Floristic diversity, stand structure, and composition 11 years after herbicide site preparation[1]

James H. Miller, Robert S. Boyd, and M. Boyd Edwards

Abstract: This study tested for effects of site preparation herbicides applied at high labeled rates 11 years earlier on plant species richness, diversity, and stand structure and composition. Four study sites in three physiographic provinces were established in central Georgia in 1984. Six herbicide treatments were included on each site: hexazinone liquid, hexazinone pellets, glyphosate, triclopyr, picloram, and a mixture of dicamba and 2,4-dichlorophenoxyacetic acid (2,4-D). Herbicide and untreated plots were prescribed-burned and planted to loblolly pine (*Pinus taeda* L.). Eleven years after treatment, 177 total species were identified in these dense pine plantations; 99 species were forbs and grasses-grasslikes. Treated and check plots did not differ in species richness or diversity. Structurally, the total basal area of the tree canopy was not significantly altered, but the proportion of pine to hardwoods and shrub stem density were influenced by treatment. Latent effects were detected in the abundance and frequency of ***Pinus taeda, Prunus serotina*** Ehrh., ***Quercus stellata*** Wangenh., ***Diospyros virginiana*** L., ***Vaccinium stamineum*** L., ***Vitis rotundifolia*** Michx., and ***Lespedeza bicolor*** Turcz. Most are potential mast producers for wildlife. Herbicide site preparation had little influence on total species numbers or their diversity ll years after treatment but affected composition by altering perennial species abundance.

Résumé : Cette étude a examiné les effets de plusieurs herbicides sur la richesse et la diversité des espèces végétales, ainsi que sur la structure et la composition du peuplement. Des doses élevées d'herbicide, selon les quantités prescrites, avaient été appliquées ll ans auparavant pour la préparation des sites. Quatre parcelles d'étude ont été établies en 1984, dans trois provinces physiographiques de la Géorgie centrale. Six traitements à l'herbicide ont été appliqués dans chaque parcelle : hexazinone liquide, hexazinone granulé, glyphosate, triclopyr, picloram, ainsi qu'un mélange de dicamba et d'acide 2,4-dichlorophénoxyacétique (2,4-D). Les places échantillons traitées et non traitées à l'herbicide ont été soumises à un brûlage dirigé et plantées en pin à encens (*Pinus taeda* L.). Onze ans après le traitement, un total de 177 espèces ont été identifiées dans ces plantations de pin devenues denses, dont 99 espèces de graminées, de graminoïdes ou autres espèces herbacées. Les places échantillons traitées et témoins ne différaient pas entre elles quant à leur richesse spécifique ou leur diversité. Au point de vue de la structure, la surface terrière totale de la canopée arborée n'a pas été modifiée non plus de façon significative, mais le traitement a influencé la proportion du pin par rapport aux feuillus, ainsi que la densité des tiges chez les arbustes. Des effets latents ont été détectés dans l'abondance et la fréquence des espèces suivantes : ***Pinus taeda, Prunus serotina*** Ehrh., ***Quercus stellata*** Wangenh., ***Diospyros virginiana*** L., ***Vaccinium stamineum*** L., *Vitis rotundifolia* Michx. et ***Lespedeza bicolor*** Turcz. La plupart de ces espèces produisent une glandée pour la faune. Onze ans après le traitement, la préparation du site à l'aide d'herbicide a eu peu d'influence sur le nombre total d'espèces ou sur leur diversité. Elle a cependant affecté la composition floristique en modifiant l'abondance d'espèces vivaces.

[Traduit par la Rédaction]

Introduction

Global conservation of biodiversity will require efforts at multiple levels to be successful. Forest lands occupy one third of the U.S. landscape (Anonymous 1996), and forest management practices will significantly impact biodiversity because forests are major stores of species, habitat, and genetic diversity (Noble and Dirzo 1997). Thus, activities on forest lands will have an important impact on local, regional, and global diversity and the health and function of natural ecosystems (Kimmins 1997). Recognition of this fact has led to efforts to include biodiversity considerations in many aspects of forest land use and management (Hansen et al. 1991; Butterfield 1995; Faith et al. 1996; Fenger 1996). At

Received August 23, 1998. Accepted March ll, 1999.

J.H. Miller? Southern Research Station, USDA Forest Service, DeVall Drive, Auburn University, Aubum, AL 36849, U.S.A.
R.S. Boyd. Department of Botany and Microbiology, Auburn University, Aubum, AL 36849, U.S.A.
M.B. Edwards. Southern Research Station, USDA Forest Service, Athens, GA 30602-2044, U.S.A.

[1] Journal Series No. 6-996011 of the Alabama Agricultura1 Experiment Station, Auburn University.

[2] Corresponding author. e-mail: miller@forestry.aubum.edu

the same time, the area in pine plantations in the southeastern United States is projected to almost double from 9.7 x 10^6 ha in 1998 to 19 x 10^6 ha in 2040 (Alig et al. 1990). There is little understanding of the floristic diversity changes that will occur with this conversion of mostly natural pine and mixed pine-hardwood forests to planted pine plantations.

Forest vegetation management treatments are widely used in the southeastern United States to suppress competing plants and thereby enhance growth of plantation pines, mainly loblolly pine (*Pinus taeda* L.) (Minogue et al. 1991). Herbicide site-preparation treatments are applied to over 60 000 ha each year to control woody and herbaceous competition before crop trees are planted (Dubois et al. 1997). When effective, herbicide site preparation can initially decrease overall plant diversity (Blake et al. 1987). However, as crop trees become established, populations of noncrop plants generally rebound (Miller et al. 1995; Zutter and Miller 1998). Yet, information on the long-term influences at the species level is still lacking. The purpose of this study was to compare the diversity and structure of plant communities on herbicide-treated plots with that on nontreated plots across several physiographic provinces to gain a first approximation. This was a companion study to a recent examination of herbicide competition-release treatments on plant species diversity and richness in central Georgia (Boyd et al. 1995). Specific objectives of the current study were to (i) determine if herbicide site-preparation treatments result in changes in plant diversity 11 years after treatment; (*ii*) evaluate the nature of any changes detected in terms of shifts in species composition, representation of growth-form groups (e.g., shrubs), and abundance of keystone groups (e.g., legumes and wildlife plants); and (iii) determine the influences of herbicide site preparation treatments on the long-term proportion of pines to hardwoods and the effects of any proportional shift on plant diversity.

Methods

Study sites

The four study locations in central Georgia were part of a preexisting study comparing herbicide site-preparation and release treatments initiated in 1984 by the USDA Forest Service in cooperation with the Georgia Forestry Commission (Miller and Edwards 1995). Within the general area, annual rainfall averages 115 cm, with more than half falling in winter and early spring. Air temperatures vary from a July mean of 28°C to a January mean of 10°C. The study locations are in three physiographic provinces (Pehl and Brim 1985). The McElroy location is in the Piedmont physiographic province in the Midland Plateau Central Highlands. Surface soil texture is sandy clay loam with a clay subsoil. The Hill and Ellington sites are located in the Hilly Coastal Plain, Upper Loam Hills, and both have surface soils of loamy sands and subsoils of sandy clay loams. The Grimsley site is in the Middle Coastal Plain, Southern Loam Hills, with fine sandy loam to loamy sand surface soils and sandy clay to sandy clay loam subsoils. The 50-year site index for loblolly pine for these location ranged from 22 to 27 m, being within the range of medium to medium-high quality sites for the region. All but the sloping Ellington site were probably in row-crop production for about 100 years prior to establishment of forest stands harvested before the beginning of this study. All but the McElroy tracts are currently surrounded by extensive areas of row-crop farming with scattered forested tracts. All sites were relatively small (<35 ha), being owned by nonindustrial forest landowners. For additional site information, refer to Miller and Edwards (1995).

Plot-preparation and site-preparation treatments

Tracts had been completely harvested of all standing woody plants using conventional logging followed by fuelwood biomass harvesting at various times before site preparation. All locations had mixed stands of pines and hardwoods prior to harvest and the final biomass harvest resulted in abundant woody resprouts. The Hill and Grimsley locations were harvested 1 year prior to herbicide treatments; the Ellington location, 2 years prior; and the McElroy location, 7 years prior. The time period between harvest and treatment was ample for woody plant regrowth. The range in times since harvesting widened the scope of this exploratory study. Regrowth of woody vegetation was most dense on the sloping Ellington tract, while the apparent past farming practices on the McElroy tract kept woody regrowth at a low stature, even though 7 years had elapsed between harvest and treatment. The prior stands probably originated from pine planting on former crop lands or pine-only harvested stands.

The study used a randomized complete block design in which each study location represented a block. At each location, six herbicide treatments for site preparation and an untreated check were randomly assigned to rectangular plots. Plots averaged 0.4 ha in size and ranged from 0.3 to 1 ha. Plots were mostly contiguous and were positioned across uniform portions of larger tracts. Forestry herbicides commonly used in 1984 were applied at high labeled rates and at recommended timings. Herbicides were as follows: hexazinone liquid, hexazinone pellets, glyphosate, triclopyr, picloram, and a mixture of dicamba plus 2,4-dichlorophenoxyacetic acid (2,4-D). Glyphosate (Roundup®) and triclopyr (Garlon 4®) were applied as liquid sprays at 3.4 kg acid equivalent (a.e.)/ha and 4.4 kg a.e./ha, respectively. Picloram (Tordon 10K®) was applied as a granule at 3.4 kg a.e./ha. Two herbicides containing dicamba and one containing 2,4-D (Banvel® and Banvel 720®) were applied as a spray mixture at 4.5 kg a.e./ha dicamba plus 4.5 kg a.e./ha 2,4-D (the mixture is hereafter referred to as just dicamba). Both hexazinone products, the liquid formulation (Velpar L®) and the pelleted formulation (Pronone 10G®), were prescribed according to soil texture and percent organic matter per label recommendations. Specific application rates were 2.8 kg active ingredient (a.i.)/ha at Grimsley, 3.4 kg a.i./ha at Ellington and Hill, and 3.9 kg a.i./ha at the McElroy location.

Applications were made in the summer of 1984. Applications were by a sprayer or a spreader mounted on crawler tractors that had onboard microprocessor systems linked to speed sensors to maintain the prescribed rate with varying ground speed. Application uniformity was further assured by the use of flaggers to consistently guide the tractor across plots. Sites were prescribed burned in October or November of 1984. Machine planting of genetically improved 1-year-old loblolly pine seedlings occurred in late winter of 1985 at an approximate 1.8 x 2.7 m spacing. Check plots were also burned and planted. Tops of most woody plants on the check plots were killed by the burn, resulting in later resprouting.

Measurements

In 1995, at the start of the eleventh summer after treatment, 20 nested quadrats were established within each treatment and check plot by a restricted random procedure (i.e., randomly generated assignments to a surveyed grid). Because plot size varied from 0.3 to 1 ha, an interior sample area of 0.22 ha (24 x 92 m on most plots) was delineated within each treatment and check plot. Within each sample area, a lengthwise center transect was surveyed and 10 right-angle departures were positioned every 8 m along the length, extending both left and right of the transect. Departures were not established within 10 m of either end of the transect. Quadrat centers were positioned along each departure arm, both left and right of the center transect, using random number assignments to all possible 1-m divisions. Assignments to departures were only permitted between 4 and 10 m from the center transect to prevent quadrat overlap and to avoid any damage resulting from transect surveying and its use for repeated access.

Data for herbaceous, semiwoody, woody vine, fern, woody nonarborescent, and arborescent species in the understory (defined as ≤1.5 m tall) were collected from 20 square quadrats (2 x 2 m) per plot. Data from each quadrat consisted of a list of species present and their visually estimated percent canopy covers. All cover estimates were made by only one person. June-July cover estimates were used for species present throughout the summer, including most herbaceous species. Visits at two other times during the growing season, April and September, allowed cover estimates and identification of herbaceous and fern species active at other times of the year. Woody vine covers were not restricted to the height limit because of their vertical mode of growth and recorded as understory data.

Data on overstory arborescent and woody nonarborescent species (referred to as the overstory layer) were collected in September 1995. At each of the 20 points in each sample area a circular 0.005-ha subplot (4 m radius) was established, and all arborescent and nonarborescent woody plants taller than 1.5 m were tallied by species. Stem numbers and rootstock numbers were recorded for each species. In addition, the diameter at breast height (DBH) of each arborescent stem and the height of each woody nonarborescent stem were measured.

Data analysis

Data were pooled for each treatment plot from the 20 understory quadrats and (or) 20 overstory subplots depending upon the type of data analysis used.

Species richness

Total species counts in each treatment plot were categorized by growth form as arborescent (examining both overstory and understory data sets), nonarborescent woody (examining both overstory and understory data sets), forb (all species), forb (nonlegume only), legume forb, semiwoody, grass-grasslike, woody vine, and fern species.

Species diversity

We examined species diversity by utilizing two widely used diversity indices: Simpson and Shannon (Magurran 1988). For the overstory, density data from the 20 subplots for all arborescent and nonarborescent woody species (expressed as rootstocks per hectare) were averaged for each treatment plot and were used to calculate these indices. For the understory, cover data (for species of all growth forms) from the 20 quadrats were averaged for each treatment plot and used for diversity index calculations.

Structure and composition

Stand basal area (BA; $m^2 \cdot ha^{-1}$) was calculated and used to examine structural differences. Total BA values were tested for treatment effects, as *were* pine and hardwood BAs. Data for rootstocks per hectare, stems per hectare, sum of rootstock heights ($km \cdot ha^{-1}$), and sum of stem heights ($km \cdot ha^{-1}$) for all nonarborescent species also were analyzed. To examine changes in composition, importance values (IVs) for arborescent species were calculated as the sum of their relative frequency and relative density (based upon BA values). Relative frequency is the number of plots occupied by a species divided by 20 (and expressed as a percentage). Relative density is the mean BA of a species divided by the total plot BA (and expressed as a percentage). The maximum value for IVs is 200. The IVs for nonarborescent woody species were calculated in a similar manner as summed relative frequency and using relative density (rootstocks/ha). The IVs for understory species were calculated likewise as the summed relative frequency and using relative cover. Individual species' IVs were summed according to growth form, and the totals for each treatment plot were analyzed. Importance values for individual species were analyzed only for those species that occurred in all check plots. Presence of species in check plots indicated that they probably were present in each block prior to treatment and ranged widely enough to allow us to test for treatment effects across all locations. No species occurred just on treated plots and not on checks plots, which would have warranted additional analyses.

A randomized complete block model ANOVA was used to analyze data, in which sites were considered as blocks (Abacus Concepts, Inc. 1989). The Tukey's compromise test (Abacus Concepts, Inc. 1989) was used for post-hoc mean separation. Variables that represented proportions (i.e., IVs) were arcsine square-root transformed prior to analysis (Zar 1996). Variables representing counts (i.e., species richness, rootstocks/ha, and stems/ha) were square-root transformed prior to analysis (Zar 1996). Means of nontransformed data for all variables are presented in the Results. Differences were judged to be significant when the probability of a greater *F* value was less than 0.05.

Results

Species richness

Total species richness and richness by growth form did not significantly differ 11 years after herbicide site-preparation treatments (Table 1). A total of 177 taxa were differentiated, and all except 13 immature specimens were identified to species (see list in the Appendix, nomenclature according to Kartesz (1994)). The taxa number (later referred to as species) by growth form was as follows: 34 arborescents, 25 woody nonarborescents, 78 forbs, 21 grasses-grasslikes, 14 woody vines, 3 semiwoody plants, and 2 ferns. Of the forb species, 16 were legumes. Mean species counts ranged from 50 species for hexazinone-liquid plots to 61 species for triclopyr plots. Triclopyr plots had the greatest variation (largest SE), mainly because the number of nonlegume forbs varied among sites.

Mean species richness was greatest for arborescent plants (treatment means of 16-19 species; Table 1), followed by forbs (treatment means of 11-19 species). Nonlegume forbs were more abundant (7-14 species per treatment) than legume species (3-6 species per treatment). Richness was similar for woody nonarborescents, grasses-grasslikes, and woody vines, with treatment means ranging between five and nine species (Table 1), while fern and semiwoody species had the lowest richness values (less than three species per treatment). Considering that there were few fern or semiwoody species (Appendix, Table A1), the mean values in Table 1 reflect their consistent presence at many sites. Locations (blocks) differed significantly in both total species richness and richness for all growth-form groups except for forb and woody vine categories.

Diversity

Treatments had no significant influence on diversity 11 years after the treatments were applied (Table 2). Mean values and results of the analyses for overstory species (combining arborescents and woody nonarborescents) were similar for stems per hectare and rootstocks per hectare, and

Table 1. Treatment means for total species richness and species richness subdivided into growth form categories and *P* values of the ANOVA model for treatment.

Group	Check	Glyphosate	Triclopyr	Dicamba	Picloram	Hexazinone pellet	Hexazinone liquid	Treatment
Total species	55.0 (2.2)	59.0 (5.5)	61.0 (8.0)	53.0 (1.1)	53.0 (3.8)	58.0 (4.6)	50.0 (6.6)	0.2681
Arborescent	19.0 (2.1)	18.0 (2.5)	16.0 (1.3)	16.0 (1.8)	17.0 (1.0)	16.0 (0.9)	16.0 (2.2)	0.3690
Nonarborescent	7.8 (1.0)	8.5 (1.0)	8.5 (0.7)	8.0 (0.0)	8.5 (0.7)	8.5 (0.7)	7.8 (1.3)	0.9103
Woody vine	8.0 (0.7)	6.5 (0.9)	7.3 (0.0)	7.0 (0.3)	7.5 (0.3)	6.8 (0.5)	7.8 (0.5)	0.5267
Forbs: all	11.0 (1.6)	15.5 (1.9)	18.8 (5.5)	13.3 (2.6)	11.3 (1.5)	17.5 (4.1)	10.8 (2.3)	0.2864
Nonlegumes	7.0 (0.9)	12.0 (2.5)	14.0 (5.0)	9.5 (1.3)	8.0 (1.3)	12.0 (3.3)	8.0 (1.5)	0.2850
Legumes	4.0 (1.0)	3.5 (0.7)	4.8 (1.4)	3.8 (1.7)	3.3 (1.0)	5.5 (1.0)	2.8 (1.0)	0.4910
Grass-grasslike	6.5 (1.4)	7.8 (1.3)	8.5 (0.9)	6.3 (1.0)	5.8 (1.0)	6.8 (1.7)	5.3 (1.1)	0.2433
Semiwoody	2.3 (0.3)	2.5 (0.3)	2.3 (0.3)	2.3 (0.5)	2.3 (0.3)	2.3 (0.3)	1.8 (0.3)	0.3623
Fern	0.3 (0.3)	0.5 (0.3)	0.5 (0.3)	0.3 (0.3)	0.8 (0.5)	0.5 (0.3)	0.5 (0.3)	0.8287

Note: Values for treatments are means with SE given in parentheses. Arborescent and nonarborescent species counts included both overstory and understory data sets.

Table 2. Treatment means for plant species diversity and *P* values for treatment of the ANOVA model.

Group	Check	Glyphosate	Triclopyr	Dicamba	Picloram	Hexazinone pellet	Hexazinone liquid	Treatment *P*
Overstory[a]								
Simpson	0.84 (0.04)	0.83 (0.03)	0.79 (0.05)	0.78 (0.04)	0.80 (0.02)	0.81 (0.04)	0.78 (0.06)	0.4422
Shannon	2.3 (0.26)	2.2 (0.21)	2.1 (0.19)	2.0 (0.16)	2.1 (0.10)	2.1 (0.19)	2.0 (0.30)	0.4045
Understory[b]								
Simpson	0.91 (0.09)	0.92 (0.01)	0.90 (0.02)	0.89 (0.01)	0.89 (0.01)	0.89 (0.01)	0.88 (0.03)	0.4165
Shannon	2.8 (0.07)	2.8 (0.07)	2.8 (0.21)	2.6 (0.07)	2.6 (0.04)	2.7 (0.04)	2.6 (0.16)	0.4431

Note: Values for treatments are means with SE given in parentheses.

[a] Based on rootstocks per hectare of both arborescent and nonarborescent woody species >1.5 m tall.

[b] Based on cover of all species, including all growth forms, ≤1.5 m tall.

only results based on rootstocks per hectare are presented in Table 2. The ANOVAs of diversity index values for overstory woody species showed no significant effect of treatments upon Simpson's and Shannon's indices ($P > 0.40$ in all cases). Relative rankings of treatments were unaffected by the index used to calculate diversity; hexazinone-liquid plots averaged the lowest diversity and check plots the highest (Table 2). Overstory diversity differed significantly by location ($P < 0.0006$ in all cases), with the Ellington location having the highest diversity (e.g., mean Shannon's index 2.6) and the Hill site the lowest (e.g., mean Shannon's index 1.7), despite both sites being located in the Hilly Coastal Plain physiographic province. The prior stand on the Hill site originated from pine plantings on an old field, while the Ellington site had not been farmed for at least several tree crop rotations.

Understory species diversity (all growth forms combined) also was unaffected by treatments ($P = 0.417$ for Simpson's index, $P = 0.443$ for the Shannon's index). As with overstory diversity, understory diversity values were highest for the Ellington site (mean Shannon's index 2.9) and lowest for the Hill site (mean Shannon's index 2.7), although the range of values was much less. However, in contrast to the overstory results, understory diversity did not vary significantly among locations, although P values approached significance ($P = 0.056$ for the Simpson's index; $P = 0.098$ for the Shannon's index). Diversity index values were similar for overstory and understory layers.

Structure and composition

Overstory structure as determined by total arborescent BA was similar for all treatments ($P = 0.156$; Table 3), but the proportion of pine BA to hardwood BA was significantly altered ($P = 0.013$). Overstory arborescent BA means ranged from 20 $m^2 \cdot ha^{-1}$ for check plots to 25 $m^2 \cdot ha^{-1}$ for hexazinone-liquid plots, only a 20% range. However, the BAs of pine and hardwoods were equal on check plots; hexazinone-treated plots had 14–18% hardwood BA, and other treatments had 20–30% hardwood BA. Hexazinone treatments had significantly more pine BA and less hardwood BA than the check plots, while glyphosate plots had significantly more pine BA than check plots. For location differences, arborescent BA was significantly higher for the Hill and Grimsley locations (mean 26 $m^2 \cdot ha^{-1}$ for both sites) and lower for the Ellington and McElroy locations (means 20 and 19 $m^2 \cdot ha^{-1}$, respectively). This is consistent with differences in site index values.

Nonarborescent stem densities differed significantly by treatment ($P = 0.024$), while analysis of rootstock densities showed the treatment effect was close to significance ($P = 0.067$; Table 3). Hexazinone-liquid plots had a significant fourfold greater abundance of shrub stems than picloram treatments (Table 3), with neither differing significantly from the check. Mean stem counts ranged from 690 (picloram) to 3100/ha (hexazinone liquid), and rootstock densities varied threefold, ranging from 390 (picloram) to 1300/ha (hexazinone liquid). Interestingly, the hexazinone-liquid

Ta

Group	Check	Glyphosate	Triclopyr	Dicamba	Picloram	Hexazinone pellet	Hexazinone liquid	Treatment *P*
Arborescent								
Total BA ($m^2 \cdot ha^{-1}$)	19.5 (1.4)	23.8 (1.5)	22.0 (3.3)	22.8 (2.1)	23.2 (2.1)	23.0 (2.1)	24.9 (2.9)	0.1556
Pine BA ($m^2 \cdot ha^{-1}$)	9.7 (1.9)*a*	17.9 (2.3)*b*	16.1 (4.1)*ab*	17.1 (3.1)*ab*	16.2 (3.8)*ab*	19.7 (1.3)*b*	20.3 (1.3)*b*	0.0131
Hardwood BA ($m^2 \cdot ha^{-1}$)	9.8 (2.2)*a*	5.9 (1.5)*ab*	5.9 (2.1)*ab*	5.7 (1.9)*ab*	7.0 (2.1)*ab*	3.3 (0.8)*b*	4.6 (1.7)*b*	0.0119
Nonarborescent								
Stems/ha ($\times 10^3$)	2.0 (0.3)*ab*	1.0 (0.2)*ab*	0.9 (0.2)*ab*	1.0 (0.3)*ab*	0.7 (0.1)*b*	2.3 (0.7)*ab*	3.1 (1.2)*a*	0.0236
Sum of stem heights ($km \cdot ha^{-1}$)	5.1 (1.3)	2.5 (0.6)	2.3 (0.4)	2.7 (1.0)	2.2 (0.6)	5.8 (1.9)	7.9 (3.2)	0.0385
Rootstocks/ha ($\times 10^3$)	1.1 (0.3)	0.8 (0.9)	0.7 (0.1)	0.6 (0.2)	0.4 (0.1)	1.2 (0.3)	1.3 (0.4)	0.0669
Sum of rootstock heights ($km \cdot ha^{-1}$)	3.0 (1.0)	1.9 (0.2)	1.6 (0.3)	1.7 (0.5)	1.0 (0.2)	2.8 (0.7)	3.1 (0.9)	0.0973

Note: Values for treatments are means with SE given in parentheses. Values in a row with the same letter are not significantly different at the 0.05 level of probability as determined by Tukey's compromise test.

treatment resulted in a significantly higher value for pine, a lower value for hardwoods, and the highest number of woody nonarborescent stems (Table 3). Comparable herbicide rates of hexazinone pellets had similar results for arborescents, but the abundance of woody nonarborescents was less affected. Similar to nonarborescent densities, stem height sums were significantly different among treatments (*P* = 0.035) while rootstock height sums were not (*P* = 0.097). Tukey's comparisons for stem height sums were unable to separate any treatment means, indicating that differences in stem abundance were considerably less than those identified for stem densities. Conversely to overstory BA, nonarborescent stems were significantly greatest on the Ellington site and lowest for the Hill site (i.e., 1100 and 570 rootstocks/ha, respectively).

The compositional changes in pine and hardwoods in the overstory detected with BA were further analyzed using IVs (Table 4). Nine arborescent taxa were present on all check plots (this was the criterion for further analytical testing). Of ***these, Pinus taeda, Quercus stellata*** Wangenh., ***Prunus serotina*** Ehrh., and ***Diospyros virginiana*** L. showed significantly differing IVs due to treatments. Similar to BA, ***Pinus taeda*** had a twofold higher IV (55%) in hexazinone-liquid plots compared with check plots (26%; Table 4). The IV of ***the oak*** species, ***Quercus stellata,*** was significantly lower for hexazinone liquid compared with check and picloram plots (Table ***4). Prunus serotina*** also had a significantly lower IV on hexazinone treatments compared with triclopyr. ***Diospyros virginiana*** also was significantly affected by treatments, with the lowest IV on dicamba plots (2%) and more than fivefold higher IV on hexazinone-pellet plots (11%). The IVs of oaks in general ***(Quercus*** spp.) and the prevalent species, ***Liquidambar** styraciflua* L., were not significantly altered by treatment.

Only two woody nonarborescent taxa, ***Vaccinium*** spp. L. and ***Rhus copallinum*** L., were present in all check plots. ANOVAs showed no significant effect of treatments on IVs for those taxa (Table 4). In relative ranking, the check plots had the highest mean ***Vaccinium*** spp. IV and the kowest ***Rhus copallinum*** IV Significant block effects were documented for most of the overstory species analyzed (9 of 11 species).

Understory flora of these 1 1-year-old pine plantations had a dominant component of woody plants. Arborescent, woody vine, and woody nonarborescent growth forms predominated on the study plots, with mean IVs for each of these growth forms ranging from 19 to 77% (Table 5). Forb, grass–grasslike, and semiwoody species were secondary in importance in the understory, with mean IVs ranging from 15 to 37% (Table 5). Ferns had a very minor presence, with a maximum mean IV of 2.3% (hexazinone-liquid plots). Only woody vines differed significantly by treatments (ANOVA; ***P*** = 0.048) although without significant differentiation between means by Tukey's test. The greater IV of woody vines on hexazinone-liquid plots is most notable. Differences in woody nonarborescent IVs were close to significance ***(P*** = 0.06).

A large number of understory taxa (20) were present in the check plots of all study sites and, therefore, were analyzed for treatment effects on their IVs. Differences in arborescent IVs in the understory (representing seedlings of these species) were not evident (Table 6). The prevalent

Table 4. Overstory (>1.5 m tall) arborescent and nonarborescent mean importance values (expressed as percentages) by treatment for prevalent species and (or) genera and values of the ANOVA model for treatment.

Group	Check	Glyphosate	Triclopyr	Dicamba	Picloram	Hexazinone pellet	Hexazinone liquid	Treatment ***P***
Arborescent								
Pinus taeda	***26b***	***40ab***	***42ab***	***36ab***	***36ab***	***50ab***	55*a*	0.0444
Quercus spp.	41	48	47	37	64	29	28	0.1533
Quercus nigra	39	37	36	28	44	24	22	0.0971
Quercus stellata	6.9*a*	4.1*ab*	4.1*ab*	3.2*ab*	7.2*a*	3.2*ab*	2.5*b*	0.0125
Liquidambar styraciflua	**27**	17	32	40	33	32	34	0.0960
Prunus serotina	***15ab***	***14ab***	***19a***	11*ab*	***12ab***	9.2*ab*	9.3*b*	0.0345
Nyssa sylvatica	7.6	9.7	6.9	2.7	9.3	7.8	4.0	0.2857
Ulmus alata	7.6	10	3.9	11	2.0	2.7	6.0	0.3034
Diospyros virginiana	3.3*bc*	5.1*abc*	5.0*abc*	2.0 c	4.8*abc*	11*a*	9.2*ab*	0.0072
Nonarborescent								
Vaccinium spp.	140	55	99	96	72	79	72	0.2521
Rhus copallinum	43	130	67	87	63	86	62	0.2759

Note: Numbers in a row with the same letter are not significantly different at the 0.05 level of probability as determined by Tukey's compromise test.

Table 5. Mean understory layer importance values (expressed as percentages) separated into growth-form categories and ***P*** values of the ANOVA model for treatment.

Group	Check	Glyphosate	Triclopyr	Dicamba	Picloram	Hexazinone pellet	Hexazinone liquid	Treatment ***P***
Arborescent	58	55	41	52	51	37	42	0.1167
Nonarborescent	30	20	21	24	19	37	29	0.0598
Woody vine	55	52	49	51	48	58	77	0.0483
Forbs: all	18	28	37	21	30	27	20	0.3702
Nonlegumes	11	17	27	14	25	15	11	0.3222
Legumes	7	11	10	7	5	12	9	0.2288
Grass-grasslike	21	25	33	24	21	21	22	0.4706
Semiwoody	18	25	18	28	32	17	15	0.1010
Fern	0.7	0.6	0.9	0.2	2.1	0.8	2.3	0.5432

grasses of ***Andropogon*** spp. L. and ***Dichanthelium*** spp. L., semiwoody plants of ***Rubus*** spp. L. and vines of *Smilax* spp. L., also did not vary significantly due to treatment (Table 6).

Only four taxa (***Lespedeza bicolor*** Turcz., ***Vaccinium stamineum*** L., ***Vaccinium*** spp., and *Vitis* ***rotundifolia*** Michx.) were significantly affected by treatments, although half of the taxa examined varied significantly in abundance between study locations. ***Lespedeza bicolor,*** one of three legume taxa analyzed and the only exotic invasive species of the 20 species that were individually analyzed, was completely absent from hexazinone-liquid plots and had its highest IV in triclopyr plots. ***Vaccinium*** spp. IV was significantly higher on the check (16%) and hexazinone-pellet (20%) treatments compared with glyphosate treatment (6.9%). ***Vaccinium stamineum*** had highest IV values in dicamba plots and lowest values for glyphosate treatment (Table 6). A common woody vine, *Vitis* ***rotundifolia,*** had its peak IV (11%) in check plots and its lowest IV in dicamba plots (1.8%), with intermediate values for other treatments. Block effects were documented for fewer of these analyses (10 of the 20 taxa analyzed in Table 6) than were documented for many of the other analyses in this study.

Discussion and conclusions

It is difficult to place these results in a historical and landscape ecological context. There are no known baseline species surveys of other stand types nearby in this subregion and no historical floristic accounts of sufficient detail (e.g., Bartram's 1775 observations (Harper 1958)). Besides, a principal management objective for these forests, timber production, is historically novel. The prior land management objective was probably subsistence range management, after a century of row cropping (primarily for cotton). The establishment and management of even-aged pine plantations is yet another crop in the continuing use of these soils and this landscape. The extensive and increasing coverage of pine plantations (now about 9.7 x 10^6 ha) has only been prevalent since the 1960s when government reforestation programs became established (Alig et al. 1990). The stands previously occupying our study sites probably originated during this period and some probably were aided in their establishment by these reforestation programs.

Have plant species been conserved in these plantations? At least 176 species were present besides loblolly pine. Although some of these species are considered cosmopolitan, inhabiting disturbed sites and rights-of-way, most occur

Table 6. Understory layer mean importance values (expressed as percentages) for species occurring on all check plots by growth forms with ANOVA results.

Group	Check	Glyphosate	Triclopyr	Dicamba	Picloram	Hexazinone pellet	Hexazinone liquid	Treatment *P*
Arborescent								
spp.	11.0	12.0	11.0	10.0	13.0	6.9	5.4	0.1031
Prunus spp.	5.5	5.2	6.0	5.0	4.1	3.2	2.8	0.4810
Prunus serotina	5.5	4.8	6.0	5.0	3.7	2.5	3.2	0.4835
Nyssa sylvatica	3.7	4.6	1.2	1.0	5.5	2.6	1.6	0.2678
Ulmus alata	2.5	4.7	0.7	2.6	3.6	0.5	0.9	0.5152
Nonarborescent								
Vaccinium spp.	16.0*a*	6.9*b*	12.0*ab*	15.0*ab*	9.0*ab*	20.0*a*	9.0*ab*	0.0104
Vaccinium stamineum	6.5*ab*	2.4*b*	5.5*ab*	13.0*a*	7.1*ab*	8.0*ab*	7.0*ab*	0.0481
Forbs: nonlegumes								
Galium pilosum	2.7	1.5	1.7	1.9	1.8	2.8	2.4	0.8803
Forbs: legumes								
Lespedeza spp.	3.8	6.0	6.4	3.6	4.6	7.2	3.5	0.1643
Lespedeza bicolor	1.4*a*	0.7*ab*	2.5*a*	1.3*ab*	1.7*a*	2.1*a*	0.0*b*	0.0083
Clitoria mariana	2.2	3.5	2.2	1.6	0.2	2.0	2.5	0.1239
Grasses-grasslikes								
Andropogon spp.	11.0	6.5	15.0	11.0	9.4	9.4	6.0	0.5262
Dichanthelium spp.	6.6	12.0	12.0	11.0	8.0	8.6	6.9	0.1468
Dichanthelium commutatum	1.4	1.1	0.7	0.7	1.2	0.3	0.5	0.6238
Dichanthelium sphaerocarpon	1.7	0.6	1.4	0.3	0.5	1.0	0.6	0.2639
Semiwoody plants								
Rubus spp.	15.0	23.0	15.0	26.0	29.0	16.0	14.0	0.1807
Woody vines								
Smilax spp.	15.0	17.0	20.0	22.0	28.0	17.0	21.0	0.3960
Smilax bona-nox	2.7	3.9	2.9	0.8	2.7	2.4	2.6	0.6866
Toxicodendron radicans	5.1	4.4	1.6	4.8	3.4	7.2	6.4	0.5531
Vitis rotundifolia	11.0*a*	6.2*ab*	2.7*ab*	1.8*b*	2.7*ab*	2.4*ab*	5.7*ab*	0.0473

Note: Vine data include cover in both overstory and understory layers. Values in a row with the same letter are not significantly different at the 0.05 level of probability as determined by Tukey's compromise test.

mainly in both early and middle successional forests (Krochmal and Kologiski 1974; Peet and Allard 1993; Miller et al. 1995). None identified are listed on the U.S. Federal List of Endangered Plants. At least seven species are exotics or considered to be recently naturalized: *Ligustrum sinense* Lour., *Paspalum notatum* Fluegge, *Setaria parviflora* (Poir.) Kerguelen, *Setaria viridis* (L.) Beauv., *Duchesnea indica* (Andrz.) Focke, *Lespedeza bicolor,* and *Lonicera japonica* Thunb. The 16 somewhat evenly distributed legume species (those for which treatment was not significant) are important for stand nitrogen accretion and use for wildlife food.

On four nearby study sites (Boyd et al. 1995), 243 species were identified 7 years after pine-release herbicide treatments and at stand age 10 years (compared with 177 species at age 11 in the current study). The lesser species after site preparation were mainly fewer hardwoods (7 species), nonlegumes (35 species), and legume forbs (9 species). Compared with site-prepared plots, released plots had one-third less arborescent BA and less uniform canopies that had scattered shrub-dominated openings. Release treatments use lower herbicide rates than site preparation treatments and generally control fewer plants. More importantly, pine trees occupy the canopy sooner following site preparation compared with release and would produce more uniform shading of the mid- and under-story (Miller and Edwards 1995).

Herbicide site preparation treatments did not have a significant residual effect on overall floristic species richness or diversity 11 years after treatment compared to burned-only plots. We can therefore conclude that herbicide use did not limit recolonization by the local flora on these sites dominated by planted pines and having a long history of human disturbance. These results are limited by the experimental approach to the following degree. Pretreatment data were not taken, so that change could not be assessed. The small plot sizes examined in this study (averaging 0.4 ha) and the contiguous plot arrangement would present minimal limitations to propagule reentry to all plots compared with extensive plantation areas. None of the study tracts exceeded 35 ha, and all were along major highway rights-of-way, often bordering croplands and pine plantations. Thus, our findings address areas where plant reinvasion is not limited and pine canopies are a dominant influence.

Even with uniform seed rain and seed soil banks, changes in understory diversity could occur in response to significant changes in overstory and midstory structure and composition by their influence on moisture and light availability. Within the small range of significant overstory and midstory changes noted here (e.g., proportion of pine to hardwood BAs and shrub density), understory participants were not affected at detectable levels (i.e., no significant treatment differences with richness, diversity, or prevalent species IVs). It must be recognized that check plots were also highly impacted by harvesting, burning, and pine planting, limiting comparisons to other forest stand types.

The detected residual effects on perennial plants probably resulted from selective species control by the test herbicides. This is evident with the reductions in *Vaccinium* spp., *Vaccinium stamineum*, *Lespedeza bicolor*, and *Vitis rotundifolia* by selected herbicide treatments relative to the check. Selective responses of *Vaccinium* spp. after the same herbicides tested here have been reported by others (Zutter and Zedaker 1988; Boyd et al. 1995), specifically increases in abundance after hexazinone use. Likewise, the significant changes in overstory composition could be interpreted as herbicide selectivity effects (i.e., decreases in *Quercus stellata* on hexazinone-liquid plots relative to the check plots) and enhanced growth of released species after treatments (i.e., *Pinus taeda* and *Diospyros virginiana* increases on treated plots relative to check plots). Significant overstory increases in *Pinus taeda* and *Diospyros virginiana* were also detected on nearby herbicide release sites (Boyd et al. 1995), while others have reported decreases in *Quercus stellata* after hexazinone applications (Zutter and Zedaker 1988). Harrington and Edwards (1996) also found similar reductions in *Prunus serotina* after hexazinone treatments in Georgia as reported here.

The differences in overstory and understory composition that were found may have ecological implications. For example, *Diospyros virginiana*, *Prunus serotina*, and *Vaccinium* spp. can be important soft mast producers for wildlife species, given maturity and suitable conditions for fruit production. The treatments did not greatly affect N-fixing legumes; only the absence of the exotic invasive species *Lespedeza bicolor* was noted after hexazinone-liquid treatment. The apparent control of this very invasive exotic plant by hexazinone liquid deserves further testing. In the companion study on herbicide release (Boyd et al. 1995), legume abundance was apparently enhanced by lower release-rate applications of glyphosate and the more recently registered imazapyr herbicide (not tested here).

Studies that have examined diversity effects at shorter time intervals have detected decreased diversity shortly after forest herbicide treatment. Others have documented decreases in herbaceous plant biomass and species richness after hexazinone treatments in a loblolly pine plantation, but those differences disappeared by the end of the second growing season (Blake et al. 1987; Zutter and Zedaker 1988). In our study, the 11-year period between treatment and sampling allowed regrowth and reinvasion by species that were impacted by the original herbicide treatments.

The justification for site-preparation treatments has been based on anticipated gains in the growth of crop trees. How long lasting this effect may be is rarely measured. In this study, stand structure at age 11 had been altered by a shift in the proportion of pines to hardwoods, with hexazinone liquid having half the hardwood BA as the check but twice the pine BA. This major shift from pine-hardwood dominance to pine dominance occurred without a significant change in diversity. Likewise, mean stem numbers of nonarborescent woody plants significantly varied fourfold by treatment, but again, overall shrub richness and diversity were not significantly influenced.

Biodiversity conservation in intensively managed forested regions must depend (at least partially) on species growing in tree plantations and their margins, stream management zones, and rights-of-way. We have shown that herbicide use can result in stands as rich in species and as diverse as those only prescribed burned before pine planting. Slight changes in composition could be achieved by using different herbicides to create stands of varying composition across plantation-dominated landscapes. Selective applications to individual plants could be another refinement for enhancing crop tree growth while conserving floristic richness.

Forest management techniques affect biodiversity in a variety of ways (Burton et al. 1992; Hansen et al. 1991), but specific information on biodiversity effects often is not yet available. This study addressed the longer term effects of herbicide site-preparation treatments on plant diversity, richness, and composition. The floristic diversity of increasingly prevalent pine plantations in the mid-South was not significantly affected by short-term herbicide use, although structural composition and perennial species presence were changed.

Acknowledgments

This manuscript has been greatly improved by the review comments of Bruce R. Zutter, James D. Haywood, and Timothy B. Harrington. We thank Scott Gunn and Patrick Murphy for assistance in identifying plant species, Michael Lelong of the University of South Alabama for determining identities of *Dichanthelium* spp., Jenny Novak for calculating diversity indices, and Lise Petty for assistance with data entry and analysis. Mike Davis, Lise Petty, Hardin Waddle, and Deanna Weatherford provided valued assistance in collecting herbaceous species data. We acknowledge the invaluable contributions of the plot establishment and overstory assessment teams: Erwin Chambliss, David Combs, Richard Wood, and Bruce Abrahams. Erwin Chambliss also contributed greatly to data analyses.

References

Abacus Concepts, Inc. 1989. SuperANOVA. Abacus Concepts, Inc., Berkeley, Calif.

Alig, R.J., Hohenstein, W.G., Murray, B.C., and Haight, R.G. 1990. Changes in area of timberland in the United States, 1952–2040, by ownership, forest type, region, and state. USDA For. Serv. Gen. Tech. Rep. No. SE-64.

Anonymous. 1996. Forest resource highlights with a Georgia emphasis. D.B. Wamell School of Forest Resources and College of Agricultural and Environmental Sciences, University of Georgia, Athens.

Blake, P.M., Hurst, C.A., and Terry, T.A. 1987. Responses of vegetation and deer forage following application of hexazinone. South. J. App. For. 11: 176-180.

Boyd, R.S., Freeman, J.D., Miller, J.H., and Edwards, M.B. 1995. Forest herbicide influences on floristic diversity seven years after broadcast pine release treatments in central Georgia, U.S.A. New For. 10: 17-37.

Burton, P.J., Balisky, A.C., Coward, L.P., Cumming, S.G., and Kneeshaw, D.D. 1992. The value of managing for biodiversity. For. Chron. 68: 225-237.

Butterfield, R.P. 1995. Promoting biodiversity: advances in evaluating native species for reforestation. For. Ecol. Manage. 75: 111-121.

Dubois, M.R., McNabb, K., and Straka, T.J. 1997. Costs and cost trends for forestry practices in the South. For. Landowner, 56: 7-13.

Faith, D.P., Walker, P.A., Ive, J.R., and Belbin, L. 1996. Integrating conservation and forestry production: exploring trade-offs between biodiversity and production in regional land-use assessment. For. Ecol. Manage. 85: 251–260.

Fenger, M. 1996. Implementing biodiversity conservation through the British Columbia Forest Practices Code. For. Ecol. Manage. 85: 67-77.

Hansen, A.J., Spies, T.A., Swanson, EJ., and Ohmann, J.L. 1991. Conserving biodiversity in managed forests. BioScience, 41: 382-392.

Harper, F. (Editor). 1958. The travels of William Bartram, naturalist's edition. Yale University Press, New Haven, Conn.

Harrington, T.B., and Edwards, M.B. 1996. Structure of mixed pine and hardwood stands 12 years after various methods and intensities of site preparation in the Georgia Piedmont. Can. J. For. Res. 26: 1490-1500.

Kartesz, J.T. 1994. A synonymized checklist of the vascular flora of the United States, Canada, and Greenland. Vol. 1. Checklist. Timber Press, Portland, Oreg.

Kimmins, J.P. 1997. Biodiversity and its relationship to ecosystem health and integrity. For. Chron. 73: 229-232.

Krochmal, A, and Kologiski, R. 1974. Understory plants in a mature loblolly pine plantation in North Carolina. USDA For. Serv. Res. Note SE-208.

Magurran, A.E. 1988. Ecological diversity and its measurement. Princeton University Press, Princeton, N.J.

Miller, J.H. and Edwards, M.B. 1995. Singly applied herbicides for site preparation and release of loblolly pine in Central Georgia. In Proceedings of the Eighth Biennial Southern Silvicultural Research Conference, l-3 Nov. 1994, Auburn, Ala. M.B. Edwards. USDA For. Serv. Gen. Tech. Rep. SRS-l. pp. 573-580.

Miller, J.H., Zutter, B.R., Zedaker, S.M., Edwards, M.B., Haywood, J.D., and Newbold, R.A. 1995. Early plant succession in loblolly pine plantations as affected by vegetation management. South. J. Appl. For. 19: 109-126.

Minogue, PJ., Cantrell, R.L., and Griswold, H.C. 1991. Vegetation management after plantation establishment. In Forest regeneration manual. Kluwer Academic Publishers, Dordrecht, the Netherlands. pp. 335-358.

Noble, I.R., and Dirzo, R. 1997. Forests as human-dominated ecosystems. Science (Washington, D.C.), 277: 522-525.

Peet, R.K., and Allard D.J. 1993. Longleaf pine vegetation of the Southern Atlantic and Eastern Gulf Coast regions: a preliminary classification. Proc. Tal1 Timbers Fire Ecol. Conf. **18: 45-81.**

Pehl, C.E., and Brim, R.L. 1985. Forest habitat regions of Georgia, Landsat IV imagery. Ga. Agric. Exp. Stn. Spec. Publ. 31.

Zar, J.H. 1996. Biostatistical Analysis. Prentice-Hall, Englewood Cliffs, N.J.

Zutter, B.R., and Miller, J.H. 1998. Eleventh-year response of loblolly pine and competing vegetation to woody and herbaceous plant control on a Georgia flatwood site. South. J. Appl. For. 22: 88-95.

Zutter, B.R., and Zedaker, S.M. 1988. Short-term effects of hexazinone applications on woody species diversity in young loblolly pine (*Pinus taeda*) plantations. For. Ecol. Manage. 24: 183-189.

Appendix

Table Al. Species encountered in study plots grouped by growth form category and nomenclature by Kartesz (1994).

Arborescent growth form

Acer barbatum Michx.
Acer rubrum L.
Albizia julibrissin Durz.
Carya glabra (P. Mill.) Sweet
Carya tomentosa (Poiret) Nutt.
Celtis tenuifolia Nutt.
Cercis canadensis L.
Chionanthus virginicus L.
Cornus florida L.
Diospyros virginiana L.
Fraxinus pennsylvanica Marsh.
Zlex decidua Walter
Zlex opaca Ait.
Juniperus virginiana L.
Liquidambar styraciflua L.
Liriodendron tulipifera L.
Malus angustifolia (Ait.) Michx.
Melia azedarach L.
Morus rubra L.
Nyssa sylvatica Marsh.
Pinus taeda L.
Prunus americana Marsh.
Prunus serotina Ehrh.
Quercus alba L.
Quercus coccinea Muenchh.
Quercus falcata Michx.
Quercus laurifolia Michx.
Quercus myrtifolia Willd.
Quercus nigra L.
Quercus rubra L.
Quercus stellata Wangenh.
Quercus velutina Lam.
Sassafras albidum (Nutt.) Nees
Ulmus alata Michx.

Woody nonarborescent growth form

Aesculus pavia L.
Aralia spinosa L.
Asimina parviflora (Michx.) Duna1
Baccharis halimifolia L.
Ligustrum sinense Lour.
Myrica cerifera L.
Prunus angustifolia Marsh.
Rhus glabra L.

Table Al (*continued*).

L.
Crataegus flabellata (Spach) Kirchn.
Crataegus flava Ait.
Crataegus marshallii Egglest.
Crataegus spathulata Michx.
Crataegus uniflora Muenchh.
Euonymus americanus L.
Frangula caroliniana (Walt.) Gray
Gordonia lasianthus (L.) Ellis
Rhus copallinum L.
Rosa carolina L.
Sideroxylon lanuginosum Michx.
Vaccinium arboreum Marsh.
Vaccinium corymbosum L.
Vaccinium elliottii Chapman
Vaccinium stamineum L.
Viburnum rufidulum Raf.

Grass–grasslike growth form

Andropogon gyrans Ashe
Andropogon virginicus L.
Chasmanthium laxum (L.) Yates
Chasmanthium laxum var. sessiliflorum (Poir.) L. Clark
Cyperus lancastriensis Porter ex Gray
Danthonia sericea Nutt.
Dichanthelium spp. (A.S. Hitchc. & Chase) Gould
Dichanthelium acuminatum (Sw.) Gould & C.A. Clark
Dichanthelium commutatum (J.A. Schultes) Gould
Dichanthelium dichotomum vas. dichotomum (L.) Gould
Dichanthelium dichotomum var. tenue (Muhl.) Gould & C.A. Clark
Dichanthelium laxiflorum (Lam.) Gould
Dichanthelium scabriusculum (Ell.) Gould & C.A. Clark
Dichanthelium sphaerocarpon (Ell.) Gould
Juncus dichotomus Ell.
Paspalum notatum Fluegge
Setaria parviflora (Poir.) Kerguelen
Setaria viridis (L.) Beauv.
Unknown grass 1
Unknown grass 2
Unknown grass 3

Forb growth form: legumes

Chamaecrista fasiculata (Michx.) Greene
Clitoria mariana L.
Crotalaria purshii DC.
Crotalaria sagittalis L.
Desmodium canescens (L.) DC.
Desmodium paniculatum (L.) DC.
Desmodium strictum (Pursh) DC.
Galactia elliottii Nutt.
Lespedeza bicolor Turcz.
***Lespedeza** cuneata* (Dum.-Cours.) G. Don
Lespedeza hirta (L.) Homem.
Lespedeza procumbens Michx.
*Lespedeza **repens*** (L.) W. Bart.
Lespedeza stuevei Nutt.
Mimosa quadrivalvis L.
Tephrosia spicata (Walt.) Torr. & Gray

Forb growth form: nonlegumes

Agrimonia microcarpa Wallr.
Ambrosia artemisiifolia L.
Arenaria caroliniana Walter
***Asclepias** viridiflora* Raf.
Bidens aristosa (Michx.) Britt.
Brickellia eupatorioides var. eupatorioides (L.) Shinners
Capsella bursa-pastoris (L.) Medik.
Capsicum annuum L.
Carduus spp. L.
Chaerophyllum procumbens (L.) Crantz
Chrysopsis gossypina spp. *gossypina* (Michx.) Ell.
Commelina erecta L.
Coreopsis major Walter
Duchesnea indica (Andrz.) Focke.
Elephantopus carolinianus Raeusch.
Erechtites hieracifolia (L.) Raf. ex DC.
*Erigeron **strigosus*** Muhl. ex Willd.
Eupatorium spp. L.
Eupatorium glaucescens Ell.
Eupatorium hyssopifolium L.
Euphorbia pubentissima Michx.
Fragaria virginiana Duchesne
Galium spp. L.
Galium circaezans Michx.
Galium pilosum Ait.
Galium uniflorum Michx.
Helianthus ×*laetiflorus* Pers.
Houstonia longifolia var. tenuifolia (Nutt.) Wood
Ipomoea lacunosa L.
***Krigia** virginica* (L.) Willd.
Lobelia puberula Michx.
Lysimachia lanceolata Walt.
***Manfreda** virginica* (L.) Salisb. ex Rose
Minuartia caroliniana (Walt.) Mattf.
Mitchella repens L.
Oldenlandia uniflora L.
Oxalis dillenii spp. *filipes* (Small) Eiten
Passiflora incarnata L.
Passiflora lutea L.
Physalis pubescens L.
Pityopsis graminifolia (Michx.) Nutt.
Plantago spp. L.
Polygala grandiflora Walt.
Rumex spp. L.
Rumex hastatulus Baldw.
Silphium asteriscus L.
Solanum carolinense L.
Solidago caesia L.
Solidago canadensis var. scabra Torr. & Gray
Solidago odora Ait.
Spiranthes praecox (Walt.) S. Wats.
Tragia urens L.

Table A1

Gamochaeta purpurea (L.) Cabrera
Geranium carolinianum L.
Helianthemum carolinianum (Walt.) Michx.
Helianthemum georgianum Chapman
Helianthus spp. L.
Tragia urticifolia Michx.
Triodanis perfoliata var. *bifloria* (Ruiz. & Pavòn) Bradley
Verbena rigida Spreng.
Vernonia acaulis (Walt.) Gleason
Viola spp. L.

Semiwoody growth form

Chimaphila maculata (L.) Pursh
Hypericum hypericoides (L.) Crantz
Rubus spp. L.

Woody vine growth form

Ampelopsis arborea (L.) Koehne
Berchemia scandens (Hill) K. Koch
Bignonia capreolata L.
Campsis radicans (L.) Seem. ex Bureau
Cocculus carolinus (L.) DC.
Gelsemium sempervirens St.-Hil.
Lonicera japonica Thunb.
Parthenocissus quinquefolia (L.) Planchon
Smilax bona-nox L.
Smilax glauca Walt.
Smilax rotundifolia L.
Toxicodendron radicans (L.) Kuntze
Trachelospermum difforme (Walt.) Gray
Vitis rotundifolia Michx.

Fern growth form

Asplenium platyneuron (L.) BSP
Botrychium spp. Sw.