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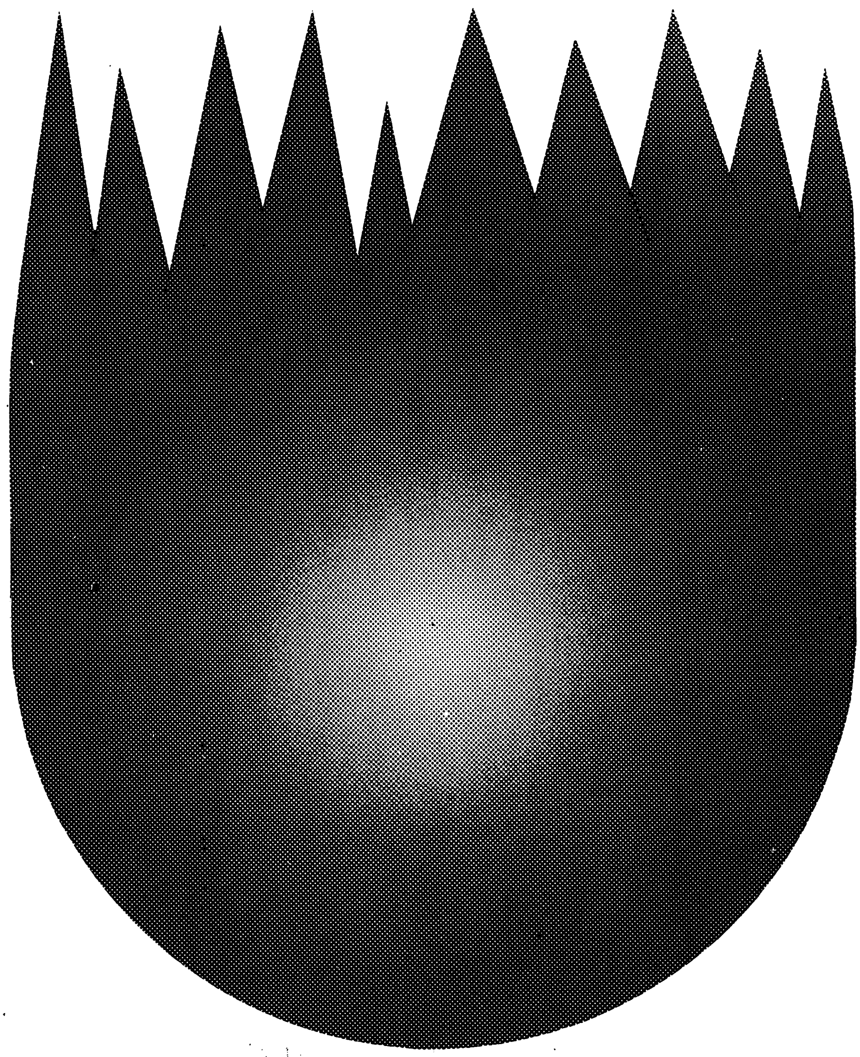

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BIOMASS IN CONIFER PLANTATIONS OF NORTHEASTERN MINNESOTA

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Establishing conifer plantations in the Great Lakes Region generally requires site preparation prior to planting and release from competing vegetation several years after planting. A good deal is known about the response of the planted trees to these silvicultural practices, but little has been reported on the response of the rest of the vegetative community in plantations. The other vegetative components of a plantation not only influence the planted trees but also the other resources, especially wildlife habitat, that managers are required to provide.

The response of tall shrub undergrowth to silvicultural practices in 53 conifer plantations from northeastern Minnesota was recently described (Ohmann 1982). This report quantifies the overall response in terms of biomass of the various plant strata and particularly the low shrub-herb layer in the same plantations. It also compares plantation biomass with other reported planted and natural community biomass values.

Biomass is a useful measure for understanding plant community dynamics (Whittaker 1962, Whittaker and Woodwell 1968). Biomass integrates plant species size (dominance) and numbers and also permits comparison of morphologically different species (Balogh 1983).

More than 300,000 acres of conifer plantations have been established in the Superior National Forest. Conifer plantations made up about 10 percent of the Forest's Isabella and Halfway (now part of the Kawishiwi) Ranger Districts at the time this study was conducted (1976-77) (Peek *et al.* 1976).

The acreage of conifer plantations in northeastern Minnesota will probably increase in response to more intensive forest management mandated by legislation that restricts timber harvest in the nearby Boundary Waters Canoe Area Wilderness.

METHODS

Field

Study plantations on relatively uniform soils (coarse loamy Dystric Eutrochrepts)[1] were selected from within a 33-mi^2 area near Isabella, Minnesota (lat. 47° 35'N, long. 91° 20'W). Parts of the area had been logged for red pine (*Pinus resinosa* Ait.) and white pine (*Pinus strobus* L.) during northern Minnesota's early logging period (ca. 1900-1920). However, the sample was selected from plantations established following the clearcut of natural stands of pine (jack pine, *Pinus banksiana* Lamb.) or mixed pine and spruce (usually black spruce, *Picea mariana* (Mill.) B.S.P.) during the mid-1940's through the 1970's.

Samples were selected to represent a spectrum of plantation ages and of silvicultural techniques practiced in the study area during the 30-year period. Plantation establishment dates, tree species planted, and site preparation and plantation release methods were depicted with overlays on a cover-type map of the area (Hagen and Meyer 1977). Based on the overlays plantations were arbitrarily classed by 5-year age classes from earliest available (1945-1949) to most recent (1970-1974) at the time of the study. The plantations were categorized on the basis of tree species planted and on the basis of two silvicultural practices: (1) site preparation for planting, and (2) release from competing vegetation.

Site preparation methods included: (1) no known site preparation treatment; (2) mechanical disking of the ground surface, probably by an Athens-type disk plow (Rudolf 1950); (3) dozer-blade shearing of woody stems and scraping at least some of the forest floor material and depositing it in specific areas, generally

[1] *Personal communication with D. F. Grigal.*

windrows (rock-raking[2]) (Noble *et al.* 1977); and (4) applying chemical herbicide (usually either 2,4-D or a mixture of 2,4-D and 2,4,5-T) to the post-logging vegetation. Plantation release methods included: (1) foliar application of chemicals (in more recent years usually 2,4-D herbicide applied by helicopter (Hagen and Meyer 1977), but earlier could have included a mixture of 2,4-D and 2,4,5-T applied from fixed-wing aircraft); (2) manual (hand removal of competing vegetation at least once); (3) manual plus chemical (a combination of both types of release, usually a manual release followed by a chemical release several years later); and (4) unknown (no record of release). Tree species planted were categorized as: (1) pine (red pine, jack pine, or a combination of both); (2) pine and spruce (white spruce, *Picea glauca* (Moench) Voss); or (3) spruce.

The plantations were chosen on the cover-type map and overlays by using random numbers selected from right angle baselines drawn on the map. Samples were drawn until at least three sites were picked to represent all combinations of categories of species planted, site preparation, and plantation release practiced within each of the 5-year establishment periods. Because silvicultural technology changed, not all of the listed practices were represented in each establishment period. For example, sites were not prepared by disking in plantations established after 1964, chemical site preparation was not practiced before 1965, all plantations established after 1965 had some type of site preparation, and rock-raking was not used until 1960.

Trees greater than 1 inch diameter at breast height were sampled by the point-centered quarter method (Cottam and Curtis 1956). This method would not normally be used to sample regularly spaced trees such as in plantations. However, most of the trees were not evenly spaced because a significant number of nonplanted trees were present (about 20 percent of the sample) and not all planted trees survived. We modified the quarter method such that biomass was determined for each point and then averaged over all points. Used in this way, the method is similar to a plotless basal area estimation. The use of a 1 inch diameter at breast height limit meant that in young plantations it was possible that some (and occasionally all) of the trees sampled were nonplanted individuals that had not been removed during harvest, had not been killed during site preparation, or had sprouted following site preparation and reached diameter growth beyond the lower sampling limit.

The first sample point was randonly selected and the remaining points were spaced about 60 feet apart in a block design of 4 rows of 5 points or 5 rows of 4 points. The direction of travel from point to point constituted one line and an imaginary line was drawn perpendicular to it, forming 4 quadrants around each point. At each point we recorded the distance to the closest tree in each quadrant (to the nearest foot) and the species and d.b.h. (to the nearest one-tenth inch).

Low shrubs, fern and fern allies, herbs, mosses and lichens were recorded as the percent of ocular ground cover they projected within a 1 by 2 foot plot at each of the 20 tree sampling points (Ohmann and Ream 1971a). Sampling was conducted throughout the growing season. Some species were difficult to identify during certain times so some species were grouped; for example, all grass species were treated as a single unit.

Analyses

Tree diameters were used in appropriate equations developed for each species from this or similar regions to estimate the aboveground ovendry biomass represented by each tree (Barney *et al.* 1978, Crow 1983, Green and Grigal 1978, Harding 1982, Ker 1980, Kinerson and Bartholomew 1977, Koerper and Richardson 1980, Monteith 1979, Pastor and Bockheim 1981, Pollard 1972, Schmitt and Grigal 1981, and Young *et al.* 1980).

For the traditional point-centered quarter method, tree diameter and distance data are collected at a number of points (usually 20 or more) in a stand. The data are then aggregated by summation over all points, and tree density and basal area are calculated on the basis of aggregated data. In this study, however, we performed the appropriate computations for biomass on data collected at each point. Summary statistics were then developed for relevant data from each point, generating means and variances. The advantage of this approach is the ability to develop measures of variation for the data.

The low shrub, herb, and fern and fern ally cover data from each plot were used in biomass estimation equations developed for species or species groups for this area (Ohmann *et al.* 1981). Average cover of mosses and lichens were converted to biomass estimates using equations based on additional sampling within northeastern Minnesota.

Total plantation herb layer biomass and biomass of major species or species groups were subjected to

[2] *A more accurate term currently used for this general form of treatment is "tractor scarification".*

logarithmic transformation and analyzed for difference within treatments by one-way analyses of variance (ANOVAs) and among treatments by three-way ANOVAs.

The effect of treatment categories was also assessed through Multiple Classification Analysis (MCA) (Andrews *et al.* 1973). MCA is a multivariate technique for examining the simultaneous interrelations between several treatments and a dependent variable. It is especially useful if the treatments are correlated to some degree and the attributes examined are not experimentally manipulated (Nie *et al.* 1975), as in this study. A unique feature of MCA is the ability to show the effect of each treatment category on the dependent variable (biomass) both before and after accounting for the effects of the other treatment(s) being considered. For MCA, a grand mean for the dependent variable (biomass) and for category means of each treatment are computed and are expressed as deviations from the grand mean after adjusting for other treatments. These adjusted values indicate the "true" effects of the treatment category on the dependent variable—the effects remaining after accounting for the variation due to other treatments.

RESULTS AND DISCUSSION

The sample consisted of nine or more plantations for each of the establishment periods except for 1970-1974 when not enough plantations were available for sampling (table 1). Some of the PREP, RELEASE, and SPECIES categories also had limited representation so only three samples were selected from each of them because of their scarcity in the plantation population (table 1).

Two of the independent variables, YEAR and PREP, were significantly positively correlated. This probably reflects changes in site preparation practices. YEAR and SPECIES, as well as PREP and SPECIES, were slightly positively related. YEAR and RELEASE, PREP and RELEASE, and SPECIES and RELEASE were weakly negatively related:

Independent Variable	Pearson's R	Probability
YEAR-PREP	0.7134	0.000
YEAR-RELEASE	−0.1100	.216
YEAR-SPECIES	.2022	.073
PREP-RELEASE	−0.0691	.312
PREP-SPECIES	.1378	.162
RELEASE-SPECIES	−0.1569	.131

It is important to recognize the degree of correlation because positively related treatments, when considered together, will explain less of the variation than when considered separately and added together. On the other hand, negatively related treatments that are positively related to the dependent variable will, when considered together, explain more of the variation in the dependent variable than when considered separately and added together. The independent variables YEAR and PREP are correlated sufficiently so that when considered together in an ANOVA or MCA the amount of variation explained is less than actually present.

Ecological landtypes (ELTs) for the Superior National Forest recently have been described, although they have not been mapped extensively. The most probable ELTs for the plantations in this study are: ELT-11 (UDHD) Upland Deep Loamy over Sandy Dry, ELT-13 (UDLDC) Upland Deep Loamy Dry Coarse, and ELT-14 (UDLDM) Upland Deep Loamy Dry Medium. These ELTs are estimated to occupy 10, 8, and 11 percent of the land area within the Superior National Forest, respectively. The results presented here would be most applicable to conifer plantations located on these ELTs.

Plantation and Strata Biomass

Generally, biomass increases with plantation age. In this case total plantation biomass[3] ranged from

[3] *Total biomass does not include conifer tree seedlings under 1 inch d.b.h..*

Table 1.—*Independent variable categories used to analyze the biomass estimates of the plant strata in 53 conifer plantations near Isabella, Minnesota*

Establishment period		Site preparation		Plantation release		Species planted	
YEAR	Plantations	PREP	Plantations	RELEASE	Plantations	SPECIES	Plantations
	Number		*Number*		*Number*		*Number*
1945-1949	9	None	11	Chemical	17	Pine	38
1950-1954	9	Disk	21	Manual	21	Pine and spruce	12
1955-1959	9	Rock-rake	18	Manual plus chemical	3	Spruce	3
1960-1964	13	Chemical	3	No record	12		
1965-1969	9						
1970-1974	4						

135,100 lbs/acre[4] in the oldest (26- to 30-year-old) to 40,500 lbs/acre in the 11- to 15-year-old plantations but then increased to 66,500 lbs/acre in the youngest plantations (table 2). Excluding the tree component, the mean biomass of all other strata was 3,100 lbs/acre. The nontree biomass from the oldest to the youngest plantation was distributed about as expected and the differences are minor between them. The greatest deviation from the mean in the nontree group was a plus 760 lbs/acre in the 21- to 25-year-old plantations and the next greatest was a minus 510 lbs/acre in the 1- to 5-year-old plantations. Therefore, the anomaly in biomass distribution by plantation age is primarily attributable to the the tree stratum. In the younger plantations fewer planted trees were large enough to be included in the sample limit of 1 inch d.b.h. and thus proportionally more nonplanted trees—trees not taken in the earlier harvest operation and not killed in site preparation, or trees that sprouted following site preparation and grew beyond the diameter limit—were included in the sample. These trees, sometimes large hardwoods, contributed a greater biomass for the tree stratum than expected in the younger plantations.

Although the literature contains few reports of biomass for young conifer plantations (Cannell 1982), total community biomass has been reported for both natural broadleaf and conifer stands and for some plantations in the region. A 32-year-old red pine plantation in Wisconsin representing 163,200 lbs/acre was reported by Wilde (1967). Biomass in 50+ year-old natural jack pine communities in northern Minnesota ranged from 73,500 lbs/acre on granite to 134,800 lbs/acre on deep till (Green and Grigal 1979). The older Isabella plantations fall within the range of most of the conifer communities listed above.

The biomass of the oldest Isabella plantations (135,000 lbs/acre) also compared favorably with reported nonpine community biomass values. Reiners (1972) reported biomass of a mature upland oak forest as 111,100 lbs/acre, a marginal fen forest as 88,100 lbs/acre, and a cedar swamp forest as 142,400 lbs/acre. Ovington (1963) found 146,700 lbs/acre of biomass in an upland oak woodland in Minnesota. From 37- to 39-year-old aspen near Dorset, Ontario, had 53,100 lbs/acre and 41-year-old aspen near Lake Itasca, Minnesota, 185,200 lbs/acre of biomass, respectively (Bray and Dudkiewicz 1963). A northern Minnesota 5-year-old aspen sucker stand contained 33,800 lbs/acre of biomass, and a mature aspen stand 132,800 lbs/acre (Silkworth and Grigal 1982). A poorly drained alder (*Alnus rugosa* (Du Roi) Spreng.)-ash (*Fraxinus nigra* Marsh.) swamp in northern Michigan had a biomass value of 47,300 lbs/acre and a well-drained alder-ash swamp (mostly alder) 27,700 lbs/acre (Parker and Schneider 1975).

Other studies report only the biomass of the tree component. Mean tree biomass in a series of 24- and 25-year-old jack pine plantations at three Lake States locations ranged from 64,400 to 102,100 lbs/acre (Zavitkovski *et al.* 1981). The lower biomass plantations were located near Isabella, Minnesota and this study site. The value for this site was the mean of 50,398, 64,670, 69,398, and 73,055 lbs/acre of jack pine biomass. In Vermont 10-year-old jack pine plantations contained 11,900, 15,300, 24,400, and 30,500 lbs/acre of tree biomass when planting space was varied (Adams 1928). And 40-year-old jack pine in central Minnesota contained 132,284 lbs/acre of jack pine biomass (Alban *et al.* 1978). Tappeiner and John (1973) reported that biomass in 50- to 90-year-old jack pine stands in Southern Minnesota ranged from 86,700 to 112,900 lbs/acre. Red pine plantations of 29, 30, and 31 years of age contained 41,210, 49,506, and 48,971

[4] *To convert from lbs/acre to kg/ha, divide by 0.8922.*

Table 2.—*Above-ground ovendry biomass by stratum for 53 conifer plantations near Isabella, Minnesota*

	Plantation age					
Stratum	1-5	6-10	11-15	16-20	21-25	26-30
			Pounds/acre			
Tree (>1 inch d.b.h.)	63,885	50,221	37,627	62,811	73,382	131,902
Tall shrub (plus hardwood trees < 1 inch d.b.h.)	2,034	2,332	2,035	2,086	2,914	2,631
Low shrub[1]	25	101	185	109	166	137
Herb	276	266	312	317	437	176
Fern and fern ally	77	60	132	96	156	82
Moss	107	268	250	156	165	156
Lichen	71	89	45	116	18	18
Total	66,475	53,337	40,586	65,691	77,238	135,102

[1]Raspberry (*Rubus strigosus*) and rose (*Rosa acicularis*) were included in the tall shrub stratum.

lbs/acre, respectively (Madgwick *et al.* 1970). Mature central Pennsylvania red pine plantations at tree densities of 435, 907, and 1,210 trees/acre had 172,156; 207,925; and 166,536 lbs/acre of biomass, respectively (Singer and Hutnik 1966). The pine biomass of the older Isabella plantations was within the range of all but the mature red pine plantations reported above (fig. 1).

No Lake States reports of biomass for nontree vegetation strata in young conifer plantations were found to directly compare with the biomass values of the Isabella plantations. Biomass has been reported for other types of plant communities by various strata; however, the definition of what is included in each stratum differs greatly. Mature jack pine communities on various bedrock types and soil depths in northern Minnesota (Green and Grigal 1979) contained more moss and lichen biomass (616 to 4,202 lbs/acre) than the 174 to 357 lbs/acre in the Isabella plantations (table 2). Biomass of the low shrub, herb, and fern and fern ally components of the mature jack pine communities were more similar to the plantations ranging from 187 to 509 lbs/acre and from 378 to 759 lbs/acre on the Isabella sites (table 2). The tall shrub stratum among plantations was much more uniform than among the mature stands where it ranged from 71 lbs/acre on Gabbro bedrock with shallow soils to 2,600 lbs/acre on deep till soils (Green and Grigal 1979). The difference in total undergrowth biomass in the mature stands (mean of 4,305 lbs/acre) and the plantations (mean of 3,100 lbs/acre) was due primarily to more moss and lichen biomass and less tall shrub biomass in the mature stands. The shrub component of a 40-year-old jack pine stand in north-central Minnesota contained 2,587 lbs/acre of biomass (Alban *et al.* 1978). Undergrowth biomass of 5-year-old postfire communities resulting from natural seeding to jack pine or sucker regeneration of aspen ranged from 1,468 lbs/acre in an aspen-birch-jack pine type to 5,099 lbs/acre in a ridgetop jack pine-oak community (Ohmann and Grigal 1979). Three of the 7 communities exceeded the amount of undergrowth biomass occurring in the 1- to 5-year-old plantations. The difference was due mainly to greater amounts of low shrubs in the postfire communities. The plantations exhibited a general increase in total undergrowth biomass with age (table 2). Based on the northern Minnesota mature jack pine communities, plantation undergrowth at 30 years had not yet peaked.

Biomass by strata has been reported for several broadleaf communities in the region. Shrub biomass of mature aspen, aspen-maple-birch, and maple-birch-aspen communities in Wisconsin was 1,540, 720, and 340 lbs/acre, respectively; ground cover was 1,240, 480, and 600 lbs/acre; and total undergrowth was 2,780, 1,200, and 940 lbs/acre (Crow 1978). Mature aspen communities at Dorset, Ontario, and Lake Itasca, Minnesota, contained undergrowth biomass values similar to the Wisconsin stands at 1,490 and 785 lbs/acre (Bray and Dudkiewicz 1963). These values were much less than either the plantations or other communities noted above. A 5-year-old aspen sucker stand and a mature aspen stand in northern Minnesota had tall shrub biomass values of 3,400 and 3,740 lbs/acre, respectively (Silkworth and Grigal 1982), which was higher than the Isabella plantations; but the other undergrowth biomass (900 lbs/acre) was within the range of that in the plantations.

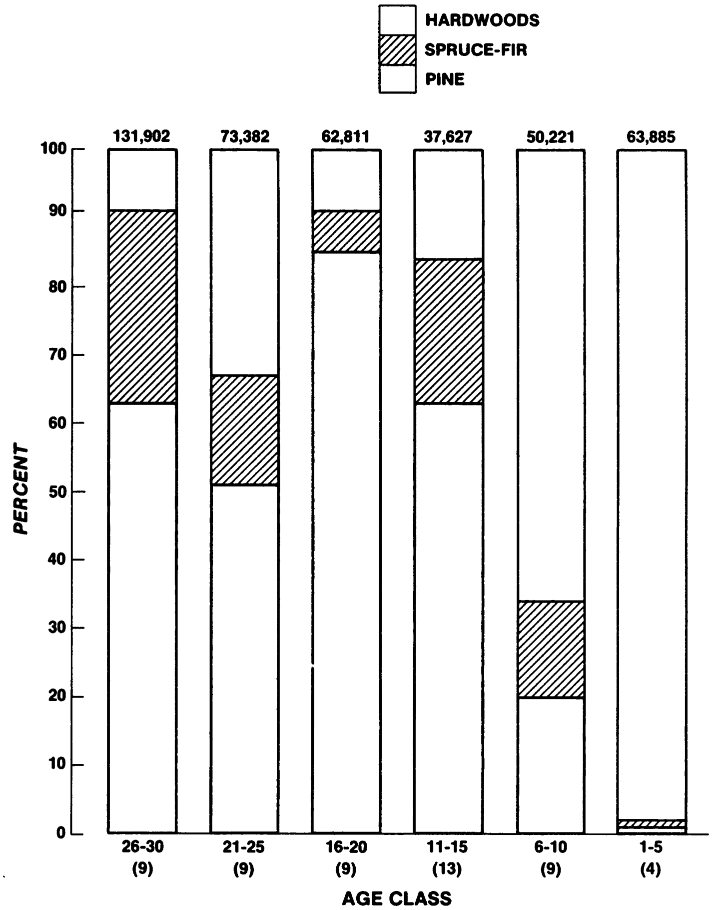

Figure 1.—*Percent pine, spruce-fir, and hardwood tree (>1 inch d.b.h.) above-ground ovendry biomass (pounds/acre) by age class (YEAR) of 53 conifer plantations near Isabella, Minnesota. Average total tree biomass at top of bar. Numbers in parentheses indicate number of plantations in each catagory.*

More studies are needed to determine if the biomass represented in vegetative strata of plantations is similar to other plant communities of the region. Based on the available evidence, at least the nontree component biomass of plantations seems to be near that found in nonplanted communities.

Tree Biomass

Red, white, and jack pine biomass comprised at least 50 percent of the tree stratum in plantations where the planted trees had time to grow large enough to be included under the sample scheme used (fig. 1). In the two younger plantation classes, pine comprised only 20 and 1 percent of the biomass. Spruce and fir species (white spruce, black spruce, balsam fir (*Abies balsamea* (L.) Mill.) and white-cedar (*Thuja occidentalis* L.) comprised from 5 to 28 percent of the tree biomass except in the youngest plantations (fig. 1). Some of the spruce-fir biomass represented planted white spruce; the remainder was due to natural regeneration of the other species and an occasional fir tree that remained from the earlier harvest. The nonplanted hardwood tree biomass (quaking aspen (*Populus tremuloides* Michx.), bigtooth aspen (*P. grandidentata* Michx.), birch (*Betula papyrifera* Marsh.), and red maple (*Acer rubrum* L.) ranged from 98 percent in the 1- to 5-year-old plantations (due in part to the sampling scheme) to 9 percent in the older plantations (fig. 1).

The sequence of declining mean tree biomass from no site preparation through disking, rock-raking, and chemical preparation (fig. 2) may reflect the partial age sequence also present in figure 1. As indicated earlier, independent variables YEAR and PREP were strongly related. However, all four 1- to 5-year-old plantations fell within the third ranked rock-rake category. Thus, in spite of the correlation between age and site preparation, more hardwood biomass seemed to be associated with the rock-rake treatment. Rock-raking can promote sprouting and suckering of hardwood species. Even when the 1- to 5-year-old plantation biomass was removed from the rock-rake rake category, the hardwood percentage was still 55 percent (fig. 2). More spruce-fir biomass was associated with the chemical site preparation treatment, probably because this treatment was used on sites planted to white spruce. The spruce-fir biomass associated with no site preparation was most likely due to natural regeneration of black spruce and some fir retained from earlier logging. The disked sites contained 30 percent more pine biomass than the nontreated sites.

The largest biomass by plantation release treatment was found in the 12 plantations with no record of release (fig. 3), which, along with the manually released plantations tended to be older (mean = 18+ years). The second highest biomass was in the 17

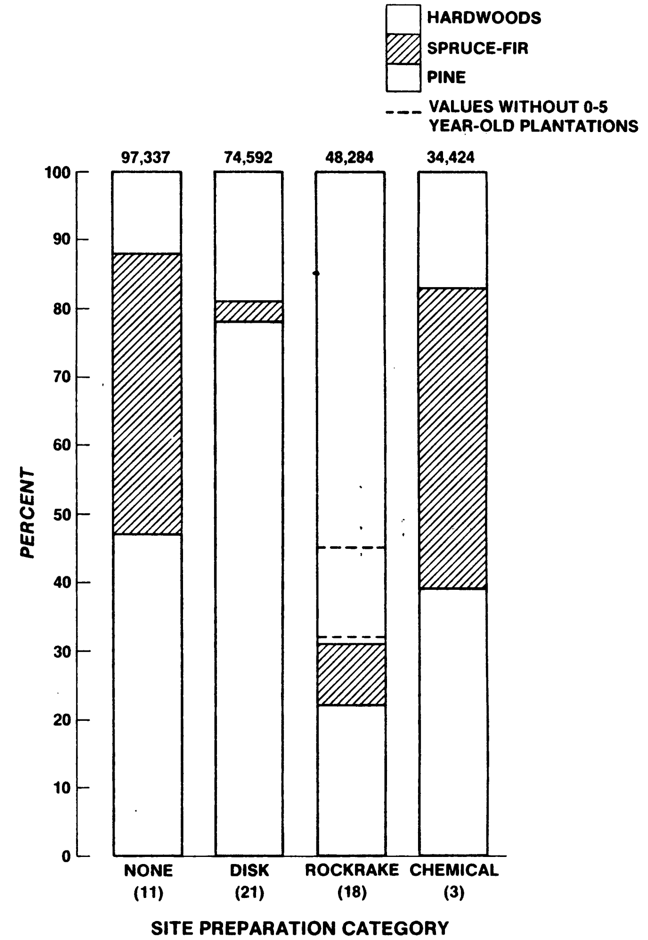

Figure 2.—*Percent pine, spruce-fir, and hardwood tree (>1 inch d.b.h.) above-ground ovendry biomass (pounds/acre) by site preparation treatment category (PREP) for 53 conifer plantations near Isabella, Minnesota. Dotted lines indicate percent values without 0-5-year old plantations. Average total tree biomass at top of bar. Numbers in parentheses indicate number of plantations in each category.*

chemically released plantations that included plantations of of all age classes but had more 11- 15-year-old members (mean = 14+ years). Hardwood tree biomass comprised from 23 to 41 percent of the treatment categories, with most hardwood biomass under conditions of no recorded release and least hardwood biomass under the chemical release treatment (fig. 3). Spruce-fir biomass was greatest in the chemical release category partly because the sites planted to spruce were within that treatment (fig. 3).

Most of the plantations (n=38) were planted to red and/or jack pine (fig. 4). This category included most of the older plantations, thus overall mean biomass (76,800 lbs/acre) was larger for sites planted to pine.

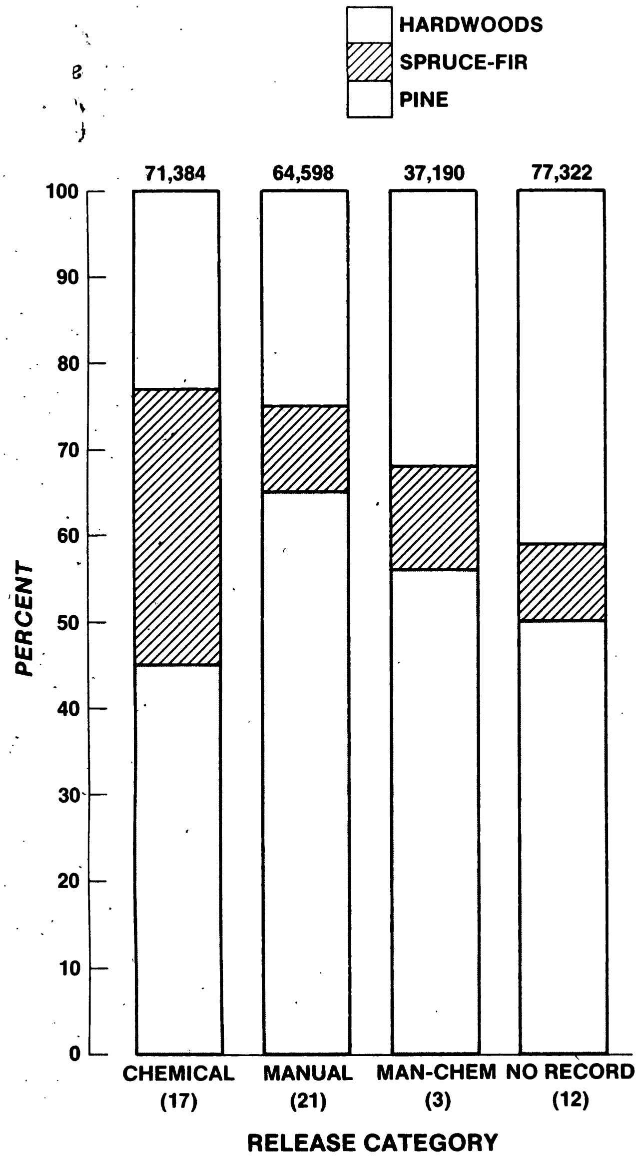

Figure 3.—*Percent pine, spruce-fir, and hardwood tree (>1 inch d.b.h.) above-ground ovendry biomass (pounds/acre) by release category (RELEASE) for 53 conifer plantations near Isabella, Minnesota. Average total tree biomass at top of bar. Numbers in parentheses indicate number of plantations in each category.*

The three 6- to 10-year-old sites planted to spruce had sufficient naturally regenerated jack pine and spruce that the percentage of biomass of the two species groups was about equal (fig. 4); but the mean total biomass was much lower. Hardwood tree biomass was about 20 to 30 percent, regardless of the conifer species planted (fig. 4).

Except for the youngest plantations, plantations were successfully established with about 80 percent pine and/or spruce and 20 percent hardwoods. The site

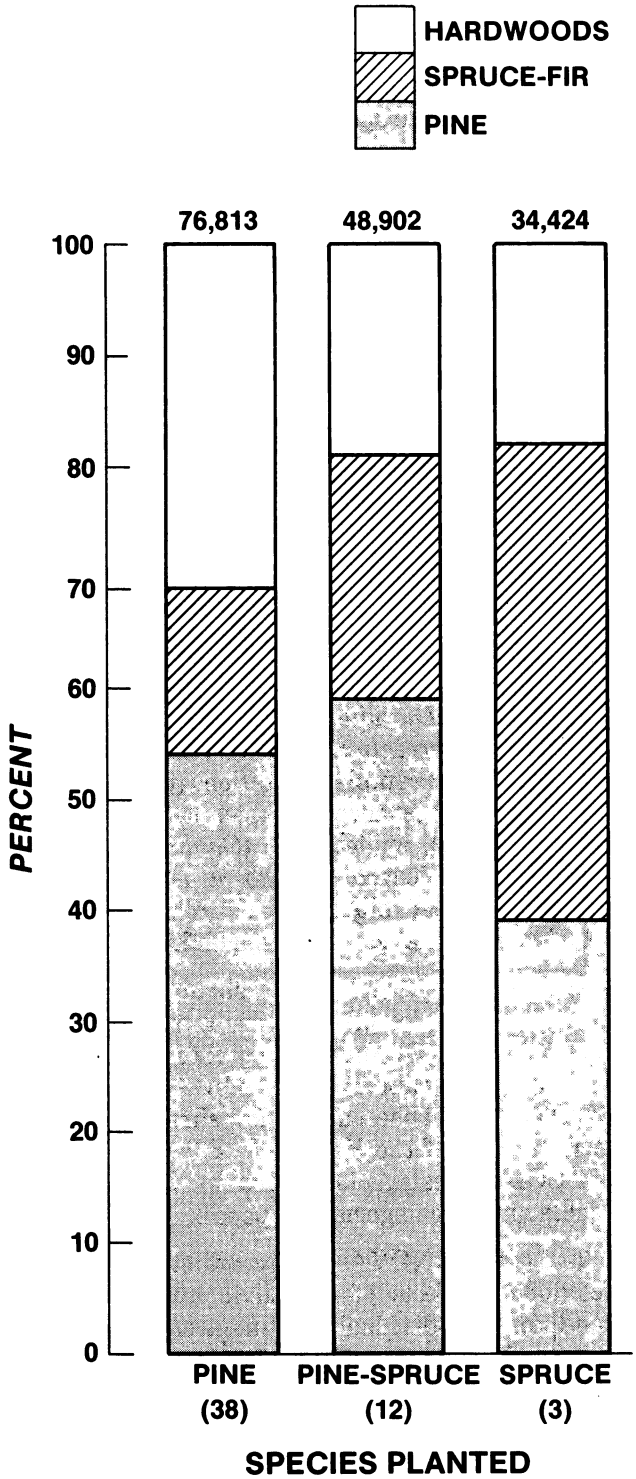

Figure 4.—*Percent pine, spruce-fir, and hardwood tree (>1 inch d.b.h.) above-ground ovendry biomass (pounds/acre) by species planted category (SPECIES) for 53 conifer plantations near Isabella, Minnesota. Average total tree biomass at top of bar. Numbers in parentheses indicate number of plantations in each category.*

preparations, planting, and release treatments were moderately successful, allowing a natural regeneration component of both conifers and hardwoods along with the planted species. Total tree component of the plantations is not only fairly diverse but also within the range of other conifer plantations and natural conifer and hardwood stands of similar age within this region.

Low Shrub and Herbaceous Stratum Biomass

The same herbaceous and low shrub species typical of natural plant communities of the area were also prominent in the plantations (Ahlgren 1960, Grigal and Arneman 1970, Ohmann and Ream 1971b, Ohmann *et al.* 1973). Of herbs, only large-leaf aster (*Aster macrophyllus* L.) and grass occurred in the sample plots of all plantations; and they, along with bracken fern (*Pteridium aquilinum* (L.) Sw.) also had the highest mean estimated biomass (table 3). Bush honeysuckle (*Diervilla Lonicera* Mill.) and late sweet blueberry (*Vaccinium angustifolium* Ait.) were found in 49 of the 53 sample plantations (table 3); and they, along with sweet fern (*Comptonia perigrina* B.& B., Small, Rydb.), wintergreen (*Gaultheria procumbens* L.), bearberry (*Arctostaphylos uva-ursi* (L.) Spreng.) and velvet-leaf blueberry (*Vaccinium mytilloides* Michx.), dominated the low shrub biomass (table 3).

In addition to total herb-low shrub layer biomass, 29 species or species groups were represented by sufficient biomass in the various categories to test for differences within treatments by ANOVA. One-way ANOVA of herbaceous and low shrub biomass values within each of the YEAR, PREP, RELEASE, and SPECIES treatments showed few significant differences among categories (Appendix tables 1-4).

Three-way ANOVAs were conducted to examine the combined effects of the silvicultural practices, in addition to individual treatment effects, on the estimated herbaceous and low shrub biomass. Some ANOVAs were not computed because of the close relationship between chemical site preparation and spruce species planted (PREP and SPECIES).

The relation of biomass to each treatment category is difficult to interpret because of the complex relation of treatments and categories and their influence on biomass. The ANOVA and MCA analyses help to clarify these relations by making it possible to examine the influence of a treatment and its categories after adjusting for the effect of the other treatments. Below, I present summary interpretations of these analyses. However, because the interpretations are based on adjusted values, the summary does not always conform to the levels depicted in figure 5.

Wood anemone

Anemone quinquefolia L., a small herb of mesic to moist woods, was sampled in 29 of the plantations and in all treatment categories; but its estimated mean biomass was low—less than 1 lb/acre (table 3). Greater amounts of biomass were associated with younger plantations (except those chemically prepared for planting to spruce); pine plantations; plantations without site preparation; and those prepared by rock-raking. Lesser amounts of biomass were associated with older plantations; sites prepared by disking or use of chemicals; plantations released by manual plus chemical or only chemical treatment; and plantations prepared chemically for planting to spruce. Individual treatment importance in explaining variation in wood anemone biomass ranked PREP (42 percent), YEAR (37 percent), RELEASE (30 percent), and SPECIES (28 percent). The treatment combination YEAR-PREP-RELEASE accounted for 41 percent of the variation in wood anemone biomass.

Spreading dogbane

Apocynum androsaemifolium L., a widespread species common throughout upland forests in northeastern Minnesota, occurred in only 15 of the plantations but was represented in all treatment categories. Its estimated biomass averaged about 4 lbs/acre (table 3). More biomass was associated with younger plantations; manual plus chemical release; and pine-spruce plantations. Less biomass was associated with older pine plantations with no record of release. The individual treatments ranked YEAR, (70 percent), RELEASE (32 percent), and SPECIES (24 percent) in importance; and combined they accounted for 71 percent of the variation in dogbane biomass.

Wild sarsaparilla

Aralia nudicaulis L. is a perennial herb common in moist to dry woods. It was sampled in 44 of the plantations and in all treatment categories with a mean biomass of 7 lbs/acre (table 3). More biomass was associated with older pine plantations that had no site preparation but were later given a manual plus chemical release. Lower biomass values were related to younger plantations; disk preparation sites or sites chemically prepared for planting to spruce; and those plantations receiving only manual release. Individual treatment importance rank was YEAR and PREP (27 percent), SPECIES (21 percent), and RELEASE (14 percent). All treatments combined accounted for 12 percent of the variation in wild sarsaparilla biomass.

Table 3.—*Mean and standard error estimates for herb, fern and fern ally, and low shrub species biomass (ovendry) in 53 conifer plantations near Isabella, Minnesota*

Species	Plantations	BIOMASS Mean	BIOMASS Standard error
	Number	*Pounds/acre*	
Herbs			
Achillea Millefolium L.	1	0.01[1]	—
Actea rubra (Ait) Willd.	2	.14	0.13
Anaphalis margaritacea (L.). Benth.& Hook	7	.01	0
Aneomone quinquefolia	29	.07	.04
Antennaria spp. Gaertn.	4	.01	0
Apocynum androsaemifolium	15	4.09	.90
Aquilegia canadensis L.	1	.01	—
Aralia nudicaulis	44	7.23	1.17
Aster ciliolatus Lindl.	5	11.00	4.14
Aster macrophyllus	53	60.81	6.39
Aster umbellatus Mill.	1	1.29	—
Circaea canadensis Hill.	1	.01	—
Clintonia borealis	39	9.63	1.35
Coptis groenlandica (Oeder) Fern.	10	.01	.01
Cornus canadensis	45	10.59	1.65
Cyperaceae	14	.30	.28
Epilobium angustifolium L.	9	.83	.25
Fragaria vesca	22	6.80	2.67
Fragaria virginiana	29	6.27	1.30
Galium triflorum Michx.	8	.09	.05
Goodyera repens (L.) R. Br.	1	.01	—
Gramineae	53	116.50	14.02
Hepatica americana (D.C.) Ker.	2	.01	0
Hieracium spp. L.	1	.01	—
Lactuca spp. L.	3	.01	0
Lathyrus ochroleucus	25	10.51	2.77
Lathyrus palustris	3	7.03	7.85
Lathyrus venosus	6	19.86	9.71
Lathyrus spp. L.	3	3.61	.42
Linnaea borealis	30	7.24	1.19
Maianthemum canadense	48	3.44	.42
Melampyrum lineare Desr.	7	.01	0
Mitella nuda L.	1	.01	—
Moneses uniflora (L.) Gray	1	.01	—
Petasites palmatus (Ait.) Gray	1	.01	—
Polygala paucifolia	25	.01	.01
Polygonum cilinode Michx.	4	.01	.01
Pyrola elliptica	1	2.56	—
Pyrola rotundifolia L.	5	2.36	.77
Pyrola secunda L.	17	2.57	.43
Pyrola virens	8	1.92	.32
Pyrola spp. L.	8	2.15	.37
Senecio spp. L.	1	.01	—
Solidago spp. L.	12	.02	.01
Streptopus roseus	17	1.02	.73
Taraxacum officinale Weber.	1	.01	—
Trientalis borealis	19	.02	.01
Unidentified herbs	11	.01	0
Vicia americana Muhl.	1	.01	—
Viola adunca	2	.62	.23
Viola spp. L.	22	.75	.13
Fernand fern allies			
Dryopteris spp. Adans.	3	.75	.45
Lycopodium annotinum L.	10	.01	0
Lycopodium clavatum L.	15	.18	.15
Lycopodium complanatum L.	8	.04	.03
Lycopodium lucidulum Michx.	2	.01	0
Lycopodium obscurum L.	14	.58	.57
Lycopodium spp. L.	1	.07	—
Pteridium aquilinum	37	106.88	15.98
Shrubs[2]			
Arctostaphylos uva-ursi	3	22.62	.75
Chimaphila umbellata	14	8.38	1.82
Comptonia peregrina	14	30.68	7.92
Diervilla Lonicera	49	38.89	5.44
Gaultheria hispidula	2	7.92	1.26
Gaultheria procumbens	17	25.66	6.27
Ledum groenlandicum Oeder.	4	8.05	7.76
Rubus pubescens	49	1.20	.33
Vaccinium angustifolium	49	15.29	3.42
Vaccinium myrtilloides	37	22.48	4.47
Total biomass[3]	53	389.39	32.03

[1]Mean for stands where species occurred in the sample.
[2]Does not include *Rosa acicularis* and *Rubus strigosus*, which were included within the tall shrub stratum.
[3]Mean of total biomass was calculated by summing raw biomass values for each species in each of the 53 plantations and dividing by 53. This value does not equal the sum of means from this table.

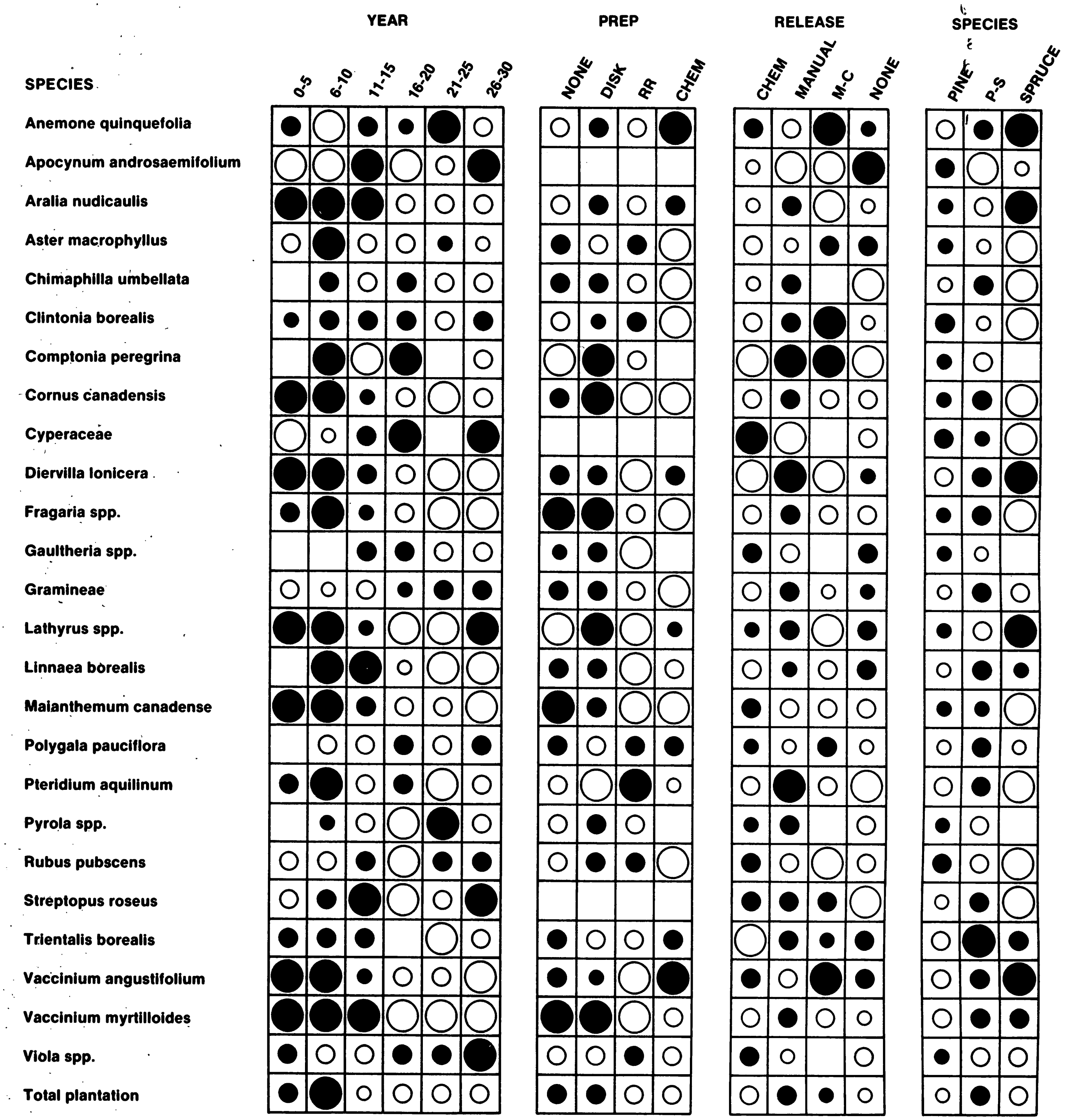

Figure 5.—*Diagrammatic representation of classification analysis results depicting the influence of silvicultural treatments on the major herb-low shrub layer species in conifer plantations near Isabella, Minnesota. Shaded circles represent a negative influence and open circles represent a positive influence. Degree of influence: small circle-slight; medium circle-average; large circle-strong. YEAR indicates the plantation age class; PREP-site preparation for planting (none, disking, rock-raking, or chemical); RELEASE-plantation release through manual, manual-plus chemical, chemical means, or no release; and species, plantation of red and/or jack pine, pine plus white spruce, or white spruce species only.*

Large-leaf aster

Aster is a rhizomatous herb that is found abundant in upland broadleaf and mixed conifer forests. It was included in samples from all plantations and in all treatment categories at a mean estimated biomass of 60 lbs/acre (table 3). Above-average biomass was associated with younger plantations (except those prepared by rock-raking); disked or chemically prepared plantations; those chemically or manually released; and plantations planted to spruce. Below-average biomass was associated with older pine plantations, especially those receiving no site preparation or release; sites prepared by rock-raking; and plantations receiving manual plus chemical release. Individual treatment importance ranked YEAR (30 percent), PREP (20 percent) RELEASE (18 percent), and SPECIES (18 percent); and the combination YEAR-PREP-RELEASE accounted for 20 percent of the variation in aster biomass.

Pipsissewa

Pipsissewa (prince's pine) is a somewhat ligneous plant with spreading stems commonly found in dry coniferous forests. It occurred in 14 of the plantations at a mean estimated biomass of 8 lbs/acre (table 3). It was not sampled in the 1- to 5-year-old plantations or within the manual plus chemical release category. More biomass was associated with older plantations with no record of release and younger plantations chemically prepared for planting to spruce. Treatments associated with reduced pipsissewa biomass were manual plantation release; disk or no site preparation; and younger plantations (except those planted to spruce). Individual treatment importance ranked RELEASE (61 percent), PREP (39 percent), SPECIES (38 percent), and YEAR (23 percent). The treatments YEAR-RELEASE-SPECIES combined accounted for 65 percent of the variation in this species' biomass.

Clinton's lily

Clintonia borealis (Ait.) Raf. is a common perennial herb primarily found in rich moist woods and wooded bogs. It was found in 39 of the sample plantations at a mean estimated biomass of 10 lbs/acre (table 3). Its biomass was positively associated with sites chemically prepared for planting to spruce and to a lesser extent older plantations with no recorded site preparation that were later chemically released. Negative treatment influences on biomass were older plantations prepared by disking; younger plantations prepared by rock-raking and planted to pine; and plantations released by either manual or manual plus chemical means. Individual treatment importance ranked PREP (39 percent), YEAR (34 percent), SPECIES (31 percent), and RELEASE (23 percent). All treatments combined accounted for 27 percent of the variability in biomass. ANOVA indicated significant interactions among both YEAR-PREP-RELEASE and YEAR-RELEASE-SPECIES treatment combinations.

Sweet fern

Sweet fern is a medium-sized shrub commonly found in dry sandy or rocky pine forests. It occurred in 14 of the plantations with a mean estimated biomass of 31 lbs/acre (table 3). It did not occur in samples from the 1- to 5- and 21- to 25-year-old plantations nor in plantations chemically prepared for planting to spruce. Above-average biomass was related to plantations that had received no site preparation and no release and sites prepared by rock-raking and planted to pine-spruce species. In addition to not occurring in the two age-class and spruce plantations mentioned above, below-average biomass was associated with disk site preparation and chemical plantation release. Sweet fern is intermediate in susceptibility to 2,4-D and highly susceptible to 2,4,5-T (Bovey 1977). Individual treatment importance ranked PREP (54 percent), YEAR (26 percent), RELEASE (24 percent), and SPECIES (17 percent); the combination of PREP, RELEASE, SPECIES accounted for 49 percent of the variation in biomass.

Bunchberry

Cornus canadensis L. is a herbaceous colonial plant that spreads from rhizomes and is abundant in moist, acid, forests and bogs. It occurred in the samples from 45 plantations at a mean estimated biomass of 11 lbs/acre (table 3). Its biomass values were positively associated with older plantations; plantations that received rock-raking as a site preparation treatment; and plantations with no record of release. More biomass was also associated with plantations chemically prepared for planting to spruce. Bunchberry biomass was reduced in younger plantations; older pine plantations established without site preparation or by disking; and plantations that received manual or manual plus chemical release. Bunchberry is resistant to 2,4-D and intermediatly resistant to 2,4,5-T (Bovey 1977). Individual treatments ranked YEAR (21 percent), PREP (10 percent), SPECIES (8 percent), and RELEASE (3 percent) in importance. Together, YEAR-PREP-RELEASE accounted for 15 percent of the variation in biomass. In a 3-way ANOVA, RELEASE and SPECIES showed a statistically significant level of interaction.

Sedges

The combination YEAR (62 percent), SPECIES (40 percent), and RELEASE (34 percent) accounted for

71 percent of the variation in sedge biomass. Sedges were found in 14 plantations and were estimated to have a mean biomass of less than 1 lb/acre (table 3). More biomass was associated with the youngest plantations (1 to 10 years old); plantations chemically prepared for planting to spruce; and plantations that received manual release or where no release was recorded. Less biomass was associated with older pine plantations that received chemical release. A 3-way ANOVA indicated YEAR, RELEASE, and SPECIES to all be significant, with a significant interaction between YEAR and RELEASE.

Bush honeysuckle

Bush honeysuckle is an erect low shrub common in mesic to dry open woods, clearings, and rocky places. It was found in 49 of the plantations at a mean estimated biomass of 39 lbs/acre (table 3). Above-average biomass was associated with older pine plantations; chemical or manual plus chemical release; and rock-rake site preparation treatment. Below-average biomass was associated with younger plantations; plantations given a manual release or where no release was recorded; and those sites chemically prepared for planting to spruce. Bush honeysuckle is susceptible to foliar applied 2,4-D (Bovey 1977). Treatment influence ranked YEAR (28 percent), RELEASE (22 percent), PREP (21 percent), and SPECIES (18 percent), with 24 percent of the biomass variation accounted for by the combination of YEAR-PREP-RELEASE treatments. A 3-way ANOVA indicated a significant interaction between RELEASE and SPECIES.

Strawberry

Strawberries (*Fragaria vesca* L. and *F. virginiana* Duchesne.) are perennial herbs that spread by stolons. Biomass values for both species were combined for this ANOVA and MCA analysis. They were found in 22 and 29 of the plantations, respectively, with mean estimated biomass values of 7 and 6 lbs/acre (table 3). More biomass was associated with older plantations that had no record of release or that had been chemically released; plantations with rock-rake site preparation; and sites chemically prepared for planting to spruce. Less biomass was associated with plantations that had been given manual or manual plus chemical release; plantations with no site preparation or disk site preparation; and sites planted to pine-spruce combinations. Treatment ranked RELEASE (32 percent), PREP (28 percent), SPECIES (24 percent), and YEAR (15 percent) in importance individually, and YEAR-PREP-RELEASE combined accounted for 28 percent of the variation in strawberry biomass. PREP and RELEASE were statistically significant in 3-way ANOVAs, and significant interaction was present between YEAR and RELEASE, YEAR and SPECIES, and RELEASE and SPECIES.

Snowberry and Wintergreen

Snowberry *Gaultheria hispidula* (L.) Muhl. is a creeping shrub of bogs and moist coniferous forests; and wintergreen is a woody low shrub common in rocky or sandy coniferous forests with leafy erect stems from horizontal rhizomes. The two species were combined for ANOVA and MCA analysis. Snowberry was sampled in only 2 plantations, while wintergreen occurred in 17 plantation samples. Mean estimated biomass was 8 lbs/acre for snowberry and 26 lbs/acre for wintergreen (table 3). Rock-rake site preparation, manual plantation release, and older plantations were related to increased biomass; disk site preparation, no record of release, and younger plantations were related to decreased biomass. Treatment importance rank was PREP (50 percent), RELEASE (48 percent), YEAR (45 percent), and SPECIES (2 percent); and together they accounted for 41 percent of the variation in estimated biomass.

Grasses

All grass species were combined for sampling and analysis. Grasses occurred in the samples from all plantations and treatment categories and were the leading contributor to the biomass of the herb-low shrub stratum with a mean value of 116 lbs/acre (table 3). Above average biomass was associated with plantations on rock-raked sites; sites chemically prepared for planting to spruce, young plantations, and chemically released plantations. Below-average biomass was associated with older plantations that had no site preparation or had been prepared by disking, plantations with only manual release, and sites planted to a pine-spruce combination. Individual treatments ranked PREP (41 percent), YEAR (35 percent), RELEASE (29 percent), and SPECIES (27 percent) in importance; while YEAR-PREP-RELEASE combined accounted for 23 percent of the variation in estimated grass biomass. A 3-way ANOVA indicated significant interaction effects between YEAR and SPECIES, and RELEASE and SPECIES.

Wild pea

The *Lathyrus* species, *Lathyrus ochroleucus* Hook., *L. palustris* L., and *L. venosus* Muhl., were combined for ANOVA and MCA analysis. These herbaceous rhizomatous perennials are common to abundant in dry upland forests, moist woods and thickets, and wet meadows and swamps. They occurred in 23, 3, and 6 plantations, respectively, at mean estimated biomass values of 11, 7, and 20 lbs/acre (table 3). More biomass was found in 15- to 20-year-old pine-spruce plantations; plantations with no site preparation; those prepared by rock-raking, and plantations that received manual plus chemical release. Less biomass was found in younger plantations prepared by disking; older plantations prepared by disking; sites chemically prepared for planting to spruce; and plantations manually released or with no record of release. Individual treatment importance ranked YEAR (52 percent), SPECIES (49 percent), PREP (36 percent), and RELEASE (24 percent); and YEAR-PREP-RELEASE combined accounted for 47 percent of the variation in biomass. The independent variables YEAR, PREP, and SPECIES were significant as determined by 3-way ANOVA, and a significant interaction effect was also present.

Twin flower

Twin flower is a trailing, creeping, slightly woody evergreen plant frequently found in moist to dry forests. It was present in 30 of the plantation samples with a mean estimated biomass of 7 lbs/acre (table 3). Above-average biomass values were associated with older plantations; plantations with manual and manual plus chemical release; plantations with rock-rake site preparation; and pine plantations. Below-average biomass values were associated with younger plantations (it was not included in the samples from the most recent sites); plantations with no record of release; plantations with disk or no site preparation; and areas planted to spruce. Importance of treatments ranked YEAR (53 percent), RELEASE (50 percent), SPECIES (17 percent), and PREP (16 percent); YEAR-PREP-RELEASE combined accounted for 56 percent of the biomass variation. This combination in a 3-way ANOVA was also statistically significant for main effect and YEAR as an independent variable.

False lily-of-the-valley

Maianthemum canadense Desf. is a small, common perennial herb that forms mats from creeping rhizomes. It was recorded in the samples from 48 of the plantations with a mean estimated biomass of 3 lbs/acre (table 3). Above-average biomass was related to plantations with no record of release or only manual release; rock-rake prepared sites; and sites chemically prepared for planting to spruce. Below-average biomass was related to younger plantations; plantations that were chemically released, disked, or received no site preparation; and spruce-pine plantations. Individual treatments ranked RELEASE (41 percent), PREP (34 percent), YEAR (26 percent), and SPECIES (7 percent) in importance, with 36 percent of the variation accounted for by YEAR-PREP-RELEASE. A 3-way ANOVA indicated the combination YEAR-PREP-RELEASE was significant, as were variables PREP and RELEASE.

Fringed milkwort

Polygala pauciflora Willd. is a widespread but uncommon prerennial plant from slender underground rhizomes found on light sandy soils in mesic to moist woods. It was included within the sample of 25 plantations with a mean biomass of less than 1 lb/acre (table 3). Above-average biomass values were associated with 21- to 25-year-old plantations prepared for planting by disking and with no record of release. Below-average biomass values were associated with pine-spruce plantations prepared by rock-raking and plantations that received manual plus chemical release. Individual treatments ranked YEAR (61 percent), PREP (33 percent), RELEASE (17 percent), and SPECIES (17 percent); YEAR-PREP-RELEASE combined accounted for 57 percent of the variation in estimated biomass.

Bracken fern

Bracken is a common fern with large deciduous fronds from stout, spreading rhizomes. It occurred in 37 of the plantations and in all treatment categories. Its mean estimated biomass was 107 lbs/acre (table 3). Above average biomass was associated with older plantations prepared by disking that received no release. Below-average biomass was associated with younger plantations; rock-rake site preparation; manual release; and pine-spruce plantings. Individual treatment ranked PREP (40 percent), RELEASE (38 percent), YEAR (24 percent), and SPECIES (6 percent), with YEAR-PREP-RELEASE combined accounting for 45 percent of the variation in estimated biomass. A 3-way ANOVA indicated that YEAR, PREP, and RELEASE were all significant independent variables.

Shinleaf

The various shinleafs are small perennial evergreen plants from spreading rhizomes commonly found in dry to moist upland forests. They were included within samples in from 1 (*Pyrola elliptica* Nutt.) to 8 (*P. virens* Schweigg.) plantations with a mean estimated biomass of about 2-3 lbs/acre (table 3). All shinleaf species were combined for ANOVA and MCA. All combinations of YEAR-PREP-RELEASE-SPECIES were significant in 3-way ANOVAS, with YEAR a significant independent variable. Individually, YEAR was the most important treatment (61 percent), followed by RELEASE (31 percent), PREP (29 percent), and SPECIES (2 percent). All treatments combined accounted for 46 percent of the variation in estimated shinleaf biomass. Above average biomass was associated with 15- to 20-year-old plantations; plantations with no record of release; plantations with no site preparation or rock-rake preparation; and sites planted to pine. Below-average biomass was associated with 20- to 25-year-old plantations; plantations manually released; and sites prepared by disking.

Dewberry

Dewberry, a perennial low shrub from profusely creeping stolons, is commonly found in bogs, moist woods, and damp slopes. It was included within the sample of 49 of the plantations and in all treatment categories. Its mean estimated biomass was about 1 lb/acre (table 3). Above-average biomass was associated with sites prepared with chemicals for planting to spruce and plantations released by manual plus chemical treatments. Below-average biomass was found in older pine plantations prepared for planting by disking and later chemically released. Dewberry is intermediate to resistant to foliar applied 2,4-D and intermediate in susceptibility to 2,4,5-T (Bovey 1977). Individual treatments ranked SPECIES (30 percent), both YEAR and PREP (29 percent), and RELEASE (26 percent) in importance; the combination SPECIES-YEAR-RELEASE accounted for 24 percent of the variation in dewberry biomass.

Twisted stalk

Streptopus roseus Michx. is a perennial herb from slender elongated rhizomes commonly found in coniferous and broadleaf mesic to moist forests. It occurred in the samples of 17 plantations with an estimated 1 lb/acre biomass (table 3). More biomass was associated with 5- to 25-year-old plantations that had no record of release. Less biomass was associated with all types of release; pine-spruce planting combinations; and 5- to 15-year-old plantations. Individual treatments ranked YEAR (60 percent), RELEASE (27 percent), and SPECIES (25 percent) in importance. PREP could not be tested in this case. The combination of treatments accounted for 50 percent of the variation in twisted stalk biomass. YEAR and RELEASE were statistically significant as independent variables in a 3-way ANOVA, and there was also significant interaction between them.

Star flower

Star flower is a low perennial herb from slender rhizomes that is widespread and common in mesic and moist woods. It was included in the sample from 19 plantations at a mean estimated biomass of less than 1 lb/acre (table 3). Above-average biomass was associated with older pine plantations; disked or rock-raked prepared sites; and chemical release. Below-average biomass was associated with younger plantations; no site preparation for planting; manual or manual plus chemical release; and planting to pine-spruce combinations. Importance of treatments ranked YEAR (67 percent), PREP (34 percent), SPECIES (21 percent), and RELEASE (20 percent). The combination of YEAR-SPECIES-RELEASE accounted for 72 percent of the variation in star flower biomass.

Late sweet blueberry

Blueberry is a colonial low shrub spreading from a stoloniferous base commonly found in dry rocky or sandy woods. It was included in samples from 49 of the plantations with a mean estimated biomass of 15 lbs/acre (table 3). Higher biomass values were found in older pine plantations; those prepared by rock-raking; and those manually released. Lower biomass values were found in younger plantations, especially those prepared chemically for planting to spruce, and plantations that received manual plus chemical or only chemical release. Blueberries are intermediate to resistant to foliar-applied 2,4-D and intermediate in resistance to foliar-applied 2,4,5-T (Bovey 1977). Individual treatment importance ranked YEAR (51 percent), PREP (39 percent), SPECIES (35 percent), and RELEASE (31 percent). The combinations YEAR-PREP-RELEASE and YEAR-RELEASE-SPECIES were statistically significant in a 3-way ANOVA and accounted for 39 and 37 percent of the variation in blueberry biomass, respectively.

Velvet-leaf blueberry

Velvet-leaf blueberry is a perennial colonial low shrub common from lowland to granite outcrops. It occurred in 37 plantations at a mean estimated biomass of 23 lbs/acre (table 3). More biomass was found in older pine plantations; rock-raked sites; plantations that received manual plus chemical release; or those that had no record of release. Less biomass was found in young plantations; spruce or pine-spruce plantings; disked sites; sites that received no preparation; and sites with manual release. Individual treatments ranked YEAR (46 percent), both PREP and SPECIES (31 percent), and RELEASE (26 percent); the combination YEAR-PREP-RELEASE accounted for 42 percent of the biomass variation. A 3-way ANOVA showed both YEAR and PREP to be statistically significant independent variables.

Violets

The *Viola* species (mostly *V. adunca* Sm.) are small rhizomatous and stoloniferous herbs common in open rocky to sandy forests. Violets were recorded in the samples from 22 plantations with a mean estimated biomass of almost 1 lb/acre (table 3). More biomass was associated with 6- to 15-year-old pine-spruce plantations; spruce plantations prepared by chemical site preparation; and plantations with no release. Less biomass was found in very young plantations; older pine plantations that received chemical release; and rock-raked sites. Individual treatments ranked YEAR (42 percent), RELEASE (36 percent), PREP (39 percent), and SPECIES (26 percent) in importance; the YEAR-PREP-RELEASE combination accounted for 31 percent of the variation in violet biomass.

Plantation total herb and low shrub biomass

Mean total herb, fern and fern ally, and low shrub biomass was estimated at 389 lbs/acre. Above-average biomass was associated with older pine plantations receiving chemical release; plantations given rock-raked site preparation; and sites chemically prepared for planting to spruce. Below-average biomass was associated with more recent plantations; plantations receiving no site preparation or disk site preparation; and plantations with manual release. No treatment explained a statistically significant amount of the variation in total plantation biomass, although a statistically significant interaction was found between YEAR and RELEASE and between RELEASE and SPECIES. YEAR was the most important individual treatment (30 percent), followed by RELEASE (20 percent), PREP (9 percent), and SPECIES (8 percent); YEAR-PREP-RELEASE combined accounted for 22 percent of the variation in total biomass.

CONCLUSIONS

Most of the undergrowth species responses to silvicultural practices found in this study are consistent with the little we know about their ecological requirements. Biologists and others have expressed concern that successful establishment of conifer plantations has a detrimental effect on the other forest flora (Swindel *et al.* 1983). This was not the case in this study, although there undoubtedly was a good deal of initial disturbance and disruption of the understory flora by the silvicultural practices. But it made a rapid recovery, which is enhanced by the clonal nature and presence of underground structures that permit vegetative reproduction of many of the major species in these plantations. The silvicultural goal of successful establishment and regeneration of conifer stands was met for these plantations, yet the stands contained undergrowth layers similar in species composition and standing crop (biomass) to those naturally regenerated after disturbance. The undergrowth layers were also similar to those found in mature conifer forest communities of the area.

Competing forest flora in conifer plantations is considered to have a negative effect on conifer growth, especially for the first few years (Newton 1981). The older Isabella plantations seem to be producing as much tree biomass as other similar natural and planted stands of the region. However, most studies of plantations do not report the tree biomass of species other than those planted. Restricting evaluation of the Isabella plantations tree biomass to only the species planted would show them to be producing less than other pine plantations cited—pine contributed only 50 to 85 percent of the tree biomass in the older plantations. On the other hand, the plantations for which only pine biomass is reported are probably not pure pine stands unless they were intensively managed. If not, the reported biomass of those plantations, at least for the tree stratum, is conservative. The presence of considerable nonpine tree biomass, while perhaps economically undesirable, is a positive ecological factor because it fulfills the requirement of maintaining species diversity within these plantations.

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APPENDIX

The Appendix contains detailed tabular information on species biomass estimates by treatment categories and the analysis of variance results for within treatment categories.

Appendix table 1.--Herb-low shrub layer biomass (ovendry), standard error of the mean, and number of plantations for each establishment-period (YEAR) category for conifer plantations near Isabella, Minnesota. Means in a row followed by the same letter do not differ at the P = 0.05 probability level1/

Species	0-5 Years			6-10 Years			11-15 Years			16-20 Years			21-25 Years			26-30 Years			ANOVA	
	Mean	SE	N	Mean	SE	N	Mean	SE	N	Mean	SE	N	Mean	SE	N	Mean	SE	N	F Ratio	Probability
	Pounds/acre																			
Herbs																				
Achillea Millefolium																0.01	-	1		
Actea rubra				0.01	-	1							0.26	-	1					
Anaphalis margaritacea				.01	0	2	0.01	0	4	0.01	-	1								
Anemone quinquefolia	0.01	-	1	.10	.09	5	.04	.02	6	.01	0	5	.01	0	5	.17	0.14	7	0.510	0.766
Antennaria spp.	.01	-	1	.01	0	2				.01	-	1								
Apocynum androsaemifolium	8.99	-	1	3.43	1.22	4	.93	.26	4	6.01	2.17	3	8.18	-	1	4.38	3.81	2	2.226	.140
Aquilegia canadensis										.01	-	1								
Aralia nudicaulis	2.27	1.70	2	2.27	0.96	6	5.13	2.10	10	7.51	1.84	9	9.32	3.75	8	8.12	2.79	9	7.620	.583
Aster ciliolatus	19.40	-	1	6.21	2.58	2				1.29	-	1	21.91	-	1					
Aster macrophyllus	56.40	10.71	4	47.85	19.09	9	71.58	15.72	13	62.95	10.37	9	70.78	19.02	9	48.46	10.11	9	.466	.799
Aster umbellatus	1.29	-	1																	
Circaea canadensis	.01	-	1																	
Clintonia borealis	7.33	2.93	6	11.27	5.25	5	9.44	3.13	4	7.20	1.48	7	14.25	3.64	9	6.18	1.82	7	.977	.446
Coptis groenlandica							.01	0	4	.01	-	1	.01	0	2	.01	0	5		
Cornus canadensis	4.08	.76	3	7.72	3.96	7	14.69	4.64	11	8.90	2.93	6	12.18	3.37	9	9.54	3.40	9	.662	.654
Cyperaceae	1.94	1.94	2	.06	.05	4	.01	0	2	.01	0	4				.01	0	2	1.891	.196
Epilobium angustifolium							.94	.77	3	.86	-	1				.80	.35	3		
Fragaria vesca	18.40	14.39	4	3.76	.98	6	1.90	.43	3	4.99	1.89	3	4.88	2.56	2	5.73	2.40	4		
Fragaria virginiana	2.54	.80	2	8.45	2.24	6	7.81	3.05	11	3.74	.17	2	4.67	2.06	3	3.72	1.37	5	.686	.636 2/
Galium triflorum	.01	0	2	.14	.12	3	.09	.08	3											
Goodyera repens																.01	-	1		
Gramineae	142.66	50.21	4	146.51	36.77	9	129.97	30.34	13	123.47	37.69	9	108.80	40.48	9	56.16	6.83	9	.892	.494
Hepatica americana				.01	-	1	.01	-	1											
Hieracium spp.																.01	-	1		
Lactuca spp.	.01	0	2																	
Lathyrus ochroleucus	7.86	3.51	4	6.41	1.44	7	23.61	9.44	6	5.09	1.19	2	7.06	5.03	4	3.16	.74	2		
Lathyrus palustris				.80	-	1													1.757	.151 2/
Lathyrus venosus				1.29	-	1	17.69	6.00	3	63.54	-	1	1.29	-	1					
Lathyrus spp.				3.74	.68	2	3.35	-	1											
Linnaea borealis				3.32	.71	4	5.56	1.25	11	4.80	2.69	4	7.00	2.48	4	13.64	3.42	7	3.037	.036
Maianthemum canadense	1.91	.89	2	2.28	.59	9	3.58	1.06	11	3.80	1.29	9	3.53	.90	8	4.35	.82	9	.596	.703
Melampyrum lineare				.01	0	2	.01	0	2	.01	0	2	.01	-	1					
Mitella nuda				.01	-	1														
Moneses uniflora										.01	-	1								
Petasites palmatus				.01	-	1														
Polygala paucifolia				.01	0	4	.01	0	8	.01	0	3	.02	.01	4	.01	0	6	2.224	.103
Polygonum cilinode	.01	0	2	.01	-	1	.01	-	1											
Pyrola elliptica							2.56	-	1											
Pyrola rotundifolia							4.82	-	1				1.02	.92	2	2.48	.55	2		
Pyrola secunda				2.61	.30	2	3.45	.73	3	3.13	.74	4	1.41	.92	5	2.86	1.46	3		
Pyrola virens				1.93	-	1	1.93	0	2				2.03	.10	2	2.71	.78	2	2.907	.036 2/
Pyrola spp.				2.91	-	1				2.14	.21	3	.01	-	1	2.60	.57	3		
Senecio spp.				.10	-	1							.10	-	1					
Solidago spp.				.03	.02	5	.01	0	3				.01	-	1	.01	0	3		
Streptopus roseus	.37	-	1	.14	.06	2	.08	0	2	6.39	6.20	2	.53	.37	5	.23	.11	5	1.812	.191
Taraxacum officinale													.01	-	1					
Trientalis borealis	.02a	.01	1	.01a	0	4	.01a	0	6				.10b	.08	2	.01b	-	5	3.046	.053

(Appendix table 1 continued on next page)

(Appendix table 1 continued)

Species	0-5 Years Mean	SE	N	6-10 Years Mean	SE	N	11-15 Years Mean	SE	N	16-20 Years Mean	SE	N	21-25 Years Mean	SE	N	26-30 Years Mean	SE	N	ANOVA F Ratio	Proba-bility
	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	Pounds/acre	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
Unidentified spp.				0.01	0	3	0.01	0	4				.01	0	2	.01	0	2		
Vicia americana	.01	-	1																	
Viola adunca							.62	.23	2											
Viola spp.	.27	-	1	1.14	.34	6	.63	.16	5	.66	.13	2	.62	.25	3	.59	.32	5	.788	.572 2/
Fern and fern allies																				
Dryopteris spp.				1.68	-	1	0.28	-	1							.28	0	1		
Lycopodium annotinum										.01	-	1	.01	-	1	.01	0	2		
Lycopodium clavatum				.01	-	1	.06	.04	6	.01	0	2	.01	0	3	.62	.60	4	.638	.646
Lycopodium complanatum							.01	0	2	.01	-	1	.01	-	1	.07	.06	4		
Lycopodium lucidulum				.01	-	1										.01	-	1	.166	.951 2/
Lycopodium obscurum	.01	0	2	.01	0	3	.01	0	2	.01	0	2	.02	.01	3	3.98	3.97	2	1.369	.329
Lycopodium spp.							.01	-	1											
Pteridium aquilinum	73.61	34.63	3	58.09	25.22	5	131.74	40.14	11	96.43	10.00	7	155.95	55.28	6	76.65	16.27	5	.869	.513
Shrubs																				
Arctostaphylos uva-ursi				23.37	-	1							22.25	1.12	2					
Chimaphila umbellata				9.18	3.50	4	5.15	0	2	7.17	2.02	2	6.13	2.01	3	12.54	7.41	3	.413	.795
Comptonia peregrina				31.00	11.67	4	36.36	15.65	6	7.66	-	1				26.58	16.61	3	.243	.865
Diervilla Lonicera	23.31	14.69	4	25.54	9.37	8	49.82	14.07	12	49.60	14.26	9	40.22	13.71	7	32.35	8.78	9	.676	.644
Gaultheria hispidula													6.65	-	1	9.18	-	1		
Gaultheria procumbens							37.98	18.66	4	9.15	2.73	4	26.07	12.88	6	21.42	3.75	5	.904	.462 2/
Ledum groenlandicum				.01	-	1							16.08	15.22	2	.01	-	1		
Rubus pubescens	.39	.06	3	2.42	1.70	7	1.46	.81	12	1.41	.45	9	.72	.49	9	.42	.16	9	.751	.590
Vaccinium angustifolium	.05	-	1	3.24	2.15	8	26.53	11.36	13	13.95	4.88	9	14.42	4.01	9	13.67	3.87	9	1.089	.380
Vaccinium myrtilloides	1.66	-	1	5.91	2.16	7	28.77	9.34	11	20.13	5.82	7	33.46	13.66	8	21.15	13.64	3	1.034	.415
Plantation total biomass 3/	388.55	123.61	4	323.24	66.03	9	496.47	80.46	13	407.04	52.92	9	449.43	92.26	9	285.16	51.40	9	1.181	.333

1/ Based on Student-Newman-Keuls test of those means indicated as significantly different by ANOVA.
2/ For some ANOVA's species were combined: _Fragaria vesca_ and _F. virginiana_; all _Lathyrus_ species; _Lycopodium annotinum_, _complanatum_, _L. lucidulum_, and _L._ spp.; all _Pyrola_ species, _Viola_ species, and _Gaultheria_ species.
3/ Total biomass in the herbaceous and low shrub layer except for _Rosa acicularis_ and _Rubus strigosus_, which were sampled and included in the tall shrub layer.

Appendix table 2.--Herb-low shrub layer biomass (ovendry), standard error of the mean, and number of plantations for each site-preparation (PREP) category for conifer plantations near Isabella, Minnesota. Means in a row followed by the same letter do not differ at the P = 0.05 probability level[1]/

Species	None			Disk			Rockrake			Chemical			ANOVA	
	Mean	SE	N	Mean	SE	N	Mean	SE	N	Mean	SE	N	F Ratio	Probability
	Pounds/acre													
Herbs														
Achillea Millefolium	0.01	-	1											
Actea rubra	.26	-	7				0.01	-	1					
Anaphalis margaritacea	.01	-	1	0.01	-	5	.01	0	5					
Anemone quinquefolia	.19	0.16	6	.01	0.01	13	.10	.06	7	0.01	0	3	1.210	0.327
Antennaria spp.				.01	-	1	.01	0	3					
Apocynum androsaemifolium	2.75	1.83	4	5.42	1.69	5	3.38	1.55	3	6.38	-	1	.600	.628
Aquilegia canadensis				.01	-	1								
Aralia nudicaulis	9.09	2.64	10	8.11	1.82	20	4.87	1.99	12	3.18	3.08	2	.823	.489
Aster ciliolatus	21.91	-	1	1.29	-	1	14.09	5.31	2	3.63	-	1		
Aster macrophyllus	49.50	10.10	11	67.47	9.58	21	54.51	11.86	18	93.38	47.58	3	.958	.420
Aster umbellatus							1.29	-	1					
Circaea canadensis							.01	-	1					
Clintonia borealis	10.39	1.45	7	9.33	2.28	17	7.78	2.19	13	21.60	8.69	2	1.672	.191
Coptis groenlandica	.01	0	3	.01	0	5	.01	0	2					
Cornus canadensis	9.35	3.23	10	9.67	1.94	18	12.22	3.85	14	12.71	9.05	3	.210	.889
Cyperaceae	.01	-	1	.01	0	5	.56	.55	7	.20	-	1	.261	.852
Epilobium angustifolium	1.01	.43	5	.51	.20	3	.86	-	1					
Fragaria vesca	3.99	1.00	5	6.92	2.35	4	8.18	5.35	11	5.94	1.50	2		
Fragaria virginiana	3.15	.91	7	3.77	.91	8	9.29	3.02	11	9.11	2.74	3	.924	.437[2]/
Galium triflorum	.01	-	1				.12	.06	6	.01	-	1		
Goodyera repens				.01	-	1								
Gramineae	64.38a	9.73	11	108.49ab	23.42	21	137.86ab	23.80	18	235.52b	87.19	3	2.911	.044
Hepatica americana	.01	-	1							.01	-	1		
Hieracium spp.				.01	-	1				.01	-	1		
Lactuca spp.							.01	0	3					
Lathyrus ochroleucus	18.43	9.87	5	5.92	2.87	7	11.22	3.96	11	2.86	1.56	2		
Lathyrus palustris				11.38	3.47	2				.80	-	1		
Lathyrus venosus	9.22	-	1	31.37	18.00	3	7.92	6.64	2				.668	.578[2]/
Lathyrus spp.	3.35	-	1				4.42	-	1	3.05	-	1		
Linnaea borealis	8.15	2.34	9	7.46	2.47	11	6.54	1.32	9	2.92	-	1	.224	.879
Maianthemum canadense	2.06	.53	10	4.15	.68	21	3.47	.81	14	3.02	1.66	3	1.237	.308
Melampyrum lineare	.01	-	1	.01	0	2	.01	0	3	.01	-	1		
Mitella nuda										.01	-	1		
Moneses uniflora				.01	-	1								
Petasites palmatus							.01	-	1					
Polygala paucifolia	.01	0	7	.02	.01	10	.01	0	7	.01	-	1	.675	.577
Polygonum cilinode							.01	0	4					
Pyrola elliptica							2.56	-	1					
Pyrola rotundifolia	1.93	0	2	1.56	1.46	2	4.82	-	1					
Pyrola secunda	2.19	.59	5	2.53	.72	9	3.35	.76	3				1.286	.289[2]/
Pyrola virens	1.98	.05	4	1.80	1.70	2	1.93	0	2					
Pyrola spp.	1.97	.74	4	2.14	.21	3	2.91	-	1					
Senecio spp.							.01	-	1					
Solidago spp.	.01	0	4	.01	0	2	.01	0	5	.13	-	1		
Streptopus roseus	.17	.05	5	1.98	1.53	8	.18	.10	3	.19	-	1	.435	.719
Taraxacum officinale				.01	-	1								
Trientalis borealis	.01	0	5	.04	.03	5	.01	0	7	.01	0	2	.839	.493

(Appendix table 2 continued on next page)

(Appendix table 2 continued)

Species	None			Disk			Rockrake			Chemical			ANOVA	
	Mean	SE	N	Mean	SE	N	Mean	SE	N	Mean	SE	N	F Ratio	Probability
	- - - - - - -			- - - - - - -			Pounds/acre			- - - - - - -				
Unidentified species	.01	-	1	.01	0	3	.01	0	6	.01	-	1		
Vicia americana							.01	-	1					
Viola adunca							.62	.23	2					
Viola spp.	.68	.12	5	.64	.24	7	.73	.22	8	1.34	.94	2	0.732	0.545[2/]
Fern and fern allies														
Dryopteris spp.				.28	-	1	.28	-	0	1.68	-	1		
Lycopodium annotinum	.01	0	2	.01	0	2								
Lycopodium clavatum	.01	0	4	.34	.30	8	.02	.01	3	.01	-	1	.341	.796
Lycopodium complanatum	.01	.05	5	.01	0	2	.01	-	0					
Lycopodium lucidulum				.01	-	1				.01	-	1	.286	.834[2/]
Lycopodium obscurum	.02	.01	4	2.00	1.98	4	.01	0	5	.01	-	1	.790	.526
Lycopodium spp.							.07	-	1					
Pteridium aquilinum	112.96	28.82	8	140.86	28.90	13	77.02	25.15	15	64.18	-	1	1.084	.370
Shrubs														
Arctostaphylos uva-ursi	23.37	-	1	21.13	-	1				23.37	-	1		
Chimaphila umbellata	10.09	4.35	5	6.27	1.64	4	5.49	2.04	3	12.70	6.04	2	.621	.617
Comptonia peregrina	58.29	-	1	10.60	3.55	5	39.78	11.74	8				2.376	.139
Diervilla Lonicera	24.22	3.89	11	46.32	8.76	19	43.05	11.57	17	13.66	12.50	2	1.155	.337
Gaultheria hispidula	7.92	1.6	2											
Gaultheria procumbens	29.33	10.53	7	13.44	2.56	8	61.70	29.68	2				3.983	.040[2/]
Ledum groenlandicum	10.73	10.29	3							.01	-	1		
Rubus pubescens	.71a	.40	11	.84a	.24	20	1.30a	.65	15	4.89b	3.84	3	3.209	.032
Vaccinium angustifolium	11.13	3.06	11	13.11	2.86	21	23.40	10.06	15	.18	.12	2	1.012	.396
Vaccinium myrtilloides	30.69	12.45	9	19.35	4.90	12	22.84	7.65	14	1.66	0	2	.102	.558
Plantation total biomass[3/]	356.94	51.89	11	394.16	51.29	21	426.27	62.77	18	434.44	174.60	3	.222	.880

1/ Based on Student-Newman-Keuls test of those means indicated as significantly different by ANOVA.

2/ For some ANOVA's the following species were combined: *Fragaria vesca* and *F. virginiana*; all *Lathyrus* species; *Lycopodium annotinum*, *L. complanatum*, *L. lucidulum*, and *L.* spp.; all *Pyrola* species, *Viola* species, and *Gaultheria* species.

3/ Total biomass in the herbaceous and low shrub layer except for *Rosa acicularis* and *Rubus strigosus*, which were sampled and included in the tall shrub layer.

Appendix table 3.--Herb-low shrub layer biomass (ovendry), standard error of the mean, and number of plantations for each release (RELEASE) category for conifer plantations near Isabella, Minnesota. Means in a row followed by the same letter do not differ at the P = 0.05 probability level[1/]

	Chemical			Manual			Manual-chemical			No record			ANOVA	
	Mean	SE	N	Mean	SE	N	Mean	SE	N	Mean	SE	N	F Ratio	Probability
	Pounds/acre													
Herbs														
Achillea Millefolium										0.01	-	1		
Actea rubra				0.26	-	1				.01	-	1		
Anaphalis margaritacea	0.01	0	3	.01	0	2				.01	0	2		
Anemone quinquefolia	.01	0	8	.11	.08	13	0.01	0	2	.09	.07	6	0.436	0.729
Antennaria spp.	.01	-	1							.01	0	3		
Apocynum androsaemifolium	4.97	1.41	6	4.38	2.20	4	.90	-	1	3.28	1.69	4	.430	.736
Aquilegia canadensis				.01	-	1								
Aralia nudicaulis	4.83	1.27	13	7.83	2.19	19	7.40	3.18	2	9.22	2.47	10	.660	.581
Aster ciliolatus	4.57	2.21	3	21.91	-	1				19.40	-	1		
Aster macrophyllus	65.67	10.23	17	65.17	11.58	21	60.10	38.27	3	46.46	10.93	12	.489	.692
Aster umbellatus	1.29	-	1											
Circaea canadensis										.01	-	1		
Clintonia borealis	11.53	2.28	11	8.81	1.54	20	2.30	-	1	10.07	5.12	7	.490	.692
Coptis groenlandica				.01	0	7				.01	0	3		
Cornus canadensis	8.24	2.35	13	10.65	2.46	20	16.45	13.07	3	11.91	3.69	9	.504	.682
Cyperaceae	.06	.05	4	.98	.97	4				.01	0	6	1.255	.323
Epilobium angustifolium	1.22	.49	4	.34	.52	2	.16	.34	2	.86	-	1		
Fragaria vesca	4.91	.96	7	2.71	.67	9				15.12	9.39	6		
Fragaria virginiana	9.09	2.99	11	4.47	1.02	10	2.66	.92	2	5.30	2.16	6	1.333	.275 [2/]
Galium triflorum	.13	.08	5	.01	-	1				.02	.01	2		
Goodyera repens				.01	-	1								
Gramineae	160.46	30.96	17	85.62	14.96	21	90.29	21.77	3	114.83	31.28	12	1.845	.151
Hepatica americana	.01	0	2											
Hieracium spp.				.01	-	1								
Lactuca spp.	.01	-	1							.01	0	2		
Lathyrus ochroleucus	15.85	6.18	10	5.46	2.44	8	12.58	10.16	2	7.07	1.87	5		
Lathyrus palustris	4.36	3.56	2							14.85	-	1		
Lathyrus venosus	8.36	3.85	3	32.42	31.12	2	26.29	-	1				.318	.812[2/]
Lathyrus spp.	3.20	0.15	2							4.42	-	1		
Linnaea borealis	4.58	1.50	7	9.78	1.74	14	3.73	1.45	3	6.19	3.63	6	1.505	.236
Maianthemum canadense	2.42	.87	15	4.33	.62	20	2.07	.66	2	3.47	.64	11	1.473	.235
Melampyrum lineare	.01	-	1	.01	0	4				.01	0	2		
Mitella nuda	.01	-	1											
Moneses uniflora										.01	-	1		
Petasites palmatus										.01	-	1		
Polygala paucifolia	.01	0	8	.01	0	11	.01	-	1	.01	0	5	.284	.836
Polygonum cilinode	.01	-	1	.01	-	1	.01	-	1	.01	-	1		
Pyrola elliptica				2.56	-	1								
Pyrola rotundifolia	.10	-	1	3.26	.84	3				1.93	-	1		
Pyrola secunda	2.19	.55	5	2.02	.97	6				3.43	.55	6		
Pyrola virens	1.93	-	1	1.92	.54	5				1.93	0	2	1.017	.372[2/]
Pyrola spp.	2.83	.90	2	1.39	.65	3				2.47	.29	3		
Senecio spp.										.01	-	1		
Solidago spp.	.04	.03	4	.01	0	4				.01	0	4		
Streptopus roseus	.61	.46	4	1.39	1.24	10	.08	-	1	.46	.16	2	.109	.954
Taraxacum officinale	.01	-	1											
Trientalis borealis	.01	0	5	.03	.02	9	.01	-	1	.01	0	4	.267	.848

(Appendix table 3 continued on next page)

(Appendix table 3 continued)

Species	Chemical Mean	Chemical SE	Chemical N	Manual Mean	Manual SE	Manual N	Manual-chemical Mean	Manual-chemical SE	Manual-chemical N	No record Mean	No record SE	No record N	ANOVA F Ratio	ANOVA Probability
	Pounds/acre													
Unidentified spp.	.01	0	4	.01	0	3				.01	0	4		
Vicia americana										.01	-	1		
Viola adunca				.62	.23	2								
Viola spp.	.80	.24	8	.55	.17	10				1.11	.34	4	1.402	.268[2]
Fern and fern allies														
Dryopteris spp.	1.68	-	1	.28	-	1				.28	-	1		
Lycopodium annotinum	.01	-	1	.01	0	2				.01	-	1		
Lycopodium clavatum	.01	0	5	.36	.34	7	.26	-	1	.01	0	3	.372	.775
Lycopodium complanatum	.01	0	3	.01	0	4				.26	-	1		
Lycopodium lucidulum	.01	-	1							.01	-	1	1.586	.248[2]
Lycopodium obscurum	.01	0	7	1.61	1.59	5				.01	0	2	.895	.436
Lycopodium spp.							.07	-	1					
Pteridium aquilinum	131.00	27.09	13	79.81	25.55	15	180.59	155.02	2	99.01	15.89	7	1.058	.380
Shrubs														
Arctostaphylos uva-ursi	23.37	-	1	22.25	1.12	2								
Chimaphila umbellata	8.92	3.29	4	5.21	1.16	7				15.08	5.90	3	2.868	.100
Comptonia peregrina	30.11	16.21	3	35.95	15.83	6	11.95	6.80	2	33.21	14.90	3	.282	.838
Diervilla Lonicera	45.10	9.18	15	34.49	10.14	19	47.20	11.13	3	36.01	10.59	12	.275	.843
Gaultheria hispidula				6.65	-	1				9.18	-	1		
Gaultheria procumbens	15.37	3.74	5	36.82	10.45	9				9.34	3.85	3	1.942	.176[2]
Ledum groenlandicum	.01	-	1	16.08	15.22	2				.01	-	1		
Rubus pubescens	1.45	.83	15	.95	.40	21	3.82	3.28	2	.84	.28	11	1.063	.374
Vaccinium angustifolium	11.04	3.80	14	22.96	7.08	21	1.70	1.20	3	9.74	3.51	11	1.426	.248
Vaccinium myrtilloides	13.84	3.70	14	33.08	10.23	14	41.71	-	1	16.62	5.60	8	1.540	.222
Plantation total biomass[3]	465.17	55.07	17	371.85	55.95	21	395.49	172.77	3	357.41	54.92	12	.665	.577

1/ Based on Student-Newman-Keuls test of those means indicated as significantly different by ANOVA.

2/ For some ANOVA's the following species were combined: *Fragaria vesca* and *F. virginiana*; all *Lathyrus* species; *Lycopodium annotinum*, *L. complanatum*, *L. lucidulum*, and *L.* spp.; all *Pyrola* species, *Viola* species, and *Gaultheria* species.

3/ Total biomass in the herbaceous and low shrub layer except for *Rosa acicularis* and *Rubus strigosus*, which were sampled and

Appendix table 4.--Herb-low shrub layer biomass (ovendry), standard error of the mean, and number of plantations for each species planted (SPECIES) category for conifer plantations near Isabella, Minnesota. Means in a row followed by the same letter do not differ at the P = 0.05 probability level[1]

Species	Pine			Pine & spruce			Spruce			ANOVA	
	Mean	SE	N	Mean	SE	N	Mean	SE	N	F Ratio	Probability
	Pounds/acre										
Herbs											
Achillea Millefolium	0.01	-	1								
Actea rubra	.01	-	1	0.26	-	1					
Anaphalis margaritacea	.01	0	5	.01	0	2					
Anemone quinquefolia	.10	.05	20	.01	0	6	0.01	0	3	0.532	0.594
Antennaria spp.	.01	0	4								
Apocynum androsaemifolium	4.05	1.08	11	3.47	2.37	3	6.38	-	1	.235	.794
Aquilegia canadensis	.01	-	1								
Aralia nudicaulis	7.26	1.50	32	7.92	1.81	10	3.18	3.08	2	.304	.740
Aster ciliolatus	9.82	5.25	3	21.91	-	1	3.63	-	1		
Aster macrophyllus	57.72	7.50	38	62.44	11.12	12	93.38	47.58	3	.820	.446
Aster umbellatus	1.29	-	1								
Circaea canadensis	.01	-	1								
Clintonia borealis	8.79	1.53	30	9.85	2.17	7	21.60	8.69	2	2.334	.111
Coptis groenlandica	.01	0	8	.01	0	2					
Cornus canadensis	10.29	1.80	33	11.01	4.45	9	12.71	9.05	3	.071	.931
Cyperaceae	.33	.32	12	.01	-	1	.20	-	1	.043	.958
Epilobium angustifolium	.75	.20	5	.92	.55	4					
Fragaria vesca	7.77	3.66	16	3.31	1.38	4	5.94	1.50	2		
Fragaria virginiana	6.73	1.98	18	4.15	1.09	8	9.11	2.74	3	.577	.565[2]
Galium triflorum	.12	.06	6	.01	-	1	.01	-	1		
Goodyera repens	.01	-	1								
Gramineae	108.46	15.51	38	112.23	29.25	12	235.52	87.19	3	2.275	.113
Hepatica americana				.01	-	1	.01	-	1		
Hieracium spp.	.01	-	1								
Lactuca spp.	.01	0	3								
Lathyrus ochroleucus	7.90	2.58	18	22.97	8.79	5	2.86	1.56	2		
Lathyrus palustris	11.38	3.47	2				.80	-	1	2.118	.136[2]
Lathyrus venosus	20.17	14.79	4	19.26	10.04	2					
Lathyrus spp.	4.42	-	1	3.35	-	1	3.05	-	1		
Linnaea borealis	7.97	1.59	21	5.86	1.49	8	2.92	-	1	.510	.606
Maianthemum canadense	3.50	.51	34	3.39	.84	11	3.02	1.66	3	.039	.961
Melampyrum lineare	.01	0	4	.01	0	2	.01	-	1		
Mitella nuda							.01	-	1		
Moneses uniflora				.01	-	1					
Petasites palmatus	.01	-	1								
Polygala paucifolia	.01	<.01	18	.01	0	6	.01	-	1	.257	.778
Polygonum cilinode	.01	0	4								
Pyrola elliptica	2.56	-	1								
Pyrola rotundifolia	1.75	.61	4	4.82	-	1					
Pyrola secunda	2.71	.65	10	2.37	.54	7					
Pyrola virens	1.88	.54	5	2.00	.07	3					
Pyrola spp.	2.53	.29	6	1.02	.92	2				.032	.858[2]
Senecio spp.	.01	-	1								
Solidago spp.	.01	0	9	.01	0	2	.13	-	1		
Streptopus roseus	1.20	.89	14	.19	.11	2	.19	-	1	.124	.885
Taraxacum officinale	.01	-	1								
Trientalis borealis	.02	.01	13	.01	0	4	.01	0	2	.265	.771

(Appendix table 4 continued on next page)

(Appendix table 4 continued)

Species	Pine			Pine & spruce			Spruce			ANOVA	
	Mean	SE	N	Mean	SE	N	Mean	SE	N	F Ratio	Proba-bility
	- - - - - - - - - - - - - - - -Pounds/acre- - - - - - - - - - - - - - - - - -										
Unidentified spp.	.01	0	8	.01	0	2	.01	-	1		
Vicia americana	.01	-	1								
Viola adunca	.85	-	1	.39	-	1					
Viola spp.	.66	.14	17	.85	.09	3	1.34	.94	2	1.150	.336[2]
Fern and fern allies											
Dryopteris spp.	.28	-	1	.28	-	1	1.68	-	1		
Lycopodium annotinum	.01	0	4							.165	.849[2]
Lycopodium clavatum	.23	.22	11	.07	.06	4	.01	-	1	.131	.878
Lycopodium complanatum	.05	.04	6	.01	0	2					
Lycopodium lucidulum	.01	-	1				.01	-	1		
Lycopodium obscurum	.89	.88	9	.02	.01	4	.01	-	1	.241	.790
Lycopodium spp.	.07	-	1								
Pteridium aquilinum	102.13	18.59	26	123.49	35.02	10	64.18	-	1	.262	.771
Shrubs											
Arctostaphylos uva-ursi	21.13	-	1	23.37	-	1	23.37	-	1		
Chimaphila umbellata	8.98	2.77	8	5.03	1.13	4	12.70	6.04	2	.905	.433
Comptonia peregrina	26.66	6.37	11	45.45	31.92	3				.944	.350
Diervilla Lonicera	40.96	6.70	35	37.06	10.44	12	13.66	12.50	2	.493	.614
Gaultheria hispidula	7.92	1.26	2								
Gaultheria procumbens	24.61	6.91	11	27.58	13.40	6				.193	.666[2]
Ledum groenlandica	15.66	15.65	2	.86	-	1	.01	-	1		
Rubus pubescens	.93a	.30	35	1.05a	.45	11	4.89b	3.84	3	4.585	.015
Vaccinium angustifolium	13.76	3.30	35	22.28	10.05	12	.18	.12	2	.983	.382
Vaccinium myrtilloides	23.27	5.37	24	24.53	9.39	11	1.66	0	2	.615	.546
Plantation total biomass[3]	381.16	35.66	38	449.38	78.30	12	438.44	174.60	3	.424	.657

1/ Based on Student-Newman-Keuls test of those means indicated as significantly different by ANOVA.

2/ For some ANOVA's the following species were combined: *Fragaria vesca* and *F. virginiana*; all *Lathyrus* species; *Lycopodium annotinum*, *L. complanatum*, *L. lucidulum*, and *L.* spp.; all *Pyrola* species, *Viola* species, and *Gaultheria* species.

3/ Total biomass in the herbaceous and low shrub layer except for *Rosa acicularis* and *Rubus strigosus*, which were sampled and included in the tall shrub layer.

Ohmann, Lewis F.
Biomass in conifer plantations of northeastern Minnesota. Res.Pap. NC-247. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 1984. 25 p.

Provides biomass (pounds/acre) estimates for vegetative strata and herb-low shrub species for 53 conifer plantations in northeastern Minnesota. The estimates are analyzed by plantation age and silvicultural practices used to establish and release the plantations.

KEY WORDS: Site preparation, plantation release, silviculture, herbicide, biomass estimation.

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