees. In 1977 we found that when timber is harvested for a single product, such as hardwood sawlogs, the total merchantable tree bole (by inventory standards) is seldom fully recovered. Our study in Pennsylvania shows that about 17 percent of the volume in the merchantable bole is being left in the woods (Fig. 2). A portion of the loss, however, is offset by wood recovered from nongrowing-stock sources. A volume of wood equal to about 9 percent of the inventory volume total is being salvaged from treetops and from rough, rotten, and immature trees within the areas logged.

When two or more products are being harvested, the volume recovery increases from 83 percent of the inventory volume estimate to 87 percent. In a typical hardwood stand where sawlogs and pulpwood are produced, only 13 percent of the merchantable bole volume is left in the woods (Fig. 2). Much of this loss is offset by product recovery from nongrowing-stock sources equivalent to 12 percent of the inventory volume.

In 1966, only 10 percent of the sample trees were used for more than one product. By 1977, almost 25 percent of the sample trees were used for more than one product. Although the diameter of the average tree harvested has not changed significantly between 1966 and 1977, the volume of wood recovered has increased (Table 1). Sawlog processors have increased average recovery by 13 ft^3 per tree during the period. Cubic-foot recovery rates based on inventory volume estimates have jumped from 79 to 93 percent for sawlog harvesting operations and from 78

Table 1.—Average tree diameter, volume recovery, and rate of recovery, by type of harvesting in Pennsylvania, 1966 and 1977.

Type of harvesting	Diameter of average tree		Recovery from average tree		Recovery rate[a]	
	1966	1977	1966	1977	1966	1977
	- - - - - - - *inches* - - - - - - -		- - - - - - - - - ft^3 - - - - - - - - - -		- - -*percent* - - -	
Sawlogs only	16	17	30	43	79	93
Multiproduct	15	15	30	37	78	102
All types	16	16	30	41	79	95

[a]Volume recovered divided by inventory volume estimate.

to 102 percent for multiproduct operations. Even with these increased recovery rates, a portion of the merchantable material is left after conventional harvesting.

Whole-tree harvesting

Whole-tree harvesting systems are considered the only means of recovering the entire growing-stock inventory volume. In addition, according to our 1977 study, a volume of timber equivalent to 34 percent of the inventory volume total can be recovered from nongrowing-stock sources in a typical Pennsylvania hardwood timber stand (Fig. 2). The use of whole-tree harvesting compared with single product harvesting can increase timber product recovery by as much as 51 percent—17 percent from merchantable tree boles and 34 percent primarily from tops and rough, rotten, dead, and immature trees. In Pennsylvania, the average total tree volume for sawtimber-size trees is 63 ft^3—25 percent of which is not being recovered. Converting logging residue into a usable product depends largely on the availability of local markets for fiber products or fuel, and whether the added value of the material is high enough to pay for its extraction. In an analysis of southern harvesting systems, Porter (1979) found that the recovery of residues can be both economical and energy efficient. The additional machine energy input required to produce 1 Btu of residue output ranged from 0.0067 to 0.0304 Btu.

CONCLUSIONS

Our 1966 and 1977 timber use studies show that more trees are being harvested for more than one product. As a result, the average recovery rate for each tree has increased. Many multiproduct harvesting operations are recovering volumes in excess of the inventory estimate by using more of the tree bole. However, complete recovery can only be accomplished by whole-tree harvesting.

The unmerchantable tops of growing-stock trees are most easily recovered because they are concentrated, accessible, and directly related to timber harvesting levels. In Pennsylvania, the nongrowing-stock trees, while distributed at random throughout the State's timberlands, are of use when harvested with growing-stock trees. The use of whole-tree harvesting systems suggest that current timber recovery rates can be increased as the demand for wood fiber increases.

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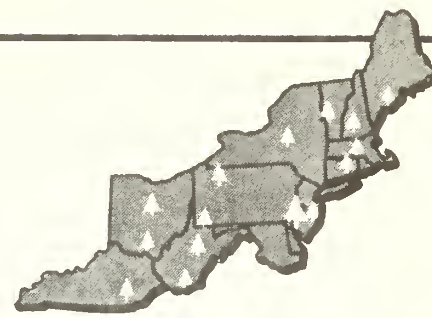

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USING TERRESTRIAL STEREO-PHOTOGRAPHY TO INTERPRET CHANGES IN TREE QUALITY CHARACTERISTICS

ODC 851--852.11--852.12

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Abstract. A technique is described for using stereo photography to evaluate tree quality changes over time. Stereo pairs were taken four times over an 18-year period. All four faces of the selected trees were photographed. Individual defect changes are shown for young upland white oak trees.

Worley and Dale (1960) described a method to record tree defects in stereo. No analytical methods or techniques were described to quantify defect change over time. This paper incorporates the use of stereo photography for defect orientation and a technique for measuring and analyzing individual quality-related variables as they change over time. Because the changes in tree quality characteristics are an integral part of total tree development, the study was designed to stereo photograph and examine limb-related defects four times over an 18-year period.

In 1960, sixteen 1-acre plots were established on the Daniel Boone National Forest in Kentucky. On each plot five trees were selected and stereo photographed to study growth and quality. The same 80 trees, all white oaks, were stereo photographed in 1965, 1972, and 1978. The stereo photos provided a photo data-bank for 18 years of growth and quality change.

The plots were maintained at stocking levels of 20, 40, 60, and 80 square feet of basal area. Tree diameters ranged from 6.5 inches to 14.0 inches in 1960, and 10.0 inches to 16.5 inches in 1978.

STEREO-PHOTO TECHNIQUE

The stereo pairs were taken of each tree bole from the four cardinal directions with a Crown Graphic camera[1] mounted on a slide base. Each photograph included at least the butt 33-foot section of the tree bole. A metal telescoping measuring pole marked in 1-foot intervals was used to determine heights (Fig. 1).

Stereo pairs were analyzed in the office using a pocket stereoscope. Tree boles were examined to a height of 17.3 feet. The quality classification system (Sonderman and Brisbin 1978) was used to measure and record the quality-related variables from each tree. The following variables were measured and recorded:

1. The number of primary limbs on each 8-foot section of the lower 16 feet of the tree bole. Only limbs ⩾ 1/3 inch were counted and tallied by live and dead categories.
2. The size of the single largest live and dead limb for each 8-foot section. Only limbs ⩾ 1/3 inch were recorded. The diameter of the measuring pole was used to estimate limb size.
3. Stem curvature was estimated in inches for the butt 16-foot section of each tree.
4. The number and extent of defect indicators (rots and seams) in the butt 16-foot section of the tree bole.
5. The number of epicormic branches in each 8-foot section of the butt 16-foot portion of the tree.
6. The number of measurable overgrowths (Sonderman 1979) in each 8-foot section of the tree bole.
7. The height, in feet, of the first fork in the butt 16-foot section of the tree bole.

Total height, crown class, crown ratio, and dbh were determined each time the trees were photographed.

Figure 1.—Stereo pair.

[1] The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture or the Forest Service of any product or service to the exclusion of others that may be suitable.

INTERPRETATION OF PHOTOS

The quality of young hardwood trees is determined by the condition, size, and extent of naturally occurring external characteristics. The stand density, aspect, and moisture all have a direct relationship to total height, dbh, crown class, crown ratio, size and number of live and dead limbs, stem curvature, epicormic branch development, forking, and external defects.

A detailed record of specific defect change and development can be made by analyzing stereo pairs at different photo intervals. Limb size, epicormic branching, and overgrowths can be recorded from one photo-measurement period to the next. Figures 2 through 5 show a progression of three individual quality changes. The inset photos indicate the detail that can be seen by examining stereo pairs. For example, the 1-inch live limb shown in Figure 2A in 1960 was dead by 1965 (Fig. 3A), but still remained on the tree in 1972 (Fig. 4A). However, by 1978 (Fig. 5A) the limb had fallen off and an overgrowth had formed. The natural pruning of this limb is possibly a result of live-limb behavior when a tree remains in a densely stocked stand. If the stand had been released to 30 square feet of basal area, the results might have been much different.

Figure 2A also shows a small 1/8-inch epicormic branch formed at the base of the above mentioned 1-inch branch. In 1965 (Fig. 3A) and 1972 (Fig. 4A) the epicormic branch was still alive and had grown to 1/4 inch and 1/3 inch, respectively. The epicormic branch was almost 1/2 inch by 1978 (Fig. 5A).

Figure 2B shows a 3/4-inch live limb in 1960. Between 1960 and 1965 this limb grew to 1 inch, but by the time the 1965 photo (Fig. 3B) was taken the limb had died. This dead limb remained on the tree another 7 years (Fig. 4B), and by 1978 (Fig. 5B) the limb had fallen off and an overgrowth remained as a past-limb indicator.

Figure 2C shows the start of a butt swell. The size and form of the butt swell appears to be diminishing (Fig. 3C and 4C), but this is an illusion because the swell remained and the tree increased in diameter (Fig. 5C). The progression shows that the absolute butt swell has stayed about the same and the relative butt swell is diminished because of tree growth.

Other tree quality characteristics that can be measured and interpreted from stereo pairs are stem curvature and forks. Stem curvature can be measured on the photograph by applying a straight edge directly along each tree bole, and then estimating the inches of departure for a given set of tree photos.

COMPARISON

For comparison, 30 white oak trees were evaluated by the quality classification system using the relative quality index (Sonderman and Brisbin 1978). The trees were evaluated in the field, and also by stereo-photo analysis in the laboratory. The results of the comparison showed that 83 percent of the trees had no change in relative quality class, and the remaining 17 percent were misclassified by only one quality class. Misclassification occurred only in the "good" and "medium" relative quality classes.

APPLICATION

The technique of interpreting stereo-pair photography provides an insight into how and why quality-related defects in trees develop and change under different cultural treatments. Interpretation of stereo photos aids in developing procedures for stratifying quality in cultural treatment studies, and provides previously unavailable information on the quality development of certain tree species. Actual results will be published in a future publication that describes the effects of thinning treatments on tree quality characteristics and growth for 18 years. The forthcoming publication will feature white oak quality development under different stocking levels and will link quality development, as recorded by this system, to silvicultural parameters.

Figure 2.—1960.

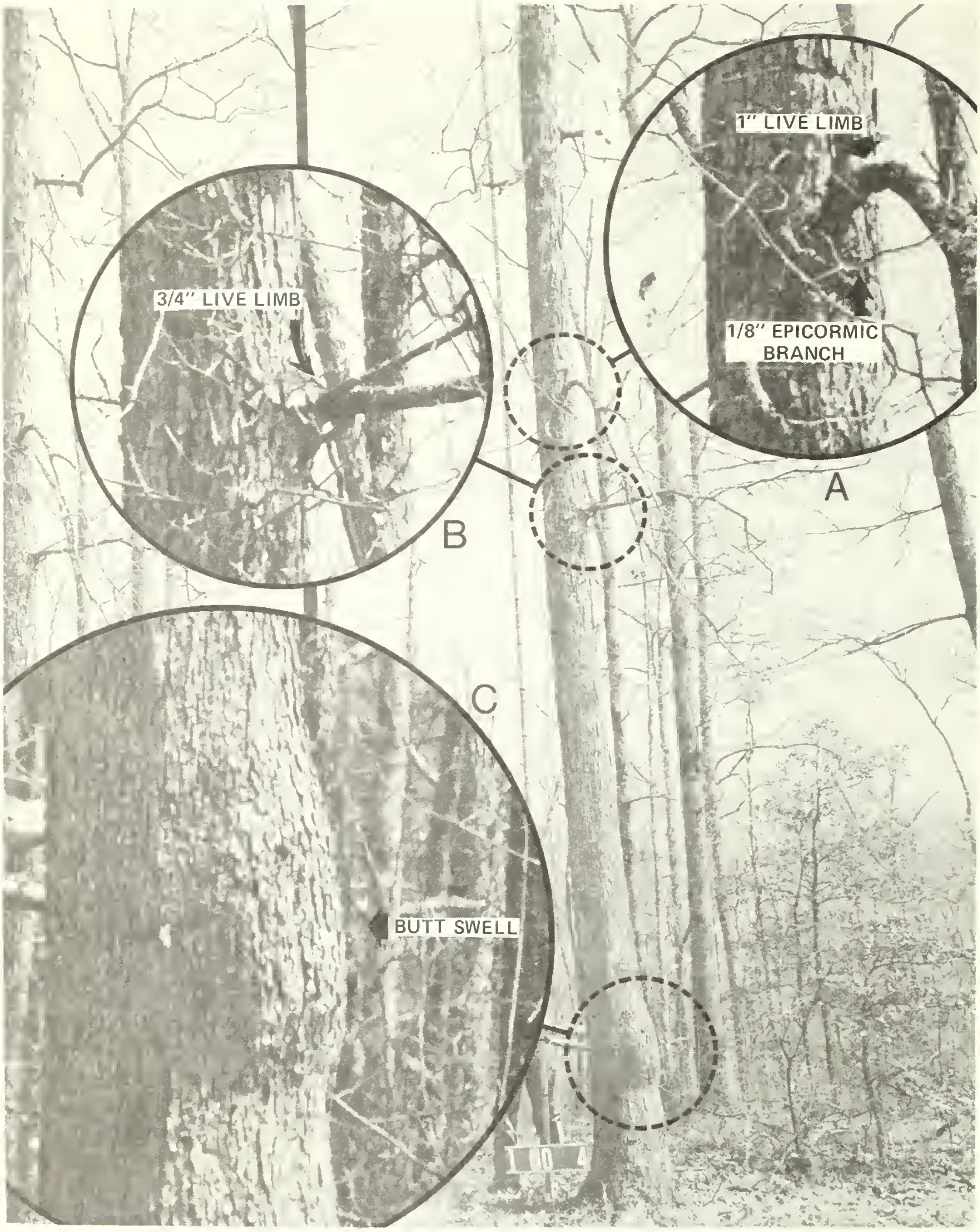

Figure 3.—1965.

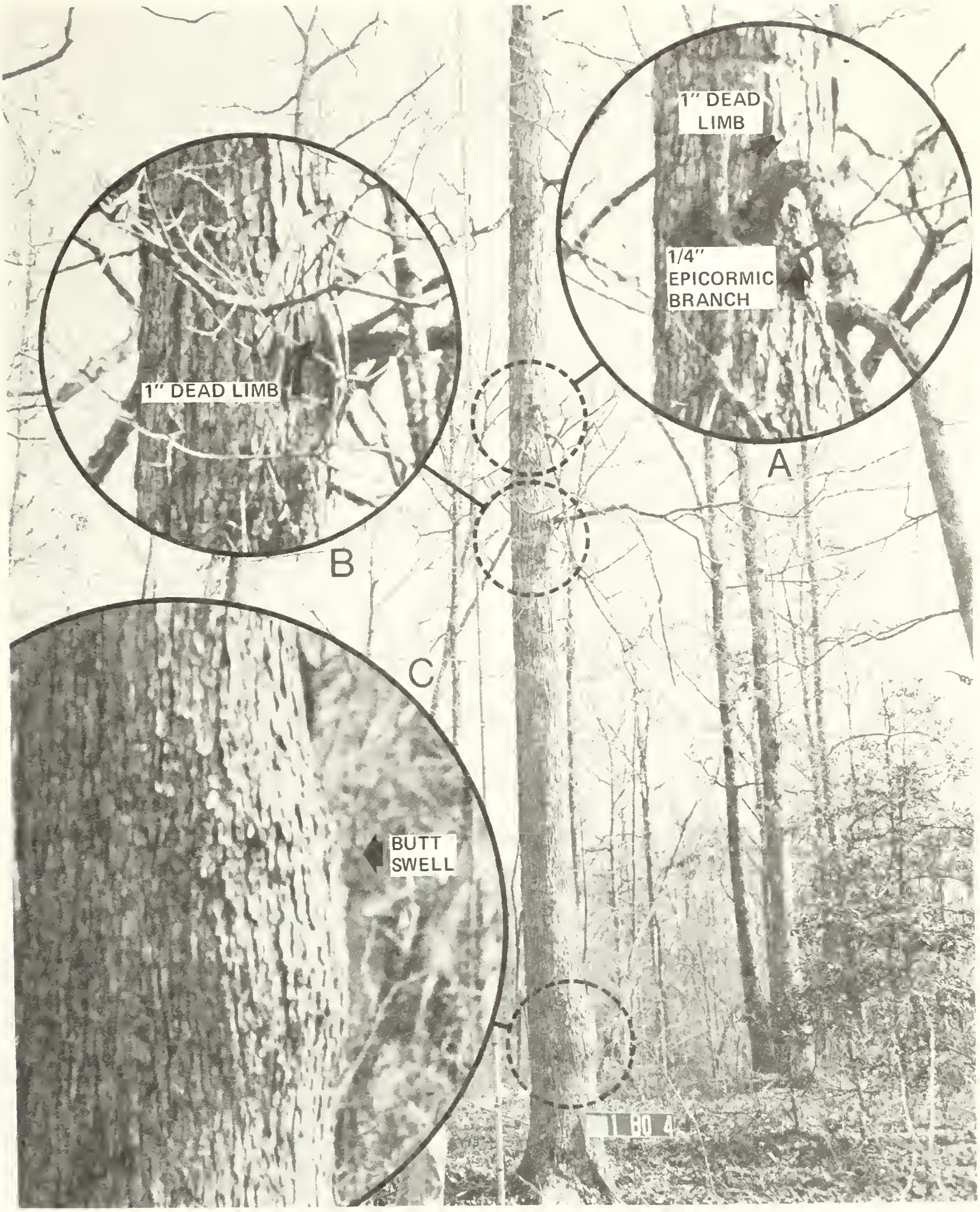

Figure 4.—1972.

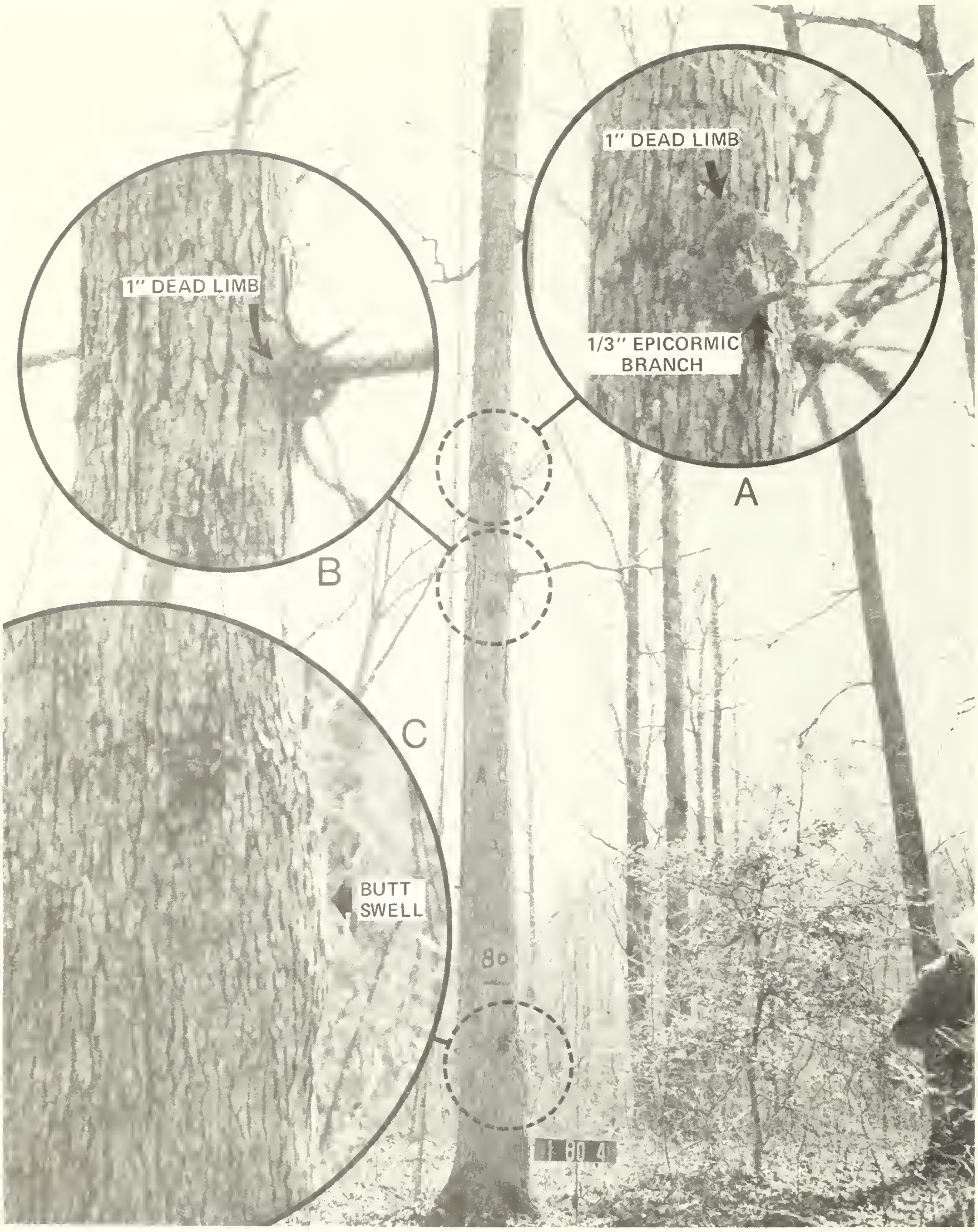

Figure 5.—1978.

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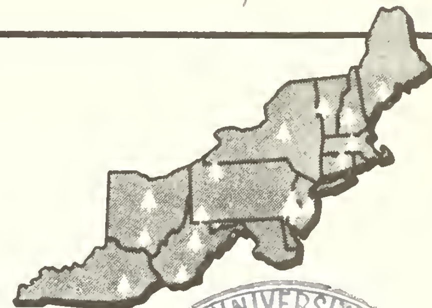

FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE, 370 REED ROAD, BROOMALL, PA. 19008

FIREWOOD AND WILDLIFE

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Abstract. The increased demand for firewood threatens the habitat of many wildlife species. Dead or dying trees that commonly are cut for firewood are vital to wildlife species that nest in tree cavities. Likewise, healthy trees of many species preferred for firewood are important components of wildlife habitat. Tree species or species groups are value-rated for both firewood and wildlife so that the ratings can be used to decide how to manage a woodland for fuel and wildlife.

As the cost of heating a home rises and the threat of fuel shortages persists, wood becomes increasingly attractive as an alternative energy source. Increased demand for firewood has widened the range of management options available to forest managers and landowners. Previously uneconomical thinning of forest stands may be profitable. Previously unmerchantable trees—the dead, dying, or injured ones—make good firewood. It might be profitable to manage certain areas solely for firewood and to cut immature trees at frequent intervals. Superficially, the economical removal of dead, dying, or injured, or malformed trees seems attractive and so does the prospect of profitable thinnings that may increase the growth of the remaining trees. However, from the chickadee's point of view, such action may be tragic. The dead, dying, or injured trees are the foraging substrate for a number of insectivorous birds, especially woodpeckers and bark-gleaning birds. Removing the low-vigor trees that provide foraging substrate and the large dead trees and "wolf" trees that provide nest cavities and dens results in an "energy crisis" for a number of wildlife species. So consider your goals carefully before deciding whether or not to harvest firewood, and if you do so, decide what tree species and how much to harvest.

Table 1.—Ratings of tree species for values to wildlife and as firewood.

Tree	Value to Wildlife				Value as firewood	Remarks
	All wildlife	Songbirds	Upland game birds	Fur and game mammals[a]		
Oaks *Quercus* spp.	Excellent	Excellent	Excellent	Excellent	Excellent	Retain a variety of species.
Black cherry *Prunus serotina*	Excellent	Excellent	Good	Good	Good	May have high timber value when mature.
Apples *Malus* spp.	Excellent	Good	Good	Good	Excellent	Rare; especially attractive to grouse.
Pines *Pinus* spp.	Excellent	Excellent	Fair	Good	Fair	Good as kindling.
Flowering dogwood *Cornus florida*	Excellent	Excellent	Good	Fair	Excellent	High aesthetic qualities.
Maples *Acer* spp.	Good	Good	Fair	Excellent	Excellent	High aesthetic qualities in the fall.
American beech *Fagus grandifolia*	Good	Fair	Fair	Excellent	Excellent	Aesthetic in the fall; important to squirrels.
Alders *Alnus* spp.	Good	Good	Good	Fair	Good	Locally important to songbirds and game birds.
Aspens *Populus* spp.	Good	Fair	Good	Excellent	Fair	Especially attractive to grouse.
Birches *Betula* spp.	Good	Fair	Good	Good	Excellent	Important to northern wildlife.
Spruces *Picea* spp.	Good	Good	Fair	Good	Fair	Good as kindling; important to northern wildlife.
Hackberry *Celtis occidentalis*	Fair	Good	Fair	Fair	Excellent	Important winter food for songbirds.
Hickories *Carya* spp.	Fair	Fair	Fair	Good	Excellent	Especially attractive to squirrels.
Ashes *Fraxinus* spp.	Fair	Fair	Fair	Fair	Excellent	Supplies mast in the fall.

firewood from tree species that are most abundant, and therefore retain the greatest variety of tree species.

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WOOD AS A FUEL

If the decision has been made to manage a forest or woodlot for a variety of products—wildlife, scenery, firewood, and timber—then there are a number of things to consider before deciding what to cut for firewood. Pound for pound, dry, sound wood differs little among species groups in the energy it contains (Shelton and Shapiro 1978). There are, however, marked differences among tree species: the ease of splitting, drying, and igniting the wood; the energy per volume of wood (some species are more dense than others); coaling qualities; tendency to produce sparks; and resin content and consequently creosote release (Baker et al. 1978, Karchesy and Koch 1978, Shelton and Shapiro 1978, U.S. Forest Service 1978, and Vivian 1978). Rather than discuss all these considerations here, certain tree species or genera are given overall ratings on a broad scale (excellent, good, and fair) in Table 1. Unfortunately, many of the species that are valuable as firewood when they are immature (for example, when removed in a thinning) are valuable as timber and to wildlife when they are mature (Martin et al. 1961). The values of black walnut for veneer and white pine for lumber are well known and such timber-related values are not discussed here. But what about wildlife?

FIREWOOD AND WILDLIFE

The relationship between cavity-using birds, such as woodpeckers, and dead or dying trees (snags) has already been mentioned. Large soft snags are too punky to produce good firewood. However, hard snags and suppressed trees are good candidates for firewood and for these trees there is a direct trade off: wood vs woodpeckers. The hairy woodpecker and the red-headed woodpecker have been placed on the Audubon Society's "early warning list" of bird species that are declining in number. The reason given was firewood cutting and particularly the cutting of dead trees (Arbib 1979).

What about other wildlife species? All trees have some value as firewood and to wildlife. Some trees, quaking aspen and alder for example, are very important to ruffed grouse and American woodcock; these trees provide maximum protective cover when in dense immature stands. Grouse and woodcock could benefit from harvesting mature trees for firewood. Apple trees, often planted by wildlife biologists to enhance wildlife clearings, are most beneficial to wildlife when mature; however, they are relatively rare on wildlands, so even immature and low-vigor trees are given special consideration. Other trees such as the oaks and hickories are abundant in some forests. These trees are important as den trees and fruit producers when mature, and an effort should be made to retain a mixture of species to ensure regular fruit crops. Time of fruit ripening differs among species, thus a mixture of ash and black cherry provides a more continuous fruit supply in the cherry-maple forest than cherry alone.

Detailed information on the food, cover, and nesting values of particular tree species to wildlife can be found in publications such as those by Martin et al. (1961) and DeGraff and Witman (1979). Because of the diversity of life styles found among American wildlife, tree-wildlife relationships are complex. Therefore, we listed groups of wildlife species rather than single species in Table 1. Trees are rated from excellent to fair for those groups and are also assigned an overall rating.

MANAGEMENT: OBJECTIVES AND ACTIONS

Select objectives clearly before managing a forest or woodlot. Knowledge of the ecology of the products desired (trees and animals managed for lumber, firewood, scenery, and recreation) is necessary to evaluate the costs and benefits of any action. For example, considerations in managing for nongame birds were discussed by Gill et al. (1974). If the choice is to manage for fuelwood and wildlife, Table 1 may be used as a guideline to evaluate actions under considerations. A good field guide to trees and shrubs, such as Trelease (1931) or Petrides (1958), will be valuable especially for identifying trees in winter.

Perhaps the best single rule of thumb to obtain a diversity of wildlife is to harvest

American basswood *Tilia americana*	Fair	Fair	Fair	Fair	Fair	Good as kindling.
Black walnut *Juglans nigra*	Fair	Fair	Fair	Fair	Excellent	May have high timber value when mature.
Black tupelo *Nyssa sylvatica*	Fair	Fair	Fair	Fair	Fair	Locally important to songbirds and game birds.
Eastern cottonwood *Populus deltoides*	Fair	Fair	Fair	Fair	Fair	Good as kindling.
Elms *Ulmus* spp.	Fair	Fair	Fair	Good	Fair	High water content when green; hard to split; cut if diseased.
Balsam fir *Abies balsamea*	Fair	Fair	Fair	Fair	Fair	Good as cover for snowshoe hares.
Eastern hemlock *Tsuga canadensis*	Fair	Fair	Fair	Fair	Fair	Attractive to northern wildlife.
Black locust *Robinia pseudoacacia*	Fair	Fair	Fair	Fair	Excellent	Low wildlife; high firewood; nitrogen-fixer.
Magnolias *Magnolia* spp.	Fair	Fair	Fair	Fair	Good	Low wildlife; good firewood.
Eastern redcedar *Juniperus virginiana*	Fair	Good	Fair	Fair	Fair	Good as kindling; attractive to songbirds.
Sassafras *Sassafrass albidum*	Fair	Fair	Fair	Fair	Good	Berries eaten by insectivorous birds.
Sweetgum *Liquidambar styraciflua*	Fair	Fair	Fair	Fair	Fair	High water content when green; high aesthetic value.
Sycamore *Platanus occidentalis*	Fair	Fair	Fair	Fair	Fair	Aesthetic; high water content when green; hard to split.
Yellow-poplar *Liriodendron tulipifera*	Fair	Fair	Fair	Fair	Fair	Good as kindling; aesthetic.
Willows *Salix* spp.	Fair	Fair	Fair	Fair	Fair	Attractive to northern wildlife.

[a]Rabbits, squirrels, foxes, skunks, etc.

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TIMBER PRICES IN THE NORTHERN UNITED STATES—1978

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Abstract. Sawtimber and cordwood prices (1978) and the range in price per unit from sales on nonindustrial private woodlands are reported for the Northern United States and subareas.

The decision to harvest timber is central to woodland management and it should be handled as a business venture. Since the price received for timber largely determines profitability of woodland management, it is important that management decisions be made with full recognition of market prices.

Timber sales on nonindustrial private woodlands represent an important source of information on market prices. The figures presented here show average prices and the range in prices received per unit for sawtimber and cordwood in the Northern United States during 1978. These figures are based on private timber sales involving state service foresters (including referrals to consultants) under the Cooperative Forestry Assistance program.

Average sale figures are subject to substantial local market variation. Prices received on individual timber sales can be strongly affected by size of sale, species, timber quality, log size, volume per acre, terrain, hauling distances, labor prices and other factors. Accordingly, Table 1 shows timber prices for subareas within the 20-state region; New England, Mid-Atlantic, Central States, and Lake States (Fig. 1).

For each subarea, local price variation is also displayed by the cumulative percent of volume sold at each price per unit of product (Figs. 2-5). Figure 2, for example, illustrates that on these timber sales half the hardwood sawtimber sold for $65 to $70 per Mbf or less. But, while $130 per Mbf was the top price in New England, over 20 percent of the hardwood sawtimber in the Central States went for more than $130 per Mbf.

Finally, the variation in total timber sale value is shown by the cumulative percent of timber sales that occurred at each value (Figs. 6-7). For example, Figure 6 shows that half the region's hardwood timber sales had total sale values of $3,250 or less, while 15 percent yielded more than $10,000.

Table 1.—Average prices received for timber in Northern U.S., based on nonindustrial private woodland timber sales, 1978.

Item	Total Region	New England	Mid-Atlantic	Central States	Lake States
Hardwood sales					
Sawtimber ($/Mbf)	174.81	64.02	85.88	361.76	80.87
Low	12.38	30.00	29.15	12.50	12.38
High	3,328.57	126.26	2,500.00	3,328.57	333.33
Cordwood ($/Cord)	4.53	4.95	4.44	—[a]	3.89
Low	1.00	1.00	1.50	—	1.00
High	12.50	12.50	12.50	—	8.00
Sale value ($/Sale)	5,524	2,666	7,488	6,824	4,148
Low	20	24	60	100	20
High	70,000	64,000	38,000	70,000	43,000
Softwood sales					
Sawtimber ($/Mbf)	51.91	51.67	49.05	—	60.56
Low	20.00	20.00	20.00	—	30.00
High	131.15	107.00	131.15	—	90.91
Cordwood ($/Cord)	5.14	4.11	—	—	6.84
Low	1.00	1.00	—	—	3.00
High	10.00	10.00	—	—	10.00
Sale value ($/Sale)	2,957	3,471	3,418	—	1,576
Low	20	48	40	—	20
High	148,000	148,000	48,000	—	14,000

[a]Insufficient number of sales.

Figure 1.—Northern U.S. and subareas.

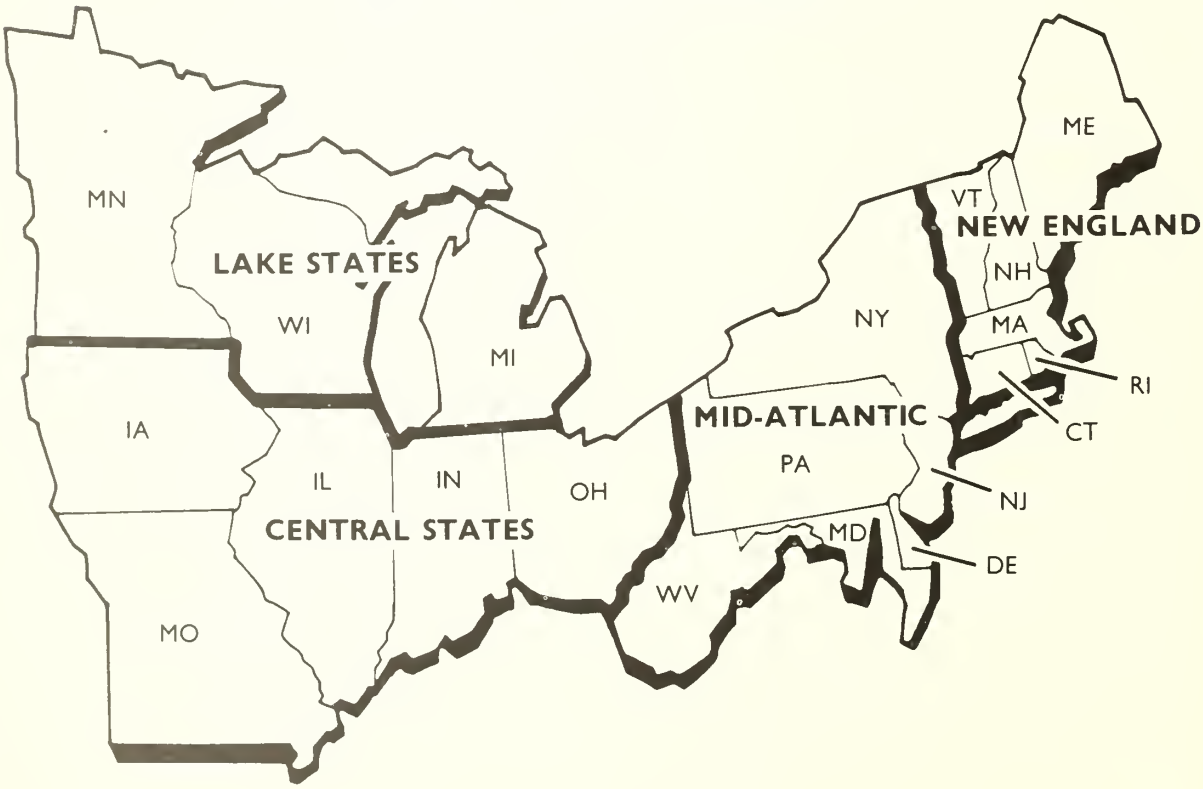


Figure 2.—Hardwood sawtimber; cumulative percent sold, by price per Mbf and location.

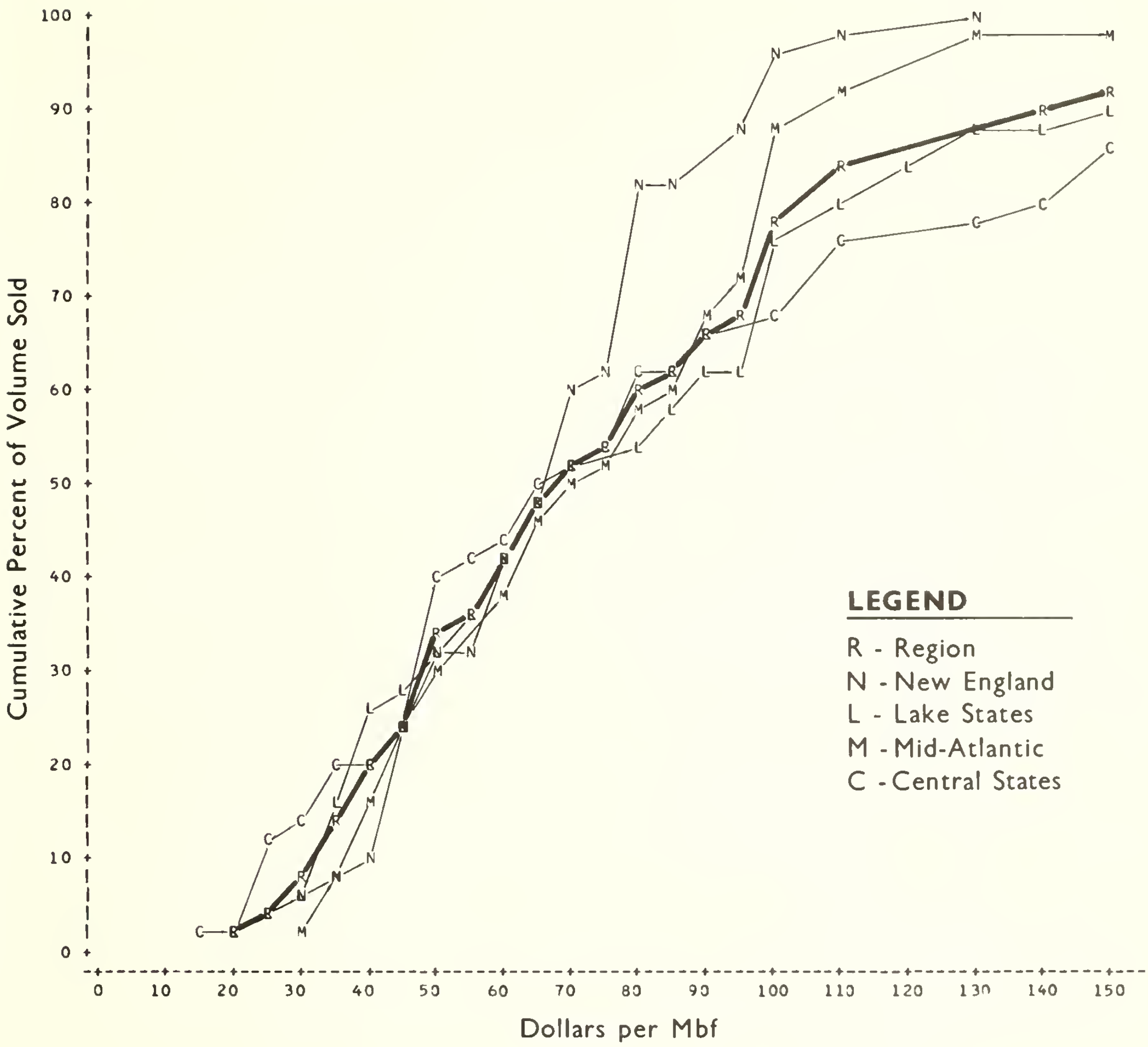


Figure 3.—Softwood sawtimber; cumulative percent sold, by price per Mbf and location.

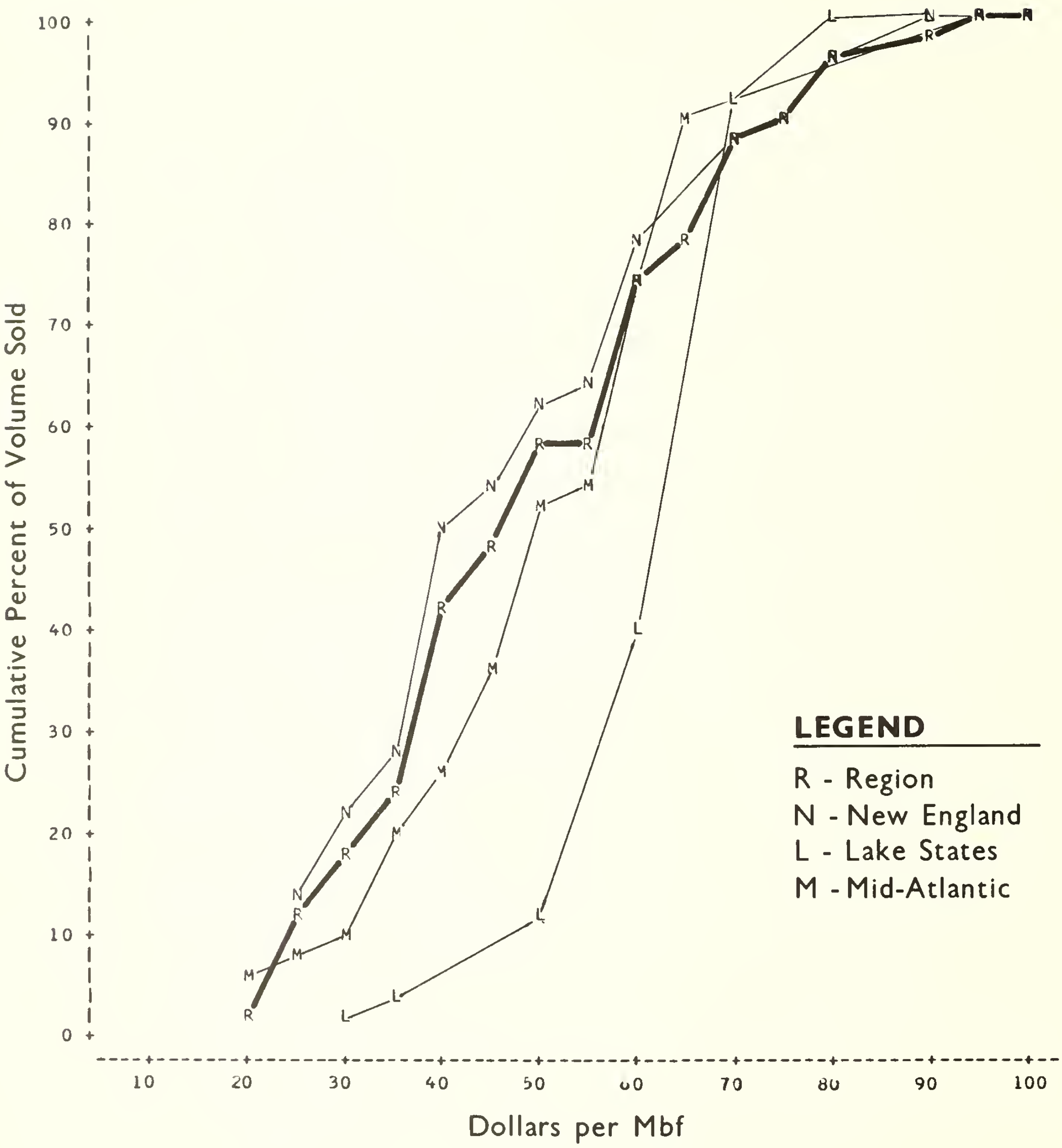


Figure 4.—Hardwood cordwood; cumulative percent sold, by price per cord and location.

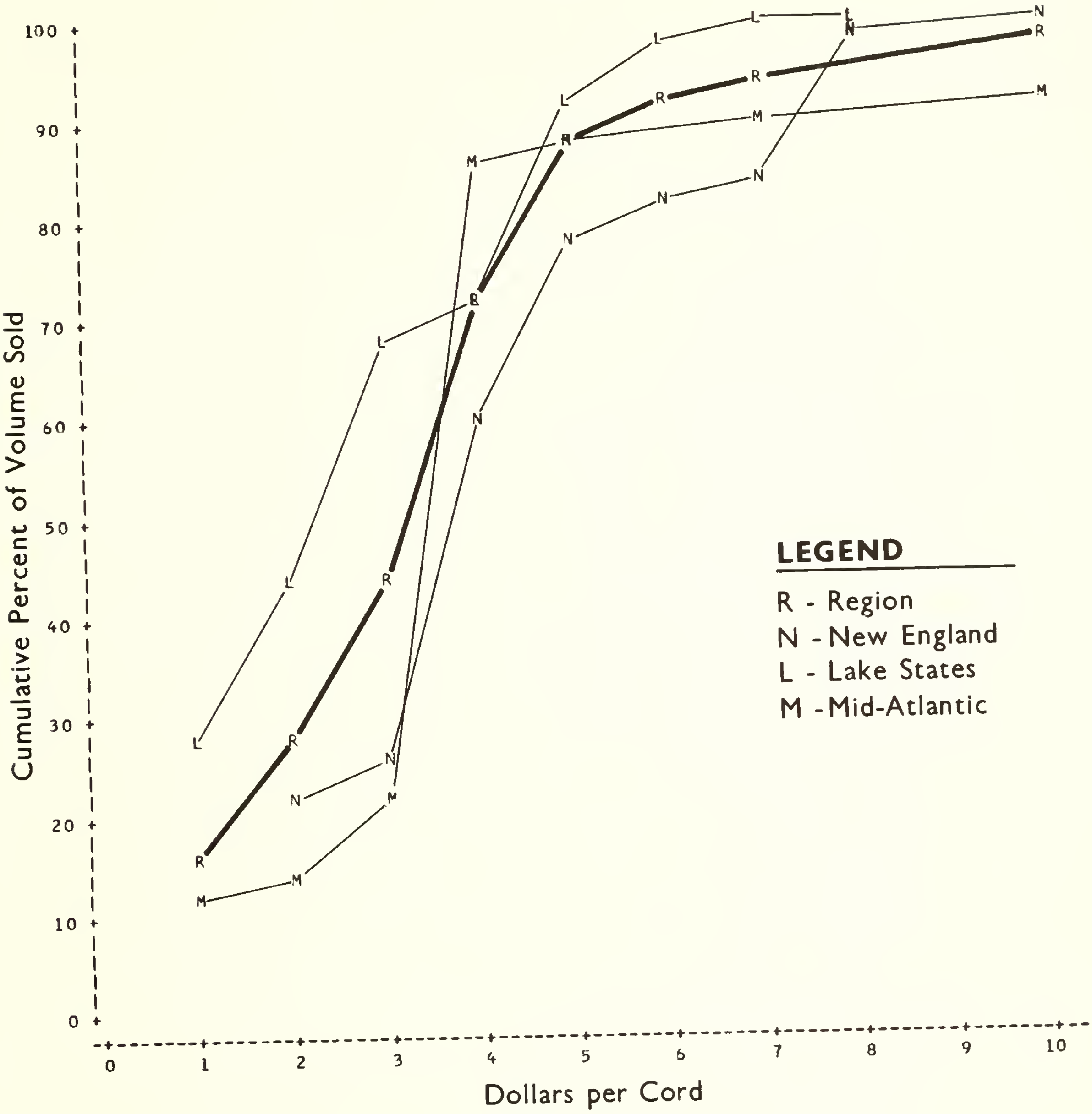


Figure 5.—Softwood cordwood; cumulative percent sold, by price per cord and location.

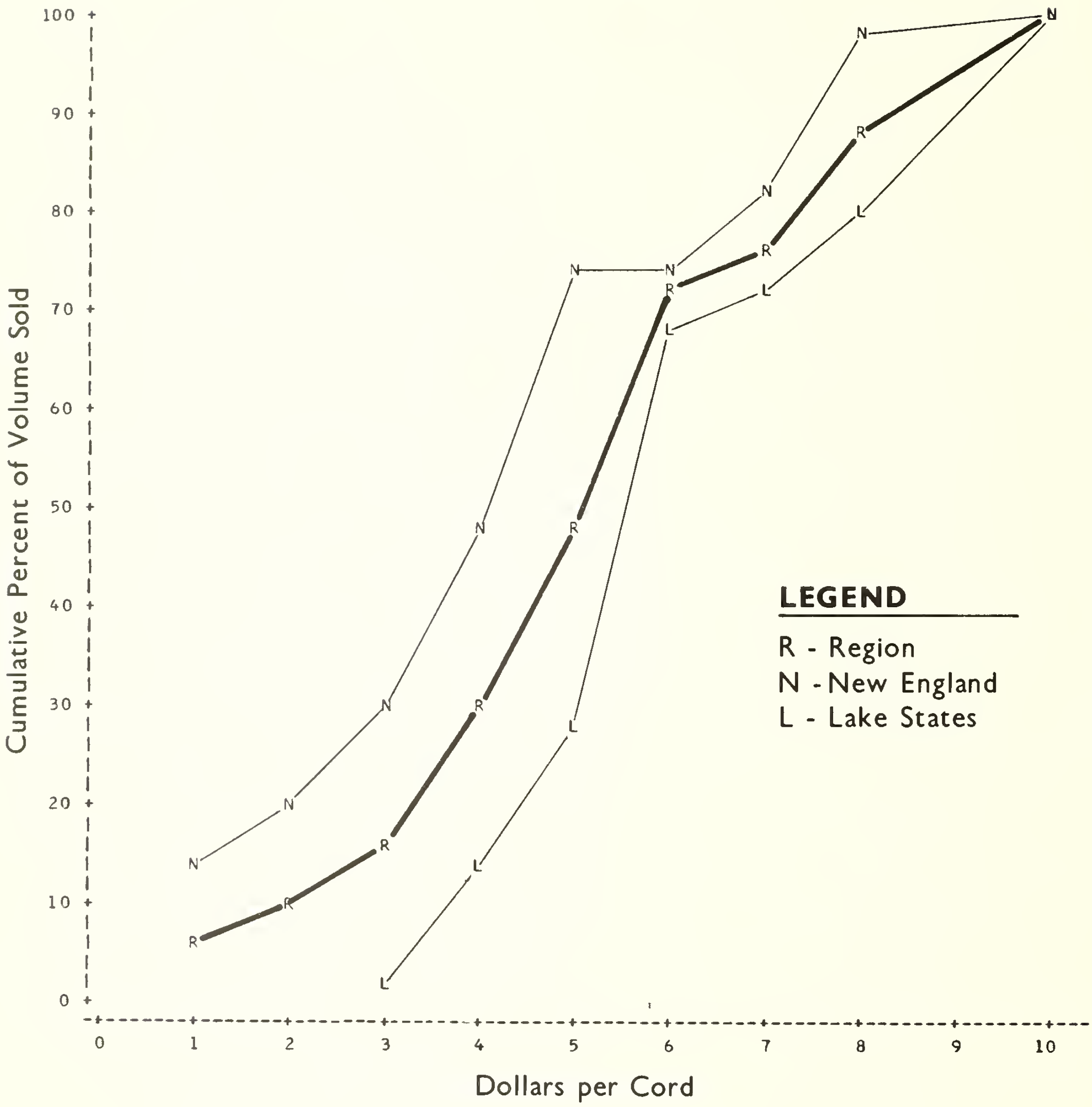


Figure 6.—Hardwood timber sales; cumulative percent of sales, by value per sale and location.

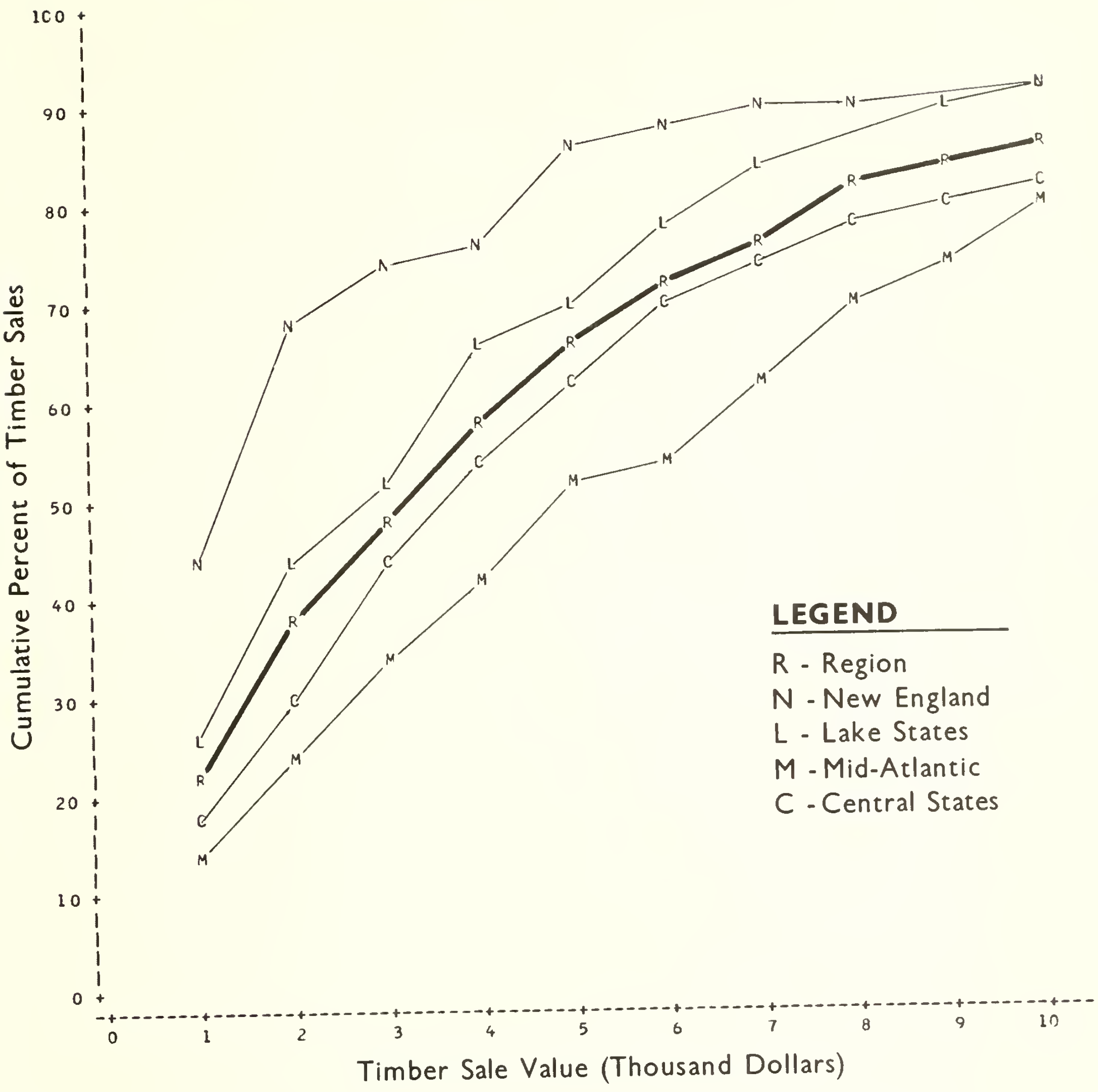
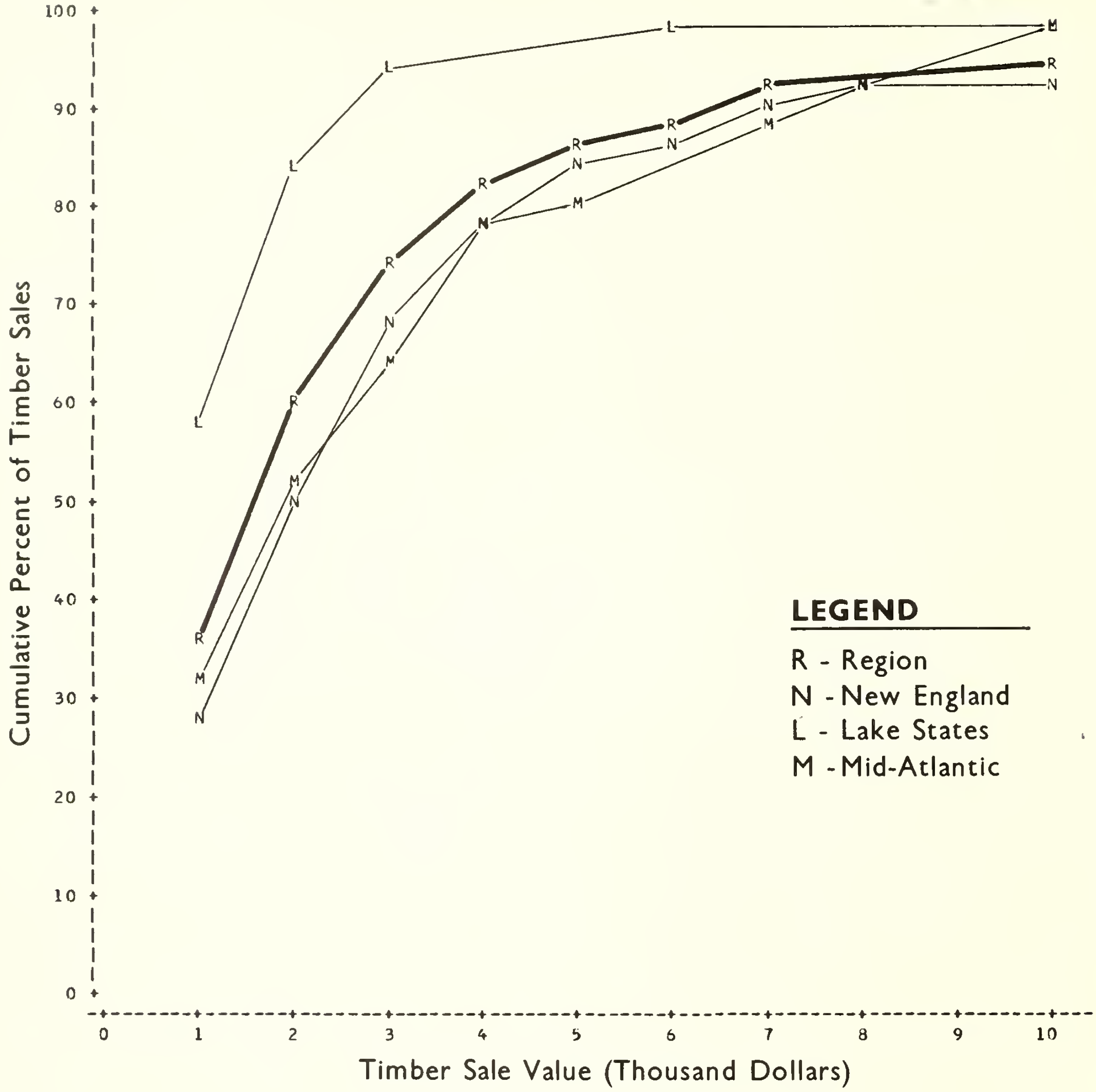


Figure 7.—Softwood timber sales; cumulative percent of sales, by value per sale and location.



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