Appalachian Surface Mine Reforestation Techniques:
Effects of Grading, Cultural Treatments and Species Selection

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ABSTRACT

Surface mining for coal in the Appalachian region has removed over 0.6 million Ha of mixed mesophytic forest. Successful reforestation would be beneficial, but questions remain concerning application of reclamation and reforestation methods on operational scales. Four experiments were performed testing these methods on newly reclaimed and previously reclaimed, but unused, former mines. On newly reclaimed sites, loose grading during reclamation reduced erosion and increased plant community diversity compared to smooth grading. Seeding only annual ryegrass (*Lolium multiflorum*) for erosion control, along with tree planting, increased plant community diversity and improved survival and growth of hybrid American chestnut (*Castanea dentata x Castanea mollissima*), compared to conventional seeding. Surface water infiltration was positively correlated with herbaceous ground cover. On older mines, subsoil ripping to alleviate compaction improved tree survival and growth, in some cases, after five growing seasons. Of the three species groups planted, including Eastern white pine (*Pinus strobus*), mixed native hardwoods had the best survival and hybrid poplar (*Populus deltoides x Populus trichocarpa*) produced the most biomass. Hybrid American chestnuts survived and grew better when planted as bare-root seedlings than when planted as ungerminated nuts in tree tubes, demonstrating the potential for planting bare-root chestnut seedlings along with other species when reforesting reclaimed surface mines. This can aid in restoring American chestnut, functionally extinct since the blight (*Cryphonectria parasitica*), to its former range. These cultural practices can be employed to accelerate reforestation of mined lands, but many questions remain about their capability to fully restore ecosystem structure and processes.

DEDICATION

This work is dedicated to those unborn children of Appalachia who will one day depend on the land as we have left it for them.

ACKNOWLEDGEMENTS

My sincere thanks to all who made this research project possible: Thank you to my Co-advisors Jim Burger and Carl Zipper for the opportunity to work on this topic at Virginia Tech and to them and Lee Daniels for endless aid in the process of this research. Thank you to Dan Evans who worked side-by-side with me for the majority of the work in the field, and also to the others who worked in the field with me: Rachel Grant, Matt Hepler, Chris Jackson and Zach Addington and those fellow graduate students who helped plant our first American chestnut trial: Charley Kelley, Pipa Elias and Scott DeBruyne. Thank you to Eddie Clapp of the Red River Coal Company for help in arranging logistics and allowing us to monitor our sites continually. Thank you also to Alpha Natural Resources in that regard. Thank you to David Mitchem for laboratory support and for archiving much of the past data that proved critical to aspects of this project. Thank you to those who funded this project: the Powell River Project, the Appalachian Regional Commission, the U.S. Office of Surface Mining and the American Chestnut Foundation. Thank you to Rick Williams and Williams Forestry for planting the trees on many of our research sites. Thank you to all of the staff and reviewers at the American Society of Mining and Reclamation who helped to shape these manuscripts as they developed. Thank you to all of the former graduate students whose work this project built on: Chad Casselman, Jason Rodrigue, Beyhan Amichev and others. All photos is this document were taken by the author unless otherwise noted. And finally, thank you to my loving friends and family for the support and patience as I have thrown myself in to this for the past three years.

ATTRIBUTION

The manuscripts herein were edited and co-authored by James A. Burger, Professor Emeritus, Department of Forest Resources and Environmental Conservation, Carl E. Zipper, Associate Professor, Department of Crop and Soil Environmental Sciences and Daniel M. Evans, Research Associate, Department of Forest Resources and Environmental Conservation; all of Virginia Polytechnic Institute and State University. Daniel M. Evans assisted with much of the field work, contributed to experimental and sampling designs and helped to edit the manuscripts for Chapters 2, 3 and 4.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER I. INTRODUCTION

Surface mining for coal is removing vast areas of forests and is re-shaping mountains in Appalachia. These lands cannot be perfectly restored to their pre-mining condition in the foreseeable future, but current reclamation practices can be improved. The goal of the research described in this thesis was to investigate potential methods of reclamation that might improve the condition of post-mining forest ecosystems. Forest improvement can create societal benefits by enhancing ecosystem structure, functions and services. The experiments described here were intended to determine effects of specific management actions on forest restoration success. This thesis concerns the initial years of forest establishment in two general, common cases: 1) lands that are being reclaimed as forests immediately following active mining, and 2) lands that were reclaimed in the past for non-forest usage but that are now being rehabilitated as forests. Chapter 2 addresses the former situation and Chapter 3 the latter. Chapter 4 looks at one unique opportunity that mined land reforestation offers: restoring American chestnut (*Castanea dentata*) to the heart of its native range.

The importance of successfully rehabilitating Appalachian ecosystems following surface coal mining cannot be overstated. The extent of this surface mining in the region, past and present, is not currently known with precision, but is well over half a million hectares. That figure will increase for the foreseeable future. It is clear from the past that ecosystems are severely impaired following this form of mining and that they do not return to their former form and function either on their own or with any amount of human intervention heretofore attempted. Certainly there are practices that are better than others, and these need further development. Nevertheless, it must first be recognized that some things are irreplaceable and cannot be fixed after the fact. It should not be pretended that even the best reclamation produces a landscape that is the same as what was there before, and this thesis does not make such a pretense. This thesis is about developing reclamation techniques to achieve improvements compared to the results of past practices. Improvement here is defined as achieving better reclaimed mined land productivity, greater survival and growth rates for trees, the succession of native plants, greater diversity of plant communities and increased resistance of the landscape to soil loss through erosion.

It has become clear over the last few decades that excessive compaction and herbaceous plant competition commonly found on mined sites are serious impediments to the survival and growth of trees. Further study was needed on the effects of the proposed remedies to these problems, which included loose grading, subsoil ripping, planting of non-competitive groundcovers, and the use of herbicides, fertilization and tree protection tubes. Chapter 2 contains the results of an experiment that shows how avoiding those two major problems in the first place using the Forestry Reclamation Approach (Burger et al., 2005) affects tree survival and growth for native species assemblages and how it affects other problematic ecosystem processes such as soil erosion on steeply sloped sites, surface water infiltration and herbaceous plant succession. Chapter 3 is a report on how remediating these problems where they exist affects the survival and growth of three forest types on flat sites across a spectrum of soil parent materials. Chapter 4 is a report on methods applicable to either situation for improving American chestnut performance. All three of these studies also report on species selection effects on tree and stand performance. These studies were conducted with the intent that they would contribute to improvement and better understanding of forest restoration practices.

These experiments showed that loose grading was a superior choice to smooth grading for reducing erosion and improving biodiversity, and that it can be achieved with less effort than smooth grading. Subsoil ripping helped alleviate the effects of compaction on trees, but inconsistently and at great additional effort, indicating that compaction should be avoided in the first place. Planting only annual ryegrass as a groundcover was found to be a superior choice for ecological reasons and improved tree performance when compared to two other groundcover mixes currently used. Hybrid poplar (*Populus deltoids x Populus trichocarpa*) was found to have superior growth compared to other species groups on rehabilitated mined sites. Hybrid poplar is a promising choice for woody biomass plantations on mined lands. Successful establishment of such plantations would lessen demands on native forests to satisfy future woody biomass demands. American chestnuts were found to become established on mine sites as well as other hardwood species and performed best when planted as bare-root seedlings, similar to how other hardwoods are planted. This indicates that their blight-resistant hybrids can be included in planting mixes for future reforestation efforts.

The effort now to preserve and to restore these Appalachian lands is an effort for a vast future. Today, we have the means to improve the health and livelihoods of all generations who are yet to come to be in this place, but this opportunity may not always exist. Forests and all they provide are a foundation for a healthy economy and ecology both now and after the coal industry has moved on. Effective forest preservation where mining can be avoided, coupled with effective re-forestation where it cannot, is necessary for creating a future for people in Appalachia worthy of their past and present cultural richness.

Literature Cited

Burger, J., Graves, D., Angel, P., Davis, V., Zipper, C. 2005. The Forestry Reclamation Approach. Forest Reclamation Advisory No. 2. U.S. Office of Surface Mining. 4pp.

CHAPTER II. SOIL GRADING AND SEEDING EFFECTS ON FOREST RESTORATION AFTER SURFACE COAL MINING

Abstract. Recent experience suggests that native Appalachian hardwood trees can be successfully established on coal surface mining sites if appropriate reclamation techniques are used. The Forestry Reclamation Approach (FRA) is a set of mine reclamation techniques developed for that purpose. Questions remain regarding how soil surface grading and choice of herbaceous vegetation during mine reclamation affect tree survival, soil erosion and plant succession. An experiment was begun in the spring of 2008 with the goal of evaluating effects of grading and hydroseeding treatments prescribed by the FRA on reforestation success. Three steep (approximately 60% slopes) reclaimed mine sites were prepared in the coalfield of southwest Virginia. Half of each site was smooth-graded using conventional grading practices that often cause compaction of surface soil. The other half was loose-graded as per FRA recommendations. Within each grading treatment at each site, one third of the area was seeded with a conventional herbaceous vegetation mix that included competitive grasses and legumes; one third with a tree-compatible herbaceous mix comprised of less competitive grasses and legumes; and one third with only annual ryegrass. All experimental areas were planted with the same mix of native hardwood trees. Tree survival and surviving tree heights were similar on the loose (71%, 100 mm) and compacted (70%, 121 mm) grading treatments, as well as on the conventional (65%, 97 mm), tree-compatible (71%, 114 mm), and annual ryegrass (75%, 119 mm) seeding treatments. Non-planted herbaceous species richness was greatest on the annual ryegrass treatment (12 volunteer species), suggesting this revegetation practice creates the most favorable conditions for natural succession. Soil erosion rates were significantly higher on the smooth treatment (-8mm soil surface change) than on the loose treatment (+10 mm soil surface change) over the course of two years. The annual ryegrass treatment produced significantly less ground cover (55% total) after two years than the conventional ground cover treatment (83% total), but soil erosion was not increased. Loose-grading and planting only annual ryegrass as a groundcover are recommended as future practices to improve reforestation success.

Additional Key Words: compaction, grading, ground cover, reforestation, native hardwoods, reclamation, mine land succession

1. Introduction

1.1. Background and Rationale

Recent progress has been made in the science and implementation of the Forestry Reclamation Approach (FRA), which is a guideline used for revegetating lands disturbed by surface mining for coal in the Appalachian region. The FRA is a mine reclamation protocol designed to improve the establishment of high-value hardwoods, increase the survival and growth of planted trees, and accelerate forest succession (Burger et al., 2005a). The FRA has been approved by surface coal mining regulatory agencies (Angel et al., 2005) and can be implemented more cost-effectively than traditional mine reforestation approaches prescribing extensive soil grading and dense herbaceous cover (Burger and Zipper, 2002). The FRA is intended to restore forested ecosystems on reclaimed mine sites that produce economically valued forest products such as harvestable timber while providing ecosystem services such as production of clean water and air, sequestration of atmospheric carbon and provision of wildlife habitat (Angel et al., 2005).

Key aspects of the FRA include maintaining a loose soil surface and using tree-compatible ground covers. Maintaining loose soil surfaces helps planters install trees at the proper depth, allows rain to readily infiltrate the soil, reduces erosive surface flows, increases soil moisture availability, improves soil aeration, and facilitates root growth by the planted trees. Low compaction grading is less expensive than conventional grading practices because it requires fewer passes with grading equipment (Sweigard et al., 2007). Numerous studies have demonstrated that high soil bulk density, which occurs as a result of excessive soil compaction, has a negative effect on tree growth (Torbert and Burger, 1990; Andrews et al., 1998; Torbert and Burger, 2000; Rodrigue and Burger, 2004; Jones et al., 2005). Therefore, tree survival and growth are expected to be higher on mine sites with loose soil surfaces than on sites prepared using traditional methods that employ heavy grading (Torbert and Burger, 1990).

Traditional coal-mine reclamation methods have employed fast-growing grasses and legumes in a manner intended to establish dense vegetative cover rapidly and to control soil erosion. Excessive herbaceous competition, however, impairs survival and growth of planted trees on mine sites, as occurs on natural soils (Davidson et al., 1984). Several studies have found that herbaceous vegetation control aids establishment of planted trees on coal mine sites (Chaney et al., 1995; Ashby, 1997; Torbert et al., 2000; Burger et al., 2005b). Hence, the FRA emphasizes establishment of low density, low-growing herbaceous vegetation for the purpose of minimizing soil moisture competition and allowing sufficient light penetration for tree seedling growth (Burger et al., 2008, 2009).

Low density, low-growing herbaceous vegetation minimizes soil moisture competition and allows sufficient light penetration for tree seedling growth. Because of the vigorous nature of many forage species used for hay or pasture applications, most are not conducive to tree seedling establishment and growth. These species include Kentucky-31 tall fescue (*Festuca arundinacea*), red clover (*Trifolium pratense*) and sweet clover (*Melilotus alba*). Less-competitive legumes, considered to be more compatible with tree survival and growth and commonly recommended for use in the FRA, include birdsfoot trefoil (*Lotus corniculatus*) and white or ladino clover (*Trifolium repens*), while recommended annual grasses include foxtail millet (*Setaria italica*) and annual ryegrass (*Lolium multiflorum* Lam.). Perennial grasses that are considered "tree compatible" include perennial ryegrass (*Lolium perenne*), timothy *(Phleum pratense)* and orchardgrass (*Dactylis glomerata*) on steep slopes. Weeping lovegrass (*Eragrostis curvla*) is a tall grass that is useful on low soil pH sites at low seeding rates (Burger and Zipper, 2002).

1.2. Goals and Objectives

This study was conducted to assess the effects of surface grading intensity and herbaceous seeding practices on forest ecosystem re-establishment on active mining operations.

We tested the following hypotheses:

- Increased intensity of grading and tracking by mining equipment reduces the survival of planted native hardwood trees and accelerates soil erosion.
- Increased levels of competitive herbaceous ground cover from seeding practices reduce the survival of planted native hardwood trees and hinder the recruitment of native vegetation.

Testing these hypotheses will allow refinement and improvement of the FRA prescriptions with a corresponding improvement in survival of planted trees and accelerated forest succession.

This paper reports second-year results for a study that was described after the first year by Fields-Johnson et al. (2009).

2. Methods and Materials

2.1. Overview of Treatments and Design

Three experimental sites (blocks) were established by cooperating mining firms on active mining sites in southwestern Virginia (Figures 1-5). At each site, two grading treatments and three ground cover vegetation treatments (Figures 6-8) were installed as a 2 x 3 factorial randomized block design, resulting in six treatment combinations and 18 total treatment plots. Each block was approximately 2.5 ha and the treatment plots averaged approximately 0.4 ha in size, although individual treatment plot sizes varied from this average. The two grading treatments were 1) smooth-grading with tracking-in (i.e. covering the surface with dozer cleat marks) or back-blading (dragging the bulldozer blade backwards across the site to create a smooth surface); and 2) loose-grading with a single dozer pass. Three seeding treatments were sown on each grading treatment plot: 1) a conventional mix of herbaceous species intended to create >90% ground cover within the first few months of a growing season after seeding, 2) a tree-compatible mix (designated as "Powell River Project mix" in Fields-Johnson et al., 2009) intended to create a moderate level of initial ground cover while eventually covering the soil surfaces fully, and 3) annual ryegrass, intended to create the lowest level of ground cover by planted species (Table 1). All experimental plantings were established on coal-mined areas in the coalfield of southwestern Virginia, USA. Prior to mining, the areas were occupied by the mixed mesophytic forest type. The area gets approximately 119 cm of precipitation per year and is in plant hardiness zone 6 with average yearly minimum temperatures of -23°C to -18°C.

The conventional ground cover treatment seed mix prescription is one that is commonly applied by a commercial hydroseeding firm on coal mining operations in southwestern Virginia. The tree-compatible mix prescription has been developed by the researchers using a process of trial, error and observation of various herbaceous species. Following final grading of mine spoil,

Figure I.1. Location of Blocks 1 and 2 near Norton, Virginia.

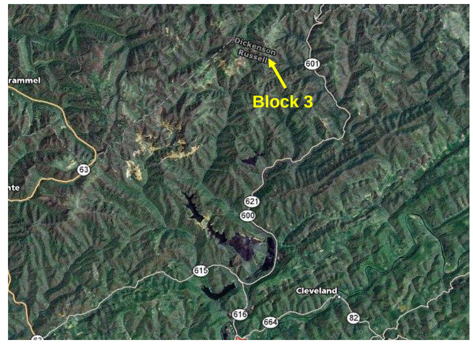


Figure I.2. Location of Block 3 near Carbo, Virginia.

Figure II.3. Block 1, winter 2007-2008.

Figure II.4. Block 2, winter 2007-2008.

Figure II.5. Block 3, winter 2007-2008.

Figure II.6. Conventional, Aug. 2008.

Figure II.7. Tree-compatible, Aug. 2008.

Figure II.8. Annual ryegrass, Aug. 2008.

Table II.1. Prescribed seed and mulch mixtures for ground cover treatments.

Annual Ryegrass Only	Rate
Seed Mix:	(kg ha^{-1})
Annual ryegrass (*Lolium multiflorum*)	22
Wood Cellulose Fiber	1680
Tree-Compatible Mix	Rate
Seed Mix:	(kg ha^{-1})
Annual ryegrass (*Lolium multiflorum*)	22
Perennial ryegrass (*Lolium perenne*)	11
Timothy (*Phleum pretense*)	6
Birdsfoot trefoil (*Lotus corniculatus*)	6
Ladino clover (*Trifolium repens*)	3
Weeping Lovegrass (*Eragrostis curvula*)	2
Wood Cellulose Fiber	1680
Conventional Mix	Rate
Seed Mix:	(kg ha^{-1})
Rye grain (*Secale cereale*)	34
Orchardgrass (*Dactylis glomerata*)	22
Perennial ryegrass (*Lolium perenne*)	11
Korean lespedeza (*Lespedeza cuneata*)	6
Birdsfoot trefoil (*Lotus corniculatus)*	6
Ladino clover (*Trifolium repens*)	6
Redtop (*Agrostis gigantea)*	3
Weeping lovegrass (*Eragrostis curvula*)	2
Wood Cellulose Fiber	1680

hydroseeding was performed by a commercial contractor using operational procedures under supervision by the mining firms but using our prescriptions. Fertilizer was prescribed for inclusion in all hydroseeding mixtures at an approximate rate of 22 kg ha^{-1} nitrogen (N), 68 kg ha^{-1} phosphorous (P) and 18 kg ha^{-1} potassium. This fertilization prescription for reforestation has been developed by trial and error as a way to provide trees ample P without causing excessive herbaceous growth with large amounts of N. Block 1 was hydroseeded in the fall of 2007, Block 2 was hydroseeded in the winter of 2007-2008, and Block 3 was hydroseeded in early spring of 2008. Mining was completed for these sites at different times, hence the staggered hydroseeding schedule.

All sites were planted with the same mix of native trees (Table 2) by a commercial tree-planting contractor in mid-January of 2008. The tree species mix prescription has also been developed by trial, error and observation and included 205 trees ha^{-1} for each of seven commercially valuable hardwoods, lesser rates for two other commercial species, and low rates for several species of specific wildlife value. The planting contractors modified the actual planting rates based on available nursery stock and deviated somewhat from the planting prescription. These trees were all planted in early 2008 as one-year-old, bare-root seedlings without supplemental watering or fertilization. The overall tree survival rate in 2008 was 39% (Fields-Johnson et al. 2009), a rate considered unacceptably low by reclamation standards. As a result, all sites were re-planted in January of 2009 to bring them back to full stocking (Table 2). Photographs and maps for treatments and block locations can be found in Fields-Johnson et al. (2009).

Table II.2. 2008 planting prescription and actual survival rates and 2009 re-planting prescription for trees to be planted alongside surviving trees to replace trees lost to mortality.

	2008 Planting Prescription	**2008 Survival**		**2009 Re-planting Prescription**
Species	**(trees ha^{-1})**	**(trees ha^{-1})**	**Rate[a]**	**(trees ha^{-1})**
Crop Tree Species				
White Ash (*Fraxinus americana*)	205	138	67%	67
White Oak (*Quercus alba*)	205	119	58%	86
Sugar Maple (*Acer saccharum*)	205	28	14%	177
Black Cherry (*Prunus serotina*)	205	93	45%	112
Red Oak (*Quercus rubra*)	205	88	43%	117
Chestnut Oak (*Quercus prinus*)	205	67	33%	138
Black Oak (*Qurecus velutina*)	205	65	32%	140
Yellow-poplar (*Liriodendron tulipifera*)	124	33	27%	91
Wildlife and Nurse Tree Species				
Gray Dogwood (*Cornus racemosa*)	54	27	50%	27
Red Mulberry (*Morus rubra*)	25	12	49%	13
Redbud (*Cercis canadensis*)	54	27	50%	27
White Pine (*Pinus strobus*)	91	6	6%	85
Shagbark Hickory (*Carya ovata*)	62	3	4%	59
Total	**1,845**	**728**	**39%**	**1,139**

[a] Calculated from prescribed planting rate, which may have differed from the actual rate.

2.2. Erosion Measurement

Erosion pins made of 1/2-inch (1.25 cm) diameter steel rebar were used to estimate loss and accumulation of surface soil. Nine erosion pins were driven into the ground to a depth of approximately 60 cm in each of the 18 treatment plots (Figure 9). Once installed, the sections of the pins that remained exposed were measured in height to the nearest mm on the uphill side. Thereafter, the pins were measured before the growing season (May) and after the growing season (November) of each year.

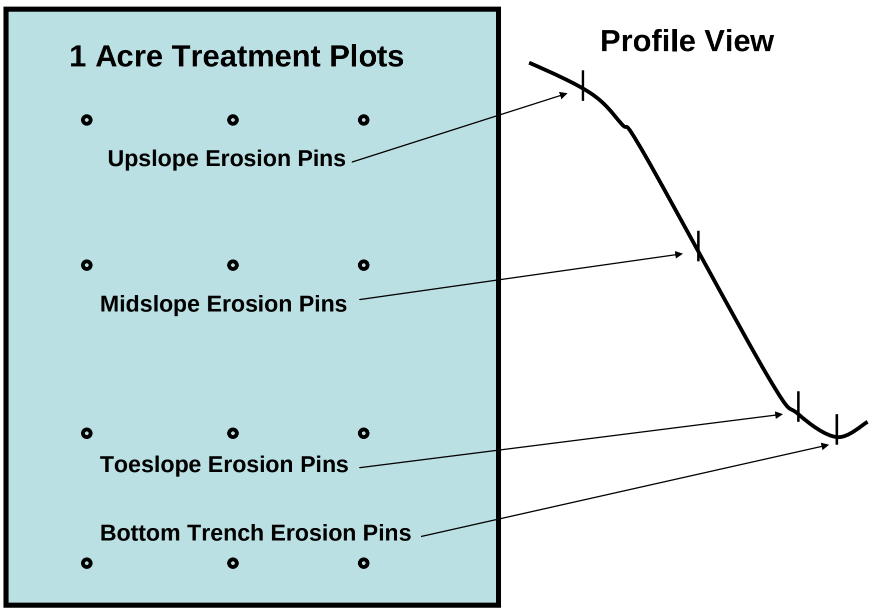


Figure II.9. Conceptual map of erosion pin (and soil sample) layout on plots. Bottom trench erosion pins were not used after the first year.

2.3. Surface Water Infiltration

Surface water infiltration was measured at set intervals along a transect across the midslope of each experimental block. Transects were begun by pacing upslope a random distance from a block corner. Sample locations were determined by measuring exactly 6.1 m with a measuring tape and staying on contour with an inclinometer set to zero degrees. Points were selected in this fashion from one end of a block to the other without regard for plot boundaries. A ring of

0.0562 m^2 was set on the ground without disturbing the vegetation or soil within the ring and 4 L of water applied on the inside of the ring with a perforated watering apparatus to saturate the soil. After the soil was allowed to drain for 10 minutes to reach its field capacity, the shortest time in which 4 L of water could be applied to the soil surface within the ring using the perforated watering apparatus such that the water was applied evenly throughout the ring, without causing runoff to the outside of the ring, was measured with a stopwatch. The percent ground cover, as visually estimated, slope angle of the macrotopography, microtopography, and treatment plot type within each circle were also noted for each sample location. Microtopographic features, on a scale of 0.1 – 10 m, included ridges, the tops of continuous convex features; ridge sides, the sides of convex features; flat slopes, even slopes with no relief apart from macrotopography; gullies, the bottoms of continuous concave features extending up and down slope; gully sides, the sides of continuous concave features extending up and down slope; and crevasses, open cracks in the surface connected to voids beneath. It was decided *a priori* that if the ground within the ring was made up totally of one continuous impermeable rock that the ring would be moved down slope until 25% of the ring was not over top of the rock. Data recorded at each point along the transect were treated independently and analyzed using regression and correlation. Data so recorded within discrete plots were aggregated by treatment plot for ANOVA analysis and mean separation to compare with plot-level data on erosion.

2.4. Soil Sampling and Testing

Soil samples were gathered for each of the 18 plots in the Spring of 2008. Each treatment-plot sample was composed of nine sub-samples, each taken one meter directly to the right of an erosion pin while facing upslope (Figure 9). For each subsample, the surface 5 cm of soil were removed in order to eliminate hydroseeding materials, and a 10-cm depth sample taken (i.e. 5 – 15 cm below the soil surface). Soil samples were air dried then sieved through a #10 screen to separate coarse and fine fractions. Fines were analyzed for pH, extractable cations, cation exchange capacity, soluble salts and organic carbon content (Soils data are in Fields-Johnson, 2009 and Appendix A). Coarse fragments (>2mm) were analyzed to determine the percent of each major rock type (weathered brown sandstone, unweathered gray sandstone, siltstone, black shale, and coal).

2.5. Vegetation Sampling

Five 0.02-ha, circular, woody-plant measurement plots were established on each treatment plot (Figure 10). All trees within measurement plots were enumerated by species and counted, and height was measured as distance from soil surface to highest live bud, in June and November of 2009. Volunteer trees were counted and measured the same as planted trees. 2009 survival was determined by dividing the number of trees counted in November by the number of trees in June. The 2009 growth increment was determined by subtracting the average June height from the average November height of surviving trees within each treatment plot. Trees were also surveyed using this method in November of 2008 and the species present at that time are noted here in aggregate with 2009 species found for the species list found in the results.

Additionally, four 0.0004-ha circular herbaceous plant plots were nested inside of each woody plant measurement plot (Figure 10). Within each herbaceous plot an ocular estimate of total living and dead herbaceous ground cover, expressed as a percent of ground area, was made in August of 2009 by comparing observed coverage with prepared diagrams of various coverage rates. This same procedure was used for individual herbaceous species within each herbaceous plot, recording their percent coverage of the entire ground area. Timothy and perennial rye were grouped together and all clovers were grouped together because of difficulty in differentiating them into ground cover classes in the field. Where individuals of different species overlapped vertically, the overlapped ground area was given to the overtopping individual. Woody species, though rarely falling within these plots, were ignored in herbaceous plots except in the case of newly sprouted plants that were determined to be red mulberry after they had already been counted. Species found only to be present in trace amounts of less than 1% ground coverage were given a value of 0.25% for data analysis purposes. Vegetation was observed with species noted also in 2008 and in June of 2009. Samples of all observed plant species were collected for identification and separated into “planted” versus “volunteered” categories in order to distinguish each species’ origin. If a species was on the prescription list or known to be a seed contaminant it was listed as planted. Species were also classified as either “native” vs. “alien”; and also as “invasive” or “non-invasive” according to their status listed by the Southeast Exotic Pest Plant Council (SE-EPPC, http://www.se-eppc.org/weeds.cfm). Diversity indices of herbaceous species were calculated for all treatment plots. Simpson’s Diversity Index (Simpson, 1949) was used as a measure of diversity weighted toward co-dominant species and was calculated as $1-\Sigma p_i^2$ where p_i is the proportion of each species’ groundcover within a plot to the total groundcover within a plot. Shannon’s Diversity Index (Shannon, 1948) was used as a measure of diversity weighted toward rare species and was calculated as $-\Sigma p_i \ln p_i$ where p_i is determined as above. Herbaceous species were also sampled using this method in August of 2008, with only species present noted here in aggregate with 2009 species.

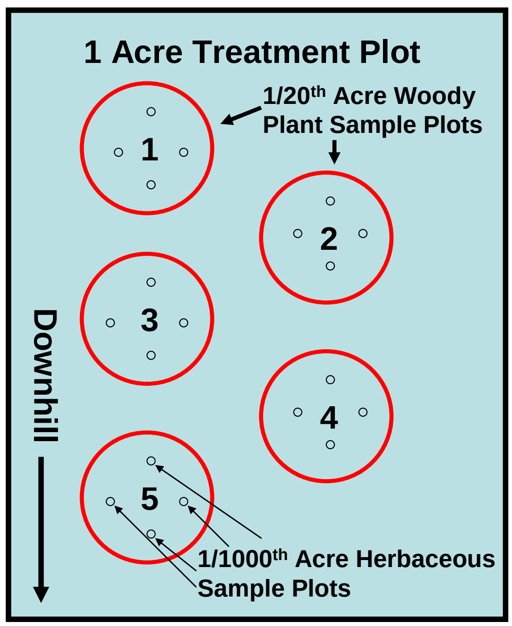


Figure II.10. Layout of woody and herbaceous plot sampling within each treatment plot.

2.6. Statistical Analysis

Data were analyzed using JMP 7.0 (SAS Institute Inc., Cary NC). Differences among treatments were determined using a randomized block ANOVA. Tukey-Kramer HSD was used for mean separations ($P < 0.10$) (Tukey, 1953; Kramer, 1956). Regression residuals for infiltration data were tested for normality using the Shapiro-Wilk test (Shapiro and Wilk, 1965). Residuals of infiltration were significantly non-normal at $\alpha = 0.05$, therefore regression was performed nonparametrically on the ranks (Conover and Iman, 1976, 1981). Correlations were performed using the Spearman procedure.

3. Results

Soil properties varied widely within and between experimental blocks (Table 3). Coarse fragments generally were greater than 50% of soil volume and organic matter was low, but soluble salts, base saturation and available nutrients were not limiting.

Table II.3. Soil physical and chemical properties at onset of experiment in the spring of 2008 (ppm = parts per million, CEC = cation exchange capacity, BS = base saturation (%), OM = organic matter by loss on ignition (%), SS = soluble salts by electrical conductivity).

Block-		<2mm		ppm				meq/100g			ppm
Grading	Cover Type	% Fines	pH	P	K	Ca	Fe	CEC	BS	OM	SS
1-Loose	Annual Ryegrass	47%	5.96	36	62	823	62.6	6	98	1.3	269
1-Loose	Conventional Mix	55%	5.52	32	59	928	49.8	7.5	92.1	1.2	602
1-Loose	Tree-compatible Mix	47%	5.51	46	62	1284	79.7	9.6	93.8	1.2	909
1-Compact	Conventional Mix	50%	4.59	27	50	774	73.7	7.6	75.7	1.2	563
1-Compact	Powell River Project Mix	40%	5.80	70	62	1447	86.6	10.1	97.6	1.2	973
1-Compact	Native Invasion Mix	48%	6.93	49	75	977	73.6	7.2	99.9	1.5	115
2-Loose	Native Invasion Mix	27%	7.93	47	74	2617	197	17.4	100	1.6	218
2-Loose	Conventional Mix	29%	8.10	22	66	3009	122.5	19.6	100	1.4	218
2-Loose	Powell River Project Mix	45%	7.46	78	63	1309	77.3	9.6	100	2	230
2-Compact	Conventional Mix	42%	7.21	75	60	1466	71.2	10.3	100	1.8	627
2-Compact	Powell River Project Mix	39%	7.20	77	64	1122	68.7	8.4	100	2.3	218
2-Compact	Native Invasion Mix	36%	6.76	70	66	1120	65.8	8.1	99.9	1.8	384
3-Loose	Powell River Project Mix	45%	7.19	28	44	910	42.5	6.3	100	0.9	51
3-Loose	Native Invasion Mix	30%	6.76	41	48	740	54.9	5.7	99.5	0.9	51
3-Loose	Conventional Mix	41%	7.20	48	51	1036	66.8	7.7	100	0.8	77
3-Compact	Conventional Mix	32%	6.23	46	47	846	45	6.9	99.1	0.9	64
3-Compact	Powell River Project Mix	37%	7.02	52	50	1088	49.7	8.4	100	0.9	51
3-Compact	Native Invasion Mix	42%	6.95	43	49	949	53.4	7.3	100	0.9	64

The rock composition in the coarse fraction differed among soil grading treatments (Table 4). Smooth-grading treatment plots had higher average levels of weathered sandstone spoil, whereas loose-grading treatments had higher levels of unweathered sandstone.

Table II.4. Coarse fragment rock type analysis: percentage by weight of soil samples made up of > 2mm coarse fragments, and percentage by volume of > 2mm fragments made up of weathered brown sandstone, unweathered gray sandstone, siltstone, shale and coal. Means within treatment groups followed by different letters are significantly different, α = 0.10.

Treatment	Coarse Fragments	Weathered Sandstone	Unweathered Sandstone	Silt-stone	Shale	Coal
Grading:						
Smooth	59%	47% a	15% b	36%	1.1%	1.4%
Loose	59%	39% b	28% a	31%	0.7%	1.6%
Seeding:						
Conventional Mix	59%	46%	23%	29%	0.3%	0.8%
Tree Compatible Mix	58%	45%	18%	33%	1.3%	2.5%
Annual Ryegrass Only	62%	38%	22%	38%	1.0%	1.3%

Grading treatment had no significant effect on herbaceous ground cover, tree survival or tree growth over the 2009 growing season (Table 5). The conventional seeding treatment produced significantly more cover than the annual ryegrass treatment, but tree survival and growth differences between seeding types were not statistically significant.

Table II.5. Treatment effects on percent ground cover (living + dead) rates and surviving trees in 2009. Means within treatment groups followed by different letters are significantly different, α = 0.10.

Grading:	Ground Cover (%)	Survival (%): Crop Trees, All Trees	Ht Growth (mm): Crop Trees, All Trees
Smooth	72	71, 70	111, 121
Loose	70	66, 71	103, 100
Ground Cover:			
Conventional Mix	83 a	69, 65	95, 97
Tree Compatible Mix	75 ab	70, 71	105, 114
Annual Ryegrass Only	55 b	67, 75	120, 119

Differences were observed in the survival and growth of individual tree species (Tables 6 and 7). Crop trees performed similarly to all the tree species aggregated and did not have individual responses to treatments. Overall survival rates by two minor planted and one volunteer species (white pine, gray dogwood, and red maple) were 100%, greater than shagbark hickory which had the lowest survival. Red maple occurred only as a volunteer species, making it impossible to differentiate true survivors from newly recruited trees during June-November. Only redbud survival showed a significant response to grading, with greater survival in the smooth grading

Table II.6. Survival rates (%) of tree species by treatment category (AR = annual ryegrass, Con = Conventional and TC = Tree-compatible) during 2009 with significant differences, alpha = 0.10, indicated by different lowercase letters in columns and uppercase letters in rows.

	Grading Treatment		Seeding Treatment			
Crop Tree Species	**Smooth**	**Loose**	**AR**	**Con**	**TC**	**Overall**
Black Cherry (*Prunus serotina*)	75	83	95	68	73	**79 ab**
Black Oak (*Qurecus velutina*)	99	90	93	99	91	**95 a**
Chestnut Oak (*Quercus prinus*)	57	56	66	53	52	**57 b**
Red Oak (*Quercus rubra*)	45	45	51	53	56	**53 b**
Sugar Maple (*Acer saccharum*)	64	37	34	40	77	**51 b**
White Ash (*Fraxinus americana*)	71	66	67	68	69	**68 ab**
White Oak (*Quercus alba*)	78	67	63	74	82	**73 ab**
Yellow-poplar (*Liriodendron tulipifera*)	82	60	63	89	62	**71 ab**
Wildlife and Nurse Tree Species						
Gray Dogwood (*Cornus racemosa*)	130	97	128 A	137 A	71 B	**113**
Red Maple (*Acer rubrum*) (volunteer)	28	173	201	0	0	**101**
Red Mulberry (*Morus rubra*)	28	78	68 AB	65 B	138 A	**87**
Redbud (*Cercis canadensis*)	52 B	80 A	63	61	75	**66**
Shagbark Hickory (*Carya ovata*)	20	16	24	9	22	**18**
White Pine (*Pinus strobus*)	138	115	116	133	137	**127**

Table II.7. Height growth (mm) of planted tree species (negative values indicate stem dieback) by treatment category during 2009 with significant differences, alpha = 0.10, indicated by different lowercase letters in columns and different uppercase letters in rows.

	Grading Treatment		Seeding Treatment			
Crop Tree Species	**Smooth**	**Loose**	**AR**	**Con**	**TC**	**Overall**
Black Cherry (*Prunus serotina*)	199	198	171	167	258	**199 a**
Black Oak (*Qurecus velutina*)	72	77	99	59	66	**75 bcd**
Chestnut Oak (*Quercus prinus*)	95	84	142	29	99	**90 bcd**
Red Oak (*Quercus rubra*)	78	19	85	112	- 52	**48 cd**
Sugar Maple (*Acer saccharum*)	71	20	48	- 5	95	**46 d**
White Ash (*Fraxinus americana*)	117	145	173	121	99	**131 abc**
White Oak (*Quercus alba*)	98	128	116	123	100	**113 bcd**
Yellow-poplar (*Liriodendron tulipifera*)	157	150	124	156	179	**153 ab**
Wildlife and Nurse Tree Species						
Gray Dogwood (*Cornus racemosa*)	261	205	173	318	208	**233**
Red Maple (*Acer rubrum*)	23	4	23	- 6	24	**14**
Red Mulberry (*Morus rubra*)	268	177	208	168	291	**222**
Redbud (*Cercis canadensis*)	132	157	111	126	196	**145**
Shagbark Hickory (*Carya ovata*)	21	- 80	96 A	- 118 B	- 67 AB	**- 30**
White Pine (*Pinus strobus*)	99	113	102	110	106	**106**

treatment. The greatest growth was achieved by two minor species, gray dogwood and red mulberry, while the growth of shagbark hickory was negative due to die-back of living tissue. Among crop tree species, black cherry's growth was greater than all species but yellow-poplar and white ash.

In some cases the exposed height of erosion pins decreased over time, indicating a positive soil surface change (Table 8). This unexpected result was attributed to soil expansion caused by physical unloading, freeze-thaw processes, mineral slaking, moisture swell, and rooting expansion. Hence, erosion-pin measurements are expressed as "surface change," a relative measurement calculated from the pins' exposed heights; with negative change (erosion) indicating increased erosion-pin exposure. Visual observations indicated that soil was being lost even at sites where measured surface change was positive. Loose grading resulted in significantly less apparent erosion (as indicated by measured surface change) than compact grading. The tree compatible and annual ryegrass ground cover treatments eroded nominally less than the conventional seeding treatment.

Table II.8. Cumulative treatment effects on surface change over the 2008 and 2009 growing seasons, surface water infiltration and on number of 2009 volunteer species. Significant differences are depicted by different letters beside values within categories.

Grading	**Surf Change** (mm)	**α = 0.10**	**Infiltration** ($Lm^{-2}min^{-1}$)	**α = 0.10**	**Volunteer Species**	**α = 0.10**
Loose	10	a	21.2	a	8	a
Smooth	-8	b	20.9	a	6	a
Seeding						
Annual Ryegrass Only	8	a	13.5	b	12	a
Tree Compatible Mix	2	a	24.9	a	5	b
Conventional Mix	-7	a	24.6	a	4	b

Grading had no significant effect on volunteer herbaceous species richness or water infiltration, but the annual ryegrass treatment allowed more volunteer species to establish than the other two treatments; annual ryegrass seeding also decreased infiltration rates, relative to the other two seeding treatments (Table 8). Microfeatures caused significant differences in infiltration rate (Table 9). No significant interaction effects between seeded ground cover type and grading type were found for tree survival and soil erosion rates.

Table II.9. Surface water infiltration rates observed for each microfeature type with mean separations indicated by different letters beside values within categories.

Microfeature	Infiltration (L m^{-2} min^{-1})	α = 0.10
Crevasse	31.4	*
Ridge Side	24.4	ab
Flat Slope	24.1	a
Ridge	18.3	abc
Gully Side	12.3	bc
Gully	7.2	c

* excluded from statistical determinations because only a single observation was recorded.

Grading treatments had no significant effect on surface water infiltration rate (Table 8), but the presence of microfeatures did have a significant effect (Table 9). The tree compatible and conventional seeding treatments caused significantly greater infiltration than the annual ryegrass. Infiltration was highly correlated with ground cover percentage (Table 10).

Table II.10. Factors correlated to surface water infiltration rate using Spearman's ρ values for non-normally distributed data.

Factor	Correlation (r)	Significance (Prob > ∣ρ∣)
Slope	-0.0515	0.5560
Ground cover	0.7154	<0.0001
Erosion	0.0721	0.7761

Fifty nine plant species were identified with all vegetation sampling during 2008 and 2009 (Table 11). Ground coverage was dominated by three planted herbaceous species groups: clovers, birdsfoot trefoil and agricultural grasses (Table 12). Crownvetch, an inadvertently seeded invasive species in block 1, was the next most dominant (although it occurred only in the block where seeded) and the two most dominant volunteer species were wild lettuce and coltsfoot, the last being invasive.

Loose grading significantly increased diversity compared to smooth grading according to one index that favors diversity of co-dominant species (Simpsons DI) (Table 13), but planting annual ryegrass only nominally increased biodiversity according to one index that favors diversity of rare species (Shannon’s DI).

Table II.11. All plant species identified in vegetation sampling of woody and herbaceous plots in 2008 and 2009. "Planted" = species on prescription lists or otherwise known to be planted, "volunteered" = other species, "native" = species known to have originated in North America and to inhabit central Appalachia, "non-native" = species originating on another continent or known to have not inhabited central Appalachia prior to being introduced and "invasive" species = designated as invasive by the Southeast Exotic Pest Plant Council.

Common Name	Scientific Name	Planted	Volunteered	Native	Non-native	Invasive
red maple	*Acer rubrum*		X	X		
sugar maple	*Acer saccharum*	X		X		
redtop	*Agrostis gigantea*	X			X	X
ragweed	*Ambrosia*		X	X		
hog-peanut	*Amphicarpaua bracteata*		X	X		
dwarf pussytoes	*Antennaria microphylla*		X	X		
silverweed	*Argentina anserina*		X	X		
aster	*Asteraceae*		X	X		
thistle	*Asteraceae*		X	X		
shagbark hickory	*Carya ovata*	X		X		
redbud	*Cercis canadensis*	X		X		
lambsquarters	*Chenopodium berlandieri*		X	X		
gray dogwood	*Cornus racemosa*	X		X		
orchardgrass	*Dactylis glomerata*	X			X	X
wild carrot	*Daucus carota*		X		X	X
autumn-olive	*Eleagnus umbellata*		X		X	X
fireweed	*Epilobium angustifolium*		X	X		
weeping lovegrass	*Eragrostis curvula*	X			X	
pea	*Fabacea*		X			
white ash	*Fraxinus americana*	X		X		
wild lettuce	*Lactuca virosa*		X		X	
mint	*Lamiaceae*		X	X		
sericea lespedeza	*Lespedeza cuneata*		X		X	X
yellow-poplar	*Liridendron tulipifera*	X		X		
annual ryegrass	*Lolium multiflorum*	X			X	
perennial ryegrass	*Lolium perenne*	X			X	

birdsfoot trefoil	*Lotus corniculatus*	**X**			**X**	**X**
alfalfa	*Medicago sativa*	**X**			**X**	
lemon balm	*Melissa officinalis*		**X**		**X**	
red mulberry	*Morus rubra*	**X**	**X**	**X**		
wood-sorrel	*Oxalis*		**X**	**X**		
timothy	*Phleum pratense*	**X**			**X**	**X**
pokeweed	*Phytolacca*		**X**	**X**		
pitch pine	*Pinus rigida*	**X**		**X**		
white pine	*Pinus strobus*	**X**		**X**		
loblolly pine	*Pinus taeda*	**X**			**X**	
Virginia pine	*Pinus virginiana*		**X**	**X**		
American sycamore	*Platanus occidentalis*	**X**		**X**		
black cherry	*Prunus serotina*	**X**		**X**		
white oak	*Quercus alba*	**X**		**X**		
chestnut oak	*Quercus prinus*	**X**		**X**		
red oak	*Quercus rubra*	**X**		**X**		
black oak	*Quercus velutina*	**X**		**X**		
black locust	*Robinia pseudoacacia*		**X**	**X**		
blackberry	*Rubus fructicosus*		**X**	**X**		
dock	*Rumex*		**X**		**X**	**X**
stone-breakers	*Saxifraga*		**X**	**X**		
figwort	*Scrophularia*		**X**	**X**		
rye grain	*Secale cereale*	**X**			**X**	
crownvetch	*Securigera varia*	**X**			**X**	**X**
foxtail millet	*Setaria italica*	**X**			**X**	**X**
goldenrod	*Solidago*		**X**	**X**		
nightshade	*Solanum*		**X**		**X**	**X**
dandelion	*Taraxacum*		**X**	**X**		
red clover	*Trifolium pratense*	**X**			**X**	
white clover	*Trifolium repens*	**X**			**X**	
coltsfoot	*Tussilago farfara*		**X**		**X**	**X**
common mullein	*Verbascum thapsus*		**X**		**X**	**X**
violet	*Viola*		**X**	**X**		

Table II.12. Percent ground cover by species for each treatment in August of 2009 with mean separation (Tukey HSD α = 0.10) indicated by different lowercase letters in columns and different uppercase letters in rows within categories of grading type and seeding type; "trace" indicates species present in amounts averaging below 0.1%.

Species		**Smooth**	**Loose**	**Annual Ryegrass**	**Conven-tional**	**Tree Compatible**	**Overall**
Clover	*Trifolium*	18.7 a	17.8 a	11.8 a	20.5 a	22.5 a	18.3 a
Birdsfoot Trefoil	*Lotus corniculatus*	19.1 a	15.0 a	3.4 bc	22.5 a	25.3 a	17.0 ab
Timothy and Perennial Ryegrass	*Phleum pratense and Lolium perenne*	13.6 a	12.3 a	4.0 bc	26.3 a	8.6 b	12.9 b
Crownvetch	*Securigera varia*	4.2 b	3.3 b	9.2 ab	1.5 b	0.5 c	3.7 c
Wild Lettuce	*Lactuca virosa*	2.0 b	2.0 b	2.4 bc	0.3 b	3.2 bc	2.0 c
Redtop	*Agrostis gigantea*	0.9 b	2.0 b	1.6 c	2.4 b	0.4 c	1.4 c
Coltsfoot	*Tussilago farfara*	1.9 b	0.5 b	0.8 c	0.7 b	2.1 bc	1.2 c
Epilobium 3	*Epilobium 3*	0.9 b	1.1 b	2.3 bc	0.2 b	0.6 c	1.0 c
Annual ryegrass	*Lolium multiflorum*	trace b	1.4 b	1.3 c	0.7 b	0.1 c	0.7 c
red stemmed fireweed	*Epilobium 2*	0.3 b	0.2 b	0.4 c	trace b	0.3 c	0.3 c
Rye grain	*Secale cereale*	trace b	0.2 b	trace c	0.1 b	0.2 c	0.1 c
Foxtail millet	*Setaria italica*		0.2 b			0.3c	0.1 c
Sericea lespedeza	*Lespedeza cuneata*	0.1 b	trace b	0.2 c	trace b	trace c	0.1 c
Orchardgrass	*Dactylis glomerata*	trace b	0.1 b	trace c	trace b	0.2 c	0.1 c
Lambsquarters	*Chenopodium berlandieri*	trace b	0.1 b	0.1 c	trace b		0.1 c
Alfalfa	*Medicago sativa*	0.1 b	trace b		0.1 b	trace c	trace c
Thistle	*Asteraceae 2*	0.1 b	trace b	0.1 c		trace c	trace c
Ragweed	*Ambrosia*	trace b	0.1 b	0.1 c		trace c	trace c
Blackberry	*Rubus fructicosus*	trace b	trace b	0.1 c			trace c
Silverweed	*Argentina anserina*		trace b	trace c			trace c
Wood-sorrel	*Oxalis*		trace b	trace c			trace c
Pokeweed	*Phytolacca*	trace b				trace c	trace c
Stone-breakers	*Saxifraga*		trace b	trace c			trace c
Hog-peanut	*Amphicarpaua bracteata*	trace b				trace c	trace c
Aster	*Asteraceae*	trace b	trace b	trace c			trace c

Common Mullein	*Verbascum thapsus*		trace b	trace c			trace c
Wild Carrot	*Daucus carota*	trace b	trace b	trace c			trace c
(purple flower)	*Angiospermae 2*	trace b	trace b	trace c	trace b	trace c	trace c
Fireweed	*Epilobium angustifolium*		trace b	trace c			trace c
(tall, weeping flower)	*Angiospermae*		trace b		trace b		trace c
Dwarf Pussytoes	*Antennaria microphylla*	trace b		trace c			trace c
Red Mulberry	*Morus rubra*	trace b	trace b	trace c			trace c
(small white flower)	*Angiospermae 4*		trace b	trace c			trace c
(large basal spatulate, serrated)	*Angiospermae 3*		trace b	trace c			trace c
Nightshade	*Solanum*	trace b	trace b	trace c	trace b	trace c	trace c
Lemon Balm	*Melissa officinalis*	trace b	trace b	trace c		trace c	trace c
Dandelion	*Taraxacum*	trace b		trace c			trace c
Dandelion 2	*Taraxacum 2*		trace b	trace c			trace c
(pea-like)	*Fabaceae*		trace b		trace b		trace c
Dock	*Rumex*	trace b	trace b	trace c			trace c
Goldenrod	*Solidago*	trace b	trace b	trace c	trace b	trace c	trace c
Violet	*Viola*	trace b	trace b	trace c			trace c

Table II.13. Simpson's and Shannon's Diversity Indices for FRA treatment plots in August of 2009 following 2 seasons of growth and succession. Means within treatment groups followed by different letters are significantly different, α = 0.10.

Treatment	Simpson's DI	Shannon's DI
Loose	0.70 a	1.52 a
Smooth	0.63 b	1.28 a
Annual Ryegrass	0.67 a	1.63 a
Conventional	0.66 a	1.25 a
Tree-compatible	0.67 a	1.31 a

There was significantly more ground coverage resulting from planted species than from volunteer species, and from alien species than from native species; and nominally more from invasive than non-invasive species across the entire experiment (Table 14). The annual ryegrass seeding produced the lowest coverage of planted, alien and invasive species; while the conventional seeding produced the lowest coverage of volunteer species and the highest of invasive species.

Table II.14. Percent ground cover overall by plant status and by treatment and plant status with mean separation (Tukey HSD α = 0.10) indicated by different lowercase letters in columns and different uppercase letters in rows within categories.

Treatment	Planted	Volunteered	Native	Alien	Invasive
Grading					
Smooth	56.5% a	5.4% a	1.4% a	60.5% a	39.7% a
Loose	52.4% a	4.1% a	1.6% a	54.9% a	33.6% a
Seeding					
Conventional	74.1% a	1.2% b	0.2% b	75.1% a	53.4% a
Tree-compatible	58.1% a	6.3% a	1.0% ab	63.4% a	37.4% b
Annual Ryegrass	31.2% b	6.7% a	3.3% a	34.6% b	19.1% c
Total	54.5% A	4.7% B	1.5% B	57.7% A	36.6%

Ground coverage by volunteer herbaceous species on annual ryegrass treatments was dominated by non-invasive species both overall and on loose grading treatments (Table 15). The annual ryegrass only treatment had the lowest ground coverage of alien and invasive species seeded and the conventional seeding treatment had the highest ground coverage by invasive species, with more ground coverage by invasive than non-invasive species planted (Table 16). Annual ryegrass and loose grading show a consistent pattern of increasing biodiversity according to the indices of species richness and Shannon's Diversity Index, and this is especially true of volunteer and native species for these two indices (Figure 11).

Table II.15. Volunteer plant groundcover percentage of noninvasive, invasive, native and alien species for annual rye only treatment plots with mean separation (Tukey HSD α = 0.10) indicated by different lowercase letters in columns within categories.

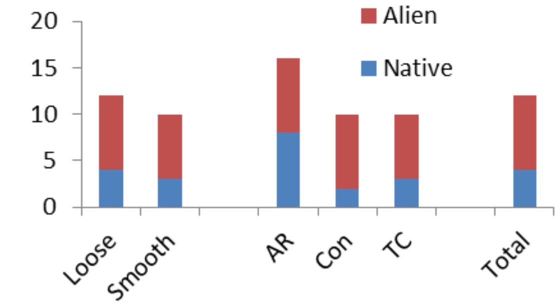
Status	Smooth	Loose	Overall
Invasivity			
Non-invasive	5.7% a	5.7% a	5.7% a
Invasive	1.7% a	0.3% b	1.0% b
Nativity			
Native	3.0% a	3.5% a	3.3% a
Alien	4.4% a	2.4% a	3.4% a

Table II.16. Percent groundcover of planted species analyzed by treatment and ecological status; all planted species were alien. Mean separation (Tukey HSD α = 0.10) is indicated by different lowercase letters in columns and different uppercase letters within rows within categories.

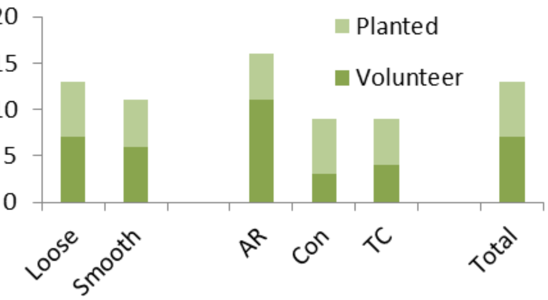
Treatment	**Alien**	**Invasive**	**Non-invasive**
Conventional	74.1% a	52.7% a,A	21.4% a,B
Tree-compatible	58.1% a	35.2% b,A	22.9% a,A
Annual Ryegrass*	31.2% b	18.1% c,A	13.1% a,A

* Crownvetch, an invasive species, was a contaminant in the Annual Ryegrass seeding treatment on Block 1.

Herbaceous Species Richness

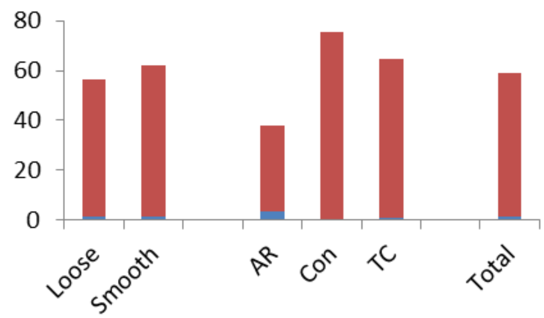


11a.



11b.

Groundcover %



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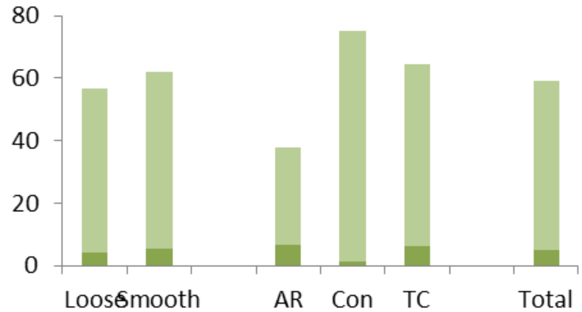
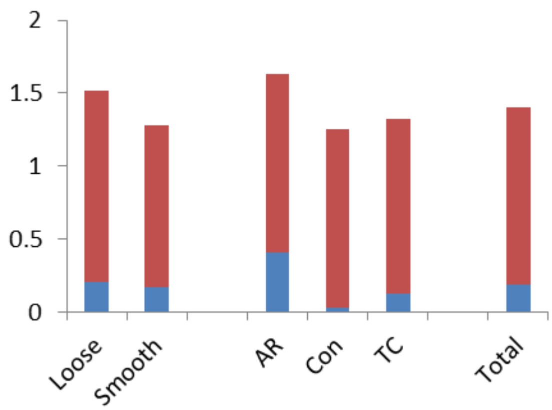


11d.

Shannon's Diversity Index



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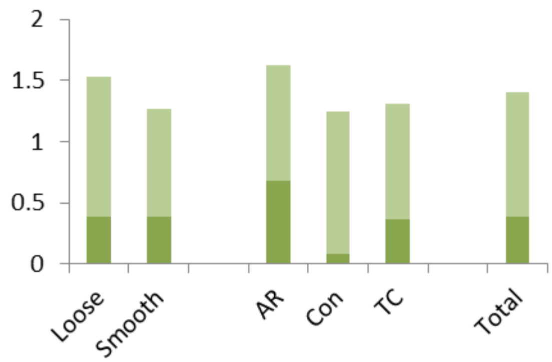

11f.

Figure II.11. Graphic summary of biodiversity indices; left column shows proportion of native and alien species making up species richness (2a), ground cover percentage (2c), and Shannon's Diversity Index (2e); right column shows proportion of volunteered and planted species making up these same indices (2b, 2d and 2f, respectively); AR = annual ryegrass only, Con = Conventional and TC = Tree compatible seeding treatments.

4. Discussion

4.1. Grading Treatments

Neither the amount of ground cover nor tree survival was significantly affected by grading treatments after the second growing season (Table 5), a result similar to that found by Torbert and Burger (1992). The confounding effect of different spoil types on the surface may have obscured the effects of grading treatments (Table 4). Past experiments have shown that tree survival and growth for most species improves with reduced grading activity (Torbert and Burger 1990, Angel et al., 2006). Loose graded plots in this experiment had significantly more unweathered sandstone ($p = 0.01$) and less weathered sandstone ($p = 0.10$) than smooth-graded plots. Research demonstrates that weathered sandstone in this region is an excellent substrate for growing native trees (Showalter and Burger, 2006; Emerson et al., 2009), and weathered sandstone materials are recommended for surface placement where available (Burger et al., 2005a). Although efforts were made to control spoil selection during experimental plot construction, variability in local sources resulted in measurable differences in spoil type between grading treatments. Another possible explanation for grading not having an effect on tree survival may relate to plot steepness (often 60% slopes or steeper). Mining equipment creates less compaction on steep slopes than on near-level grades (Andrews et al., 1998). Although we did not find a difference among tree responses to the grading treatments at year two, the long term response on very steep slopes has yet to be determined. Other research shows that severe soil compaction effects remain evident over the long-term (Burger and Evans, 2010).

4.2. Seeding Treatments

Although significant differences in ground cover were achieved by the different seeding treatments, less plant cover did not result in significantly better tree survival. Nominally, tree survival did vary inversely with ground cover percentage across the three treatments (Table 5), indicating that significant relationships might emerge with more time. Over the first year after replanting, tree survival was considered acceptable across the entire experiment at 65-75%. The positive effects of lower herbaceous ground cover rates on tree survival on reclaimed mined land have been demonstrated (Torbert et al., 2000, Burger et al., 2005b, Skousen et al., 2006). Tree-compatible and annual-ryegrass-only seeding treatments may produce significant long-term differences in tree growth and survival due to the reduced competition between trees and herbaceous vegetation for water, sunlight and soil nutrients as the transplanted trees move from the establishment into the growth phase. Re-planting brought all plots up to full stocking before the 2009 growing season, during which rainfall was abundant. The fact that re-planted trees were not subjected to significant moisture stress during their first summer may have influenced the lack of observed effects by grading and seeding treatments on tree survival.

4.3. Erosion and Water Infiltration

We hypothesized that higher levels of compaction would lead to higher levels of surface erosion, and this basic hypothesis is supported by our study results (Table 8) and those of Torbert and Burger (1992). Our hypothesis was based on previous research findings that the increased erosion associated with greater grading intensities results from reduced soil macro-porosity and slow water infiltration (Evans and Loch, 1998) caused by excessive grading, but the exact mechanism causing our results has not been determined. Although our results did not demonstrate a grading effect on tree survival, other effects, such as lower grading costs and less soil erosion, are also important reasons to limit grading and soil-surface compaction. One of the cooperating mining firms reported that it required approximately 7.5 to 8.5 additional machine hours per ha to complete conventional grading treatments compared to loose graded treatments.

Our hypothesis was that grading treatments would exert primary controls over erosion rates and that all three experimental ground cover treatments would control erosion equally well. This was the case at the end of year two (Table 8). Past study has shown that ground cover with as little as 50% coverage can drastically reduce runoff and erosion compared to bare soil (Loch, 2000). Even though the annual ryegrass ground cover died back after the first year, this treatment resulted in the least nominal soil erosion. Heavy first-year growth of annual ryegrass created a dense mat of dead biomass that protected the site the second year. Furthermore, the ryegrass cover allowed more recruitment of non-planted species (Figure 2), which may also contribute to erosion control over longer intervals.

Relationships among surface water infiltration, erosion, and the experimental treatments were complex (Figure 12), but lead to logical conclusions. Infiltration was statistically related to erosion, though more weakly than expected; and the relationship was not statistically significant. Higher groundcover rates led to higher infiltration, but seeding treatments with higher groundcover rates had erosion pin measurements similar to those of seeding treatments with lower groundcover rates. One explanation concerns the gravity-induced consolidation of mine spoils, also called "settlement" which occurs commonly on mine sites (Zipper and Winters, 2010). It is possible that the higher water infiltration rates on areas with full groundcover are causing the settlement process to occur more rapidly within the soil surface, as it is well know that movement of water into and through mine spoil materials accelerates settlement and consolidation (Zipper and Winters, 2010). The higher rates of downward translocation of fine soil particles through the soil profile would be expected to cause subsidence at the surface as the remaining particles collapse into the voids. This process must be faster during the initial two years than soil surface losses due to down-slope erosion resulting from proportional increased surface flow of water when infiltration is less.

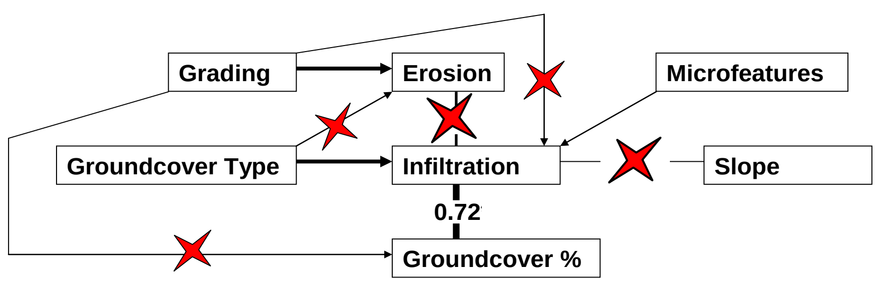

Figure II.12. Hypothesized relationships between study factors relating to erosion. Connections without red stars indicate significant effects at $\alpha = 0.10$. Numbers connecting factors are Spearman's p correlation values.

Infiltration transects indicated a greater frequency of encountering gullies on annual ryegrass plots. It is possible that the reduced infiltration that occurred with lower ground cover may have caused increased gullying, but on a scale that was not detected by our erosion pin measurements. Erosion pins consistently revealed swelling of surface soil, particularly during the first year, indicating that heaving, slaking and unloading forces are causing rocks to physically weather into soil-sized particles and soil with greater porosity than the rock material. This process likely negated superficial soil compaction and resulted in compacted and loose plots having nearly identical surface water infiltration rates. They likely also have nearly identical surface runoff rates, at least until the point where subsoil materials, presumably having a difference in bulk density and macroporosity due to compaction, become saturated and force the whole-soil to behave differently in terms of water flow compared to when just the surface soil is saturated. Given that loose plots had less relative soil loss than compacted plots, dislodged soil might be trapped by the rough microtopography of the loose plots and be picked up by erosion pin measurements, whereas soil moving on compacted plots might be moving off site due to the smooth microtopography. Given that loose and smooth plots had similar ground cover and infiltration rates, yet significantly different erosion rates, this is an alternative hypothesis for future investigations.

Macrotopography slope angles did not vary much from one plot the next, averaging 56%, and could not account for much of the high variability of surface water infiltration rates in this study. Loose grading reduced erosion immediately, but reductions in erosion from seeding choice may not be revealed until the processes of soil genesis described reach a different equilibrium. Infiltration was affected by microfeatures, and this may explain how microfeatures reinforce themselves over time. Mass erosion on plots was observed to be occurring almost entirely in gullies, the most significant of which had water concentrated into them by roads and other engineered structures at the tops of slopes. Gullying was far from uniform and appeared to be influenced by factors other than our experimental treatments.

The surface water infiltration measurement method used in this study was designed to estimate the maximum rainfall rates that could fall on mine soil and herbaceous vegetation without surface runoff occurring and to accommodate very steep slopes and rocky soil materials. The use of constant-head ring infiltrometers or ponded pit infiltration was impossible in this situation, with this objective. This method simulated the actual process of rainfall by sprinkling water on the undisturbed surface. Other research involving the capture of subsurface water flow has revealed that loose-dumped spoil materials have hydrologic characteristics comparable to undisturbed forest soils, in contrast to compacted spoils which show higher peak flows and runoff volumes than natural soils (Taylor et al., 2009a; Taylor et al., 2009b). It is clear that loose graded spoils are superior to compacted spoils in terms of erosion and hydrology.

4.4. Succession of Vegetation

The evidence supports the hypothesis that planting only annual ryegrass results in faster recruitment of volunteer plants and succession relative to the other two ground cover treatments (Figure 13). Earlier studies have shown that plantings of non-native, aggressive ground covers can impede herbaceous plant succession (Holl, 2002; Burger et al. 2005b). Furthermore, planting only annual ryegrass allows succession without increasing apparent erosion or reducing tree survival. Succession occurs naturally on reclaimed mine sites, especially at locations with near native seed sources and with soil properties that are favorable for native volunteer species establishment (Groninger et al., 2007). Many of the volunteer plants encountered were annuals indicative of the onset of natural succession (Table 11), but mid-succession species have not yet taken widespread hold. Loose grading increased herbaceous biodiversity compared to smooth grading, perhaps because higher soil porosity and lower soil strength support the germination, health and vigor of a wider variety of plants, including those which are planted and those which volunteer.

Figure II.13. Research personnel on the loose grading, annual ryegrass treatment of Block 1 in late summer of experimental Year 2. The photo shows how a variety of unplanted species are being recruited to the reclaimed area (Photo by Carl E. Zipper).

One concern with seeding practices that produce low levels of groundcover, such as the annual ryegrass in this experiment, is that they may result in exotic species invasion along with desirable natives. An alternative hypothesis is that less competitive groundcovers result in faster native plant recruitment, thus reducing the potential for exotic species invasion (Burger et al., 2009), and this hypothesis was supported here. Furthermore, seeding only annual ryegrass instead of the other two species assemblages seeded here, which themselves include many invasives and aliens in the seeding mix, directly reduced the ground coverage of invasive and alien species from the outset, especially after one season when the annual ryegrass died off. Past study has shown that native trees can become established on sites even when they are not planted, where aggressive groundcover is not present (Skousen et al., 2006). Our finding that seeding with annual ryegrass is compatible with native plant recruitment is consistent with this earlier study. Further monitoring will be necessary to determine how herbaceous ground covers affect long-term recruitment of both desirable and undesirable species. Invasive species were encountered during vegetation sampling, but did not dominate the research sites except where birdsfoot trefoil, agricultural grasses and crown vetch were planted. Non-invasives have covered more ground than invasives on the annual ryegrass treatments, where the fewest invasives were seeded. Another longer-term question regarding the annual ryegrass treatment, which can only be answered with long-term monitoring, is whether the lack of planted N-fixing legumes will negatively affect available soil N and, as a result, decrease forest productivity.

4.5. Tree Species Selection

Differing responses of individual tree species (Tables 6 and 7) to reclamation conditions indicates that species selection will affect reforestation success and that species composition of mature forests will be different than the planted composition. Species such as red oak, shagbark hickory, chestnut oak and sugar maple survived poorly in our study. If they dominate a mix of planted trees, overall success can be expected to be poorer than with a mix dominated by species that are capable of achieving higher survival rates: black cherry, black oak, white pine, white oak and yellow-poplar, based on our study. If species with poorer survival are desired to be a particular proportion of the species in the mature forest stand, then excess trees of these species would need to be planted in anticipation of higher mortality.

5. Conclusions

Loose grading reduced erosion rates compared to compacted grading by creating rough microtopography which prevented soil from moving down slope. This experiment is too young to judge the final effect of grading on reforestation success, but after two years loose and compacted mine soils were producing similar plant performance, but less downward surface movement (an indicator of soil erosion) occurred on the loose-graded plots. Infiltration and erosion interact in a complex set of relationships with grading, slope, microfeatures and groundcover. Loose grading also increased herbaceous biodiversity. The FRA recommends that grading be minimized on reforestation areas. Results of this study support the effectiveness of that practice.

Annual ryegrass as a seeding treatment produced lower rates of groundcover than conventional revegetation treatments, nominally increased overall tree survival and accelerated natural succession, as indicated by non-invasive volunteer species observed; but it did not result in greater rates of surface soil loss. Based on prior research and the success of native volunteers, we expect vegetative groundcover to continue increasing with time in the annual ryegrass treatment. Planting only annual ryegrass during hydroseeding operations is supported by the results of this study.

Tree species respond differently to reclamation conditions and should be planted in proportion to both the desired population outcome for the mature forest and known success rates in past plantings. Greater overall stand survival could be achieved with species such as black oak, black cherry, white pine, white oak and yellow-poplar. However, species such as red oak, shagbark hickory, chestnut oak and sugar maple need to be planted in surplus so that desired numbers of them remain following natural mortality.

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CHAPTER III. DEEP RIPPING, FERTILIZATION, TREE SPECIES AND SITE EFFECTS ON REHABILITATION OF UNUSED RECLAIMED MINED LANDS FOR FORESTRY

Abstract. There is renewed interest in restoring forests on 0.6 million ha of mining-disturbed lands in the Appalachian mountains of the Eastern United States. Many coal-mined lands reclaimed to meet requirements of US federal law have dense ground covers and dense soil materials. Three mine sites, each mined and reclaimed with herbaceous vegetation to meet legal requirements, were studied. At each site, Eastern white pine (*Pinus strobes*), hybrid poplar (*Populus deltoids x Populus trichocarpa*), and mixed Appalachian hardwoods were established using three levels of silvicultural intensity (weed control only, weed control with subsoil ripping, and weed control with subsoil ripping and fertilization). Trees were measured in October of 2008 after five years of growth. Across all states and treatments, the survival rate was 61% for mixed hardwoods, 51% for hybrid poplar and 41% for Eastern white pine. Total biomass index per tree was 19,742 cm^3 for hybrid poplar, 806 cm^3 for Eastern white pine, and 217 cm^3 for mixed hardwoods. Use of ripping plus weed control as a pre-planting silvicultural treatment increased cumulative survival across all sites and species from 41% to 64%. The addition of subsoil ripping increased hybrid poplar biomass ha^{-1} from 1.51 Mg to 8.97 Mg and Eastern white pine biomass from 0.10 Mg to 0.32 Mg. When restoring forest vegetation to previously reclaimed mine sites with unfavorable soil and vegetation properties, the use of weed control and subsoil ripping, with or without fertilization, can aid survival. Hybrid poplar grew significantly more biomass (5.58 Mg ha^{-1}) than Eastern white pine (0.20 Mg ha^{-1}) and mixed Appalachian hardwoods (0.12 Mg ha^{-1}).

Additional Key Words: compaction, ground cover, fertility, reforestation, native hardwoods, white pine, hybrid poplar, reclamation

1. Introduction

Over 0.6 million ha have been disturbed by coal mining operations in the Appalachian region of the eastern United States since 1980 under the USA's national coal mine reclamation law, the Surface Mining Control and Reclamation Act (SMCRA), (United States Office of Surface Mining). Much of this area was designated in mining permits to be used for hay or pasture following reclamation (Angel et al. 2005; US GAO 2009). However, most of these lands have not been used for that purpose and are experiencing arrested succession under the influence of exotic species (Groninger et al., 2007) that include persistent grasses and legumes established during reclamation. The result has been a failure to re-establish either agriculture or productive forest on a substantial portion of the Appalachian coal-mined land base. Though such sites do have some wildlife value, their current conditions produce little opportunity for future economic activities. This paper concerns one management option for these lands: rehabilitation using intensive silvicultural methods to establish productive forest vegetation. Effective reforestation of these lands can produce economic and aesthetic benefits for landowners, as productive timber stands, and environmental benefits to society through the restoration of ecosystem services such as native species diversity and habitat, watershed protection, and sequestration of atmospheric carbon.

In recent years, some coal miners have used advanced mine reclamation methods intended to re-establish native forests (Burger et al. 2005a; Angel et al. 2009), but areas mined and reclaimed using conventional post-SMCRA methods often remain unmanaged and unproductive. Restoration of forest vegetation on these sites requires effort and expenditure. Landowners or agencies choosing to reforest mined sites have choices regarding the level of silvicultural inputs to be applied and thus the level of establishment cost to be borne. These choices will affect the success of their land rehabilitation efforts, as indicated by survival and productivity of planted trees. Three common site limitations for trees on reclaimed mined sites are herbaceous competition, soil compaction, and low fertility. Various tree species can be selected for planting on such sites based on rehabilitation goals. This research examined the effectiveness of these silvicultural and species factors.

We evaluated the effects of two silvicultural treatments, subsoil ripping and fertilization, applied with herbicide treatment for weed control, on the early survival and growth of two woody species established as monocultures and of mixed-species native hardwood plantings in the Appalachian coalfield.

2. Methods and Materials

2.1. Experimental Design

This experiment employed a 3 x 3 x 3 factorial combination of silvicultural treatments, species plantings and locations using a randomized complete block design. Three experimental blocks were established at each of three locations, in Lawrence County, Ohio (OH), Wise County, Virginia (VA) and Nicholas County, West Virginia (WV) respectively (Figure 1). The silvicultural treatments applied experimentally were subsoil ripping (R) and fertilization (F); all plots were also treated with weed control (WC) using herbicide. Planted species were Eastern white pine (*Pinus strobus*), hybrid poplar (*Poplus spp.*) and a mix of native Appalachian hardwoods (Figure 2) (Table 1). Treatment plot locations were randomized within each block.

The experiment was initiated with site preparation in late 2003 - early 2004, and planted in March of 2004. Here, we analyze measurements taken in October of 2008 following the fifth growing season. Greater detail on the establishment and first-year results can be found in Casselman (2005) and Casselman et al. (2006).

2.2. Site Descriptions

The OH sites were located at 38.75°N; 82.63°W in Lawrence County, the WV sites at 38.13°N; 80.65°W in Nicholas County, and the VA sites at 37.05°N; 82.70°W in Wise County (Casselman et al., 2006). These sites had all been previously mined for coal before being reclaimed to grass in August – September of 1994 for the Ohio sites, in August – October of 1999 for the WV sites, and in 2002 – 2003 for the VA sites (Amichev, 2007). Grasses and legumes formed a dense vegetative cover on all sites at the time of tree establishment. Siltstones dominated the mine spoils on the sites in OH, shales dominated the WV sites and sandstones dominated the VA sites (Table 1). These rock types are collectively representative of the range of overburdens removed and then returned as spoils and soil substitutes on mined areas that are reclaimed in the Appalachian region (Casselman et al., 2006).

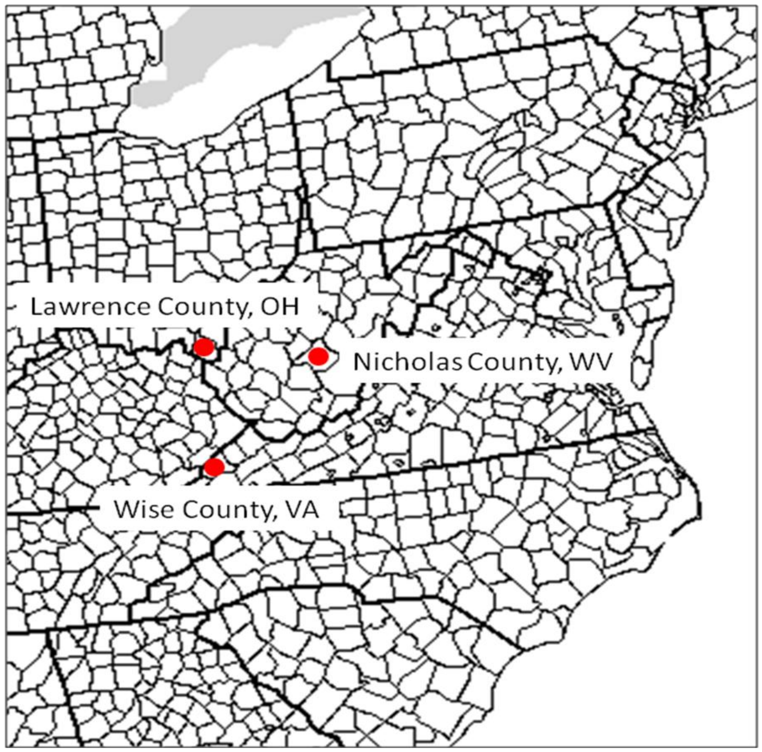

Figure III.1. Locations of experimental sites in Ohio, West Virginia and Virginia.

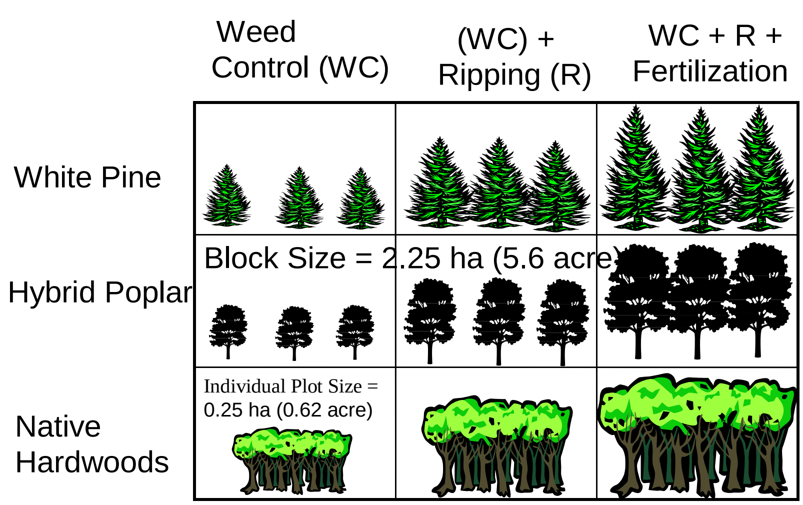

Figure III.2. Conceptual layout of each experimental block with three levels of silvicultural input and three tree species groups.

There were other notable differences in reclamation techniques, vegetation and soil properties between the three sites. The OH siltstone mine soils had topsoil returned to cap the study areas to a depth of 5 to 51 cm. This was the sites' pre-mining topsoil that had been stored for post-mining replacement. The topsoil was more acidic, had lower electrical conductivity and lower bulk density than the underlying mine spoils. Having been reclaimed approximately ten years previously, the OH sites were well vegetated with tall fescue (*Festuca arundinacea*) and sericea lepedeza (*Lespedeza cuneata*). Topsoil "capping," as occurred on the experimental sites, is a common reclamation practice in OH. The WV shale mine soils had no topsoil cap and, upon reclamation approximately ten years previously, had been revegetated with tall fescue that had been actively used for grazing. This mine soil had high coarse fragment content and a high bulk density. The VA sandstone mine soils were capped with a soil substitute of crushed sandstone to a depth of 0 to 47 cm across the study area. The VA soils had a high bulk density and high proportion of coarse fragments (Casselman et al., 2006).

Table III.1. Chemical and physical properties for spoil and soil materials: surface (upper 10 cm for WV; surface soil material for VA and OH) and subsoil (additional depth to 30 cm). Data from Casselman (2006). Mean values with different letters are significantly different (p<.10), with differences determined separately within the surface and subsurface soil groupings. Bulk density was not measured for subsoils in WV, and for 2 of the 3 VA blocks.

State	pH	EC	CEC	Extract-able P	Total N	--Coarse Fragments (%)--				Tex-ture	Bulk Dens.
						Total	Sand-stone	Silt-stone	Shale		
		($ds\ m^{-1}$)	($cmolc\ kg^{-1}$)	($mg\ kg^{-1}$)	($g\ kg^{-1}$)						($g\ cm^{-3}$)
Surface											
OH	5.4	0.10 ^{b}	8.67 ^{a}	7.79 ^{b}	1.15 ^{b}	8 ^{b}	23 ^{b}	73 ^{a}	0 ^{b}	L	1.46
VA	5.8	0.28 ^{a}	5.75 ^{b}	11.27 ^{b}	0.67 ^{c}	42 ^{a}	61 ^{a}	27 ^{b}	0 ^{b}	L	1.70
WV	5.7	0.21 ^{ab}	8.34 ^{a}	19.66 ^{a}	2.72 ^{a}	52 ^{a}	9 ^{b}	14 ^{b}	77 ^{a}	SL	1.68
Subsurface											
OH	6.6	0.47 ^{a}	14.47 ^{a}	0.39 ^{c}	0.48 ^{b}	20 ^{b}	16 ^{b}	82 ^{a}	0 ^{b}	SiCL	1.70
VA	6.9	0.25 ^{ab}	5.94 ^{b}	3.03 ^{b}	0.71 ^{b}	57 ^{a}	56 ^{a}	40 ^{b}	0 ^{b}	SL	1.74
WV	6.2	0.11 ^{b}	6.12 ^{b}	5.58 ^{a}	1.07 ^{a}	58 ^{a}	10 ^{b}	13 ^{b}	66 ^{a}	SL	-

Note: Data from Casselman (2006).

2.3. Silvicultural Treatments

Weed Control (WC). All of the study areas received 9.35 l ha^{-1} of glyphosate broadcast across the study areas in August of 2003. In addition, 4.92 l ha^{-1} of a pre-emergent herbicide with pendimethalin for grass control was broadcast across all study areas in April of 2004 prior to leaf-out by planted deciduous seedlings. Glyphosate was then used in spot applications immediately around each tree seedling in July of 2004 with the exception of one study block in Virginia where no competing vegetation was present. During the July application process, seedlings were shielded from drifting herbicide.

Subsoil Ripping (R). Six of the nine study plots at each replication were tilled with a subsoil ripping device in the spring of 2004 prior to tree planting. Differing local availability caused different equipment to be used for the ripping operations including multiple shanks, single shank with bed-creating coulters, and single shank only. Ripping depths were set at 61 to 91 cm (Casselman et al., 2006).

Fertilization (F). Three of the ripped experimental plots within each replication were fertilized beginning in May of 2004 after tree planting. Diammonium phosphate was applied to each planting row in a banded pattern at a rate of 272 kg ha^{-1}, adding 49.0 kg ha^{-1} Nitrogen (N) and 55.1 kg ha^{-1} Phosphorus (P). Around the base of each seedling, 91 kg ha^{-1} of muriate of potash and 20 kg ha^{-1} of a micronutrient mix was applied manually, adding 46.8 kg ha^{-1} Potassium (K), 1.8 kg ha^{-1} Sulfur (S), 0.2 kg ha^{-1} Boron (B), 0.2 kg ha^{-1} Cu (Copper), 0.8 kg ha^{-1} Manganese (M) and 4.0 kg ha^{-1} Zinc (Zn) (Casselman et al., 2006).

2.4. Planting Descriptions

Eastern white pine (EWP) has been commonly planted as a crop tree on southern Appalachian reclaimed surface mine lands (Torbert and Burger, 2000). Hybrid polar (*Populus trichocarpa* L. (Torr. and Gray ex Hook.) x *Populus deltoides* (Bartr. Ex Marsh.) hybrid 52-225) (HP) was also planted as an experimental treatment with the intention of exploring it as a choice for superior biomass production for purposes of meeting energy and fiber needs. The third species group included a mix of native Appalachian hardwoods (MH) intended to restore a forest composition similar to each experimental area's native forests (Table 2).

Table III.2. Planting rates (trees ha^{-1}) for mixed hardwood treatments, as determined by first year survey of planted trees within measurement plots.

Species	**OH**	**VA**	**WV**
Bitternut hickory (*Carya cordiformis*)	62	82	55
Black oak (*Quercus velutina*)	59	24	20
Chestnut oak (*Quercus prinus*)	75	0	0
Flowering dogwood (*Cornus florida*)	56	62	51
Northern red oak (*Quercus rubra*)	822	486	491
Red maple (*Acer rubrum*)	0	0	157
Redbud (*Cercis canadensis*)	46	62	43
Scarlet oak (*Quercus coccinea*)	34	0	0
Sugar maple (*Acer saccharum*)	46	110	89
Tulip poplar (*Liriodendron tulipifera)*	79	101	120
Washington hawthorn (*Cretaegus phaenopyrum*)	65	109	62
White ash (*Fraxinus americana*)	0	140	132
White oak (*Quercus alba*)	0	169	124

Trees were planted in March of 2004. EWP was planted as 2-0 bare root seedlings, MH were planted as 1-0 bare root seedlings and HP was planted as approximately 20 cm-long stem cuttings. Planting density for all species and treatments was 2.4 m x 3.0 m, which is 7.2 m^2 per tree or 1,345 trees per hectare (Casselman et al., 2006).

2.5. Tree Measurement

Each treatment plot was 0.25 ha with a 0.04 ha 50-tree measurement plot nested within. Tree survival and growth were measured within each measurement plot at the conclusion of the fourth (late October – early November of 2007) and fifth (late October – early November of 2008) growing seasons; unless otherwise noted, data reported here are from the fifth growing season. Survival was determined by dividing the number of living trees by the number of trees counted when measurement plots were first established.

Ground line diameter, diameter at breast height, and height to tallest live bud were measured and species positively identified on all trees. A biomass index (BI) was calculated for each tree by: BI (cm^3) = D^2 (cm^2) x H (cm) using groundline diameter for D, and distance from the ground to the top of the highest shoot for H. The biomass indices of surviving trees were summed to determine a plot biomass which was then divided by the number of surviving trees to determine average biomass per surviving tree as a productivity measure independent of survival rates. Total biomass per hectare was also calculated for each plot using wood density (Chave et al., 2009a,b), individual tree biomass index and numbers of surviving trees in measurement plots. The MH treatment was also analyzed for survival and biomass per tree by species to determine how factors affected species individually.

2.6 Data Analysis

Treatment, state and species averages as well as averages of combinations of these factors were calculated by averaging corresponding plot averages of biomass and survival rates. When more trees were found in year 5 than in year 1 for a given species within a measurement plot, this was calculated as being greater than 100% survival for that species in that plot. Data were analyzed using JMP 7.0 (SAS Institute Inc., Cary NC). Differences in performance characteristics among treatments were determined using a randomized block ANOVA. Differences in survival and growth among treatments were determined using Tukey-Kramer HSD ($p<0.10$).

Three plots within one block in Virginia were destroyed by re-mining in 2008 before they could be measured. Data for these plots were imputed by taking the average incremental change in survival and biomass from the end of the 2007 to the end of the 2008 growing season for the corresponding species x treatment combinations on the other two blocks in Virginia and applying those average increments to the 2007 data for the missing 2008 plots. Data for individual hardwood species in these destroyed plots were imputed by applying the mean annual increment of mortality and growth after four years to the cumulative fourth year survival and biomass to simulate an extra year of growth. This was done differently than the overall group-level imputations because the species make-up of sister plots within the repetition scheme varied widely. Those imputed data were then entered and analyzed normally.

3. Results

3.1. Tree Survival

Survival across all species and treatments was nominally improved by R, but F had no additional effect (Table 3). MH responded most directly to R, as survival was greater for the WC+R treatment than WC only in all three states. Survival for WC+R was nominally greater for HP in all three states, and for EWP in two of the three, but those differences were significant only for HP in WV and EWP in VA. Addition of F produced no significant increases in survival, but it did cause survival to decline for EWP in VA, for HP in OH and WV, and for MH in VA.

Table III.3. Mean percent survival of all replications by species, state and treatment after five years (EWP = Eastern white pine, HP = Hybrid poplar, MH = mixed hardwoods).

Site and Treatment	Species Means						All-species Means	
	EWP		**HP**		**MH**			
Ohio								
WC	28%	a	46%	ab	48%	b	**41%**	**a**
WC+R	14%	a	55%	a	71%	a	**47%**	**a**
WC+R+F	15%	a	26%	b	47%	b	**29%**	**a**
Species Mean	**19%**	**Y**	**42%**	**Z**	**55%**	**Z**	**39%**	**B**
Virginia								
WC	50%	b	69%	a	60%	a	**59%**	**b**
WC+R	81%	a	84%	a	86%	a	**84%**	**a**
WC+R+F	48%	b	69%	a	81%	a	**66%**	**ab**
Species Mean	**60%**	**Z**	**74%**	**Z**	**76%**	**Z**	**70%**	**A**
West Virginia								
WC	31%	a	14%	b	22%	b	**22%**	**b**
WC+R	62%	a	63%	a	57%	a	**61%**	**a**
WC+R+F	43%	a	37%	b	75%	a	**52%**	**a**
Species Mean	**45%**	**Z**	**38%**	**Z**	**51%**	**Z**	**45%**	**B**
All Sites Mean								
WC	36%	a	43%	a	43%	**b**	**41%**	**b**
WC+R	52%	a	67%	a	71%	**a**	**64%**	**a**
WC+R+F	35%	a	44%	a	68%	**a**	**49%**	**b**
All Sites Species Mean	**41%**	**Y**	**51%**	**YZ**	**61%**	**Z**	**51%**	**Grand Mean**

*The same letter connecting treatment response data for each species means no significant difference at p < .10. Lowercase a's and b's: statistically same treatment means within site vertically. Uppercase A's and B's: statistically same site means across all treatments and species vertically. Uppercase Z's and Y's: statistically same species means across all treatments horizontally.

3.2. Tree Biomass

Measured above-ground biomass index after five growing seasons across the entire experiment followed the same pattern as survival, with a nominal increase as a response to R but no further increase as a response to F. HP was larger on average than EWP and MH. Because of high variability, R increased biomass index only for HP in WV, despite the fact that most state/species combinations experienced nominal increases (Table 4).

Table III.4. Mean biomass index per surviving tree [(groundline diameter)^2 x height] in cm^3 of all replications by species, site and treatment after five years (EWP = Eastern white pine, HP = hybrid poplar, MH = mixed hardwoods).

Site and Treatment	Species Means						All-species Means	
	EWP		HP		MH			
Ohio								
WC	276	a	2,017	a	72	a	**788**	**a**
WC+R	96	a	7,935	a	86	a	**2,706**	**a**
WC+R+F	35	a	13,623	a	44	a	**4,567**	**a**
Species Mean	**136**	**Y**	**7,858**	**Z**	**67**	**Y**	**2,687**	**A**
Virginia								
WC	688	a	11,398	a	322	a	**4,136**	**a**
WC+R	1,114	a	25,349	a	303	a	**8,922**	**a**
WC+R+F	788	a	28,554	a	700	a	**10,014**	**a**
Species Mean	**863**	**Y**	**21,767**	**Z**	**442**	**Y**	**7,691**	**A**
West Virginia								
WC	595	a	4,153	b	90	a	**1,613**	**a**
WC+R	2,055	a	48,471	a	221	a	**16,916**	**a**
WC+R+F	1,309	a	36,177	ab	119	a	**12,535**	**a**
Species Mean	**1,320**	**Y**	**29,600**	**Z**	**144**	**Y**	**10,355**	**A**
All Sites Means								
WC	520	a	5,856	b	161	a	**2,179**	**a**
WC+R	1,089	a	27,252	a	203	a	**9,514**	**a**
WC+R+F	710	a	26,118	a	288	a	**9,039**	**a**
All Sites Species Means	**773**	**Y**	**19,742**	**Z**	**217**	**Y**	**6,911**	**Grand Mean**

*The same letter connecting treatment response data for each species means no significant difference at p = .10. Lowercase a's and b's: statistically same treatment means within state vertically. Uppercase A's and B's: statistically same state means across all treatments and species vertically. Uppercase Z's and Y's: statistically same species means across all treatments horizontally.

3.3. Stand Biomass

Biomass index on a per-hectare basis produced a similar pattern of results. HP produced more biomass per hectare than the other species group by far. The ha^{-1} biomass of HP and EWP were significantly improved by adding R to WC (Table 5).

Table III.5. Mean Mg ha^{-1} of above-ground biomass index following five growing seasons with mean separation (Tukey HSD, alpha = 0.10) indicated by different lowercase letters in columns and uppercase letters in rows.

Treatment	**E. White Pine**	**Hybrid Poplar**	**Mixed Hardwoods**
WC	0.10 b	1.51 b	0.08 a
WC+R	0.32 a	8.97 a	0.11 a
WC+R+F	0.20 ab	6.25 ab	0.17 a
State			
Ohio	0.02 y	1.74 z	0.03 y
Virginia	0.28 z	7.49 z	0.27 z
West Virginia	0.35 z	7.49 z	0.06 y
Species Mean	0.20 B	5.58 A	0.12 B

3.5. Mixed Hardwood Performance by Species

Red oak, although planted abundantly, experienced significantly higher mortality across all sites and treatments than did flowering dogwood, Washington hawthorn, white ash and white oak (Table 6). There was an array of differences in growth among species, with white ash, tulip-poplar, and Washington hawthorn being the top performers, as they outgrew oaks (red, black), maples (red, sugar), and flowering dogwood.

Application of R+F increased the survival of red maple and white ash and the growth of Washington hawthorn, white ash and white oak compared to the use of WC alone. Application of R, both with and without F, increased the survival of red oak and sugar maple compared to the use of WC alone. Chestnut oak and Washington hawthorn had greater survival than sugar maple, and tulip poplar had greater growth than all species but flowering dogwood, red maple and scarlet oak when only WC was employed. White ash had greater growth than six other species when all three silvicultural treatments were applied. White ash, white oak, and Washington hawthorn grew faster with R+F than with WC alone.

Table III.6. Mean survival rates (%) (on left side) and biomass index per tree (cm^3) (on right side) by silvicultural treatment following five growing seasons with mean separation (Tukey HSD, alpha = 0.10) indicated by different lowercase letters in columns and uppercase letters in rows (WC = weed control, WC,R = weed control and ripping, WC,R,F = weed control, ripping and fertilization).

Species	WC	WC,R	WC,R,F	Mean	WC	WC,R	WC,R,F	Mean
B. hick	40 ab	71	73	59 ab	62 b	9	134 b	69 cd
B. oak	100 ab	54	57	66 ab	7 b	4	47 b	26 bcd
C. oak	100 a	51	75	75 ab	63 b	51	47ab	55 abcd
F. dog.	100 ab	77	100	86 a	51 ab	56	79 b	63 cd
W. haw.	80 a	83	100	86 a	157 b,B	341 AB	695 ab,A	357 abc
Redbud	67 ab	70	67	68 ab	47 b	139	532 ab	194 abcd
R. maple	17 ab,B	61 AB	97 A	58 ab	0 ab	36	23 b	25 bcd
R. oak	27 ab,B	61 A	59 A	49 b	21 b	46	73 b	47 d
S. maple	24 b,B	84 A	89 A	62 ab	122 b	166	80 b	127 bcd
S. oak	100 ab	25	50	50 ab	0 ab	3	320 ab	108 abcd
T-poplar	48 ab	70	60	59 ab	891 a	242	434 ab	466 ab
W. ash	66 ab,B	85 AB	100 A	83 a	164 b,B	428 AB	944 a,A	512 a
W. oak	67 ab	93	100	90 a	33 b,B	91 AB	293 ab,A	154 abcd

4. *Discussion*

4.1. Control of Herbaceous Competition

Herbaceous competition is one potential cause of tree stress and mortality on reclaimed mined lands. Past experimentation has demonstrated the effectiveness of using herbicides to increase the early survival and growth of trees planted on surface mines with dense vegetative cover by reducing competition from herbaceous vegetation (Ashby, 1997; Burger et al. 2005b; 2008). This is especially true of tree species known to be sensitive to competition (Burns and Honkala, 1990; Ashby, 1997).

4.2. Reducing Soil Density

Soil density is another common problem for trees planted on mine sites (Torbert and Burger, 1990; Andrews et al., 1998; Torbert and Burger, 2000; Rodrigue and Burger, 2004; Jones et al., 2005). Dense soil conditions limit water movement creating anaerobic conditions in times of high precipitation which kills a portion of the roots of many species. In periods of low precipitation, trees in dense soils are drought-stressed from the compounding effects of root loss and rooting volume limitations (Ashby, 1997).

Mitigation of dense soil conditions via deep tillage has been found to have positive effects on mine soils in other studies. Better survival and growth has been demonstrated when compacted mine soils are ripped (Philo et al., 1982). Ripping compacted minesoil increased the survival of red oak and black walnut (Ashby, 1996) and increased their 14-year heights and stem diameters. Ripping of compacted mine soils also improved the performance of tree species tested in other experiments (Ashby, 1997; Skousen et al., 2009; Burger and Evans, 2010). Although ripping is not always found to be effective at improving tree performance (Kost et al., 1998), better survival and growth is a common response when compacted mine soils are ripped (Philo et al., 1982). We found the addition of ripping to herbaceous weed control as silvicultural treatments to produce superior survival at two of the three sites, and nominally superior growth.

High soil density also impairs mine soils' capabilities to perform other ecosystem services. Jacinthe and Lal, 2006 found that loose soil conditions inhibited methane formation and emissions, relative to denser sites. Torbert and Burger (1992) found that ripping of a young eastern Kentucky mine soil prior to tree establishment reduced soil erosion, likely because the ripping increased water infiltration. Mine soils reclaimed using conventional reclamation methods commonly produce runoff that is elevated, relative to unmined forested landscapes, in response to heavy rains (Negley and Eshleman, 2006; Simmons et al. 2008), but young mine soils have more favorable hydrologic characteristics when placed on the landscape in a loose and non-compacted state (Taylor et al. 2009), findings that suggest soil loosening via deep tillage may also have favorable hydrologic effects.

4.3. Improving Mine Soil Fertility

Topsoil substitutes made up of pulverized rock fragments are often used to cap mined sites when topsoil is unavailable for reclamation. The initial fertility of this material is poor before nitrogen and organic matter are able to naturally accumulate. Fertilization relieves this poor fertility only temporarily as inorganic nitrogen is readily leached while inorganic phosphorus is readily fixed in non-available forms in Appalachian mine soils (Howard et al., 1988). Large, positive effects of fertilization on early tree performance have been observed for some species on mine sites, indicating that these sites can be nutrient limited. Hybrid poplar is well known to have high fertility requirements for optimum growth on natural soils. N and P fertilization of planted hybrid poplar cuttings resulted in 253-329% increases in first-year growth (Brown and Van den Driessche, 2002). Over the course of four years, dense HP plantings decreased soil extractable P by one-half, suggesting the need for P fertilization for optimal growth of this species (Bowersox and Ward, 1977). Silver maple (*Acer saccharinum*) survival and green ash (*Fraxinus pennsylvanica*) growth on mine sites were increased by N and P fertilization of trees (Bowersox and Ward, 1977). Working on Ohio mine sites with calcareous mine spoils, fertilization with just P was found to be ineffective and N fertilization was found to be the more effective way to improve tree growth (Kost et al., 1998), indicating that N was the limiting nutrient on those sites. Fertilization presents an opportunity for increased return on investment over other treatments given its relatively low cost (Baker et al., 2008). It is well established that N accumulates in mine soils over time (Li and Daniels, 1994), so there are likely differences in fertility needs for young versus old reclaimed sites.

In our experiment, adding fertilizer along with weed control and ripping failed to produce any additional improvement in survival or growth for the species groups. The only instance where it seems to have made a great nominal difference was for growth of mixed hardwoods in Virginia. This may have been a chance result or may have been because a different application technique was used there that did not harm the trees, as discussed below. Other studies have shown that fertilization improves survival or growth if applied appropriately, but this research did not produce a comparable finding. The site in West Virginia had been actively grazed by cattle for several years before being prepared for this experiment, and this likely resulted in it having higher available nutrient levels due to supplemental fertilization and / or manure deposition during active grazing (Table 1). It is notable that the highest nominal biomass indexes for HP and EWP were achieved by the unfertilized and ripped treatments on the WV sites. Applying granular fertilizer to the base of young seedlings can cause severe damage and even mortality. Parts of the fertilization treatment in this experiment were applied in this manner. The negative, although nominal, reduction in survival for the R+F treatment, compared to R alone, recorded for this experiment suggests that fertilizers may have been applied improperly; and this may have been why fertilization as a treatment generally failed to improve tree performance.

4.4. Species, Site, Soil, and Geologic Factors

The WV sites, with their shale-based, uncapped, and more fertile mine soils, produced nearly four times the growth per tree of the OH sites, with siltstone mine soils capped with low-fertility topsoil-like material. OH consistently had the lowest value for biomass per hectare across the three species groups. This indicates that the return of topsoil-like materials to mined sites is not necessarily the most critical factor in, nor a guarantee of, maximizing post-reclamation productivity if those materials are of poor quality. Whether the soil capping applied to the OH mine site was actual topsoil, or a topsoil-like material derived from subsoil and/or weathered rocks, is unknown. The VA sandstone-based sites had significantly greater survival rates across all treatments and species than WV and OH sites; it has been noted by others that sandstone spoils have qualities that favor tree survival (Torbert et al., 1990). Experimentation has found brown, weathered sandstone in particular to be a good choice as a tree growth medium (Angel et al., 2008; Emerson et al., 2009). It is also notable that MH growth on the VA sites was nominally greater than on the WV sites, despite fertility differences, possibly reflecting the superiority of sandstone spoil materials for these generally soil-sensitive species. However, macroscopic site factors appear to affect survival differently from how they affect growth, and these mechanisms need further investigation.

MH are an efficient choice for achieving desired stocking rates due to their higher rate of survival. Because browsing activity was commonly observed in this and other experiments (Kost et al., 1998) and because EWP was the only species used in this experiment that is incapable of re-sprouting following top-kill by herbivores (Burns and Honkala, 1990), it is likely that the greater survival of MH compared to EWP is in part due to the ability of all of MH species to re-sprout after being browsed.

HP, bred from two species which thrive on young, coarse-textured soils similar to those encountered on reclaimed mine sites and known to be among the fastest growing trees in North America (Burns and Honkala, 1990), grew more biomass per hectare by far than the other species groups. Ripping improved the biomass produced per hectare for both HP and EWP, two species that do best on well-drained sites. MH had the best growth per hectare on the VA sandstone-based minesoils compared to the other state sites, suggesting sandstone-based material might the best for native forest species site productivity.

Tulip-poplar had greater growth than all other species on OH topsoil-like material over siltstone, perhaps because it prefers loose soils. These sites had a bulk density of 1.46 g cm^{-3}, the lowest of all sites (Casselman et al., 2006). Northern red oak had generally poor survival and growth, perhaps because it prefers sites with thick A-horizons (Burns and Honkala, 1990) which recent mine soils lack. White ash, tulip-poplar and Washington hawthorn had the highest overall growth, but it is unclear what common set of qualities these three disparate species have that allows them to out-perform the others. White ash and tulip poplar also were among the better performers for Emerson et al. (2009). Red maple and Washington hawthorn had higher survival with WC+R+F compared to WC only, and Washington hawthorn, white ash and white oak had greater growth in this comparison as well, indicating that these four species are responsive to the combination of subsoil ripping and fertilization. Red oak and sugar maple had better survival with WC+R compared to WC only, but survival was not improved with fertilization, indicating that these two species responded only to ripping.

Under WC alone, chestnut oak and Washington hawthorn had higher survival than sugar maple, and tulip-poplar had better growth than scarlet oak, red maple and flowering dogwood; indicating that these three species may be better choices for situations where R cannot be employed. Under WC+R+F, white ash had greater growth than many other species, demonstrating its relatively high responsiveness to increasing silvicultural intensity. White ash is reported to demand high soil fertility for maximum performance (Burns and Honkala, 1990), and this may help explain its positive response to fertilization compared to other species. Although not planted here, the closely related green ash (*Fraxinus pennsylvanica*) had overall survival rates of 91% across all topsoiling, ripping and fertilizing treatments applied in an earlier study (Kost et al., 1998) and is another species with good potential, although there is concern about the recent invasion of the emerald ash borer and its potential negative effect on this species. White ash, black oak, Washington hawthorn, flowering dogwood and red oak had positive responses to sandstone sites compared to others. White oak had greater growth than many species on shale spoil.

4.5. Growing Hybrid Poplar

HP is easily propagated through planted cuttings (Brunner et al., 2009). The high growth rate of HP in this experiment is consistent with that reported on other mine soils (McGill et al., 2004) and on natural soils (Van den Driessche, 1999). Fast growth is characteristic of the *populus* genus (Bradshaw et al., 2000) and it is clearly the best choice for biomass production of the options studied in this experiment, producing 1.8 Mg ha^{-1} yr^{-1} of dry biomass above ground on WC+R treatments, despite having a survival rate of only 67%. If survival could be improved to nearly 100%, the growth rate would be 2.7 Mg ha^{-1} yr^{-1}, approaching that achieved for mined land in Germany (3-6 Mg ha^{-1} yr^{-1}) (Bungart and Huttl, 2004). Our best treatment block, the WC+R at site WV-2, produced 25 Mg ha^{-1} biomass above ground, or 5 Mg ha^{-1} yr^{-1}, a level that demonstrate's this species' potential. Closer poplar spacing has also led to higher biomass than wider poplar spacing (Bowersox and Ward, 1976).

The mined land HP growth is less than the growth of 12 Mg ha^{-1} yr^{-1} observed for HP on lands formerly used for agriculture in Germany using the same clones (Bungart and Huttl, 2004). Over a six to eight year period of growth under intensive cultivation on agricultural land, HP has produced up to 17-30 Mg ha^{-1} yr^{-1} (Bradshaw et al., 2000). This is comparable to the fastest growing sources of biomass in the Southeast United States: loblolly pine (*Pinus taeda*) at 22.4 Mg ha^{-1} yr^{-1} (Fox et al., 2007) and switchgrass (*Panicum virgatum*) at 24.4 Mg ha^{-1} yr^{-1} (McLaughlin and Kszos, 2005). HP may be the best option for woody biomass that can be grown in the mountain environment of Appalachia and is ideal for intensive management, as a means of producing harvestable biomass so as to reduce harvest pressures on natural forests (Bradshaw et al., 2000). Side-by-side comparison to other hybrid woody biomass options that can survive in the mountains, such as pitch-loblolly pine (*Pinus rigida x taeda*), would be useful to further explore the available options.

HP production is a means of sequestering atmospheric carbon (Bradshaw et al., 2000; Scott and Kuhn, 2000) and since it grows faster at elevated carbon dioxide concentrations (Bosac et al., 1995), it is useful for both climate change mitigation and adaptation. Wullschleger et al. (2005) reported that 62% of its biomass is concentrated in the above-ground shoots and stem and is available for conventional harvest as an energy or fiber crop. The remainder cycles into the soil through roots and litter deposition and provide a longer-term carbon sink. Afforestation of mined lands can partially offset the carbon emissions of mining and coal usage in this way (Akala and Lal, 2000; Metting et al., 2002).

4.6. Logistical Concerns

The variation between blocks that were designed as replications was often as great, or greater than, the variation between the species x state x treatment combinations that were being compared. This could be due to micro-site factors related to the specific origin and geologic makeup of mine spoils deposited with each spoil load which may have differed from one block to the next, to differences in browse activity amongst the blocks, or to any number of other variables that might not have been adequately controlled such as topography and microclimate. Better experimental controls and isolation of variables than achieved here would better establish the true effects of experimental treatments. Tree species trials on-site at a small scale followed by careful observation are one way of integrating all factors specific to site and species in order to identify the species which can be most successful on a given site for future reforestation.

Herbivory, likely by deer, was a factor that appeared to affect survival and growth. Damage to planted trees by herbivores is common (Kost et al., 1998) and has been reported to mute the positive effects of weed control in cases where weed control failed to improve tree performance (Ashby, 1997). Control of animal damage has been found to be the most likely way to improve tree survival in other mined land experimentation (Kost et al., 1998).

5. Conclusions

Forest productivity of unused post-mining lands originally reclaimed as grasslands can be improved using traditional silvicultural practices. In this study, we investigated the relative effectiveness of three such practices for restoring forest vegetation and productivity on previously-reclaimed mine sites. Those practices are weed control only; weed control plus subsoil ripping; and weed control plus subsoil ripping and fertilization. Experimental plots were planted with eastern white pine, hybrid poplar, and mixed Appalachian hardwoods. After five years, subsoil ripping and weed control, when applied together, increased both survival and, in some cases, growth of planted trees compared to the effect of weed control alone. Subsoil ripping is therefore an effective, recommended treatment. The addition of fertilization did not increase overall survival or growth relative to the other treatments, but did improve performance of several species.

Silvicultural treatment effects exhibited high variability between locations and species, indicating that planted seedlings' survival and growth response to silvicultural treatments will, in many cases, be site and species specific. Hybrid poplar demonstrated superior growth on a per-hectare basis and is a promising species for biomass plantations in the Appalachians.

Woody plant establishment is critical to reforestation efforts on old mine sites. Established trees naturally give rise to more trees and to other forest organisms and non-living components (Ashby, 1997). Rehabilitating lands to the point where forests of any type establish ensures that natural processes will perpetuate those forests, so long as future human disturbances are not so severe.

The site-to-site differences here demonstrate the importance of identifying site and management factors that contribute to successful rehabilitation of these older mined land sites. Even within individual treatment and species groups, differences among survival and growth effects were dramatic. Given the areal extent of older mined lands that are in arrested succession and unused, and the resources that are required to apply silvicultural treatments for the purpose of re-establishing forest, it becomes essential to apply those resources in a manner that maximizes potentials for successful outcomes. These results can contribute to the development of that knowledge base, as can further study.

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CHAPTER IV. RESTORING AMERICAN CHESTNUT ON MINED LANDS USING THE FORESTRY RECLAMATION APPROACH

Abstract Hybrids of American chestnut (*Castanea dentata*) with blight-resistance of Chinese chestnut (*Castanea mollissima*) are being developed by the American Chestnut Foundation. These chestnuts are intended for establishment within Appalachian forests, anticipating that they could fill the ecological role formerly occupied by chestnut prior to the species' near-extirpation by the chestnut blight (*Cryphonectria parasitica*). Reclamation of mined land in the Appalachians can aid the hybrids' introduction because of the coincidence of the Appalachian coalfield with the central range of the American chestnut and the large areas of land available for afforestation. There are questions about mined lands being a suitable habitat for the American chestnut, about how the survival of various backcross generations from the breeding program will compare in the field, and about the best planting practices to aid establishment. Two experiments were used to test the performance of several breeding generations of chestnut, as they were affected by establishment method on reclaimed surface mined land. Six breeding generations of chestnuts were direct seeded in 2008 on three sites within three different groundcover seeding mixtures: a conventional mine-reclamation mix of tree-competitive legumes and grasses, a tree-compatible mix of less-competitive legumes and grasses, and annual ryegrass only. These trees were planted as nuts in a mix of potting soil, native forest soil and mine soil, and within a tree tube shelter. After two years of growth, the annual ryegrass treatment allowed greater survival and height growth (71%, 67 mm) than the conventional tree-competitive seeding mix (50%, 28 mm). In 2009, five breeding generations were planted on four sites, with half planted as unprotected, bare-root seedlings and the other half direct seeded with shelters. After one season, survival of the bare-root seedlings (83%) was higher than that of the direct seeded trees (76%) and the first-year total height of the bare-root seedlings (470 mm) was also greater than that of the planted nuts (347 mm). Survival and growth varied among the various hybrid breeding generations, but none demonstrated consistently superior performance. Labor, time per tree for planting, and supply costs were greater for the direct-seeded trees than for those planted as bare-root seedlings. Overall, early chestnut survival on a variety of reclaimed mined land was comparable to that of other Appalachian hardwood species. These results suggest that if blight resistance can be effectively conveyed through breeding, reclaimed mined land has potential for use in restoring American chestnut as a component of re-established multi-species forests across central Appalachia.

Additional Key Words: ground cover, reforestation, American chestnut, reclamation

1. Introduction

1.1. Background and Rationale

Successful afforestation of lands surface mined for coal in Appalachia presents the opportunity to also restore American chestnut (*Castanea dentata*) that has been genetically improved to convey chestnut blight (*Cryphonectria parasitica*) resistance to its native range. Chestnut was an important component of the pre-blight mixed mesophytic forest (MMF). The MMF type is the oldest and most diverse of the eastern deciduous forests (Braun 1950) and is being significantly impacted by ongoing surface mining (Wickham et al., 2007; Sayler, 2008). The full restoration of the MMF on mined lands will require chestnut's success in tandem with that of many other native species. The MMF, the Appalachian coal basin, and the core of the American chestnut's former range are all geographically coincident (Figure 1).

American chestnut was a foundation species of the MMF and also of the Appalachian subsistence culture, but the chestnut blight (*Cryphonectria parasitica*) has functionally eliminated it. With efforts to breed a blight-resistant chestnut that is also botanically indistinguishable from American chestnut making progress, restoration of the chestnut in form and function is becoming possible. Over 0.6 million ha of land in the Appalachians has been surface mined for coal (data from United States Office of Surface Mining). These lands, formerly occupied predominantly by MMF, are frequently capped with a topsoil substitute selected from available rock types and therefore are reduced to having no remaining vegetation. This material is used as a starting substrate for revegetation. Afforestation of reclaimed mine areas using the Forestry Reclamation Approach (FRA) (Burger et al., 2005) has become common practice in some areas of the Appalachian coalfield (Angel et al. 2009). Successful implementation of the FRA, which is a five-step process for reforesting mined lands (Burger et al., 2005), within the MMF's range can combine with the successful chestnut breeding programs to achieve the reintroduction of the chestnut on vast expanses of land. The mined lands provide an opportunity for chestnut restoration, having little competing forest vegetation which would otherwise make full-scale chestnut reintroduction more problematic.

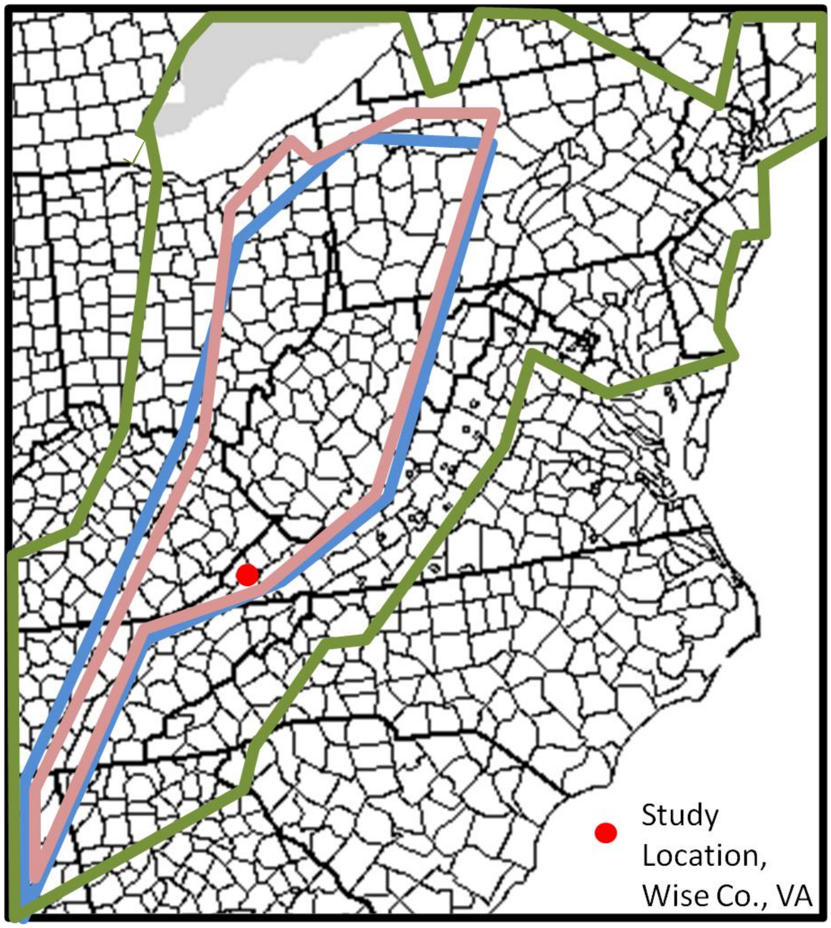

Figure IV.1. Study site location, relative to area occupied by mixed mesophytic forest (blue), the Appalachian coal basin (red) and the former native range of the American chestnut (green).

1.2. Chestnut Breeding

The American Chestnut Foundation has been breeding American chestnut (A) *(Castanea dentata)* with Chinese chestnut (C) *(Castanea mollisima)* and then using a backcross breeding technique since the early 1980's in order to achieve a blight-resistant hybrid with the form and ecological functions of American chestnut (Hebard, 2001; Diskin et al., 2006; Jacobs, 2007). The ACF back-crossed the initial A x C hybrids with American chestnut three successive times to create three backcrosses (B1, B2 and B3) with successively higher percentages of American chestnut genes. The first generation of each of the backcrosses was then bred to create an F1, F2 and F3 generation for each backcross. At the time of this experiment, the F3 generation was available for B1 and B2, but the F2 generation was the latest available for B3. Thus three backcross generations (B1F3, B2F3 and B3F2) and two non-hybridized controls for comparison (A and C) were available for our field trials on mined sites. These represent a continuum between American and Chinese chestnut that may produce measurable differences in survival and growth on mined lands.

1.3. American Chestnut as a Foundation Species

Foundation species create and define ecological communities and ecosystems through their structure and function. A small number of strong interactions shape community and ecosystem dynamics in systems dominated by them, such as the forests once dominated by American chestnut (Ellison et al., 2005). The loss of foundation species has dramatic effects on landscape perceptions as well as on the functioning and stability of ecosystems and all associated biota. The decline of American chestnut altered terrestrial and aquatic systems over large areas of the eastern US because of the widely ranging environments it dominated. Wild American chestnut is now functionally extinct. Its current shrubby form, mostly stump sprouts from trees that succumbed to the blight, produces relatively little leaf area and woody biomass and few nuts. Without this tree fulfilling its historical role, the health of the MMF is compromised (Ellison et al., 2005).

The idea of "forest health" invokes the concept of ecological integrity as well as an expectation of the presence of all forest relationships and components in a fully functional and self-renewing way (Oak, 2005). One of the most important factors in the creation of the present Appalachian forest condition is the chestnut blight. Prior to and during the blight outbreak, heavy forest disturbances from harvesting and fire were also occurring. These disturbances benefited the chestnut since it was a species that could quickly re-sprout and take advantage of canopy gaps. As blight-caused chestnut losses progressed, extensive harvests and related disturbances also slowed due to changes in policy and management. The result was replacement of chestnut with stands of moderately shade intolerant species such as oak (*Quercus spp.*) and hickory (*Carya spp.*) with high stand densities and uniform ages within stands. These stands do not have the ability to replace themselves in the absence of widespread disturbance because of the presence of more shade tolerant species like maple (*Acer spp.*) and beech (*Fagus spp.*) (Oak, 2005). The status of the health of the Appalachian forest in this current state is an ongoing question. Afforestation of mined lands with chestnuts and other species that have become less common due to introduced pathogens and pests and due to lack of forest disturbance, using the springboard of mined sites where succession has been reset to time zero, is one potential avenue for the health of the forest to be improved.

Loss of American chestnut as a dominant component of the MMF has other ecological effects. For example, the gypsy moth (*Lymantria dispar*), to which American chestnut is resistant, favors oaks as a food source and has thus disproportionately defoliated current forest landscapes in comparison to what would have been likely pre-blight (Oak, 2005). The large decrease in hard mast production with the loss of the chestnut is furthered by gypsy moth induced oak decline with a subsequent drop in acorn production. This loss of hard mast production has had unknown, but probably significant, effects on wildlife and human communities that depended on this food source for sustenance (Oak, 2005). This example highlights how the consequences of the loss of a single foundation species, such as American chestnut, cascade into a series of disruptive consequences for the entire ecosystem. It also demonstrates the need for science-based strategies that lead to the reintroduction of chestnut.

1.4. Silvics, Ecology and Management of American Chestnut

Knowledge of American chestnut's silvicultural and ecological characteristics is limited because it lost its former ecological role before the advent of modern forest ecology principles, but American chestnut is known to have excellent growth and competitive abilities and can survive in forest understories for prolonged periods before quickly taking advantage of canopy disturbances (Jacobs, 2007).

Fast growth and competitiveness of chestnut makes reintroduction in mixed stands with other hardwoods a viable option; however, there is a limited area of sites available for reforestation following logging in the chestnut's range for two reasons: there are policy concerns on public lands regarding the hybrid genetics of improved chestnut, and there are economic concerns on private lands regarding the uncertainty of success at growing chestnut of commercial size (Jacobs, 2007). Afforestation plantings, on surface mines or abandoned agricultural lands, may avoid the issues of policy on public land and opportunity costs on private land. Since the American chestnut's original range is all-inclusive of the Appalachian Coal

Basin, afforestation of these sites with chestnut following reclamation is a logical means of helping the species recover (Jacobs, 2007).

Most mine soils are derived from rock overburdens that are used as topsoil substitutes. Based on previous research on the influence of chestnut on soils, it appears the species has a disproportionately positive effect on soil quality compared to other native species. In a study of American chestnut trees growing in Wisconsin, outside of the original range of the chestnut and the blight, Rhoades (2007) reported that chestnut stands produced higher soil carbon, nitrogen and moisture than mixed hardwood stands on sandy-loam soils. American chestnut may have these beneficial effects on sandstone-derived mine soils.

Techniques for establishing American chestnut have been explored by past researchers. Phelps et al. (2005) tested the success and effects of different methods of planting American chestnut trees in cleared forest sites. They found that when deer browse activity was absent, tree tube shelters gave trees no advantage in height growth. When there was frequent deer browse activity, tree tube shelters were necessary for establishment. Seedlings were able to successfully compete when the other competing species were cut to ground level mechanically at the time of chestnut planting. Direct seeding was found to be the most cost effective and efficient planting method, but planting of seedlings was found to ensure greater survival, better control over tree placement and enhanced ability to compete with other vegetation. Direct seeded trees did not compete adequately with re-sprouting vegetation that had been cleared (Phelps et al. 2005). On mined land, deer browse and other types of predation is a concern (Fields-Johnson et al., 2009), but competition from re-sprouting woody plant species commonly found on sites disturbed by logging or fire would be absent because all vegetation is completely removed in the process of mining. Experimentation with direct seeding versus planting of seedlings is needed on mined land. Herbaceous species competition would be a concern on mined lands, being a function of the herbaceous species and seeding rate used for erosion control. Experimentation with different seeding prescriptions of herbaceous ground covers with planted chestnut is also needed.

1.5. Additional Challenges to Chestnut Restoration

Chestnut restoration efforts were begun as early as 1920 by the US Department of Agriculture but failed and were abandoned by the 1960's. The slow process of the dissemination of hypovirus to infected trees has prevented successful treatment of populations of chestnut with hypovirulent strains of the fungus. Other threats to American chestnut that must be overcome include *Phytophthora* root rot (*Phytophthora cinnamomi*), the oriental gall wasp (*Dryocosmus kuriphilus*), and ambrosia beetles (*Xylosandrus crassiulus and Xylosandrus saxeseni*). A limited number of genotypes of American chestnut have provided the basis for the hybrid breeding program and as wild sprouts lose their vigor and die out there is less genetic stock for future breeding. This may undermine restoration due to a lack of adaptation to local environments or to the adaptation of the blight (*Cryphonectria parasitica*) to overcome bred-in resistance genes (Jacobs, 2007).

American chestnut is highly susceptible to *Phytophthora* root rot even when soil compaction and soil moisture are at moderate levels. *Phytophthora* has been isolated from recently reclaimed mine sites with cappings of loose mine spoil (Ward, 2009), indicating that it can be present on mined lands into which chestnut is planted. It will be important to avoid wet and compacted sites that promote *Phytophthora* root rot when planting chestnut trees. Root damage which pre-disposes trees to *Phytophthora*, and transmission of the disease itself to new locations, are both associated with transplanting bare-root seedlings (Rhoades, 2003).

1.6. Key Aspects of Reclaimed Mined Land Plantings

Three key aspects of planting chestnuts on mined land are: finding the best hybrid generation of chestnuts to plant, developing the best method of planting the chestnuts themselves, and establishing site conditions through reclamation, including herbaceous groundcover, that are compatible with chestnut establishment.

Among the backcross breeding generations, the pure Americans would be expected to succumb to the chestnut blight and never achieve canopy dominance, though they may repeatedly re-sprout. The pure Chinese would be expected to have a low, spreading growth habit that would also keep them from achieving canopy dominance. Only the hybrids could be expected to have the combination of blight resistance and upright, tall form that would allow them to rise to canopy dominance amidst other native Appalachian hardwoods. This research addresses the initial establishment of these breeding generations; however, several decades of observation will be needed to determine the ultimate success of any of these generations in the mature forest canopy. Two potential methods for planting chestnuts are to use young bare-root seedlings or to plant nuts themselves with protective shelters to prevent their consumption by rodents. The bare-root seedling technique requires a year or more of growth in a nursery followed by transplantation. Using nuts for field establishment requires no nursery time, but more intensive activity in the field to increase the probability of successful germination and avoidance of early predation. Current methods for establishing nuts in the field use plastic tree-shelters and steel rebar, both of which will remain as non-biodegradable debris if not retrieved, with the rebar acting as a potential hazard to people and equipment with approximately 30 cm protruding vertically from the ground. These two methods of establishment were compared for effect on survival and growth, anticipating that results may reveal a preferred establishment method.

It is also well known that herbaceous groundcover influences the survival and growth of trees that are planted on coal surface mines (Burger et al. 2008). Three categories of herbaceous ground cover are 1) those which have been used conventionally in mine reclamation to establish thick, persistent ground cover but also competes with trees; 2) those which are persistent but made up of species which do not compete as vigorously with trees (Burger et al. 2009); and 3) an annual species to create an initial groundcover and then yield to volunteer vegetation (Fields-Johnson et al. 2009, 2010). These three types of ground cover may produce differences in early survival and growth of chestnut; since some ground cover is necessary to prevent early site erosion and to satisfy legal requirements, it is important to know which ground cover type is most compatible with chestnut.

1.7. Experimental Objectives

Our goal was to determine which chestnut planting techniques and reclamation strategies can be applied to aid effective American chestnut restoration on reclaimed surface-mined lands. Our objectives were to compare the effects of:

1) different breeding generations (Chinese, American, and three generations of backcrosses);
2) three groundcover treatments (conventional, tree-compatible and annual ryegrass only);
3) two planting methods (direct seeding in tree shelters and planting unprotected bare-root seedlings),

on survival and growth of Chestnut planted on reclaimed mined land.

2. Methods and Materials

Two separate experiments were conducted. The first, begun in 2008, tested the effects of backcross generation selection and ground cover prescription on survival and total height during the 2009 growing season. The second, begun in 2009, tested the effects of backcross generation selection and planting method (direct seeding with tube shelters vs. planting of unprotected bare root seedlings) on survival and total height during the 2009 growing season. These experiments both employed three backcross generations (B1F3, B2F3 and B3F2) as main treatments plus non-hybridized American (A) and Chinese (C) chestnut as controls for comparison.

Both experimental plantings were established on coal-mined areas in the coalfield of southwestern Virginia, USA. Prior to mining, the areas were occupied by MMF. The area gets approximately 119 cm of precipitation per year and is in plant hardiness zone 6 with average yearly minimum temperatures of -23°C to -18°C.

Soil samples were taken from a depth of 5-10 cm across each experimental treatment area at random locations and aggregated by treatment plot for analysis. Soils were prepared by drying and sieving thorough a 2 mm screen to separate coarse and fine fractions. The coarse fraction was then washed and a visual estimate of percent of each rock type present was made. The fine fraction was then subjected to particle size analysis, phosphorus (sodium bicarbonate extraction followed by ICP analysis) and nitrogen (anaerobic incubation followed by potassium chloride extraction and colorimetric analysis) and testing of pH, electrical conductivity, organic matter by loss on ignition, total carbon and nitrogen (gas chromatograph of dry soil) and exchangeable cations (Mehlich 1 extraction followed by ICP analysis). Laboratory analysis results were then aggregated by block.

2.1. 2008 American Chestnut Planting: Ground Cover Trial

Six breeding generations of chestnut (2 lines of A and 1 each of C, B1F3, B2F3 and B3F2), provided by the ACF, were planted in mid-March of 2008 with three hydroseed groundcover treatments at three locations (blocks) in southwest Virginia. These sites had all been surface mined for coal and reclaimed in the previous year with steep slopes of approximately 60% and aspects by block of south, east and southeast. The sites were constructed with varying spoil materials to serve as growth media (gray sandstone, brown sandstone, siltstone and some shale). The American chestnuts plantings were established in loosely graded areas (Fields-Johnson et al., 2010). Each block contained three treatment plots, each roughly 0.4 ha in size and seeded with a different ground cover vegetation: 1) a conventional mix of herbaceous species intended to create >90% ground cover within the first few months of a growing season after seeding, 2) a tree-compatible mix intended to create a moderate level of initial ground cover while eventually covering the soil surfaces fully, and 3) annual ryegrass, intended to create the lowest level of groundcover by planted species while allowing recruitment of native plant species volunteers (Table 1). Within each of treatment plot, approximately 75 nuts were randomly planted among 12 species of Appalachian hardwoods and Eastern white pine (*Pinus strobus*) which were also being established as seedlings on these sites (Fields-Johnson et al., 2010).

The conventional ground cover treatment seed mix prescription is one that is commonly applied by a commercial hydroseeding firm on coal mining operations in southwestern Virginia. The tree-compatible mix prescription has been developed through reclamation research using a process of experimentation and observation of many herbaceous species over many years (Burger et al. 2009). Hydroseeding was performed by a commercial contractor using operational procedures, under supervision by the mining firms but using our prescriptions, following final grading of mine spoil. Fertilizer was prescribed for inclusion in all hydroseeding mixtures at an approximate rate of 22 kg ha^{-1} nitrogen (N), 68 kg ha^{-1} phosphorus (P) and 18 kg ha^{-1} potassium. This fertilization prescription for reforestation was developed via experimentation as a way to provide trees ample P without causing excessive herbaceous growth with large amounts of N. Block 1 was hydroseeded in the fall of 2007, block 2 was hydroseeded in the winter of 2007-2008, and block 3 was hydroseeded in early spring of 2008. Mining was completed for these sites at different times, hence the staggered hydroseeding schedule.

Chestnut seeds were planted and protected using procedures developed by The American Chestnut Foundation (Figure 2). These procedures involved digging a ~10cm wide x ~20cm deep hole, and filling it with a mix of potting soil, native forest topsoil for biotic inoculation, and on-site mine soil. Seeds were then placed on top of this material and covered with an additional 2-3 cm layer of the soil mix. A tree tube (manufactured by Tubex), 6-10 cm in diameter and 38 cm tall, was then placed with its base inserted 2 cm deep into the soil medium and over the seed and moored to a piece of 1-cm thick rebar driven firmly into the ground. Rocks collected on site were piled around the base of each tube to provide additional protection for the buried nut. Nuts were planted in mid-March and germination was assessed in early May. Thereafter, survival, tree height to the highest live bud, and stem diameter at the top of the tree tube were measured in late October – early November at the conclusion of each growing season. Two growing seasons of data were collected for the 2008 planting, with cumulative growth and survival reported here.

Figure IV.2. Photo of chestnut planting method, March of 2008.

Table IV.1. Hydroseed ground cover treatments for the 2008 chestnut planting.

Annual Ryegrass Only	Rate
Seed Mix:	(kg ha^{-1})
Annual ryegrass (*Lolium multiflorum*)	22
Wood Cellulose Fiber	1680
Tree-Compatible Mix	Rate
Seed Mix:	(kg ha^{-1})
Annual ryegrass (*Lolium multiflorum*)	22
Perennial ryegrass (*Lolium perenne*)	11
Timothy (*Phleum pretense*)	6
Birdsfoot trefoil (*Lotus corniculatus*)	6
Ladino clover (*Trifolium repens*)	3
Weeping Lovegrass (*Eragrostis curvula*)	2
Wood Cellulose Fiber	1680
Conventional Mix	Rate
Seed Mix:	(kg ha^{-1})
Rye grain (*Secale cereale*)	34
Orchardgrass (*Dactylis glomerata*)	22
Perennial ryegrass (*Lolium perenne*)	11
Korean lespedeza (*Lespedeza cuneata*)	6
Birdsfoot trefoil (*Lotus corniculatus)*	6
Ladino clover (*Trifolium repens*)	6
Redtop (*Agrostis gigantea)*	3
Weeping lovegrass (*Eragrostis curvula*)	2
Wood Cellulose Fiber	1680

2.2. 2009 Chestnut Planting: Planting Method Trial

Five of the six breeding generations of chestnut established in the 2008 experiment, including only one pure American line, were also planted in late March of 2009 on four mined sites in southwest Virginia using two planting methods. Two of the planting sites were recently mined areas being actively reclaimed using the FRA. The mine soils were a mix of gray and brown sandstone and siltstone. These two sites were both steep (slopes of approximately 60%) with southerly aspects The third site was a steep area (slope of approximately 60%) with an easterly aspect adjacent to a mine site with surface materials comprised predominantly of soil and weathered sandstone materials which had been re-graded loosely in association with the mining operation. The fourth site was gently sloping, had been mined and reclaimed in the early 1990s with a mix of spoil materials (gray sandstone, brown sandstone and siltstone) and revegetated with grasses, and had been left in an unmanaged condition until December of 2007, when it was treated with a subsoil ripper to relieve soil compaction and then left in an unmanaged state until this planting. Approximately 180 trees were planted on each of the 4 sites, with half planted as nuts using methods described for the 2008 chestnut planting; and the other half planted as one year-old bare root seedlings without any tube shelters or staking. The bare root seedlings were grown in a nursery by the American Chestnut Foundation. Within each block, each row was planted with a single breeding generation; and the direct seeded nuts were alternated with the bare-root seedlings within each row. Survival, tree height to the highest live bud, and stem diameter at ground level, for the bare-root seedlings only, were measured in late October – early November of the first growing season.

2.3. Statistical Analysis

Data were analyzed using JMP 7.0 (SAS Institute Inc., Cary NC). Differences in performance characteristics among treatments were determined using a randomized block ANOVA. Tukey-Kramer HSD was used for mean separations ($\alpha = 0.10$). Data from the 2008 and 2009 experiments were analyzed separately. The ground cover trial was designed as a randomized complete block design with ground cover treatment as the main plot and breeding generation as the subplot. The planting method trial was designed as a randomized complete block design with breeding generation as the main plot and planting method as the subplot.

3. Results

Soil physical and chemical properties were variable among blocks, as was chestnut survival, but growth was relatively uniform (Table 2).

Chestnut survival was significantly greater in the annual ryegrass groundcover than the conventional groundcover, but groundcover type had no significant effect on growth after two growing seasons (Table 3). Trees planted as bare root seedlings had significantly greater survival and total height than trees planted as nuts with tree tubes after one growing season (Table 4).

Table IV.2. Soil characteristics for each block of the 2008 and 2009 Chestnut studies (Blocks as follows: 2008: 1 RR = Red River Coal Site, 2 PR = Powell River Site, 3 CR = Carrie Ridge Site; 2009: 1 OF = Over FRA B1 Site, 2 CF = Cliff Face Site, 3 BH = Brown Hill Site and 4 PR = Powell River Project Site).

	2008 Study			**2009 Study**			
Blocks:	**1 RR**	**2 PR**	**3 CR**	**1 OF**	**2 CF**	**3 BH**	**4PR**
Chestnut Survival %	68	73	40	72	76	93	76
Chestnut Height mm	307	235	289	403	399	433	397
Coarse Fragments %	50	66	61	53	64	40	40
Brown Sandstone %	44	23	50	50	53	98	93
Gray Sandstone %	40	28	15	25	44	0	3
Siltstone %	15	43	35	20	1	0	3
Shale %	0	2	0	0	0	0	0
Coal %	1	4	0	5	3	1	1
Fine (<2mm) Fraction %	50	34	39	47	36	60	60
Sand %	51	43	55	36	45	55	39
Silt %	23	29	25	33	28	23	33
Clay %	25	28	20	31	27	22	29
Soil Texture	SCL	CL	SL	CL	L	SCL	CL
pH (1:1 Soil:Water)	5.72	7.44	6.89	4.85	5.62	4.90	7.30
Organic Matter % (LOI 360°C)	1.3	1.8	0.9	2.2	1.7	1.4	3.9
Soluble Salts ppm (1:2 Soil:Water)	572	316	60	84	120	38	128
CNS Total Carbon %	1.4	2.9	0.5	2.1	2.3	0.6	3.8
CNS Total Nitrogen %	0.05	0.09	0.03	0.08	0.08	0.03	0.16
CNS C:N Ratio	28	33	16	26	29	19	22
Baseline NH_4^+ (KCl extract) ppm	2.67	1.32	1.47	1.14	1.12	0.87	5.00
Baseline NO_3^- (KCl extract) ppm	4.40	2.58	1.13	0.00	0.10	0.00	1.46
Anaerobic 8-days NH_4^+ (KCl) ppm	7.41	3.08	1.62	2.49	4.41	1.25	112.97
(NH_4OAc) CEC $cmol_{q+}$ kg^{-1}	8.7	11.6	6.9	4.0	5.0	0.7	17.6
(NH_4OAc) Base Saturation %	100%	99%	100%	99%	100%	89%	100%
ICP (NaHCO3) P ppm	6.9	4.0	8.6	4.5	10.0	3.4	6.4
ICP (Mehlich 1) K ppm	62	66	48	60	59	51	60
ICP (Mehlich 1) Ca ppm	1039	1774	928	426	624	110	2720
ICP (Mehlich 1) Mg ppm	255	392	278	181	180	44	167
ICP (Mehlich 1) Zn ppm	3.1	4.3	1.9	4.4	3.7	1.1	1.0
ICP (Mehlich 1) Mn ppm	49	99	43	31	31	15	22
ICP (Mehlich 1) Cu ppm	2.2	3.2	1.8	4.8	3.1	1.4	0.7
ICP (Mehlich 1) Fe ppm	71	100	52	61	68	22	19
ICP (Mehlich 1) B ppm	0.1	0.1	0.1	0.1	0.1	0.1	0.2

Table IV.3. Cumulative groundcover and genotype effects on survival and total height after two growing seasons for the ground cover trial, with mean separation (Tukey HSD, α = 0.10) indicated by different letters beside values within categories.

Groundcover	**Survival**		**Ht mm**		**2009 Ht growth mm**	
Annual Ryegrass	71%	a	286	a	67	a
Tree Compatible	60%	ab	295	a	29	b
Conventional	50%	b	236	a	28	b
Genotype						
Chinese	84%	a	373	a	42	a
B1F3	73%	ab	352	a	49	a
B3F2	65%	abc	276	ab	56	a
American 2	58%	abc	203	b	42	a
American 1	58%	abc	244	ab	42	a
B2F3	48%	bc	273	ab	53	a

Table IV.4. Planting treatment and genotype effects on survival and total height after one growing season for the planting method trial, with mean separation (Tukey HSD) indicated by different letters beside values within categories.

Planting Treatment	**Survival**	**α = 0.10**	**Ht mm**	**α = 0.10**
Seedlings	83%	a	470	a
Nuts	76%	b	347	b
Genotype				
Chinese	89%	a	740	a
American	87%	a	432	b
B1F3	84%	a	310	c
B3F2	73%	ab	273	c
B2F3	66%	b	287	c

There were also significant differences in survival and height among several of the genotypes. Chinese chestnut survival was greater than that of the B2F3 generation, in both sets of plantings, while American and B1F3 survival were also greater than B2F3 in the planting method trial. Chinese chestnuts grew taller than one American chestnut variety for the planting method trial; and they grew taller than all other varieties in the ground cover trial.

4. Discussion

The greater survival and first-year height of planted seedlings over planted nuts with tree tubes, combined with the much reduced planting labor and costs, demonstrate that use of bare root seedlings is likely to be a more effective reintroduction technique if tree tube shelters are not needed for protection from herbivores (Phelps et al., 2005). The 38 cm tall shelters used in this experiment were intended to protect nuts and emerging trees from rodents. Taller shelters would be required for protection from deer or livestock. The seedlings could be planted in less than one minute each with the use of a hoe-dad, whereas direct seeding required over six minutes per seed to dig the hole, add the native soil mix and erect all of the tree protection apparatus, plus additional time to prepare and stage the soils and materials. The cost of labor and supplies for the additional steps of mixing and applying soil and constructing tree shelters when direct seeding caused us to find direct seeding to be more expensive than planting seedlings in contrast to the findings of Phelps et al. (2005). The young trees established as seedlings were taller than those established as nuts, which is not surprising since seedlings had height at the time of planting and are essentially one year older than the trees planted as nuts. The greater height of young trees established as seedlings can be expected to give them an advantage in over-topping herbaceous vegetation during the first and subsequent growing seasons if the additional height effect persists as would be expected. Another advantage to the seedling transplant method is that this method is used commonly for re-establishing other tree species on surface mined lands, providing potential for easier integration of American chestnut within existing mined-land reforestation methods.

Use of only annual ryegrass as a ground cover improved survival and second year height growth compared with the conventional ground cover treatment. This was likely due to the lower overall seeding rate and the die-off of the annual rye after 2008 decreasing competition with trees for resources compared to the conventional groundcover treatment.

The greatest nominal survival and height growth rates in the planting methods trial were achieved on block three of the 2009 study. This block had the lowest soil levels of cation exchange capacity, base saturation, nitrogen, phosphorus, carbon and organic matter of the seven blocks used. It is peculiar that chestnut did the best in the block with the lowest levels of these soil qualities that typically improve survival and growth when increased. This raises the question: What is the best competitive soil niche for the chestnut to succeed? Brown weathered sandstone, which is the predominant soil-forming component only in block three, appears to provide that niche here and this might be confirmed with formal study of mine soil types and chestnut.

In light of the result that the chestnuts performed significantly better with the annual ryegrass only treatment, it is likely that herbaceous competition is as important a factor for establishment as the soil properties. However, it is possible that the higher quality soils of the other blocks promoted greater herbaceous vegetation growth than on block three of the 2009 study, which then suppressed tree performance through resource competition and caused the observed higher chestnut survival and growth to appear in block three of the 2009 study compared to the other blocks. That is an issue for future study, as is the question of how the chestnuts will fare in the long run, once they close canopy and make herbaceous cover less important, on rich versus poor soils. Chestnut survival was poor on block 3, Carrie Ridge, of the 2008 groundcover trial, perhaps due to the presence of several feral horses grazing and browsing the site over the preceding year. This observation suggests herbivore damage might be found to be a significant cause of mortality were it to be formally studied. Mice were commonly found dead in the bases of tree tubes, having killed the trees. Placing the tube stake on the inside of the tube instead of on the outside, as was done here, might deny rodents entry into the tube while providing them an exit before they kill the growing tree as they starve should they get into the tube anyway.

No consistently dominant backcross generation of hybrid chestnut emerged in these studies, which may change if they differ in sensitivity to Chestnut blight and or in competitive growth form at later growth stages. First-year growth and survival data for the ground cover trial showed few significant differences between groundcover treatments (Fields-Johnson et al., 2009), compared to second-year results, indicating that treatment effects may continue to diverge with time**.** The third generation of the third backcross generation (BC3F3) has the botanical characteristics to be classified as American chestnut and is putatively resistant to the blight, but the resemblance of its structural morphology to that of the American chestnut in the long-term has yet to be tested. BC3F3 nuts were first attained in 2005 and will likely be available in larger quantities for reintroduction efforts within one decade (Diskin et al., 2006; Jacobs, 2007).

Several other experimental efforts are underway in the Appalachian region testing methods of planting chestnut on reclaimed mined lands, and these results are generally consistent with our findings. French et al. (2008) found that American chestnut direct-seeded on the Cumberland

Plateau had greater first-year survival (61.8%) than containerized transplants (51.2%), but height and diameter growth were greater for the containerized transplants. Bare-root seedling transplants survived better than direct-seeded chestnuts in our study, indicating that bare-root seedling transplants may respond differently to out-planting stresses than containerized transplants. Miller et al. (2009) found survival rates of 30%-72% for direct-seeded chestnut in Eastern Tennessee after two months of emergence and growth, and they found that fertilization resulted in a significant decrease in emergence and survival. The trees in our study had generally higher survival rates overall, perhaps due to uniform fertilization applied via hydroseeding rather than to individual trees, but these difference might also have been due to other site or climatic factors. Working in West Virginia, Skousen et al. (2009) found that direct-seeded chestnuts had an overall first-year survival rate of 72%, with 82% for Chinese, 67% for American and 69%-74% for hybrid backcrosses. They found a significant difference in survival between nuts planted with (81%) and without (63%) tree tube shelters, and that the addition of peat to planting holes significantly reduced survival. Our study had a comparable first-year survival rate for nuts planted with tube shelters and comparable patterns of survival by breeding generation.

Our results combined with other chestnut establishment studies can only provide early indications of planting success since all plantings are in early growth stages. To date, research concerning establishment of hybridized American chestnot on coal surface mines suggest bare-root seedling transplants experience greater survival than direct-seeded chestnuts and direct-seeding results in greater survival than use of containerized transplants. They also suggest direct-seeded chestnuts have greater early survival when protected with tree tube shelters than when planted without shelters, have greater survival and growth when only annual ryegrass is planted as a ground cover than when more competitive and persistent ground covers are used, and have greater survival without additions of peat or direct fertilization of trees at planting than when peat is added or individual trees fertilized.

Survival rates so far in our work, as in some of the other experiments mentioned above, are nominally comparable to those of other mixed native hardwoods planted for research purposes on reclaimed mined land using the Forestry Reclamation Approach. Burger et al. (2008) recorded overall mixed-hardwood survival after 5 years of 69% in research assessing the effects of ground cover control, while Fields-Johnson et al. (2010) recorded survival rates ranging from 71%-75% in 2009 for mixed hardwoods planted as seedlings in association with our ground cover trial of American chestnut, as described above. These early results suggest that, once blight-resistance is effectively conferred, hybrid chestnuts carry the potential to be successfully introduced throughout American chestnut's former range through reclaimed surface mined land plantings in tandem with other native hardwoods. Blight resistance of the hybrids will take several more years to evaluate. It will also be necessary for the hybrid trees to have a forest-tree architecture suitable to make them competitive in reaching the forest canopy and competing there with many other species. The success or failure of this will not be evident for many more years, extending beyond the time of crown closure, and this too must ultimately be achieved ahead of out-planting through selective breeding programs in order for American Chestnut to be truly restored in the mixed mesophytic forest.

5. Conclusions

Planting bare-root chestnut seedlings and hydroseeding annual ryegrass as a sole groundcover were found to be effective ways to improve early chestnut performance on reclaimed surface mined land in the Appalachians. These techniques are also more cost-effective than the alternatives studied. Restoring American chestnut to its native range through plantings on reclaimed mined lands, following the tenets of the Forestry Reclamation Approach, appears promising at this stage so long as blight-resistance and forest-tree architecture is effectively conferred through breeding programs.

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CHAPTER V. CONCLUSIONS

Loose grading surface soil materials on newly reclaimed mined lands, using as few equipment passes as necessary to achieve the necessary grade, and seeding only annual ryegrass as a groundcover proved to be better than smooth grading and seeding multi-species ground cover mixes for reestablishing forested ecosystems on newly reclaimed mined lands. The combination of these two techniques should ultimately result in higher survival rates for planted trees, less surface soil erosion, greater biodiversity of herbaceous vegetation and less introduction of alien and invasive species through planting. It may be possible to prevent much of the evident mass erosion through better engineering of roads and drainage structures that influence mine slopes, as such structures were observed to contribute heavily to gully formation in cases where they concentrated water at the top of research plots. Special attention is needed in selecting tree species' planting rates in recognition of species' varied responses to mined land conditions. Greater overall survival was achieved with black oak, black cherry, white pine, white oak and yellow-poplar than with red oak, shagbark hickory, chestnut oak and sugar maple. Though planting each species at an equal rate may be a more efficient choice when using planting crews in the field, planting surplus numbers of certain species in anticipation of their greater mortality would be necessary to achieve equivalent final stocking rates when the forest stand approaches canopy closure.

Ripping of unused compacted mine sites in combination with weed control using herbicides resulted in better survival and growth of trees than weed control alone when these sites were intended for future forestry usage. Although our studies did not demonstrate growth improvements consistently and with statistical significance, most of the research plots did demonstrate this effect; and this effect has been demonstrated by other studies. Fertilization of trees should improve the performance of some species, when applied properly. Many survival and growth effects of ripping and fertilization on trees are site- and species-specific and better survival and growth could be achieved by placing the right tree in the right place. Hybrid poplar produced the greatest biomass of all species studied after five years of growth and was the most promising as a source of woody bioenergy grown on unused mined lands. Mixed hardwoods had the greatest rate of survival of the three species assemblages planted on the older mine sites despite having relatively slow growth, indicating their resilience and adaptability to a variety of conditions.

Planting hybrid American chestnut as bare-root seedlings was the best option for optimizing their performance while incorporating them into ongoing mixed hardwood plantings. Seeding only annual ryegrass around them as a groundcover further improved their performance. Tube shelters are optional, but recommended when deer browse is anticipated to be a problem on a site, but tube stakes should be placed inside the tube to avoid damage from rodents who would otherwise use the stake to climb into the tube. Early survival of hybrid chestnuts was comparable to that of other Appalachian hardwoods studied in other experiments under similar conditions. So long as blight resistance and forest-tree architecture is conferred through breeding programs, these trees should be competitive in the long-term as members of mixed forests on mined lands.

Many questions remain following the results and incidental observations of these experiments:

If grading has no effect on initial tree establishment, at what point in the life of the tree and/or under what climatic conditions will it have a significant effect?

How will herbaceous seeding choice affect long-term succession and biodiversity? How will herbaceous seeding choice affect long-term tree performance? Will the annual ryegrass treatment allow enough nitrogen to be accumulated on the site to support long-term forest productivity?

Why did fertilization of the older previously reclaimed sites fail to produce a positive effect in most cases? How can fertilization be made effective for trees without promoting excessive herbaceous competition?

What is the right tree species for a site given its soil parent materials, aspect, slope and desired land use and past land use history?

Will the hybrid chestnuts have the blight resistance and forest tree architecture to be successful as a canopy species in restored forests?

What is the quantitative erosion rate of a mined site and how do grading, infiltration, groundcover and slope angle and length interact to affect it?

How does proximity to un-mined corridors affect biodiversity and succession? How does the best biodiversity and succession achieved on reclaimed mined lands compare to un-mined sites?

What is the effect of herbivory on these trees as they establish and how can that be mitigated?

Will these established forests ever be economically viable and how will they be managed? What do all of these options cost and what is the true value gained through these practices?

Are these forests truly being restored to something approximating their original condition or are they something entirely different and new? If the latter, how much of the mixed mesophytic forest overlying the Appalachian coal field must be preserved without mining to ensure it survives intact as a biological resource?

These questions can only be answered with long-term study of these and other experimental sites whose establishment is well documented. In conclusion, it is my hope that these studies' findings can be employed immediately by industry and regulators alike, that future researchers will maintain these sites and continue the process of answering those questions, and that the findings of these studies lead to greater success where they are employed.

APPENDIX A

Data Tables for :

CHAPTER II. SOIL GRADING AND SEEDING EFFECTS ON FOREST RESTORATION AFTER SURFACE COAL MINING

Table A.1. Soil physical and chemical properties at onset of experiment, Spring 2008. Con = Conventional; AR = annual ryegrass only, and TC = tree-compatible seeding.

Block	Grading	Seeding	% Fines	pH	P	K	Ca	Mn	Fe
				ppm	ppm	ppm	ppm	ppm	ppm
1	Loose	AR	47%	5.96	36	62	823	46.2	62.6
1	Loose	Con	55%	5.52	32	59	928	33.7	49.8
1	Loose	T C	47%	5.51	46	62	1284	42.5	79.7
1	Smooth	Con	50%	4.59	27	50	774	44.2	73.7
1	Smooth	T C	40%	5.80	70	62	1447	60.7	86.6
1	Smooth	AR	48%	6.93	49	75	977	63.9	73.6
2	Loose	AR	27%	7.93	47	74	2617	135.3	197
2	Loose	Con	29%	8.10	22	66	3009	160.7	122.5
2	Loose	T C	45%	7.46	78	63	1309	86.4	77.3
2	Smooth	Con	42%	7.21	75	60	1466	80.7	71.2
2	Smooth	T C	39%	7.20	77	64	1122	69.4	68.7
2	Smooth	AR	36%	6.76	70	66	1120	58.7	65.8
3	Loose	T C	45%	7.19	28	44	910	35.8	42.5
3	Loose	AR	30%	6.76	41	48	740	43.6	54.9
3	Loose	Con	41%	7.20	48	51	1036	54.6	66.8
3	Smooth	Con	32%	6.23	46	47	846	37.5	45
3	Smooth	T C	37%	7.02	52	50	1088	44.4	49.7
3	Smooth	AR	42%	6.95	43	49	949	43.4	53.4

Block	Grading	Seeding	CEC	Acidity	BS	OM	SS
			(meq/100g)	(%)	(%)	(%)	(ppm)
1	Loose	AR	6.0	2	98	1.3	269
1	Loose	Con	7.5	7.9	92.1	1.2	602
1	Loose	T C	9.6	6.2	93.8	1.2	909
1	Smooth	Con	7.6	24.3	75.7	1.2	563
1	Smooth	T C	10.1	2.4	97.6	1.2	973
1	Smooth	AR	7.2	0.1	99.9	1.5	115
2	Loose	AR	17.4	N/A	100	1.6	218
2	Loose	Con	19.6	N/A	100	1.4	218
2	Loose	T C	9.6	N/A	100	2	230
2	Smooth	Con	10.3	N/A	100	1.8	627
2	Smooth	T C	8.4	N/A	100	2.3	218
2	Smooth	AR	8.1	0.1	99.9	1.8	384
3	Loose	T C	6.3	N/A	100	0.9	51

3	Loose	AR	5.7	0.5	99.5	0.9	51
3	Loose	Con	7.7	N/A	100	0.8	77
3	Smooth	Con	6.9	0.9	99.1	0.9	64
3	Smooth	T C	8.4	N/A	100	0.9	51
3	Smooth	AR	7.3	N/A	100	0.9	64

Table A.2. Surface water infiltration (liters per square meter per minute), cumulative soil surface change (erosion, mm), and groundcover (%, as visually estimated during the infiltration experiment); Con = Conventional; AR = annual ryegrass only, and TC = tree-compatible seeding. Fall 2009.

Block	Grading	Seeding	Infiltration	Apparent Erosion	Ground-cover (%)
1	Smooth	Con	4.21	-9	89%
1	Smooth	AR	4.07	-1	49%
1	Smooth	TC	6.85	6	99%
1	Loose	Con	4.67	1	79%
1	Loose	AR	4.06	20	58%
1	Loose	TC	7.17	9	96%
1			5.07		77%
2	Smooth	Con	4.95	-50	63%
2	Smooth	AR	1.87	-34	26%
2	Smooth	TC	1.87	-9	11%
2	Loose	Con	5.18	9	61%
2	Loose	AR	3.54	20	8%
2	Loose	TC	4.44	16	44%
2			3.63		38%
3	Smooth	Con	9.65	4	100%
3	Smooth	AR	2.48	10	31%
3	Smooth	TC	11.05	9	99%
3	Loose	Con	8.28	6	96%
3	Loose	AR	4.25	8	25%
3	Loose	TC	5.98	6	61%
3			6.92		68%

Table A.3. Woody plot data by plot, treatments and species, initial June 2009 values for stocking (Tree Ha^{-1}) and average height to highest live bud (Ht mm) are given along with 2009 survival and height growth increment as of November 2009; AR = annual ryegrass only, Con = conventional, TC = tree-compatible seeding, a = white ash, bc = black cherry, bo = black oak, co = chestnut oak, d = gray dogwood, h = shagbark hickory, mu = red mulberry, rb = redbud, rm = red maple, ro = red oak, sm = sugar maple, wo = white oak, wp = white pine, yp = yellow polar.

Block	**T Plot**	**Grading**	**Seeding**	**Species**	**Tree Ha^{-1}**	**2009 Survival**	**Ht mm**	**2009 Ht Growth mm**
1	1	Loose	AR	a	316	0.53	416	230
1	2	Loose	Con	a	257	0.31	374	236
1	3	Loose	TC	a	277	0.93	420	209
1	4	Smooth	Con	a	277	0.39	324	177
1	5	Smooth	TC	a	148	0.93	422	102
1	6	Smooth	AR	a	287	0.59	327	380
2	1	Loose	AR	a	148	0.8	400	62
2	2	Loose	Con	a	207	0.71	358	98
2	3	Loose	TC	a	198	0.6	344	53
2	5	Smooth	Con	a	148	0.6	344	-12
2	6	Smooth	TC	a	198	0.55	411	62
2	7	Smooth	AR	a	247	0.68	341	47
3	1	Loose	TC	a	158	0.38	290	77
3	2	Loose	AR	a	168	0.59	333	228
3	3	Loose	Con	a	119	1.08	385	110
3	4	Smooth	Con	a	99	1	338	118
3	5	Smooth	TC	a	128	0.77	394	92
3	6	Smooth	AR	a	168	0.88	380	90
1	1	Loose	AR	bc	158	1	437	237
1	2	Loose	Con	bc	59	0.83	376	226
1	3	Loose	TC	bc	128	1.62	470	412
1	4	Smooth	Con	bc	237	0.71	403	209
1	5	Smooth	TC	bc	168	0.47	429	470
1	6	Smooth	AR	bc	109	1.09	341	368
2	1	Loose	AR	bc	158	1	298	85
2	2	Loose	Con	bc	207	0.52	297	88
2	3	Loose	TC	bc	168	0.24	321	123
2	5	Smooth	Con	bc	148	0.47	315	124
2	6	Smooth	TC	bc	257	0.65	341	109
2	7	Smooth	AR	bc	296	0.57	351	66
3	1	Loose	TC	bc	20	0.5	340	306
3	2	Loose	AR	bc	158	1.06	427	123
3	3	Loose	Con	bc	69	0.71	380	180
3	4	Smooth	Con	bc	138	0.86	444	173
3	5	Smooth	TC	bc	148	0.93	448	127
3	6	Smooth	AR	bc	237	0.96	436	148
1	1	Loose	AR	bo	178	0.67	340	101

1	2	Loose	Con	bo	346	0.54	340	51
1	3	Loose	TC	bo	138	0.79	354	52
1	4	Smooth	Con	bo	198	1	351	80
1	5	Smooth	TC	bo	168	1.06	375	6
1	6	Smooth	AR	bo	168	1	332	186
2	1	Loose	AR	bo	119	0.83	262	61
2	2	Loose	Con	bo	138	0.79	364	27
2	3	Loose	TC	bo	158	1.19	332	17
2	5	Smooth	Con	bo	138	1.07	317	63
2	6	Smooth	TC	bo	109	0.82	289	97
2	7	Smooth	AR	bo	148	0.87	302	91
3	1	Loose	TC	bo	119	0.83	378	182
3	2	Loose	AR	bo	247	0.96	283	116
3	3	Loose	Con	bo	79	1.5	228	88
3	4	Smooth	Con	bo	198	1.05	318	43
3	5	Smooth	TC	bo	138	0.79	370	42
3	6	Smooth	AR	bo	148	1.27	318	39
1	1	Loose	AR	co	277	0.39	370	174
1	2	Loose	Con	co	326	0.58	427	124
1	3	Loose	TC	co	168	0.41	418	185
1	4	Smooth	Con	co	287	0.41	374	87
1	5	Smooth	TC	co	148	0.67	325	194
1	6	Smooth	AR	co	178	0.56	321	292
2	1	Loose	AR	co	59	1	348	85
2	2	Loose	Con	co	207	0.57	377	-12
2	3	Loose	TC	co	119	0.67	436	-33
2	5	Smooth	Con	co	99	0.8	485	-168
2	6	Smooth	TC	co	188	0.68	418	65
2	7	Smooth	AR	co	227	0.52	414	-37
3	1	Loose	TC	co	148	0.2	405	-30
3	2	Loose	AR	co	158	0.81	390	180
3	3	Loose	Con	co	207	0.43	418	89
3	4	Smooth	Con	co	237	0.38	434	54
3	5	Smooth	TC	co	257	0.46	428	210
3	6	Smooth	AR	co	287	0.66	376	158
1	1	Loose	AR	d	40	1.5	163	309
1	2	Loose	Con	d	30	1	341	155
1	3	Loose	TC	d	40	0.75	273	722
1	4	Smooth	Con	d	30	1.67	178	474
1	5	Smooth	TC	d	0	.	.	688
1	6	Smooth	AR	d	49	1.6	400	537
2	1	Loose	AR	d	40	1.5	325	31
2	2	Loose	Con	d	20	1	300	74
2	3	Loose	TC	d	10	1	230	303
2	5	Smooth	Con	d	20	1.5	234	187
2	6	Smooth	TC	d	79	0.63	442	-97

2	7	Smooth	AR	d	40	1.25	262	47
3	1	Loose	TC	d	10	0	572	-572
3	2	Loose	AR	d	30	1	528	40
3	3	Loose	Con	d	0	.	.	782
3	4	Smooth	Con	d	30	1.67	321	238
3	5	Smooth	TC	d	49	1.2	377	204
3	6	Smooth	AR	d	69	0.86	436	74
1	1	Loose	AR	h	128	0.62	114	270
1	2	Loose	Con	h	59	0.33	192	50
1	3	Loose	TC	h	30	0	286	-286
1	4	Smooth	Con	h	59	0	93	-93
1	5	Smooth	TC	h	49	0.4	202	43
1	6	Smooth	AR	h	40	0.5	38	220
2	1	Loose	AR	h	10	0	77	-77
2	2	Loose	Con	h	59	0	217	-217
2	3	Loose	TC	h	49	0	124	-124
2	5	Smooth	Con	h	49	0.2	235	39
2	6	Smooth	TC	h	49	0.2	180	15
2	7	Smooth	AR	h	40	0.25	110	72
3	1	Loose	TC	h	20	0.5	151	-49
3	2	Loose	AR	h	89	0	114	-114
3	3	Loose	Con	h	40	0	171	-171
3	4	Smooth	Con	h	20	0	315	-315
3	5	Smooth	TC	h	0	.	.	0
3	6	Smooth	AR	h	119	0.08	138	204
1	1	Loose	AR	mu	10	0	0	0
1	2	Loose	Con	mu	10	1	247	101
1	3	Loose	TC	mu	20	1.5	287	492
1	4	Smooth	Con	mu	20	0.5	407	206
1	5	Smooth	TC	mu	10	2	0	718
1	6	Smooth	AR	mu	30	0.67	351	798
2	1	Loose	AR	mu	30	1	297	83
2	2	Loose	Con	mu	20	0.5	176	-116
2	3	Loose	TC	mu	20	0.5	392	266
2	5	Smooth	Con	mu	40	0.25	241	319
2	6	Smooth	TC	mu	20	1.5	393	-60
2	7	Smooth	AR	mu	0	.	.	0
3	1	Loose	TC	mu	0	.	.	330
3	2	Loose	AR	mu	40	0.75	373	336
3	3	Loose	Con	mu	20	1	422	105
3	4	Smooth	Con	mu	0	.	.	395
3	5	Smooth	TC	mu	0	.	.	0
3	6	Smooth	AR	mu	49	1	267	33
1	1	Loose	AR	rb	89	0.56	214	94
1	2	Loose	Con	rb	40	0.75	355	180
1	3	Loose	TC	rb	30	1.33	261	368

1	4	Smooth	Con	rb	40	0.5	376	139
1	5	Smooth	TC	rb	69	0.71	237	610
1	6	Smooth	AR	rb	49	0.4	235	229
2	1	Loose	AR	rb	69	0.43	272	155
2	2	Loose	Con	rb	79	0.88	225	96
2	3	Loose	TC	rb	49	0.6	245	30
2	5	Smooth	Con	rb	89	0.56	150	261
2	6	Smooth	TC	rb	59	0.83	141	162
2	7	Smooth	AR	rb	40	0.75	159	21
3	1	Loose	TC	rb	10	1	172	215
3	2	Loose	AR	rb	59	0.67	203	55
3	3	Loose	Con	rb	10	1	240	218
3	4	Smooth	Con	rb	20	0	137	-137
3	5	Smooth	TC	rb	20	0	207	-207
3	6	Smooth	AR	rb	20	1	186	114
1	1	Loose	AR	rm	10	2	51	2
1	2	Loose	Con	rm	10	0	36	-36
1	3	Loose	TC	rm	0	.	.	0
1	4	Smooth	Con	rm	0	.	.	0
1	5	Smooth	TC	rm	0	.	.	142
1	6	Smooth	AR	rm	0	.	.	0
2	1	Loose	AR	rm	0	.	.	0
2	2	Loose	Con	rm	0	.	.	0
2	3	Loose	TC	rm	0	.	.	0
2	5	Smooth	Con	rm	10	0	0	0
2	6	Smooth	TC	rm	20	0	0	0
2	7	Smooth	AR	rm	0	.	.	0
3	1	Loose	TC	rm	0	.	.	0
3	2	Loose	AR	rm	306	3.19	0	69
3	3	Loose	Con	rm	0	.	.	0
3	4	Smooth	Con	rm	0	.	.	0
3	5	Smooth	TC	rm	0	.	.	0
3	6	Smooth	AR	rm	385	0.85	0	69
1	1	Loose	AR	ro	188	1.11	264	104
1	2	Loose	Con	ro	217	0.64	312	212
1	3	Loose	TC	ro	138	1.5	297	97
1	4	Smooth	Con	ro	277	0.82	338	163
1	5	Smooth	TC	ro	158	0.94	309	-35
1	6	Smooth	AR	ro	128	0.31	336	133
2	1	Loose	AR	ro	89	0.67	478	10
2	2	Loose	Con	ro	99	0.6	304	35
2	3	Loose	TC	ro	207	0.33	337	74
2	5	Smooth	Con	ro	207	0.24	339	87
2	6	Smooth	TC	ro	178	0.28	327	23
2	7	Smooth	AR	ro	99	0.4	402	-39
3	1	Loose	TC	ro	79	0	440	-440

3	2	Loose	AR	ro	188	0.37	412	10
3	3	Loose	Con	ro	79	0.38	356	69
3	4	Smooth	Con	ro	119	0.5	328	106
3	5	Smooth	TC	ro	207	0.33	465	-29
3	6	Smooth	AR	ro	138	0.21	259	290
1	1	Loose	AR	sm	257	0.35	114	73
1	2	Loose	Con	sm	49	0.6	143	44
1	3	Loose	TC	sm	89	1	163	69
1	4	Smooth	Con	sm	79	1	141	137
1	5	Smooth	TC	sm	20	2	99	185
1	6	Smooth	AR	sm	69	0.71	184	41
2	1	Loose	AR	sm	128	0.23	106	22
2	2	Loose	Con	sm	109	0.18	187	-89
2	3	Loose	TC	sm	178	0.28	164	116
2	5	Smooth	Con	sm	138	0.21	98	49
2	6	Smooth	TC	sm	138	0.36	242	197
2	7	Smooth	AR	sm	138	0.14	168	9
3	1	Loose	TC	sm	10	0	70	-70
3	2	Loose	AR	sm	138	0.29	83	15
3	3	Loose	Con	sm	0	.	.	0
3	4	Smooth	Con	sm	10	0	172	-172
3	5	Smooth	TC	sm	10	1	70	70
3	6	Smooth	AR	sm	257	0.35	72	125
1	1	Loose	AR	wo	168	0.71	307	126
1	2	Loose	Con	wo	198	0.8	357	156
1	3	Loose	TC	wo	277	0.86	383	241
1	4	Smooth	Con	wo	158	1	411	108
1	5	Smooth	TC	wo	59	1.5	365	6
1	6	Smooth	AR	wo	267	0.7	395	231
2	1	Loose	AR	wo	79	0.38	241	142
2	2	Loose	Con	wo	69	1	201	145
2	3	Loose	TC	wo	148	0.93	290	66
2	5	Smooth	Con	wo	207	0.43	287	70
2	6	Smooth	TC	wo	178	0.44	341	108
2	7	Smooth	AR	wo	168	0.47	332	26
3	1	Loose	TC	wo	119	0.25	301	49
3	2	Loose	AR	wo	217	0.5	281	124
3	3	Loose	Con	wo	168	0.59	301	105
3	4	Smooth	Con	wo	99	0.6	277	153
3	5	Smooth	TC	wo	119	0.92	394	130
3	6	Smooth	AR	wo	237	1	348	46
1	1	Loose	AR	wp	89	0.78	181	121
1	2	Loose	Con	wp	49	1.2	184	110
1	3	Loose	TC	wp	0	.	.	297
1	4	Smooth	Con	wp	20	1.5	160	227
1	5	Smooth	TC	wp	20	1.5	297	-10

1	6	Smooth	AR	wp	40	1.5	165	135
2	1	Loose	AR	wp	10	1	195	50
2	2	Loose	Con	wp	49	0.6	150	120
2	3	Loose	TC	wp	20	1.5	259	85
2	5	Smooth	Con	wp	20	2	108	205
2	6	Smooth	TC	wp	59	0.83	171	41
2	7	Smooth	AR	wp	59	1.67	143	93
3	1	Loose	TC	wp	20	2	195	105
3	2	Loose	AR	wp	69	1	135	132
3	3	Loose	Con	wp	0	.	.	0
3	4	Smooth	Con	wp	0	.	.	0
3	5	Smooth	TC	wp	20	1	198	119
3	6	Smooth	AR	wp	49	1	153	82
1	1	Loose	AR	yp	128	0.69	310	37
1	2	Loose	Con	yp	158	0.31	379	275
1	3	Loose	TC	yp	59	0.5	273	225
1	4	Smooth	Con	yp	158	0.56	388	114
1	5	Smooth	TC	yp	148	0.67	274	239
1	6	Smooth	AR	yp	109	0.55	426	186
2	1	Loose	AR	yp	109	0.55	388	133
2	2	Loose	Con	yp	99	0.5	271	5
2	3	Loose	TC	yp	138	0.36	352	154
2	5	Smooth	Con	yp	119	0.67	223	93
2	6	Smooth	TC	yp	148	0.47	239	117
2	7	Smooth	AR	yp	158	0.63	277	48
3	1	Loose	TC	yp	89	1.11	261	126
3	2	Loose	AR	yp	128	0.92	204	213
3	3	Loose	Con	yp	40	0.5	273	183
3	4	Smooth	Con	yp	49	2.8	298	269
3	5	Smooth	TC	yp	109	0.64	330	217
3	6	Smooth	AR	yp	138	0.43	226	128

Note: Missing Survival and Growth data means no trees were found in June or Nov. Missing survival data but present growth data means trees were found in November but not June, indicating a re-sprout or a volunteer whose entire growth happened in 2009.

Table A.4. Woody plot summary data (trees per acre) of initial 2008 prescription, final 2008 numbers, 2009 numbers following re-planting and final 2009 numbers and annual survival rates (decimal form).

Block	Plot	Grad-ing	Seed-ing	Prescription	Fall 08	08 Surv	June 09	Nov. 09	09 Surv
1	1	Loose	AR	747	356	0.48	808	544	0.67
1	2	Loose	Con	747	300	0.40	716	416	0.58
1	3	Loose	TC	747	268	0.36	552	540	0.98
1	4	Smooth	Con	747	328	0.44	720	512	0.71
1	5	Smooth	TC	747	116	0.16	468	416	0.89
1	6	Smooth	AR	747	372	0.50	620	440	0.71
2	1	Loose	AR	747	320	0.43	420	304	0.72
2	2	Loose	Con	747	268	0.36	552	332	0.60
2	3	Loose	TC	747	316	0.42	568	328	0.58
2	5	Smooth	Con	747	288	0.39	592	320	0.54
2	6	Smooth	TC	747	324	0.43	684	376	0.55
2	7	Smooth	AR	747	364	0.49	672	412	0.61
3	1	Loose	TC	747	76	0.10	324	168	0.52
3	2	Loose	AR	747	360	0.48	828	860	1.04
3	3	Loose	Con	747	144	0.19	352	232	0.66
3	4	Smooth	Con	747	276	0.37	420	332	0.79
3	5	Smooth	TC	747	372	0.50	484	360	0.74
3	6	Smooth	AR	747	400	0.54	932	680	0.73

Table A.5. Infiltration transect data for each measurement point. Microtopography symbols: gs = gully side; fs = flat slope; g = gully; rs = ridge side; r = ridge; f = flat; c = crevasse.

Plot #	Block	Grad-ing	Seed-ing	Ground-cover	Slope	Micro topo	4 Liter Time	Liters / minute	L/m^2*min
1	2	Loose	AR	0.04	0.65	gs	11.5	0.09	6.19
2	2	Loose	AR	0.00	0.58	gs	4.92	0.20	14.47
3	2	Loose	AR	0.25	0.48	fs	2.88	0.35	24.71
4	2	Loose	AR	0.10	0.49	fs	4.98	0.20	14.29
5	2	Loose	AR	0.00	0.55	g	6.35	0.16	11.21
6	2	Loose	Con	0.35	0.75	rs	2.10	0.48	33.89
7	2	Loose	Con	0.00	0.58	g	17.87	0.06	3.98
8	2	Loose	Con	0.60	0.70	fs	4.88	0.20	14.58
9	2	Loose	Con	1.00	0.61	fs	5.35	0.19	13.30
10	2	Loose	Con	0.65	0.62	fs	4.35	0.23	16.36
11	2	Loose	Con	0.95	0.61	fs	2.98	0.34	23.88
12	2	Loose	Con	0.40	0.65	fs	14.08	0.07	5.05
13	2	Loose	Con	0.90	0.60	fs	1.30	0.77	54.75
14	2	Loose	TC	0.85	0.62	fs	5.50	0.18	12.94
15	2	Loose	TC	0.10	0.67	r	14.88	0.07	4.78
16	2	Loose	TC	0.35	0.62	gs	19.53	0.05	3.64
17	2	Loose	TC	0.30	0.68	gs	1.30	0.77	54.75
18	2	Loose	TC	0.75	0.57	fs	2.50	0.40	28.47
19	2	Loose	TC	0.60	0.61	fs	7.88	0.13	9.03
20	2	Loose	TC	0.15	0.63	r	6.67	0.15	10.67
21	2	Smooth	Con	0.40	0.58	g	5.35	0.19	13.30
22	2	Smooth	Con	0.65	0.62	r	8.23	0.12	8.65
23	2	Smooth	Con	0.95	0.55	fs	2.93	0.34	24.29
24	2	Smooth	Con	0.00	0.56	g	40.67	0.02	1.75
25	2	Smooth	Con	0.30	0.60	rs	6.10	0.16	11.67
26	2	Smooth	Con	0.90	0.50	r	2.86	0.35	24.89
27	2	Smooth	Con	0.90	0.50	gs	5.52	0.18	12.89
28	2	Smooth	Con	0.95	0.51	fs	1.17	0.85	60.83
29	2	Smooth	TC	0.10	0.52	fs	7.43	0.13	9.58
30	2	Smooth	TC	0.05	0.52	fs	16.53	0.06	4.31
31	2	Smooth	TC	0.05	0.56	gs	31.2	0.03	2.28
32	2	Smooth	TC	0.15	0.54	fs	10.67	0.09	6.67
33	2	Smooth	TC	0.05	0.59	gs	31.27	0.03	2.28
34	2	Smooth	TC	0.00	0.62	g	22.13	0.05	3.22
35	2	Smooth	TC	0.10	0.57	fs	4.17	0.24	17.07
36	2	Smooth	TC	0.35	0.56	fs	4.95	0.20	14.38
37	2	Smooth	AR	0.00	0.39	g	15.00	0.07	4.74
38	2	Smooth	AR	0.00	0.35	g	11.77	0.08	6.05
39	2	Smooth	AR	0.20	0.39	fs	7.43	0.13	9.58
40	2	Smooth	AR	0.30	0.42	fs	6.67	0.15	10.67

41	2	Smooth	AR	0.10	0.41	gs	17.13	0.06	4.15
42	2	Smooth	AR	0.75	0.45	fs	9.87	0.10	7.21
43	2	Smooth	AR	0.00	0.44	gs	9.20	0.11	7.74
44	2	Smooth	AR	0.75	0.44	gs	7.30	0.14	9.75
45	3	Smooth	AR	0.75	0.56	gs	29.73	0.03	2.39
46	3	Smooth	AR	0.02	0.56	fs	13.13	0.08	5.42
47	3	Smooth	AR	0.40	0.61	fs	5.00	0.20	14.23
48	3	Smooth	AR	0.02	0.55	fs	8.73	0.11	8.15
49	3	Smooth	AR	0.10	0.60	gs	6.13	0.16	11.61
50	3	Smooth	AR	0.05	0.56	fs	4.47	0.22	15.92
51	3	Smooth	AR	0.15	0.64	gs	5.53	0.18	12.87
52	3	Smooth	AR	0.95	0.54	fs	8.20	0.12	8.68
53	3	Smooth	TC	1.00	0.51	fs	2.40	0.42	29.66
54	3	Smooth	TC	1.00	0.57	fs	1.67	0.60	42.62
55	3	Smooth	TC	0.95	0.56	fs	2.60	0.38	27.37
56	3	Smooth	TC	1.00	0.52	fs	1.40	0.71	50.84
57	3	Smooth	TC	1.00	0.55	fs	1.33	0.75	53.51
58	3	Smooth	TC	1.00	0.52	fs	1.33	0.75	53.51
59	3	Smooth	TC	1.00	0.55	fs	1.33	0.75	53.51
60	3	Smooth	TC	1.00	0.52	fs	1.67	0.60	42.62
61	3	Smooth	Con	1.00	0.54	fs	1.53	0.65	46.52
62	3	Smooth	Con	1.00	0.54	fs	1.73	0.58	41.14
63	3	Smooth	Con	1.00	0.47	fs	1.67	0.60	42.62
64	3	Smooth	Con	1.00	0.58	fs	1.67	0.60	42.62
65	3	Smooth	Con	1.00	0.49	fs	1.73	0.58	41.14
66	3	Smooth	Con	1.00	0.53	fs	1.87	0.53	38.06
67	3	Smooth	Con	1.00	0.50	fs	2.33	0.43	30.55
68	3	Smooth	Con	1.00	0.56	fs	2.73	0.37	26.07
69	3	Loose	Con	1.00	0.58	fs	2.67	0.37	26.66
70	3	Loose	Con	0.95	0.65	fs	1.80	0.56	39.54
71	3	Loose	Con	1.00	0.61	fs	3.93	0.25	18.11
72	3	Loose	Con	0.80	0.55	gs	2.27	0.44	31.35
73	3	Loose	Con	1.00	0.54	fs	1.73	0.58	41.14
74	3	Loose	Con	1.00	0.50	rs	1.80	0.56	39.54
75	3	Loose	Con	1.00	0.48	fs	2.00	0.50	35.59
77	3	Loose	AR	0.70	0.49	r	2.00	0.50	35.59
78	3	Loose	AR	0.15	0.47	g	4.67	0.21	15.24
79	3	Loose	AR	0.05	0.50	rs	7.00	0.14	10.17
80	3	Loose	AR	0.60	0.53	fs	2.13	0.47	33.42
81	3	Loose	AR	0.30	0.46	fs	4.87	0.21	14.61
82	3	Loose	AR	0.03	0.45	g	14.13	0.07	5.04
83	3	Loose	AR	0.10	0.42	gs	6.73	0.15	10.58
84	3	Loose	AR	0.10	0.45	rs	6.27	0.16	11.35
85	3	Loose	TC	1.00	0.48	fs	2.47	0.40	28.82
86	3	Loose	TC	0.80	0.46	fs	4.40	0.23	16.18
87	3	Loose	TC	0.50	0.48	fs	4.13	0.24	17.23

88	3	Loose	TC	0.80	0.49	fs	2.13	0.47	33.42
89	3	Loose	TC	1.00	0.53	fs	2.47	0.40	28.82
90	3	Loose	TC	0.30	0.53	fs	2.07	0.48	34.38
91	3	Loose	TC	0.15	0.50	gs	4.40	0.23	16.18
92	3	Loose	TC	0.30	0.50	gs	4.33	0.23	16.44
93	1	Loose	AR	1.00	0.72	fs	3.33	0.30	21.37
94	1	Loose	AR	0.30	0.58	fs	10.13	0.10	7.03
95	1	Loose	AR	0.03	0.64	fs	7.40	0.14	9.62
96	1	Loose	AR	0.75	0.52	c	2.27	0.44	31.35
97	1	Loose	AR	0.05	0.60	fs	7.00	0.14	10.17
98	1	Loose	AR	0.90	0.60	fs	4.80	0.21	14.83
99	1	Loose	AR	1.00	0.62	rs	3.67	0.27	19.39
100	1	Loose	Con	1.00	0.65	rs	3.24	0.31	21.97
101	1	Loose	Con	0.98	0.67	fs	4.33	0.23	16.44
102	1	Loose	Con	0.6	0.68	r	6.33	0.16	11.24
103	1	Loose	Con	1.00	0.67	rs	3.52	0.28	20.22
104	1	Loose	Con	0.20	0.60	r	7.27	0.14	9.79
105	1	Loose	Con	0.95	0.60	r	2.20	0.45	32.35
106	1	Loose	TC	0.85	0.59	r	3.13	0.32	22.74
107	1	Loose	TC	0.98	0.59	fs	2.33	0.43	30.55
108	1	Loose	TC	1.00	0.59	fs	2.00	0.50	35.59
109	1	Loose	TC	1.00	0.61	fs	2.27	0.44	31.35
110	1	Loose	TC	0.99	0.72	fs	3.07	0.33	23.18
111	1	Smooth	Con	1.00	0.72	fs	2.73	0.37	26.07
112	1	Smooth	Con	0.90	0.63	r	3.67	0.27	19.39
113	1	Smooth	Con	0.85	0.66	fs	3.20	0.31	22.24
114	1	Smooth	Con	0.80	0.66	fs	7.07	0.14	10.07
115	1	Smooth	Con	0.70	0.58	fs	4.87	0.21	14.61
116	1	Smooth	Con	0.95	0.59	fs	5.67	0.18	12.55
117	1	Smooth	Con	1.00	0.57	fs	5.33	0.19	13.35
118	1	Smooth	Con	0.95	0.62	fs	4.33	0.23	16.44
119	1	Smooth	TC	1.00	0.48	fs	3.73	0.27	19.08
120	1	Smooth	TC	1.00	0.47	fs	3.40	0.29	20.93
121	1	Smooth	TC	1.00	0.45	fs	3.40	0.29	20.93
122	1	Smooth	TC	1.00	0.52	fs	3.20	0.31	22.24
123	1	Smooth	TC	1.00	0.54	rs	1.00	1.00	71.17
124	1	Smooth	TC	0.98	0.56	r	3.40	0.29	20.93
125	1	Smooth	TC	1.00	0.62	fs	2.80	0.36	25.42
126	1	Smooth	TC	0.90	0.61	fs	3.87	0.26	18.39
127	1	Smooth	AR	0.95	0.64	rs	5.73	0.17	12.42
128	1	Smooth	AR	0.98	0.64	fs	4.53	0.22	15.71
129	1	Smooth	AR	0.25	0.57	rs	2.67	0.37	26.66
130	1	Smooth	AR	0.30	0.60	rs	5.13	0.19	13.87
131	1	Smooth	AR	0.30	0.60	fs	8.27	0.12	8.61
132	1	Smooth	AR	0.02	0.64	gs	6.16	0.16	11.55
133	1	Smooth	AR	0.40	0.64	fs	3.20	0.31	22.24

134	1	Smooth	AR	0.70	0.72	fs	3.73	0.27	19.08

Note: “76” was not used as a Plot #.

Table A.6. Plot summary data of the number of volunteer plant species encountered.

Block	Plot	Grading	Seeding	Vols
1	1	Loose	AR	11
1	2	Loose	Con	5
1	3	Loose	PRP	5
1	4	Smooth	Con	1
1	5	Smooth	PRP	6
1	6	Smooth	AR	11
2	1	Loose	AR	10
2	2	Loose	Con	8
2	3	Loose	PRP	7
2	5	Smooth	Con	6
2	6	Smooth	PRP	8
2	7	Smooth	AR	7
3	1	Loose	PRP	3
3	2	Loose	AR	20
3	3	Loose	Con	3
3	4	Smooth	Con	2
3	5	Smooth	PRP	2
3	6	Smooth	AR	14

Table A.7. August 2009 percent groundcover data by treatment plot; groundcover types are: AR: annual ryegrass only, Con: conventional tree-competitive mix and TC: tree-compatible mix, Compact = smooth; ocular estimates were made of the percent of the ground covered by living vegetation (Alive) and by dead vegetation (Dead) where there was not also living vegetation covering the same point and of the total of these two figures.

Block	Treat Plot #	Grading	Groundcover	Alive	Dead	Total
1	1	Loose	AR	40	30	69
1	2	Loose	Con	72	23	95
1	3	Loose	TC	53	37	90
1	4	Compact	Con	78	16	94
1	5	Compact	TC	76	23	98
1	6	Compact	AR	49	31	81
1	Mean			61	27	88
2	1	Loose	AR	14	0	14
2	2	Loose	Con	52	1	52
2	3	Loose	TC	55	0	55
2	5	Compact	Con	61	0	61
2	6	Compact	TC	23	0	23
2	7	Compact	AR	59	0	59
2	Mean			44	0	44
3	1	Loose	TC	95	0	95
3	2	Loose	AR	44	21	66
3	3	Loose	Con	96	0	96
3	4	Compact	Con	98	0	98
3	5	Compact	TC	92	0	92
3	6	Compact	AR	28	13	41
3	Mean			75	6	81
	Grand Mean			60	11	71

Table A.8. Identification of herbaceous species found in August of 2009, AR = annual ryegrass only, Con = conventional, TC = tree compatible.

Block	T Plot	Grading	Seeding	Spp	Spp	Spp
1	1	Loose	AR	10	Rubus fructicosus	Blackberry
1	2	Loose	Con	10	Rubus fructicosus	Blackberry
1	3	Loose	TC	10	Rubus fructicosus	Blackberry
1	4	Smooth	Con	10	Rubus fructicosus	Blackberry
1	5	Smooth	TC	10	Rubus fructicosus	Blackberry
1	6	Smooth	AR	10	Rubus fructicosus	Blackberry
2	1	Loose	AR	10	Rubus fructicosus	Blackberry
2	2	Loose	Con	10	Rubus fructicosus	Blackberry
2	3	Loose	TC	10	Rubus fructicosus	Blackberry
2	5	Smooth	Con	10	Rubus fructicosus	Blackberry
2	6	Smooth	TC	10	Rubus fructicosus	Blackberry
2	7	Smooth	AR	10	Rubus fructicosus	Blackberry
3	1	Loose	TC	10	Rubus fructicosus	Blackberry
3	2	Loose	AR	10	Rubus fructicosus	Blackberry
3	3	Loose	Con	10	Rubus fructicosus	Blackberry
3	4	Smooth	Con	10	Rubus fructicosus	Blackberry
3	5	Smooth	TC	10	Rubus fructicosus	Blackberry
3	6	Smooth	AR	10	Rubus fructicosus	Blackberry
1	1	Loose	AR	13	Epilobium angustifolium	Fireweed
1	2	Loose	Con	13	Epilobium angustifolium	Fireweed
1	3	Loose	TC	13	Epilobium angustifolium	Fireweed
1	4	Smooth	Con	13	Epilobium angustifolium	Fireweed
1	5	Smooth	TC	13	Epilobium angustifolium	Fireweed
1	6	Smooth	AR	13	Epilobium angustifolium	Fireweed
2	1	Loose	AR	13	Epilobium angustifolium	Fireweed
2	2	Loose	Con	13	Epilobium angustifolium	Fireweed
2	3	Loose	TC	13	Epilobium angustifolium	Fireweed
2	5	Smooth	Con	13	Epilobium angustifolium	Fireweed
2	6	Smooth	TC	13	Epilobium angustifolium	Fireweed
2	7	Smooth	AR	13	Epilobium	Fireweed

					angustifolium	
3	1	Loose	TC	13	Epilobium angustifolium	Fireweed
3	2	Loose	AR	13	Epilobium angustifolium	Fireweed
3	3	Loose	Con	13	Epilobium angustifolium	Fireweed
3	4	Smooth	Con	13	Epilobium angustifolium	Fireweed
3	5	Smooth	TC	13	Epilobium angustifolium	Fireweed
3	6	Smooth	AR	13	Epilobium angustifolium	Fireweed
1	1	Loose	AR	15	Epilobium 2	Epilobium 2
1	2	Loose	Con	15	Epilobium 2	Epilobium 2
1	3	Loose	TC	15	Epilobium 2	Epilobium 2
1	4	Smooth	Con	15	Epilobium 2	Epilobium 2
1	5	Smooth	TC	15	Epilobium 2	Epilobium 2
1	6	Smooth	AR	15	Epilobium 2	Epilobium 2
2	1	Loose	AR	15	Epilobium 2	Epilobium 2
2	2	Loose	Con	15	Epilobium 2	Epilobium 2
2	3	Loose	TC	15	Epilobium 2	Epilobium 2
2	5	Smooth	Con	15	Epilobium 2	Epilobium 2
2	6	Smooth	TC	15	Epilobium 2	Epilobium 2
2	7	Smooth	AR	15	Epilobium 2	Epilobium 2
3	1	Loose	TC	15	Epilobium 2	Epilobium 2
3	2	Loose	AR	15	Epilobium 2	Epilobium 2
3	3	Loose	Con	15	Epilobium 2	Epilobium 2
3	4	Smooth	Con	15	Epilobium 2	Epilobium 2
3	5	Smooth	TC	15	Epilobium 2	Epilobium 2
3	6	Smooth	AR	15	Epilobium 2	Epilobium 2
1	1	Loose	AR	17	Taraxacum	Dandelion
1	2	Loose	Con	17	Taraxacum	Dandelion
1	3	Loose	TC	17	Taraxacum	Dandelion
1	4	Smooth	Con	17	Taraxacum	Dandelion
1	5	Smooth	TC	17	Taraxacum	Dandelion
1	6	Smooth	AR	17	Taraxacum	Dandelion
2	1	Loose	AR	17	Taraxacum	Dandelion
2	2	Loose	Con	17	Taraxacum	Dandelion
2	3	Loose	TC	17	Taraxacum	Dandelion
2	5	Smooth	Con	17	Taraxacum	Dandelion
2	6	Smooth	TC	17	Taraxacum	Dandelion
2	7	Smooth	AR	17	Taraxacum	Dandelion
3	1	Loose	TC	17	Taraxacum	Dandelion

3	2	Loose	AR	17	Taraxacum	Dandelion
3	3	Loose	Con	17	Taraxacum	Dandelion
3	4	Smooth	Con	17	Taraxacum	Dandelion
3	5	Smooth	TC	17	Taraxacum	Dandelion
3	6	Smooth	AR	17	Taraxacum	Dandelion
1	1	Loose	AR	19	Phleum pretense and Lolium perenne [1]	Timothy and Perennial Rye
1	2	Loose	Con	19	Phleum pratense and Lolium perenne	Timothy and Perennial Rye
1	3	Loose	TC	19	Phleum pratense and Lolium perenne	Timothy and Perennial Rye
1	4	Smooth	Con	19	Phleum pratense and Lolium perenne	Timothy and Perennial Rye
1	5	Smooth	TC	19	Phleum pratense and Lolium perenne	Timothy and Perennial Rye
1	6	Smooth	AR	19	Phleum pratense and Lolium perenne	Timothy and Perennial Rye
2	1	Loose	AR	19	Phleum pratense and Lolium perenne	Timothy and Perennial Rye
2	2	Loose	Con	19	Phleum pratense and Lolium perenne	Timothy and Perennial Rye
2	3	Loose	TC	19	Phleum pratense and Lolium perenne	Timothy and Perennial Rye
2	5	Smooth	Con	19	Phleum pratense and Lolium perenne	Timothy and Perennial Rye
2	6	Smooth	TC	19	Phleum pratense and Lolium perenne	Timothy and Perennial Rye
2	7	Smooth	AR	19	Phleum pratense and Lolium perenne	Timothy and Perennial Rye
3	1	Loose	TC	19	Phleum pratense and Lolium perenne	Timothy and Perennial Rye
3	2	Loose	AR	19	Phleum pratense and Lolium perenne	Timothy and Perennial Rye
3	3	Loose	Con	19	Phleum pratense and Lolium perenne	Timothy and Perennial Rye
3	4	Smooth	Con	19	Phleum pratense and Lolium perenne	Timothy and Perennial Rye
3	5	Smooth	TC	19	Phleum pratense and Lolium perenne	Timothy and Perennial Rye
3	6	Smooth	AR	19	Phleum pratense and Lolium perenne	Timothy and Perennial Rye
1	1	Loose	AR	20	Solidago	Goldenrod
1	2	Loose	Con	20	Solidago	Goldenrod
1	3	Loose	TC	20	Solidago	Goldenrod
1	4	Smooth	Con	20	Solidago	Goldenrod
1	5	Smooth	TC	20	Solidago	Goldenrod

1	6	Smooth	AR	20	Solidago	Goldenrod
2	1	Loose	AR	20	Solidago	Goldenrod
2	2	Loose	Con	20	Solidago	Goldenrod
2	3	Loose	TC	20	Solidago	Goldenrod
2	5	Smooth	Con	20	Solidago	Goldenrod
2	6	Smooth	TC	20	Solidago	Goldenrod
2	7	Smooth	AR	20	Solidago	Goldenrod
3	1	Loose	TC	20	Solidago	Goldenrod
3	2	Loose	AR	20	Solidago	Goldenrod
3	3	Loose	Con	20	Solidago	Goldenrod
3	4	Smooth	Con	20	Solidago	Goldenrod
3	5	Smooth	TC	20	Solidago	Goldenrod
3	6	Smooth	AR	20	Solidago	Goldenrod
1	1	Loose	AR	22	Medicago sativa	Alfalfa
1	2	Loose	Con	22	Medicago sativa	Alfalfa
1	3	Loose	TC	22	Medicago sativa	Alfalfa
1	4	Smooth	Con	22	Medicago sativa	Alfalfa
1	5	Smooth	TC	22	Medicago sativa	Alfalfa
1	6	Smooth	AR	22	Medicago sativa	Alfalfa
2	1	Loose	AR	22	Medicago sativa	Alfalfa
2	2	Loose	Con	22	Medicago sativa	Alfalfa
2	3	Loose	TC	22	Medicago sativa	Alfalfa
2	5	Smooth	Con	22	Medicago sativa	Alfalfa
2	6	Smooth	TC	22	Medicago sativa	Alfalfa
2	7	Smooth	AR	22	Medicago sativa	Alfalfa
3	1	Loose	TC	22	Medicago sativa	Alfalfa
3	2	Loose	AR	22	Medicago sativa	Alfalfa
3	3	Loose	Con	22	Medicago sativa	Alfalfa
3	4	Smooth	Con	22	Medicago sativa	Alfalfa
3	5	Smooth	TC	22	Medicago sativa	Alfalfa
3	6	Smooth	AR	22	Medicago sativa	Alfalfa
1	1	Loose	AR	23	Asteracea	Aster
1	2	Loose	Con	23	Asteracea	Aster
1	3	Loose	TC	23	Asteracea	Aster
1	4	Smooth	Con	23	Asteracea	Aster
1	5	Smooth	TC	23	Asteracea	Aster
1	6	Smooth	AR	23	Asteracea	Aster
2	1	Loose	AR	23	Asteracea	Aster
2	2	Loose	Con	23	Asteracea	Aster
2	3	Loose	TC	23	Asteracea	Aster
2	5	Smooth	Con	23	Asteracea	Aster
2	6	Smooth	TC	23	Asteracea	Aster
2	7	Smooth	AR	23	Asteracea	Aster

3	1	Loose	TC	23	Asteracea	Aster
3	2	Loose	AR	23	Asteracea	Aster
3	3	Loose	Con	23	Asteracea	Aster
3	4	Smooth	Con	23	Asteracea	Aster
3	5	Smooth	TC	23	Asteracea	Aster
3	6	Smooth	AR	23	Asteracea	Aster
1	1	Loose	AR	25	Agrostis gigantea	Redtop
1	2	Loose	Con	25	Agrostis gigantea	Redtop
1	3	Loose	TC	25	Agrostis gigantea	Redtop
1	4	Smooth	Con	25	Agrostis gigantea	Redtop
1	5	Smooth	TC	25	Agrostis gigantea	Redtop
1	6	Smooth	AR	25	Agrostis gigantea	Redtop
2	1	Loose	AR	25	Agrostis gigantea	Redtop
2	2	Loose	Con	25	Agrostis gigantea	Redtop
2	3	Loose	TC	25	Agrostis gigantea	Redtop
2	5	Smooth	Con	25	Agrostis gigantea	Redtop
2	6	Smooth	TC	25	Agrostis gigantea	Redtop
2	7	Smooth	AR	25	Agrostis gigantea	Redtop
3	1	Loose	TC	25	Agrostis gigantea	Redtop
3	2	Loose	AR	25	Agrostis gigantea	Redtop
3	3	Loose	Con	25	Agrostis gigantea	Redtop
3	4	Smooth	Con	25	Agrostis gigantea	Redtop
3	5	Smooth	TC	25	Agrostis gigantea	Redtop
3	6	Smooth	AR	25	Agrostis gigantea	Redtop
1	1	Loose	AR	32	Taraxacum 2	Dandelion 2
1	2	Loose	Con	32	Taraxacum 2	Dandelion 2
1	3	Loose	TC	32	Taraxacum 2	Dandelion 2
1	4	Smooth	Con	32	Taraxacum 2	Dandelion 2
1	5	Smooth	TC	32	Taraxacum 2	Dandelion 2
1	6	Smooth	AR	32	Taraxacum 2	Dandelion 2
2	1	Loose	AR	32	Taraxacum 2	Dandelion 2
2	2	Loose	Con	32	Taraxacum 2	Dandelion 2
2	3	Loose	TC	32	Taraxacum 2	Dandelion 2
2	5	Smooth	Con	32	Taraxacum 2	Dandelion 2
2	6	Smooth	TC	32	Taraxacum 2	Dandelion 2
2	7	Smooth	AR	32	Taraxacum 2	Dandelion 2
3	1	Loose	TC	32	Taraxacum 2	Dandelion 2
3	2	Loose	AR	32	Taraxacum 2	Dandelion 2
3	3	Loose	Con	32	Taraxacum 2	Dandelion 2
3	4	Smooth	Con	32	Taraxacum 2	Dandelion 2
3	5	Smooth	TC	32	Taraxacum 2	Dandelion 2
3	6	Smooth	AR	32	Taraxacum 2	Dandelion 2
1	1	Loose	AR	36	Angiospermae	Angiosperm

1	2	Loose	Con	36	Angiospermae	Angiosperm
1	3	Loose	TC	36	Angiospermae	Angiosperm
1	4	Smooth	Con	36	Angiospermae	Angiosperm
1	5	Smooth	TC	36	Angiospermae	Angiosperm
1	6	Smooth	AR	36	Angiospermae	Angiosperm
2	1	Loose	AR	36	Angiospermae	Angiosperm
2	2	Loose	Con	36	Angiospermae	Angiosperm
2	3	Loose	TC	36	Angiospermae	Angiosperm
2	5	Smooth	Con	36	Angiospermae	Angiosperm
2	6	Smooth	TC	36	Angiospermae	Angiosperm
2	7	Smooth	AR	36	Angiospermae	Angiosperm
3	1	Loose	TC	36	Angiospermae	Angiosperm
3	2	Loose	AR	36	Angiospermae	Angiosperm
3	3	Loose	Con	36	Angiospermae	Angiosperm
3	4	Smooth	Con	36	Angiospermae	Angiosperm
3	5	Smooth	TC	36	Angiospermae	Angiosperm
3	6	Smooth	AR	36	Angiospermae	Angiosperm
1	1	Loose	AR	39	Melissa officinalis	Lemon balm
1	2	Loose	Con	39	Melissa officinalis	Lemon balm
1	3	Loose	TC	39	Melissa officinalis	Lemon balm
1	4	Smooth	Con	39	Melissa officinalis	Lemon balm
1	5	Smooth	TC	39	Melissa officinalis	Lemon balm
1	6	Smooth	AR	39	Melissa officinalis	Lemon balm
2	1	Loose	AR	39	Melissa officinalis	Lemon balm
2	2	Loose	Con	39	Melissa officinalis	Lemon balm
2	3	Loose	TC	39	Melissa officinalis	Lemon balm
2	5	Smooth	Con	39	Melissa officinalis	Lemon balm
2	6	Smooth	TC	39	Melissa officinalis	Lemon balm
2	7	Smooth	AR	39	Melissa officinalis	Lemon balm
3	1	Loose	TC	39	Melissa officinalis	Lemon balm
3	2	Loose	AR	39	Melissa officinalis	Lemon balm
3	3	Loose	Con	39	Melissa officinalis	Lemon balm
3	4	Smooth	Con	39	Melissa officinalis	Lemon balm
3	5	Smooth	TC	39	Melissa officinalis	Lemon balm
3	6	Smooth	AR	39	Melissa officinalis	Lemon balm
1	1	Loose	AR	50	Trifolium	Clover
1	2	Loose	Con	50	Trifolium	Clover
1	3	Loose	TC	50	Trifolium	Clover
1	4	Smooth	Con	50	Trifolium	Clover
1	5	Smooth	TC	50	Trifolium	Clover
1	6	Smooth	AR	50	Trifolium	Clover
2	1	Loose	AR	50	Trifolium	Clover
2	2	Loose	Con	50	Trifolium	Clover

2	3	Loose	TC	50	Trifolium	Clover
2	5	Smooth	Con	50	Trifolium	Clover
2	6	Smooth	TC	50	Trifolium	Clover
2	7	Smooth	AR	50	Trifolium	Clover
3	1	Loose	TC	50	Trifolium	Clover
3	2	Loose	AR	50	Trifolium	Clover
3	3	Loose	Con	50	Trifolium	Clover
3	4	Smooth	Con	50	Trifolium	Clover
3	5	Smooth	TC	50	Trifolium	Clover
3	6	Smooth	AR	50	Trifolium	Clover
1	1	Loose	AR	51	Lotus corniculatus	Birdsfoot trefoil
1	2	Loose	Con	51	Lotus corniculatus	Birdsfoot trefoil
1	3	Loose	TC	51	Lotus corniculatus	Birdsfoot trefoil
1	4	Smooth	Con	51	Lotus corniculatus	Birdsfoot trefoil
1	5	Smooth	TC	51	Lotus corniculatus	Birdsfoot trefoil
1	6	Smooth	AR	51	Lotus corniculatus	Birdsfoot trefoil
2	1	Loose	AR	51	Lotus corniculatus	Birdsfoot trefoil
2	2	Loose	Con	51	Lotus corniculatus	Birdsfoot trefoil
2	3	Loose	TC	51	Lotus corniculatus	Birdsfoot trefoil
2	5	Smooth	Con	51	Lotus corniculatus	Birdsfoot trefoil
2	6	Smooth	TC	51	Lotus corniculatus	Birdsfoot trefoil
2	7	Smooth	AR	51	Lotus corniculatus	Birdsfoot trefoil
3	1	Loose	TC	51	Lotus corniculatus	Birdsfoot trefoil
3	2	Loose	AR	51	Lotus corniculatus	Birdsfoot trefoil
3	3	Loose	Con	51	Lotus corniculatus	Birdsfoot trefoil
3	4	Smooth	Con	51	Lotus corniculatus	Birdsfoot trefoil
3	5	Smooth	TC	51	Lotus corniculatus	Birdsfoot trefoil
3	6	Smooth	AR	51	Lotus corniculatus	Birdsfoot trefoil
1	1	Loose	AR	52	Lactuca virosa	Wild lettuce
1	2	Loose	Con	52	Lactuca virosa	Wild lettuce
1	3	Loose	TC	52	Lactuca virosa	Wild lettuce
1	4	Smooth	Con	52	Lactuca virosa	Wild lettuce
1	5	Smooth	TC	52	Lactuca virosa	Wild lettuce
1	6	Smooth	AR	52	Lactuca virosa	Wild lettuce
2	1	Loose	AR	52	Lactuca virosa	Wild lettuce
2	2	Loose	Con	52	Lactuca virosa	Wild lettuce
2	3	Loose	TC	52	Lactuca virosa	Wild lettuce
2	5	Smooth	Con	52	Lactuca virosa	Wild lettuce
2	6	Smooth	TC	52	Lactuca virosa	Wild lettuce
2	7	Smooth	AR	52	Lactuca virosa	Wild lettuce
3	1	Loose	TC	52	Lactuca virosa	Wild lettuce
3	2	Loose	AR	52	Lactuca virosa	Wild lettuce
3	3	Loose	Con	52	Lactuca virosa	Wild lettuce

3	4	Smooth	Con	52	Lactuca virosa	Wild lettuce
3	5	Smooth	TC	52	Lactuca virosa	Wild lettuce
3	6	Smooth	AR	52	Lactuca virosa	Wild lettuce
1	1	Loose	AR	53	Dactylis glomerata	Orchardgrass
1	2	Loose	Con	53	Dactylis glomerata	Orchardgrass
1	3	Loose	TC	53	Dactylis glomerata	Orchardgrass
1	4	Smooth	Con	53	Dactylis glomerata	Orchardgrass
1	5	Smooth	TC	53	Dactylis glomerata	Orchardgrass
1	6	Smooth	AR	53	Dactylis glomerata	Orchardgrass
2	1	Loose	AR	53	Dactylis glomerata	Orchardgrass
2	2	Loose	Con	53	Dactylis glomerata	Orchardgrass
2	3	Loose	TC	53	Dactylis glomerata	Orchardgrass
2	5	Smooth	Con	53	Dactylis glomerata	Orchardgrass
2	6	Smooth	TC	53	Dactylis glomerata	Orchardgrass
2	7	Smooth	AR	53	Dactylis glomerata	Orchardgrass
3	1	Loose	TC	53	Dactylis glomerata	Orchardgrass
3	2	Loose	AR	53	Dactylis glomerata	Orchardgrass
3	3	Loose	Con	53	Dactylis glomerata	Orchardgrass
3	4	Smooth	Con	53	Dactylis glomerata	Orchardgrass
3	5	Smooth	TC	53	Dactylis glomerata	Orchardgrass
3	6	Smooth	AR	53	Dactylis glomerata	Orchardgrass
1	1	Loose	AR	54	Setaria italica	Foxtail millet
1	2	Loose	Con	54	Setaria italica	Foxtail millet
1	3	Loose	TC	54	Setaria italica	Foxtail millet
1	4	Smooth	Con	54	Setaria italica	Foxtail millet
1	5	Smooth	TC	54	Setaria italica	Foxtail millet
1	6	Smooth	AR	54	Setaria italica	Foxtail millet
2	1	Loose	AR	54	Setaria italica	Foxtail millet
2	2	Loose	Con	54	Setaria italica	Foxtail millet
2	3	Loose	TC	54	Setaria italica	Foxtail millet
2	5	Smooth	Con	54	Setaria italica	Foxtail millet
2	6	Smooth	TC	54	Setaria italica	Foxtail millet
2	7	Smooth	AR	54	Setaria italica	Foxtail millet
3	1	Loose	TC	54	Setaria italica	Foxtail millet
3	2	Loose	AR	54	Setaria italica	Foxtail millet
3	3	Loose	Con	54	Setaria italica	Foxtail millet
3	4	Smooth	Con	54	Setaria italica	Foxtail millet
3	5	Smooth	TC	54	Setaria italica	Foxtail millet
3	6	Smooth	AR	54	Setaria italica	Foxtail millet
1	1	Loose	AR	55	Tussilago farfara	Coltsfoot
1	2	Loose	Con	55	Tussilago farfara	Coltsfoot
1	3	Loose	TC	55	Tussilago farfara	Coltsfoot
1	4	Smooth	Con	55	Tussilago farfara	Coltsfoot

1	5	Smooth	TC	55	Tussilago farfara	Coltsfoot
1	6	Smooth	AR	55	Tussilago farfara	Coltsfoot
2	1	Loose	AR	55	Tussilago farfara	Coltsfoot
2	2	Loose	Con	55	Tussilago farfara	Coltsfoot
2	3	Loose	TC	55	Tussilago farfara	Coltsfoot
2	5	Smooth	Con	55	Tussilago farfara	Coltsfoot
2	6	Smooth	TC	55	Tussilago farfara	Coltsfoot
2	7	Smooth	AR	55	Tussilago farfara	Coltsfoot
3	1	Loose	TC	55	Tussilago farfara	Coltsfoot
3	2	Loose	AR	55	Tussilago farfara	Coltsfoot
3	3	Loose	Con	55	Tussilago farfara	Coltsfoot
3	4	Smooth	Con	55	Tussilago farfara	Coltsfoot
3	5	Smooth	TC	55	Tussilago farfara	Coltsfoot
3	6	Smooth	AR	55	Tussilago farfara	Coltsfoot
1	1	Loose	AR	56	Ambrosia	Ragweed
1	2	Loose	Con	56	Ambrosia	Ragweed
1	3	Loose	TC	56	Ambrosia	Ragweed
1	4	Smooth	Con	56	Ambrosia	Ragweed
1	5	Smooth	TC	56	Ambrosia	Ragweed
1	6	Smooth	AR	56	Ambrosia	Ragweed
2	1	Loose	AR	56	Ambrosia	Ragweed
2	2	Loose	Con	56	Ambrosia	Ragweed
2	3	Loose	TC	56	Ambrosia	Ragweed
2	5	Smooth	Con	56	Ambrosia	Ragweed
2	6	Smooth	TC	56	Ambrosia	Ragweed
2	7	Smooth	AR	56	Ambrosia	Ragweed
3	1	Loose	TC	56	Ambrosia	Ragweed
3	2	Loose	AR	56	Ambrosia	Ragweed
3	3	Loose	Con	56	Ambrosia	Ragweed
3	4	Smooth	Con	56	Ambrosia	Ragweed
3	5	Smooth	TC	56	Ambrosia	Ragweed
3	6	Smooth	AR	56	Ambrosia	Ragweed
1	1	Loose	AR	57	Epilobium 3	Epilobium 3
1	2	Loose	Con	57	Epilobium 3	Epilobium 3
1	3	Loose	TC	57	Epilobium 3	Epilobium 3
1	4	Smooth	Con	57	Epilobium 3	Epilobium 3
1	5	Smooth	TC	57	Epilobium 3	Epilobium 3
1	6	Smooth	AR	57	Epilobium 3	Epilobium 3
2	1	Loose	AR	57	Epilobium 3	Epilobium 3
2	2	Loose	Con	57	Epilobium 3	Epilobium 3
2	3	Loose	TC	57	Epilobium 3	Epilobium 3
2	5	Smooth	Con	57	Epilobium 3	Epilobium 3
2	6	Smooth	TC	57	Epilobium 3	Epilobium 3

2	7	Smooth	AR	57	Epilobium 3	Epilobium 3
3	1	Loose	TC	57	Epilobium 3	Epilobium 3
3	2	Loose	AR	57	Epilobium 3	Epilobium 3
3	3	Loose	Con	57	Epilobium 3	Epilobium 3
3	4	Smooth	Con	57	Epilobium 3	Epilobium 3
3	5	Smooth	TC	57	Epilobium 3	Epilobium 3
3	6	Smooth	AR	57	Epilobium 3	Epilobium 3
1	1	Loose	AR	58	Argentina anserina	Silverweed
1	2	Loose	Con	58	Argentina anserina	Silverweed
1	3	Loose	TC	58	Argentina anserina	Silverweed
1	4	Smooth	Con	58	Argentina anserina	Silverweed
1	5	Smooth	TC	58	Argentina anserina	Silverweed
1	6	Smooth	AR	58	Argentina anserina	Silverweed
2	1	Loose	AR	58	Argentina anserina	Silverweed
2	2	Loose	Con	58	Argentina anserina	Silverweed
2	3	Loose	TC	58	Argentina anserina	Silverweed
2	5	Smooth	Con	58	Argentina anserina	Silverweed
2	6	Smooth	TC	58	Argentina anserina	Silverweed
2	7	Smooth	AR	58	Argentina anserina	Silverweed
3	1	Loose	TC	58	Argentina anserina	Silverweed
3	2	Loose	AR	58	Argentina anserina	Silverweed
3	3	Loose	Con	58	Argentina anserina	Silverweed
3	4	Smooth	Con	58	Argentina anserina	Silverweed
3	5	Smooth	TC	58	Argentina anserina	Silverweed
3	6	Smooth	AR	58	Argentina anserina	Silverweed
1	1	Loose	AR	59	Verbascum thapsus	Common mullien
1	2	Loose	Con	59	Verbascum thapsus	Common mullien
1	3	Loose	TC	59	Verbascum thapsus	Common mullien
1	4	Smooth	Con	59	Verbascum thapsus	Common mullien
1	5	Smooth	TC	59	Verbascum thapsus	Common mullien
1	6	Smooth	AR	59	Verbascum thapsus	Common mullien
2	1	Loose	AR	59	Verbascum thapsus	Common mullien
2	2	Loose	Con	59	Verbascum thapsus	Common mullien
2	3	Loose	TC	59	Verbascum thapsus	Common mullien
2	5	Smooth	Con	59	Verbascum thapsus	Common mullien
2	6	Smooth	TC	59	Verbascum thapsus	Common mullien
2	7	Smooth	AR	59	Verbascum thapsus	Common mullien
3	1	Loose	TC	59	Verbascum thapsus	Common mullien
3	2	Loose	AR	59	Verbascum thapsus	Common mullien
3	3	Loose	Con	59	Verbascum thapsus	Common mullien
3	4	Smooth	Con	59	Verbascum thapsus	Common mullien
3	5	Smooth	TC	59	Verbascum thapsus	Common mullien
3	6	Smooth	AR	59	Verbascum thapsus	Common mullien

1	1	Loose	AR	60	Daucus carota	Wild carrot
1	2	Loose	Con	60	Daucus carota	Wild carrot
1	3	Loose	TC	60	Daucus carota	Wild carrot
1	4	Smooth	Con	60	Daucus carota	Wild carrot
1	5	Smooth	TC	60	Daucus carota	Wild carrot
1	6	Smooth	AR	60	Daucus carota	Wild carrot
2	1	Loose	AR	60	Daucus carota	Wild carrot
2	2	Loose	Con	60	Daucus carota	Wild carrot
2	3	Loose	TC	60	Daucus carota	Wild carrot
2	5	Smooth	Con	60	Daucus carota	Wild carrot
2	6	Smooth	TC	60	Daucus carota	Wild carrot
2	7	Smooth	AR	60	Daucus carota	Wild carrot
3	1	Loose	TC	60	Daucus carota	Wild carrot
3	2	Loose	AR	60	Daucus carota	Wild carrot
3	3	Loose	Con	60	Daucus carota	Wild carrot
3	4	Smooth	Con	60	Daucus carota	Wild carrot
3	5	Smooth	TC	60	Daucus carota	Wild carrot
3	6	Smooth	AR	60	Daucus carota	Wild carrot
1	1	Loose	AR	61	Chenopodium berlandieri	Lambsquarters
1	2	Loose	Con	61	Chenopodium berlandieri	Lambsquarters
1	3	Loose	TC	61	Chenopodium berlandieri	Lambsquarters
1	4	Smooth	Con	61	Chenopodium berlandieri	Lambsquarters
1	5	Smooth	TC	61	Chenopodium berlandieri	Lambsquarters
1	6	Smooth	AR	61	Chenopodium berlandieri	Lambsquarters
2	1	Loose	AR	61	Chenopodium berlandieri	Lambsquarters
2	2	Loose	Con	61	Chenopodium berlandieri	Lambsquarters
2	3	Loose	TC	61	Chenopodium berlandieri	Lambsquarters
2	5	Smooth	Con	61	Chenopodium berlandieri	Lambsquarters
2	6	Smooth	TC	61	Chenopodium berlandieri	Lambsquarters
2	7	Smooth	AR	61	Chenopodium berlandieri	Lambsquarters
3	1	Loose	TC	61	Chenopodium berlandieri	Lambsquarters
3	2	Loose	AR	61	Chenopodium	Lambsquarters

					berlandieri	
3	3	Loose	Con	61	Chenopodium berlandieri	Lambsquarters
3	4	Smooth	Con	61	Chenopodium berlandieri	Lambsquarters
3	5	Smooth	TC	61	Chenopodium berlandieri	Lambsquarters
3	6	Smooth	AR	61	Chenopodium berlandieri	Lambsquarters
1	1	Loose	AR	63	Viola	Violet
1	2	Loose	Con	63	Viola	Violet
1	3	Loose	TC	63	Viola	Violet
1	4	Smooth	Con	63	Viola	Violet
1	5	Smooth	TC	63	Viola	Violet
1	6	Smooth	AR	63	Viola	Violet
2	1	Loose	AR	63	Viola	Violet
2	2	Loose	Con	63	Viola	Violet
2	3	Loose	TC	63	Viola	Violet
2	5	Smooth	Con	63	Viola	Violet
2	6	Smooth	TC	63	Viola	Violet
2	7	Smooth	AR	63	Viola	Violet
3	1	Loose	TC	63	Viola	Violet
3	2	Loose	AR	63	Viola	Violet
3	3	Loose	Con	63	Viola	Violet
3	4	Smooth	Con	63	Viola	Violet
3	5	Smooth	TC	63	Viola	Violet
3	6	Smooth	AR	63	Viola	Violet
1	1	Loose	AR	64	Saxifraga	Stone-breakers
1	2	Loose	Con	64	Saxifraga	Stone-breakers
1	3	Loose	TC	64	Saxifraga	Stone-breakers
1	4	Smooth	Con	64	Saxifraga	Stone-breakers
1	5	Smooth	TC	64	Saxifraga	Stone-breakers
1	6	Smooth	AR	64	Saxifraga	Stone-breakers
2	1	Loose	AR	64	Saxifraga	Stone-breakers
2	2	Loose	Con	64	Saxifraga	Stone-breakers
2	3	Loose	TC	64	Saxifraga	Stone-breakers
2	5	Smooth	Con	64	Saxifraga	Stone-breakers
2	6	Smooth	TC	64	Saxifraga	Stone-breakers
2	7	Smooth	AR	64	Saxifraga	Stone-breakers
3	1	Loose	TC	64	Saxifraga	Stone-breakers
3	2	Loose	AR	64	Saxifraga	Stone-breakers
3	3	Loose	Con	64	Saxifraga	Stone-breakers
3	4	Smooth	Con	64	Saxifraga	Stone-breakers

3	5	Smooth	TC	64	Saxifraga	Stone-breakers
3	6	Smooth	AR	64	Saxifraga	Stone-breakers
1	1	Loose	AR	65	Oxalis	Wood-sorrel
1	2	Loose	Con	65	Oxalis	Wood-sorrel
1	3	Loose	TC	65	Oxalis	Wood-sorrel
1	4	Smooth	Con	65	Oxalis	Wood-sorrel
1	5	Smooth	TC	65	Oxalis	Wood-sorrel
1	6	Smooth	AR	65	Oxalis	Wood-sorrel
2	1	Loose	AR	65	Oxalis	Wood-sorrel
2	2	Loose	Con	65	Oxalis	Wood-sorrel
2	3	Loose	TC	65	Oxalis	Wood-sorrel
2	5	Smooth	Con	65	Oxalis	Wood-sorrel
2	6	Smooth	TC	65	Oxalis	Wood-sorrel
2	7	Smooth	AR	65	Oxalis	Wood-sorrel
3	1	Loose	TC	65	Oxalis	Wood-sorrel
3	2	Loose	AR	65	Oxalis	Wood-sorrel
3	3	Loose	Con	65	Oxalis	Wood-sorrel
3	4	Smooth	Con	65	Oxalis	Wood-sorrel
3	5	Smooth	TC	65	Oxalis	Wood-sorrel
3	6	Smooth	AR	65	Oxalis	Wood-sorrel
1	1	Loose	AR	66	Morus rubra	Red mulberry
1	2	Loose	Con	66	Morus rubra	Red mulberry
1	3	Loose	TC	66	Morus rubra	Red mulberry
1	4	Smooth	Con	66	Morus rubra	Red mulberry
1	5	Smooth	TC	66	Morus rubra	Red mulberry
1	6	Smooth	AR	66	Morus rubra	Red mulberry
2	1	Loose	AR	66	Morus rubra	Red mulberry
2	2	Loose	Con	66	Morus rubra	Red mulberry
2	3	Loose	TC	66	Morus rubra	Red mulberry
2	5	Smooth	Con	66	Morus rubra	Red mulberry
2	6	Smooth	TC	66	Morus rubra	Red mulberry
2	7	Smooth	AR	66	Morus rubra	Red mulberry
3	1	Loose	TC	66	Morus rubra	Red mulberry
3	2	Loose	AR	66	Morus rubra	Red mulberry
3	3	Loose	Con	66	Morus rubra	Red mulberry
3	4	Smooth	Con	66	Morus rubra	Red mulberry
3	5	Smooth	TC	66	Morus rubra	Red mulberry
3	6	Smooth	AR	66	Morus rubra	Red mulberry
1	1	Loose	AR	67	Angiospermae 2	Angiosperm 2
1	2	Loose	Con	67	Angiospermae 2	Angiosperm 2
1	3	Loose	TC	67	Angiospermae 2	Angiosperm 2
1	4	Smooth	Con	67	Angiospermae 2	Angiosperm 2
1	5	Smooth	TC	67	Angiospermae 2	Angiosperm 2

1	6	Smooth	AR	67	Angiospermae 2	Angiosperm 2
2	1	Loose	AR	67	Angiospermae 2	Angiosperm 2
2	2	Loose	Con	67	Angiospermae 2	Angiosperm 2
2	3	Loose	TC	67	Angiospermae 2	Angiosperm 2
2	5	Smooth	Con	67	Angiospermae 2	Angiosperm 2
2	6	Smooth	TC	67	Angiospermae 2	Angiosperm 2
2	7	Smooth	AR	67	Angiospermae 2	Angiosperm 2
3	1	Loose	TC	67	Angiospermae 2	Angiosperm 2
3	2	Loose	AR	67	Angiospermae 2	Angiosperm 2
3	3	Loose	Con	67	Angiospermae 2	Angiosperm 2
3	4	Smooth	Con	67	Angiospermae 2	Angiosperm 2
3	5	Smooth	TC	67	Angiospermae 2	Angiosperm 2
3	6	Smooth	AR	67	Angiospermae 2	Angiosperm 2
1	1	Loose	AR	68	Lolium multiflorum	Annual ryegrass
1	2	Loose	Con	68	Lolium multiflorum	Annual ryegrass
1	3	Loose	TC	68	Lolium multiflorum	Annual ryegrass
1	4	Smooth	Con	68	Lolium multiflorum	Annual ryegrass
1	5	Smooth	TC	68	Lolium multiflorum	Annual ryegrass
1	6	Smooth	AR	68	Lolium multiflorum	Annual ryegrass
2	1	Loose	AR	68	Lolium multiflorum	Annual ryegrass
2	2	Loose	Con	68	Lolium multiflorum	Annual ryegrass
2	3	Loose	TC	68	Lolium multiflorum	Annual ryegrass
2	5	Smooth	Con	68	Lolium multiflorum	Annual ryegrass
2	6	Smooth	TC	68	Lolium multiflorum	Annual ryegrass
2	7	Smooth	AR	68	Lolium multiflorum	Annual ryegrass
3	1	Loose	TC	68	Lolium multiflorum	Annual ryegrass
3	2	Loose	AR	68	Lolium multiflorum	Annual ryegrass
3	3	Loose	Con	68	Lolium multiflorum	Annual ryegrass
3	4	Smooth	Con	68	Lolium multiflorum	Annual ryegrass
3	5	Smooth	TC	68	Lolium multiflorum	Annual ryegrass
3	6	Smooth	AR	68	Lolium multiflorum	Annual ryegrass
1	1	Loose	AR	69	Amphicarpaua bracteata	Hog-peanut
1	2	Loose	Con	69	Amphicarpaua bracteata	Hog-peanut
1	3	Loose	TC	69	Amphicarpaua bracteata	Hog-peanut
1	4	Smooth	Con	69	Amphicarpaua bracteata	Hog-peanut
1	5	Smooth	TC	69	Amphicarpaua bracteata	Hog-peanut
1	6	Smooth	AR	69	Amphicarpaua bracteata	Hog-peanut
2	1	Loose	AR	69	Amphicarpaua	Hog-peanut

					bracteata	
2	2	Loose	Con	69	Amphicarpaua bracteata	Hog-peanut
2	3	Loose	TC	69	Amphicarpaua bracteata	Hog-peanut
2	5	Smooth	Con	69	Amphicarpaua bracteata	Hog-peanut
2	6	Smooth	TC	69	Amphicarpaua bracteata	Hog-peanut
2	7	Smooth	AR	69	Amphicarpaua bracteata	Hog-peanut
3	1	Loose	TC	69	Amphicarpaua bracteata	Hog-peanut
3	2	Loose	AR	69	Amphicarpaua bracteata	Hog-peanut
3	3	Loose	Con	69	Amphicarpaua bracteata	Hog-peanut
3	4	Smooth	Con	69	Amphicarpaua bracteata	Hog-peanut
3	5	Smooth	TC	69	Amphicarpaua bracteata	Hog-peanut
3	6	Smooth	AR	69	Amphicarpaua bracteata	Hog-peanut
1	1	Loose	AR	70	Antennaria microphylla	Dwarf pussytoes
1	2	Loose	Con	70	Antennaria microphylla	Dwarf pussytoes
1	3	Loose	TC	70	Antennaria microphylla	Dwarf pussytoes
1	4	Smooth	Con	70	Antennaria microphylla	Dwarf pussytoes
1	5	Smooth	TC	70	Antennaria microphylla	Dwarf pussytoes
1	6	Smooth	AR	70	Antennaria microphylla	Dwarf pussytoes
2	1	Loose	AR	70	Antennaria microphylla	Dwarf pussytoes
2	2	Loose	Con	70	Antennaria microphylla	Dwarf pussytoes
2	3	Loose	TC	70	Antennaria microphylla	Dwarf pussytoes
2	5	Smooth	Con	70	Antennaria microphylla	Dwarf pussytoes
2	6	Smooth	TC	70	Antennaria microphylla	Dwarf pussytoes
2	7	Smooth	AR	70	Antennaria	Dwarf pussytoes

					microphylla	
3	1	Loose	TC	70	Antennaria microphylla	Dwarf pussytoes
3	2	Loose	AR	70	Antennaria microphylla	Dwarf pussytoes
3	3	Loose	Con	70	Antennaria microphylla	Dwarf pussytoes
3	4	Smooth	Con	70	Antennaria microphylla	Dwarf pussytoes
3	5	Smooth	TC	70	Antennaria microphylla	Dwarf pussytoes
3	6	Smooth	AR	70	Antennaria microphylla	Dwarf pussytoes
1	1	Loose	AR	71	Asteraceae 2	Thistle
1	2	Loose	Con	71	Asteraceae 2	Thistle
1	3	Loose	TC	71	Asteraceae 2	Thistle
1	4	Smooth	Con	71	Asteraceae 2	Thistle
1	5	Smooth	TC	71	Asteraceae 2	Thistle
1	6	Smooth	AR	71	Asteraceae 2	Thistle
2	1	Loose	AR	71	Asteraceae 2	Thistle
2	2	Loose	Con	71	Asteraceae 2	Thistle
2	3	Loose	TC	71	Asteraceae 2	Thistle
2	5	Smooth	Con	71	Asteraceae 2	Thistle
2	6	Smooth	TC	71	Asteraceae 2	Thistle
2	7	Smooth	AR	71	Asteraceae 2	Thistle
3	1	Loose	TC	71	Asteraceae 2	Thistle
3	2	Loose	AR	71	Asteraceae 2	Thistle
3	3	Loose	Con	71	Asteraceae 2	Thistle
3	4	Smooth	Con	71	Asteraceae 2	Thistle
3	5	Smooth	TC	71	Asteraceae 2	Thistle
3	6	Smooth	AR	71	Asteraceae 2	Thistle
1	1	Loose	AR	72	Angiospermae 3	Angiosperm 3
1	2	Loose	Con	72	Angiospermae 3	Angiosperm 3
1	3	Loose	TC	72	Angiospermae 3	Angiosperm 3
1	4	Smooth	Con	72	Angiospermae 3	Angiosperm 3
1	5	Smooth	TC	72	Angiospermae 3	Angiosperm 3
1	6	Smooth	AR	72	Angiospermae 3	Angiosperm 3
2	1	Loose	AR	72	Angiospermae 3	Angiosperm 3
2	2	Loose	Con	72	Angiospermae 3	Angiosperm 3
2	3	Loose	TC	72	Angiospermae 3	Angiosperm 3
2	5	Smooth	Con	72	Angiospermae 3	Angiosperm 3
2	6	Smooth	TC	72	Angiospermae 3	Angiosperm 3
2	7	Smooth	AR	72	Angiospermae 3	Angiosperm 3
3	1	Loose	TC	72	Angiospermae 3	Angiosperm 3

3	2	Loose	AR	72	Angiospermae 3	Angiosperm 3
3	3	Loose	Con	72	Angiospermae 3	Angiosperm 3
3	4	Smooth	Con	72	Angiospermae 3	Angiosperm 3
3	5	Smooth	TC	72	Angiospermae 3	Angiosperm 3
3	6	Smooth	AR	72	Angiospermae 3	Angiosperm 3
1	1	Loose	AR	73	Fabaceae	Pea
1	2	Loose	Con	73	Fabaceae	Pea
1	3	Loose	TC	73	Fabaceae	Pea
1	4	Smooth	Con	73	Fabaceae	Pea
1	5	Smooth	TC	73	Fabaceae	Pea
1	6	Smooth	AR	73	Fabaceae	Pea
2	1	Loose	AR	73	Fabaceae	Pea
2	2	Loose	Con	73	Fabaceae	Pea
2	3	Loose	TC	73	Fabaceae	Pea
2	5	Smooth	Con	73	Fabaceae	Pea
2	6	Smooth	TC	73	Fabaceae	Pea
2	7	Smooth	AR	73	Fabaceae	Pea
3	1	Loose	TC	73	Fabaceae	Pea
3	2	Loose	AR	73	Fabaceae	Pea
3	3	Loose	Con	73	Fabaceae	Pea
3	4	Smooth	Con	73	Fabaceae	Pea
3	5	Smooth	TC	73	Fabaceae	Pea
3	6	Smooth	AR	73	Fabaceae	Pea
1	1	Loose	AR	75	Secale cereale	Rye grain
1	2	Loose	Con	75	Secale cereale	Rye grain
1	3	Loose	TC	75	Secale cereale	Rye grain
1	4	Smooth	Con	75	Secale cereale	Rye grain
1	5	Smooth	TC	75	Secale cereale	Rye grain
1	6	Smooth	AR	75	Secale cereale	Rye grain
2	1	Loose	AR	75	Secale cereale	Rye grain
2	2	Loose	Con	75	Secale cereale	Rye grain
2	3	Loose	TC	75	Secale cereale	Rye grain
2	5	Smooth	Con	75	Secale cereale	Rye grain
2	6	Smooth	TC	75	Secale cereale	Rye grain
2	7	Smooth	AR	75	Secale cereale	Rye grain
3	1	Loose	TC	75	Secale cereale	Rye grain
3	2	Loose	AR	75	Secale cereale	Rye grain
3	3	Loose	Con	75	Secale cereale	Rye grain
3	4	Smooth	Con	75	Secale cereale	Rye grain
3	5	Smooth	TC	75	Secale cereale	Rye grain
3	6	Smooth	AR	75	Secale cereale	Rye grain
1	1	Loose	AR	76	Lespedeza cuneata	Sericea lespedeza
1	2	Loose	Con	76	Lespedeza cuneata	Sericea lespedeza

1	3	Loose	TC	76	Lespedeza cuneata	Sericea lespedeza
1	4	Smooth	Con	76	Lespedeza cuneata	Sericea lespedeza
1	5	Smooth	TC	76	Lespedeza cuneata	Sericea lespedeza
1	6	Smooth	AR	76	Lespedeza cuneata	Sericea lespedeza
2	1	Loose	AR	76	Lespedeza cuneata	Sericea lespedeza
2	2	Loose	Con	76	Lespedeza cuneata	Sericea lespedeza
2	3	Loose	TC	76	Lespedeza cuneata	Sericea lespedeza
2	5	Smooth	Con	76	Lespedeza cuneata	Sericea lespedeza
2	6	Smooth	TC	76	Lespedeza cuneata	Sericea lespedeza
2	7	Smooth	AR	76	Lespedeza cuneata	Sericea lespedeza
3	1	Loose	TC	76	Lespedeza cuneata	Sericea lespedeza
3	2	Loose	AR	76	Lespedeza cuneata	Sericea lespedeza
3	3	Loose	Con	76	Lespedeza cuneata	Sericea lespedeza
3	4	Smooth	Con	76	Lespedeza cuneata	Sericea lespedeza
3	5	Smooth	TC	76	Lespedeza cuneata	Sericea lespedeza
3	6	Smooth	AR	76	Lespedeza cuneata	Sericea lespedeza
1	1	Loose	AR	77	Securigera varia	Crown vetch
1	2	Loose	Con	77	Securigera varia	Crown vetch
1	3	Loose	TC	77	Securigera varia	Crown vetch
1	4	Smooth	Con	77	Securigera varia	Crown vetch
1	5	Smooth	TC	77	Securigera varia	Crown vetch
1	6	Smooth	AR	77	Securigera varia	Crown vetch
2	1	Loose	AR	77	Securigera varia	Crown vetch
2	2	Loose	Con	77	Securigera varia	Crown vetch
2	3	Loose	TC	77	Securigera varia	Crown vetch
2	5	Smooth	Con	77	Securigera varia	Crown vetch
2	6	Smooth	TC	77	Securigera varia	Crown vetch
2	7	Smooth	AR	77	Securigera varia	Crown vetch
3	1	Loose	TC	77	Securigera varia	Crown vetch
3	2	Loose	AR	77	Securigera varia	Crown vetch
3	3	Loose	Con	77	Securigera varia	Crown vetch
3	4	Smooth	Con	77	Securigera varia	Crown vetch
3	5	Smooth	TC	77	Securigera varia	Crown vetch
3	6	Smooth	AR	77	Securigera varia	Crown vetch
1	1	Loose	AR	78	Angiospermae 4	Angiospem 4
1	2	Loose	Con	78	Angiospermae 4	Angiospem 4
1	3	Loose	TC	78	Angiospermae 4	Angiospem 4
1	4	Smooth	Con	78	Angiospermae 4	Angiospem 4
1	5	Smooth	TC	78	Angiospermae 4	Angiospem 4
1	6	Smooth	AR	78	Angiospermae 4	Angiospem 4
2	1	Loose	AR	78	Angiospermae 4	Angiospem 4
2	2	Loose	Con	78	Angiospermae 4	Angiospem 4
2	3	Loose	TC	78	Angiospermae 4	Angiospem 4

2	5	Smooth	Con	78	Angiospermae 4	Angiospem 4
2	6	Smooth	TC	78	Angiospermae 4	Angiospem 4
2	7	Smooth	AR	78	Angiospermae 4	Angiospem 4
3	1	Loose	TC	78	Angiospermae 4	Angiospem 4
3	2	Loose	AR	78	Angiospermae 4	Angiospem 4
3	3	Loose	Con	78	Angiospermae 4	Angiospem 4
3	4	Smooth	Con	78	Angiospermae 4	Angiospem 4
3	5	Smooth	TC	78	Angiospermae 4	Angiospem 4
3	6	Smooth	AR	78	Angiospermae 4	Angiospem 4
1	1	Loose	AR	79	Rumex	Dock
1	2	Loose	Con	79	Rumex	Dock
1	3	Loose	TC	79	Rumex	Dock
1	4	Smooth	Con	79	Rumex	Dock
1	5	Smooth	TC	79	Rumex	Dock
1	6	Smooth	AR	79	Rumex	Dock
2	1	Loose	AR	79	Rumex	Dock
2	2	Loose	Con	79	Rumex	Dock
2	3	Loose	TC	79	Rumex	Dock
2	5	Smooth	Con	79	Rumex	Dock
2	6	Smooth	TC	79	Rumex	Dock
2	7	Smooth	AR	79	Rumex	Dock
3	1	Loose	TC	79	Rumex	Dock
3	2	Loose	AR	79	Rumex	Dock
3	3	Loose	Con	79	Rumex	Dock
3	4	Smooth	Con	79	Rumex	Dock
3	5	Smooth	TC	79	Rumex	Dock
3	6	Smooth	AR	79	Rumex	Dock
1	1	Loose	AR	80	Solanum	Nightshade
1	2	Loose	Con	80	Solanum	Nightshade
1	3	Loose	TC	80	Solanum	Nightshade
1	4	Smooth	Con	80	Solanum	Nightshade
1	5	Smooth	TC	80	Solanum	Nightshade
1	6	Smooth	AR	80	Solanum	Nightshade
2	1	Loose	AR	80	Solanum	Nightshade
2	2	Loose	Con	80	Solanum	Nightshade
2	3	Loose	TC	80	Solanum	Nightshade
2	5	Smooth	Con	80	Solanum	Nightshade
2	6	Smooth	TC	80	Solanum	Nightshade
2	7	Smooth	AR	80	Solanum	Nightshade
3	1	Loose	TC	80	Solanum	Nightshade
3	2	Loose	AR	80	Solanum	Nightshade
3	3	Loose	Con	80	Solanum	Nightshade
3	4	Smooth	Con	80	Solanum	Nightshade

3	5	Smooth	TC	80	Solanum	Nightshade
3	6	Smooth	AR	80	Solanum	Nightshade
1	1	Loose	AR	81	Phytolacca	Pokeweed
1	2	Loose	Con	81	Phytolacca	Pokeweed
1	3	Loose	TC	81	Phytolacca	Pokeweed
1	4	Smooth	Con	81	Phytolacca	Pokeweed
1	5	Smooth	TC	81	Phytolacca	Pokeweed
1	6	Smooth	AR	81	Phytolacca	Pokeweed
2	1	Loose	AR	81	Phytolacca	Pokeweed
2	2	Loose	Con	81	Phytolacca	Pokeweed
2	3	Loose	TC	81	Phytolacca	Pokeweed
2	5	Smooth	Con	81	Phytolacca	Pokeweed
2	6	Smooth	TC	81	Phytolacca	Pokeweed
2	7	Smooth	AR	81	Phytolacca	Pokeweed
3	1	Loose	TC	81	Phytolacca	Pokeweed
3	2	Loose	AR	81	Phytolacca	Pokeweed
3	3	Loose	Con	81	Phytolacca	Pokeweed
3	4	Smooth	Con	81	Phytolacca	Pokeweed
3	5	Smooth	TC	81	Phytolacca	Pokeweed
3	6	Smooth	AR	81	Phytolacca	Pokeweed

1. Phleum pretense and Lolium perenne (timothy and perenniel rye) were often mixed, and their presence was not recorded separately.

Table A.9. Ecological status of species found in August of 2009. All prescribed species were considered planted species when encountered, crown vetch was found to be a seeding contaminant where it occurred, invasive species were determined by being found on the list of invasives published by the Southeast Exotic Pest Plant Council (SE-EPPC) as of August of 2010 (http://www.se-eppc.org/weeds.cfm).

Block	T Plot	Spp	Origin	Nativity	Invasivity
1	1	10	Volunteer	Native	Noninvasive
1	2	10	Volunteer	Native	Noninvasive
1	3	10	Volunteer	Native	Noninvasive
1	4	10	Volunteer	Native	Noninvasive
1	5	10	Volunteer	Native	Noninvasive
1	6	10	Volunteer	Native	Noninvasive
2	1	10	Volunteer	Native	Noninvasive
2	2	10	Volunteer	Native	Noninvasive
2	3	10	Volunteer	Native	Noninvasive
2	5	10	Volunteer	Native	Noninvasive
2	6	10	Volunteer	Native	Noninvasive
2	7	10	Volunteer	Native	Noninvasive
3	1	10	Volunteer	Native	Noninvasive
3	2	10	Volunteer	Native	Noninvasive
3	3	10	Volunteer	Native	Noninvasive
3	4	10	Volunteer	Native	Noninvasive
3	5	10	Volunteer	Native	Noninvasive
3	6	10	Volunteer	Native	Noninvasive
1	1	13	Volunteer	Native	Noninvasive
1	2	13	Volunteer	Native	Noninvasive
1	3	13	Volunteer	Native	Noninvasive
1	4	13	Volunteer	Native	Noninvasive
1	5	13	Volunteer	Native	Noninvasive
1	6	13	Volunteer	Native	Noninvasive
2	1	13	Volunteer	Native	Noninvasive
2	2	13	Volunteer	Native	Noninvasive
2	3	13	Volunteer	Native	Noninvasive
2	5	13	Volunteer	Native	Noninvasive
2	6	13	Volunteer	Native	Noninvasive
2	7	13	Volunteer	Native	Noninvasive
3	1	13	Volunteer	Native	Noninvasive
3	2	13	Volunteer	Native	Noninvasive
3	3	13	Volunteer	Native	Noninvasive
3	4	13	Volunteer	Native	Noninvasive
3	5	13	Volunteer	Native	Noninvasive
3	6	13	Volunteer	Native	Noninvasive
1	1	15	Volunteer	Native	Noninvasive
1	2	15	Volunteer	Native	Noninvasive
1	3	15	Volunteer	Native	Noninvasive
1	4	15	Volunteer	Native	Noninvasive

1	5	15	Volunteer	Native	Noninvasive
1	6	15	Volunteer	Native	Noninvasive
2	1	15	Volunteer	Native	Noninvasive
2	2	15	Volunteer	Native	Noninvasive
2	3	15	Volunteer	Native	Noninvasive
2	5	15	Volunteer	Native	Noninvasive
2	6	15	Volunteer	Native	Noninvasive
2	7	15	Volunteer	Native	Noninvasive
3	1	15	Volunteer	Native	Noninvasive
3	2	15	Volunteer	Native	Noninvasive
3	3	15	Volunteer	Native	Noninvasive
3	4	15	Volunteer	Native	Noninvasive
3	5	15	Volunteer	Native	Noninvasive
3	6	15	Volunteer	Native	Noninvasive
1	1	17	Volunteer	Native	Noninvasive
1	2	17	Volunteer	Native	Noninvasive
1	3	17	Volunteer	Native	Noninvasive
1	4	17	Volunteer	Native	Noninvasive
1	5	17	Volunteer	Native	Noninvasive
1	6	17	Volunteer	Native	Noninvasive
2	1	17	Volunteer	Native	Noninvasive
2	2	17	Volunteer	Native	Noninvasive
2	3	17	Volunteer	Native	Noninvasive
2	5	17	Volunteer	Native	Noninvasive
2	6	17	Volunteer	Native	Noninvasive
2	7	17	Volunteer	Native	Noninvasive
3	1	17	Volunteer	Native	Noninvasive
3	2	17	Volunteer	Native	Noninvasive
3	3	17	Volunteer	Native	Noninvasive
3	4	17	Volunteer	Native	Noninvasive
3	5	17	Volunteer	Native	Noninvasive
3	6	17	Volunteer	Native	Noninvasive
1	1	19	Planted	Alien	Invasive
1	2	19	Planted	Alien	Invasive
1	3	19	Planted	Alien	Invasive
1	4	19	Planted	Alien	Invasive
1	5	19	Planted	Alien	Invasive
1	6	19	Planted	Alien	Invasive
2	1	19	Planted	Alien	Invasive
2	2	19	Planted	Alien	Invasive
2	3	19	Planted	Alien	Invasive
2	5	19	Planted	Alien	Invasive
2	6	19	Planted	Alien	Invasive
2	7	19	Planted	Alien	Invasive
3	1	19	Planted	Alien	Invasive
3	2	19	Planted	Alien	Invasive

3	3	19	Planted	Alien	Invasive
3	4	19	Planted	Alien	Invasive
3	5	19	Planted	Alien	Invasive
3	6	19	Planted	Alien	Invasive
1	1	20	Volunteer	Native	Noninvasive
1	2	20	Volunteer	Native	Noninvasive
1	3	20	Volunteer	Native	Noninvasive
1	4	20	Volunteer	Native	Noninvasive
1	5	20	Volunteer	Native	Noninvasive
1	6	20	Volunteer	Native	Noninvasive
2	1	20	Volunteer	Native	Noninvasive
2	2	20	Volunteer	Native	Noninvasive
2	3	20	Volunteer	Native	Noninvasive
2	5	20	Volunteer	Native	Noninvasive
2	6	20	Volunteer	Native	Noninvasive
2	7	20	Volunteer	Native	Noninvasive
3	1	20	Volunteer	Native	Noninvasive
3	2	20	Volunteer	Native	Noninvasive
3	3	20	Volunteer	Native	Noninvasive
3	4	20	Volunteer	Native	Noninvasive
3	5	20	Volunteer	Native	Noninvasive
3	6	20	Volunteer	Native	Noninvasive
1	1	22	Planted	Alien	Noninvasive
1	2	22	Planted	Alien	Noninvasive
1	3	22	Planted	Alien	Noninvasive
1	4	22	Planted	Alien	Noninvasive
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1	3	73	Volunteer	Native	Noninvasive
1	4	73	Volunteer	Native	Noninvasive
1	5	73	Volunteer	Native	Noninvasive
1	6	73	Volunteer	Native	Noninvasive
2	1	73	Volunteer	Native	Noninvasive
2	2	73	Volunteer	Native	Noninvasive
2	3	73	Volunteer	Native	Noninvasive
2	5	73	Volunteer	Native	Noninvasive
2	6	73	Volunteer	Native	Noninvasive
2	7	73	Volunteer	Native	Noninvasive
3	1	73	Volunteer	Native	Noninvasive
3	2	73	Volunteer	Native	Noninvasive
3	3	73	Volunteer	Native	Noninvasive
3	4	73	Volunteer	Native	Noninvasive
3	5	73	Volunteer	Native	Noninvasive
3	6	73	Volunteer	Native	Noninvasive
1	1	75	Planted	Alien	Noninvasive
1	2	75	Planted	Alien	Noninvasive
1	3	75	Planted	Alien	Noninvasive
1	4	75	Planted	Alien	Noninvasive
1	5	75	Planted	Alien	Noninvasive
1	6	75	Planted	Alien	Noninvasive
2	1	75	Planted	Alien	Noninvasive
2	2	75	Planted	Alien	Noninvasive

2	3	75	Planted	Alien	Noninvasive
2	5	75	Planted	Alien	Noninvasive
2	6	75	Planted	Alien	Noninvasive
2	7	75	Planted	Alien	Noninvasive
3	1	75	Planted	Alien	Noninvasive
3	2	75	Planted	Alien	Noninvasive
3	3	75	Planted	Alien	Noninvasive
3	4	75	Planted	Alien	Noninvasive
3	5	75	Planted	Alien	Noninvasive
3	6	75	Planted	Alien	Noninvasive
1	1	76	Volunteer	Alien	Invasive
1	2	76	Volunteer	Alien	Invasive
1	3	76	Volunteer	Alien	Invasive
1	4	76	Volunteer	Alien	Invasive
1	5	76	Volunteer	Alien	Invasive
1	6	76	Volunteer	Alien	Invasive
2	1	76	Volunteer	Alien	Invasive
2	2	76	Volunteer	Alien	Invasive
2	3	76	Volunteer	Alien	Invasive
2	5	76	Volunteer	Alien	Invasive
2	6	76	Volunteer	Alien	Invasive
2	7	76	Volunteer	Alien	Invasive
3	1	76	Volunteer	Alien	Invasive
3	2	76	Volunteer	Alien	Invasive
3	3	76	Volunteer	Alien	Invasive
3	4	76	Volunteer	Alien	Invasive
3	5	76	Volunteer	Alien	Invasive
3	6	76	Volunteer	Alien	Invasive
1	1	77	Planted	Alien	Invasive
1	2	77	Planted	Alien	Invasive
1	3	77	Planted	Alien	Invasive
1	4	77	Planted	Alien	Invasive
1	5	77	Planted	Alien	Invasive
1	6	77	Planted	Alien	Invasive
2	1	77	Planted	Alien	Invasive
2	2	77	Planted	Alien	Invasive
2	3	77	Planted	Alien	Invasive
2	5	77	Planted	Alien	Invasive
2	6	77	Planted	Alien	Invasive
2	7	77	Planted	Alien	Invasive
3	1	77	Planted	Alien	Invasive
3	2	77	Planted	Alien	Invasive
3	3	77	Planted	Alien	Invasive
3	4	77	Planted	Alien	Invasive
3	5	77	Planted	Alien	Invasive
3	6	77	Planted	Alien	Invasive

1	1	78	Volunteer	Native	Noninvasive
1	2	78	Volunteer	Native	Noninvasive
1	3	78	Volunteer	Native	Noninvasive
1	4	78	Volunteer	Native	Noninvasive
1	5	78	Volunteer	Native	Noninvasive
1	6	78	Volunteer	Native	Noninvasive
2	1	78	Volunteer	Native	Noninvasive
2	2	78	Volunteer	Native	Noninvasive
2	3	78	Volunteer	Native	Noninvasive
2	5	78	Volunteer	Native	Noninvasive
2	6	78	Volunteer	Native	Noninvasive
2	7	78	Volunteer	Native	Noninvasive
3	1	78	Volunteer	Native	Noninvasive
3	2	78	Volunteer	Native	Noninvasive
3	3	78	Volunteer	Native	Noninvasive
3	4	78	Volunteer	Native	Noninvasive
3	5	78	Volunteer	Native	Noninvasive
3	6	78	Volunteer	Native	Noninvasive
1	1	79	Volunteer	Alien	Invasive
1	2	79	Volunteer	Alien	Invasive
1	3	79	Volunteer	Alien	Invasive
1	4	79	Volunteer	Alien	Invasive
1	5	79	Volunteer	Alien	Invasive
1	6	79	Volunteer	Alien	Invasive
2	1	79	Volunteer	Alien	Invasive
2	2	79	Volunteer	Alien	Invasive
2	3	79	Volunteer	Alien	Invasive
2	5	79	Volunteer	Alien	Invasive
2	6	79	Volunteer	Alien	Invasive
2	7	79	Volunteer	Alien	Invasive
3	1	79	Volunteer	Alien	Invasive
3	2	79	Volunteer	Alien	Invasive
3	3	79	Volunteer	Alien	Invasive
3	4	79	Volunteer	Alien	Invasive
3	5	79	Volunteer	Alien	Invasive
3	6	79	Volunteer	Alien	Invasive
1	1	80	Volunteer	Alien	Invasive
1	2	80	Volunteer	Alien	Invasive
1	3	80	Volunteer	Alien	Invasive
1	4	80	Volunteer	Alien	Invasive
1	5	80	Volunteer	Alien	Invasive
1	6	80	Volunteer	Alien	Invasive
2	1	80	Volunteer	Alien	Invasive
2	2	80	Volunteer	Alien	Invasive
2	3	80	Volunteer	Alien	Invasive
2	5	80	Volunteer	Alien	Invasive

2	6	80	Volunteer	Alien	Invasive
2	7	80	Volunteer	Alien	Invasive
3	1	80	Volunteer	Alien	Invasive
3	2	80	Volunteer	Alien	Invasive
3	3	80	Volunteer	Alien	Invasive
3	4	80	Volunteer	Alien	Invasive
3	5	80	Volunteer	Alien	Invasive
3	6	80	Volunteer	Alien	Invasive
1	1	81	Volunteer	Native	Noninvasive
1	2	81	Volunteer	Native	Noninvasive
1	3	81	Volunteer	Native	Noninvasive
1	4	81	Volunteer	Native	Noninvasive
1	5	81	Volunteer	Native	Noninvasive
1	6	81	Volunteer	Native	Noninvasive
2	1	81	Volunteer	Native	Noninvasive
2	2	81	Volunteer	Native	Noninvasive
2	3	81	Volunteer	Native	Noninvasive
2	5	81	Volunteer	Native	Noninvasive
2	6	81	Volunteer	Native	Noninvasive
2	7	81	Volunteer	Native	Noninvasive
3	1	81	Volunteer	Native	Noninvasive
3	2	81	Volunteer	Native	Noninvasive
3	3	81	Volunteer	Native	Noninvasive
3	4	81	Volunteer	Native	Noninvasive
3	5	81	Volunteer	Native	Noninvasive
3	6	81	Volunteer	Native	Noninvasive

Table A.10. Groundcover percentage of species found in August of 2009. Species found as trace only are designated and were all given 0.25% ground coverage values for analysis purposes (merge with Tables 8 and 9 for re-analysis).

Block	T Plot	Grading	Groundcover	Spp	Trace Only	% Groundcover
1	1	Loose	AR	10	trace	0.250000
1	2	Loose	Con	10		0.000000
1	3	Loose	TC	10		0.000000
1	4	Compact	Con	10		0.000000
1	5	Compact	TC	10		0.000000
1	6	Compact	AR	10	trace	0.250000
2	1	Loose	AR	10		0.000000
2	2	Loose	Con	10		0.000000
2	3	Loose	TC	10		0.000000
2	5	Compact	Con	10		0.000000
2	6	Compact	TC	10		0.000000
2	7	Compact	AR	10		0.000000
3	1	Loose	TC	10		0.000000
3	2	Loose	AR	10		0.300000
3	3	Loose	Con	10		0.000000
3	4	Compact	Con	10		0.000000
3	5	Compact	TC	10		0.000000
3	6	Compact	AR	10		0.000000
1	1	Loose	AR	13		0.000000
1	2	Loose	Con	13		0.000000
1	3	Loose	TC	13		0.000000
1	4	Compact	Con	13		0.000000
1	5	Compact	TC	13		0.000000
1	6	Compact	AR	13		0.000000
2	1	Loose	AR	13	trace	0.250000
2	2	Loose	Con	13		0.000000
2	3	Loose	TC	13		0.000000
2	5	Compact	Con	13		0.000000
2	6	Compact	TC	13		0.000000
2	7	Compact	AR	13		0.000000
3	1	Loose	TC	13		0.000000
3	2	Loose	AR	13		0.000000
3	3	Loose	Con	13		0.000000
3	4	Compact	Con	13		0.000000
3	5	Compact	TC	13		0.000000
3	6	Compact	AR	13		0.000000
1	1	Loose	AR	15		0.500000
1	2	Loose	Con	15		0.000000
1	3	Loose	TC	15		0.250000
1	4	Compact	Con	15		0.000000
1	5	Compact	TC	15	trace	0.250000
1	6	Compact	AR	15		1.400000

2	1	Loose	AR	15		0.400000
2	2	Loose	Con	15	trace	0.250000
2	3	Loose	TC	15		0.150000
2	5	Compact	Con	15		0.000000
2	6	Compact	TC	15		1.400000
2	7	Compact	AR	15	trace	0.250000
3	1	Loose	TC	15		0.000000
3	2	Loose	AR	15		0.150000
3	3	Loose	Con	15		0.100000
3	4	Compact	Con	15		0.000000
3	5	Compact	TC	15		0.000000
3	6	Compact	AR	15		0.150000
1	1	Loose	AR	17		0.000000
1	2	Loose	Con	17		0.000000
1	3	Loose	TC	17		0.000000
1	4	Compact	Con	17		0.000000
1	5	Compact	TC	17		0.000000
1	6	Compact	AR	17		0.000000
2	1	Loose	AR	17		0.000000
2	2	Loose	Con	17		0.000000
2	3	Loose	TC	17		0.000000
2	5	Compact	Con	17		0.000000
2	6	Compact	TC	17		0.000000
2	7	Compact	AR	17		0.000000
3	1	Loose	TC	17		0.000000
3	2	Loose	AR	17		0.000000
3	3	Loose	Con	17		0.000000
3	4	Compact	Con	17		0.000000
3	5	Compact	TC	17		0.000000
3	6	Compact	AR	17	trace	0.250000
1	1	Loose	AR	19		3.250000
1	2	Loose	Con	19		35.850000
1	3	Loose	TC	19		0.000000
1	4	Compact	Con	19		41.550000
1	5	Compact	TC	19		0.250000
1	6	Compact	AR	19	trace	0.250000
2	1	Loose	AR	19		3.250000
2	2	Loose	Con	19		17.450000
2	3	Loose	TC	19		15.150000
2	5	Compact	Con	19		24.550000
2	6	Compact	TC	19		0.000000
2	7	Compact	AR	19		12.700000
3	1	Loose	TC	19		16.350000
3	2	Loose	AR	19		1.900000
3	3	Loose	Con	19		17.400000
3	4	Compact	Con	19		20.900000

3	5	Compact	TC	19		19.850000
3	6	Compact	AR	19		2.600000
1	1	Loose	AR	20	trace	0.250000
1	2	Loose	Con	20		0.000000
1	3	Loose	TC	20		0.000000
1	4	Compact	Con	20		0.000000
1	5	Compact	TC	20		0.000000
1	6	Compact	AR	20		0.000000
2	1	Loose	AR	20	trace	0.250000
2	2	Loose	Con	20		0.000000
2	3	Loose	TC	20		0.000000
2	5	Compact	Con	20		0.000000
2	6	Compact	TC	20	trace	0.250000
2	7	Compact	AR	20	trace	0.250000
3	1	Loose	TC	20		0.000000
3	2	Loose	AR	20	trace	0.250000
3	3	Loose	Con	20		0.000000
3	4	Compact	Con	20		0.000000
3	5	Compact	TC	20		0.000000
3	6	Compact	AR	20	trace	0.250000
1	1	Loose	AR	22		0.000000
1	2	Loose	Con	22	trace	0.250000
1	3	Loose	TC	22		0.000000
1	4	Compact	Con	22		0.000000
1	5	Compact	TC	22		0.000000
1	6	Compact	AR	22		0.000000
2	1	Loose	AR	22		0.000000
2	2	Loose	Con	22		0.000000
2	3	Loose	TC	22		0.000000
2	5	Compact	Con	22		0.500000
2	6	Compact	TC	22		0.100000
2	7	Compact	AR	22		0.000000
3	1	Loose	TC	22		0.100000
3	2	Loose	AR	22		0.000000
3	3	Loose	Con	22	trace	0.250000
3	4	Compact	Con	22		0.150000
3	5	Compact	TC	22		0.000000
3	6	Compact	AR	22		0.000000
1	1	Loose	AR	23		0.000000
1	2	Loose	Con	23		0.000000
1	3	Loose	TC	23		0.000000
1	4	Compact	Con	23		0.000000
1	5	Compact	TC	23		0.000000
1	6	Compact	AR	23		0.000000
2	1	Loose	AR	23		0.000000
2	2	Loose	Con	23		0.000000

2	3	Loose	TC	23		0.000000
2	5	Compact	Con	23		0.000000
2	6	Compact	TC	23		0.000000
2	7	Compact	AR	23		0.000000
3	1	Loose	TC	23		0.000000
3	2	Loose	AR	23		0.150000
3	3	Loose	Con	23		0.000000
3	4	Compact	Con	23		0.000000
3	5	Compact	TC	23		0.000000
3	6	Compact	AR	23		0.050000
1	1	Loose	AR	25		0.000000
1	2	Loose	Con	25		9.650000
1	3	Loose	TC	25		0.000000
1	4	Compact	Con	25		0.250000
1	5	Compact	TC	25		0.000000
1	6	Compact	AR	25		0.000000
2	1	Loose	AR	25		1.000000
2	2	Loose	Con	25		0.000000
2	3	Loose	TC	25		0.000000
2	5	Compact	Con	25	trace	0.250000
2	6	Compact	TC	25		2.200000
2	7	Compact	AR	25		0.000000
3	1	Loose	TC	25		0.050000
3	2	Loose	AR	25		5.600000
3	3	Loose	Con	25		2.000000
3	4	Compact	Con	25		2.600000
3	5	Compact	TC	25		0.000000
3	6	Compact	AR	25		2.700000
1	1	Loose	AR	32		0.000000
1	2	Loose	Con	32		0.000000
1	3	Loose	TC	32		0.000000
1	4	Compact	Con	32		0.000000
1	5	Compact	TC	32		0.000000
1	6	Compact	AR	32		0.000000
2	1	Loose	AR	32		0.000000
2	2	Loose	Con	32		0.000000
2	3	Loose	TC	32		0.000000
2	5	Compact	Con	32		0.000000
2	6	Compact	TC	32		0.000000
2	7	Compact	AR	32		0.000000
3	1	Loose	TC	32		0.000000
3	2	Loose	AR	32	trace	0.250000
3	3	Loose	Con	32		0.000000
3	4	Compact	Con	32		0.000000
3	5	Compact	TC	32		0.000000
3	6	Compact	AR	32		0.000000

1	1	Loose	AR	36		0.000000
1	2	Loose	Con	36		0.000000
1	3	Loose	TC	36		0.000000
1	4	Compact	Con	36		0.000000
1	5	Compact	TC	36		0.000000
1	6	Compact	AR	36		0.000000
2	1	Loose	AR	36		0.000000
2	2	Loose	Con	36		0.000000
2	3	Loose	TC	36		0.000000
2	5	Compact	Con	36		0.000000
2	6	Compact	TC	36		0.000000
2	7	Compact	AR	36		0.000000
3	1	Loose	TC	36		0.000000
3	2	Loose	AR	36		0.000000
3	3	Loose	Con	36	trace	0.250000
3	4	Compact	Con	36		0.000000
3	5	Compact	TC	36		0.000000
3	6	Compact	AR	36		0.000000
1	1	Loose	AR	39		0.000000
1	2	Loose	Con	39		0.000000
1	3	Loose	TC	39		0.000000
1	4	Compact	Con	39		0.000000
1	5	Compact	TC	39		0.000000
1	6	Compact	AR	39	trace	0.250000
2	1	Loose	AR	39	trace	0.250000
2	2	Loose	Con	39		0.000000
2	3	Loose	TC	39		0.000000
2	5	Compact	Con	39		0.000000
2	6	Compact	TC	39	trace	0.250000
2	7	Compact	AR	39		0.000000
3	1	Loose	TC	39		0.000000
3	2	Loose	AR	39		0.000000
3	3	Loose	Con	39		0.000000
3	4	Compact	Con	39		0.000000
3	5	Compact	TC	39		0.000000
3	6	Compact	AR	39		0.000000
1	1	Loose	AR	50		1.150000
1	2	Loose	Con	50		7.300000
1	3	Loose	TC	50		15.000000
1	4	Compact	Con	50		9.100000
1	5	Compact	TC	50		24.000000
1	6	Compact	AR	50		0.000000
2	1	Loose	AR	50		5.750000
2	2	Loose	Con	50		20.000000
2	3	Loose	TC	50		19.300000
2	5	Compact	Con	50		25.050000

2	6	Compact	TC	50		9.100000
2	7	Compact	AR	50		37.200000
3	1	Loose	TC	50		41.250000
3	2	Loose	AR	50		17.850000
3	3	Loose	Con	50		32.750000
3	4	Compact	Con	50		28.950000
3	5	Compact	TC	50		26.500000
3	6	Compact	AR	50		8.800000
1	1	Loose	AR	51		0.600000
1	2	Loose	Con	51		5.850000
1	3	Loose	TC	51		25.100000
1	4	Compact	Con	51		27.400000
1	5	Compact	TC	51		41.500000
1	6	Compact	AR	51		0.000000
2	1	Loose	AR	51		1.200000
2	2	Loose	Con	51		9.800000
2	3	Loose	TC	51		9.700000
2	5	Compact	Con	51		6.750000
2	6	Compact	TC	51		0.100000
2	7	Compact	AR	51		3.400000
3	1	Loose	TC	51		34.150000
3	2	Loose	AR	51		7.750000
3	3	Loose	Con	51		41.250000
3	4	Compact	Con	51		44.050000
3	5	Compact	TC	51		41.250000
3	6	Compact	AR	51		7.300000
1	1	Loose	AR	52		3.550000
1	2	Loose	Con	52		0.250000
1	3	Loose	TC	52		7.650000
1	4	Compact	Con	52		0.000000
1	5	Compact	TC	52		7.400000
1	6	Compact	AR	52		3.250000
2	1	Loose	AR	52		0.550000
2	2	Loose	Con	52		0.000000
2	3	Loose	TC	52		2.100000
2	5	Compact	Con	52		0.050000
2	6	Compact	TC	52		1.100000
2	7	Compact	AR	52		1.350000
3	1	Loose	TC	52		0.500000
3	2	Loose	AR	52		2.400000
3	3	Loose	Con	52		0.900000
3	4	Compact	Con	52		0.950000
3	5	Compact	TC	52		0.400000
3	6	Compact	AR	52		3.400000
1	1	Loose	AR	53	trace	0.250000
1	2	Loose	Con	53		0.000000

1	3	Loose	TC	53		0.000000
1	4	Compact	Con	53		0.000000
1	5	Compact	TC	53		0.000000
1	6	Compact	AR	53		0.000000
2	1	Loose	AR	53	trace	0.250000
2	2	Loose	Con	53	trace	0.250000
2	3	Loose	TC	53	trace	0.250000
2	5	Compact	Con	53	trace	0.250000
2	6	Compact	TC	53		0.000000
2	7	Compact	AR	53	trace	0.250000
3	1	Loose	TC	53		1.150000
3	2	Loose	AR	53	trace	0.250000
3	3	Loose	Con	53	trace	0.250000
3	4	Compact	Con	53	trace	0.250000
3	5	Compact	TC	53		0.000000
3	6	Compact	AR	53	trace	0.250000
1	1	Loose	AR	54		0.000000
1	2	Loose	Con	54		0.000000
1	3	Loose	TC	54		0.000000
1	4	Compact	Con	54		0.000000
1	5	Compact	TC	54		0.000000
1	6	Compact	AR	54		0.000000
2	1	Loose	AR	54		0.000000
2	2	Loose	Con	54		0.000000
2	3	Loose	TC	54		0.000000
2	5	Compact	Con	54		0.000000
2	6	Compact	TC	54		0.000000
2	7	Compact	AR	54		0.000000
3	1	Loose	TC	54		1.750000
3	2	Loose	AR	54		0.000000
3	3	Loose	Con	54		0.000000
3	4	Compact	Con	54		0.000000
3	5	Compact	TC	54		0.000000
3	6	Compact	AR	54		0.000000
1	1	Loose	AR	55		0.000000
1	2	Loose	Con	55		0.000000
1	3	Loose	TC	55		0.000000
1	4	Compact	Con	55		0.000000
1	5	Compact	TC	55		0.000000
1	6	Compact	AR	55		0.000000
2	1	Loose	AR	55		0.300000
2	2	Loose	Con	55	trace	0.250000
2	3	Loose	TC	55		4.100000
2	5	Compact	Con	55		4.000000
2	6	Compact	TC	55		8.650000
2	7	Compact	AR	55		4.150000

3	1	Loose	TC	55		0.050000
3	2	Loose	AR	55		0.050000
3	3	Loose	Con	55		0.000000
3	4	Compact	Con	55		0.000000
3	5	Compact	TC	55		0.000000
3	6	Compact	AR	55		0.050000
1	1	Loose	AR	56		0.000000
1	2	Loose	Con	56		0.000000
1	3	Loose	TC	56		0.000000
1	4	Compact	Con	56		0.000000
1	5	Compact	TC	56		0.000000
1	6	Compact	AR	56		0.000000
2	1	Loose	AR	56		0.000000
2	2	Loose	Con	56		0.000000
2	3	Loose	TC	56		0.000000
2	5	Compact	Con	56		0.000000
2	6	Compact	TC	56		0.000000
2	7	Compact	AR	56	trace	0.250000
3	1	Loose	TC	56	trace	0.250000
3	2	Loose	AR	56		0.550000
3	3	Loose	Con	56		0.000000
3	4	Compact	Con	56		0.000000
3	5	Compact	TC	56		0.000000
3	6	Compact	AR	56		0.000000
1	1	Loose	AR	57		2.700000
1	2	Loose	Con	57		0.750000
1	3	Loose	TC	57		2.400000
1	4	Compact	Con	57		0.150000
1	5	Compact	TC	57		1.100000
1	6	Compact	AR	57		5.700000
2	1	Loose	AR	57		0.100000
2	2	Loose	Con	57		0.000000
2	3	Loose	TC	57		0.000000
2	5	Compact	Con	57		0.000000
2	6	Compact	TC	57	trace	0.250000
2	7	Compact	AR	57	trace	0.250000
3	1	Loose	TC	57		0.000000
3	2	Loose	AR	57		4.200000
3	3	Loose	Con	57		0.000000
3	4	Compact	Con	57		0.000000
3	5	Compact	TC	57		0.000000
3	6	Compact	AR	57		1.300000
1	1	Loose	AR	58		0.000000
1	2	Loose	Con	58		0.000000
1	3	Loose	TC	58		0.000000
1	4	Compact	Con	58		0.000000

1	5	Compact	TC	58		0.000000
1	6	Compact	AR	58		0.000000
2	1	Loose	AR	58		0.000000
2	2	Loose	Con	58		0.000000
2	3	Loose	TC	58		0.000000
2	5	Compact	Con	58		0.000000
2	6	Compact	TC	58		0.000000
2	7	Compact	AR	58		0.000000
3	1	Loose	TC	58		0.000000
3	2	Loose	AR	58		0.250000
3	3	Loose	Con	58		0.000000
3	4	Compact	Con	58		0.000000
3	5	Compact	TC	58		0.000000
3	6	Compact	AR	58		0.000000
1	1	Loose	AR	59		0.000000
1	2	Loose	Con	59		0.000000
1	3	Loose	TC	59		0.000000
1	4	Compact	Con	59		0.000000
1	5	Compact	TC	59		0.000000
1	6	Compact	AR	59		0.000000
2	1	Loose	AR	59		0.050000
2	2	Loose	Con	59		0.000000
2	3	Loose	TC	59		0.000000
2	5	Compact	Con	59		0.000000
2	6	Compact	TC	59		0.000000
2	7	Compact	AR	59		0.000000
3	1	Loose	TC	59		0.000000
3	2	Loose	AR	59		0.100000
3	3	Loose	Con	59		0.000000
3	4	Compact	Con	59		0.000000
3	5	Compact	TC	59		0.000000
3	6	Compact	AR	59		0.000000
1	1	Loose	AR	60		0.000000
1	2	Loose	Con	60		0.000000
1	3	Loose	TC	60		0.000000
1	4	Compact	Con	60		0.000000
1	5	Compact	TC	60		0.000000
1	6	Compact	AR	60	trace	0.250000
2	1	Loose	AR	60		0.000000
2	2	Loose	Con	60		0.000000
2	3	Loose	TC	60		0.000000
2	5	Compact	Con	60		0.000000
2	6	Compact	TC	60		0.000000
2	7	Compact	AR	60		0.000000
3	1	Loose	TC	60		0.000000
3	2	Loose	AR	60		0.050000

3	3	Loose	Con	60		0.000000
3	4	Compact	Con	60		0.000000
3	5	Compact	TC	60		0.000000
3	6	Compact	AR	60		0.000000
1	1	Loose	AR	61		0.000000
1	2	Loose	Con	61		0.000000
1	3	Loose	TC	61		0.000000
1	4	Compact	Con	61		0.000000
1	5	Compact	TC	61		0.000000
1	6	Compact	AR	61		0.000000
2	1	Loose	AR	61	trace	0.250000
2	2	Loose	Con	61		0.000000
2	3	Loose	TC	61		0.000000
2	5	Compact	Con	61		0.000000
2	6	Compact	TC	61		0.000000
2	7	Compact	AR	61		0.000000
3	1	Loose	TC	61		0.000000
3	2	Loose	AR	61		0.800000
3	3	Loose	Con	61		0.000000
3	4	Compact	Con	61		0.150000
3	5	Compact	TC	61		0.000000
3	6	Compact	AR	61	trace	0.250000
1	1	Loose	AR	63		0.000000
1	2	Loose	Con	63		0.000000
1	3	Loose	TC	63		0.000000
1	4	Compact	Con	63		0.000000
1	5	Compact	TC	63		0.000000
1	6	Compact	AR	63		0.000000
2	1	Loose	AR	63		0.000000
2	2	Loose	Con	63		0.000000
2	3	Loose	TC	63		0.000000
2	5	Compact	Con	63		0.000000
2	6	Compact	TC	63		0.000000
2	7	Compact	AR	63		0.000000
3	1	Loose	TC	63		0.000000
3	2	Loose	AR	63	trace	0.250000
3	3	Loose	Con	63		0.000000
3	4	Compact	Con	63		0.000000
3	5	Compact	TC	63		0.000000
3	6	Compact	AR	63	trace	0.250000
1	1	Loose	AR	64		0.000000
1	2	Loose	Con	64		0.000000
1	3	Loose	TC	64		0.000000
1	4	Compact	Con	64		0.000000
1	5	Compact	TC	64		0.000000
1	6	Compact	AR	64		0.000000

2	1	Loose	AR	64		0.000000
2	2	Loose	Con	64		0.000000
2	3	Loose	TC	64		0.000000
2	5	Compact	Con	64		0.000000
2	6	Compact	TC	64		0.000000
2	7	Compact	AR	64		0.000000
3	1	Loose	TC	64		0.000000
3	2	Loose	AR	64		0.250000
3	3	Loose	Con	64		0.000000
3	4	Compact	Con	64		0.000000
3	5	Compact	TC	64		0.000000
3	6	Compact	AR	64		0.000000
1	1	Loose	AR	65		0.000000
1	2	Loose	Con	65		0.000000
1	3	Loose	TC	65		0.000000
1	4	Compact	Con	65		0.000000
1	5	Compact	TC	65		0.000000
1	6	Compact	AR	65		0.000000
2	1	Loose	AR	65		0.000000
2	2	Loose	Con	65		0.000000
2	3	Loose	TC	65		0.000000
2	5	Compact	Con	65		0.000000
2	6	Compact	TC	65		0.000000
2	7	Compact	AR	65		0.000000
3	1	Loose	TC	65		0.000000
3	2	Loose	AR	65		0.250000
3	3	Loose	Con	65		0.000000
3	4	Compact	Con	65		0.000000
3	5	Compact	TC	65		0.000000
3	6	Compact	AR	65		0.000000
1	1	Loose	AR	66		0.000000
1	2	Loose	Con	66		0.000000
1	3	Loose	TC	66		0.000000
1	4	Compact	Con	66		0.000000
1	5	Compact	TC	66		0.000000
1	6	Compact	AR	66		0.000000
2	1	Loose	AR	66		0.000000
2	2	Loose	Con	66		0.000000
2	3	Loose	TC	66		0.000000
2	5	Compact	Con	66		0.000000
2	6	Compact	TC	66		0.000000
2	7	Compact	AR	66		0.000000
3	1	Loose	TC	66		0.000000
3	2	Loose	AR	66	trace	0.250000
3	3	Loose	Con	66		0.000000
3	4	Compact	Con	66		0.000000

3	5	Compact	TC	66		0.000000
3	6	Compact	AR	66	trace	0.250000
1	1	Loose	AR	67		0.000000
1	2	Loose	Con	67		0.000000
1	3	Loose	TC	67		0.000000
1	4	Compact	Con	67		0.000000
1	5	Compact	TC	67		0.000000
1	6	Compact	AR	67		0.000000
2	1	Loose	AR	67		0.000000
2	2	Loose	Con	67		0.000000
2	3	Loose	TC	67	trace	0.250000
2	5	Compact	Con	67		0.050000
2	6	Compact	TC	67	trace	0.250000
2	7	Compact	AR	67	trace	0.250000
3	1	Loose	TC	67		0.000000
3	2	Loose	AR	67	trace	0.250000
3	3	Loose	Con	67		0.000000
3	4	Compact	Con	67		0.000000
3	5	Compact	TC	67		0.000000
3	6	Compact	AR	67		0.000000
1	1	Loose	AR	68		7.950000
1	2	Loose	Con	68		3.850000
1	3	Loose	TC	68		0.000000
1	4	Compact	Con	68		0.000000
1	5	Compact	TC	68		0.000000
1	6	Compact	AR	68		0.000000
2	1	Loose	AR	68		0.000000
2	2	Loose	Con	68		0.000000
2	3	Loose	TC	68		0.500000
2	5	Compact	Con	68		0.000000
2	6	Compact	TC	68		0.000000
2	7	Compact	AR	68		0.000000
3	1	Loose	TC	68		0.000000
3	2	Loose	AR	68		0.000000
3	3	Loose	Con	68		0.100000
3	4	Compact	Con	68		0.050000
3	5	Compact	TC	68		0.000000
3	6	Compact	AR	68	trace	0.250000
1	1	Loose	AR	69		0.000000
1	2	Loose	Con	69		0.000000
1	3	Loose	TC	69		0.000000
1	4	Compact	Con	69		0.000000
1	5	Compact	TC	69		0.000000
1	6	Compact	AR	69		0.000000
2	1	Loose	AR	69		0.000000
2	2	Loose	Con	69		0.000000

2	3	Loose	TC	69		0.000000
2	5	Compact	Con	69		0.000000
2	6	Compact	TC	69		0.000000
2	7	Compact	AR	69		0.000000
3	1	Loose	TC	69		0.000000
3	2	Loose	AR	69		0.000000
3	3	Loose	Con	69		0.000000
3	4	Compact	Con	69		0.000000
3	5	Compact	TC	69		0.250000
3	6	Compact	AR	69		0.000000
1	1	Loose	AR	70		0.000000
1	2	Loose	Con	70		0.000000
1	3	Loose	TC	70		0.000000
1	4	Compact	Con	70		0.000000
1	5	Compact	TC	70		0.000000
1	6	Compact	AR	70		0.000000
2	1	Loose	AR	70		0.000000
2	2	Loose	Con	70		0.000000
2	3	Loose	TC	70		0.000000
2	5	Compact	Con	70		0.000000
2	6	Compact	TC	70		0.000000
2	7	Compact	AR	70		0.000000
3	1	Loose	TC	70		0.000000
3	2	Loose	AR	70		0.000000
3	3	Loose	Con	70		0.000000
3	4	Compact	Con	70		0.000000
3	5	Compact	TC	70		0.000000
3	6	Compact	AR	70	trace	0.250000
1	1	Loose	AR	71		0.000000
1	2	Loose	Con	71		0.000000
1	3	Loose	TC	71		0.000000
1	4	Compact	Con	71		0.000000
1	5	Compact	TC	71		0.000000
1	6	Compact	AR	71		0.500000
2	1	Loose	AR	71		0.000000
2	2	Loose	Con	71		0.000000
2	3	Loose	TC	71		0.200000
2	5	Compact	Con	71		0.000000
2	6	Compact	TC	71	trace	0.250000
2	7	Compact	AR	71		0.000000
3	1	Loose	TC	71		0.000000
3	2	Loose	AR	71		0.000000
3	3	Loose	Con	71		0.000000
3	4	Compact	Con	71		0.000000
3	5	Compact	TC	71		0.000000
3	6	Compact	AR	71	trace	0.250000

1	1	Loose	AR	72		0.250000
1	2	Loose	Con	72		0.000000
1	3	Loose	TC	72		0.000000
1	4	Compact	Con	72		0.000000
1	5	Compact	TC	72		0.000000
1	6	Compact	AR	72		0.000000
2	1	Loose	AR	72	trace	0.250000
2	2	Loose	Con	72		0.000000
2	3	Loose	TC	72		0.000000
2	5	Compact	Con	72		0.000000
2	6	Compact	TC	72		0.000000
2	7	Compact	AR	72		0.000000
3	1	Loose	TC	72		0.000000
3	2	Loose	AR	72		0.000000
3	3	Loose	Con	72		0.000000
3	4	Compact	Con	72		0.000000
3	5	Compact	TC	72		0.000000
3	6	Compact	AR	72		0.000000
1	1	Loose	AR	73		0.000000
1	2	Loose	Con	73		0.000000
1	3	Loose	TC	73		0.000000
1	4	Compact	Con	73		0.000000
1	5	Compact	TC	73		0.000000
1	6	Compact	AR	73		0.000000
2	1	Loose	AR	73		0.000000
2	2	Loose	Con	73	trace	0.250000
2	3	Loose	TC	73		0.000000
2	5	Compact	Con	73		0.000000
2	6	Compact	TC	73		0.000000
2	7	Compact	AR	73		0.000000
3	1	Loose	TC	73		0.000000
3	2	Loose	AR	73		0.000000
3	3	Loose	Con	73		0.000000
3	4	Compact	Con	73		0.000000
3	5	Compact	TC	73		0.000000
3	6	Compact	AR	73		0.000000
1	1	Loose	AR	75		0.000000
1	2	Loose	Con	75		0.000000
1	3	Loose	TC	75		0.000000
1	4	Compact	Con	75		0.000000
1	5	Compact	TC	75		0.000000
1	6	Compact	AR	75		0.000000
2	1	Loose	AR	75		0.000000
2	2	Loose	Con	75		0.500000
2	3	Loose	TC	75		1.250000
2	5	Compact	Con	75	trace	0.250000

2	6	Compact	TC	75	trace	0.250000
2	7	Compact	AR	75	trace	0.250000
3	1	Loose	TC	75		0.000000
3	2	Loose	AR	75		0.000000
3	3	Loose	Con	75		0.000000
3	4	Compact	Con	75		0.000000
3	5	Compact	TC	75		0.000000
3	6	Compact	AR	75		0.000000
1	1	Loose	AR	76		0.250000
1	2	Loose	Con	76	trace	0.250000
1	3	Loose	TC	76		0.000000
1	4	Compact	Con	76		0.000000
1	5	Compact	TC	76		0.000000
1	6	Compact	AR	76		1.000000
2	1	Loose	AR	76		0.000000
2	2	Loose	Con	76		0.000000
2	3	Loose	TC	76		0.100000
2	5	Compact	Con	76		0.100000
2	6	Compact	TC	76		0.000000
2	7	Compact	AR	76	trace	0.250000
3	1	Loose	TC	76		0.000000
3	2	Loose	AR	76		0.000000
3	3	Loose	Con	76		0.000000
3	4	Compact	Con	76		0.000000
3	5	Compact	TC	76		0.000000
3	6	Compact	AR	76		0.000000
1	1	Loose	AR	77		19.000000
1	2	Loose	Con	77		9.000000
1	3	Loose	TC	77		1.900000
1	4	Compact	Con	77		0.000000
1	5	Compact	TC	77		1.000000
1	6	Compact	AR	77		36.400000
2	1	Loose	AR	77		0.000000
2	2	Loose	Con	77		0.000000
2	3	Loose	TC	77		0.000000
2	5	Compact	Con	77		0.000000
2	6	Compact	TC	77		0.000000
2	7	Compact	AR	77		0.000000
3	1	Loose	TC	77		0.000000
3	2	Loose	AR	77		0.000000
3	3	Loose	Con	77		0.000000
3	4	Compact	Con	77		0.000000
3	5	Compact	TC	77		0.000000
3	6	Compact	AR	77		0.000000
1	1	Loose	AR	78	trace	0.250000
1	2	Loose	Con	78		0.000000

1	3	Loose	TC	78		0.000000
1	4	Compact	Con	78		0.000000
1	5	Compact	TC	78		0.000000
1	6	Compact	AR	78		0.000000
2	1	Loose	AR	78		0.000000
2	2	Loose	Con	78		0.000000
2	3	Loose	TC	78		0.000000
2	5	Compact	Con	78		0.000000
2	6	Compact	TC	78		0.000000
2	7	Compact	AR	78		0.000000
3	1	Loose	TC	78		0.000000
3	2	Loose	AR	78		0.000000
3	3	Loose	Con	78		0.000000
3	4	Compact	Con	78		0.000000
3	5	Compact	TC	78		0.000000
3	6	Compact	AR	78		0.000000
1	1	Loose	AR	79	trace	0.250000
1	2	Loose	Con	79		0.000000
1	3	Loose	TC	79		0.000000
1	4	Compact	Con	79		0.000000
1	5	Compact	TC	79		0.000000
1	6	Compact	AR	79	trace	0.250000
2	1	Loose	AR	79		0.000000
2	2	Loose	Con	79		0.000000
2	3	Loose	TC	79		0.000000
2	5	Compact	Con	79		0.000000
2	6	Compact	TC	79		0.000000
2	7	Compact	AR	79		0.000000
3	1	Loose	TC	79		0.000000
3	2	Loose	AR	79		0.000000
3	3	Loose	Con	79		0.000000
3	4	Compact	Con	79		0.000000
3	5	Compact	TC	79		0.000000
3	6	Compact	AR	79		0.000000
1	1	Loose	AR	80		0.000000
1	2	Loose	Con	80		0.000000
1	3	Loose	TC	80		0.000000
1	4	Compact	Con	80		0.000000
1	5	Compact	TC	80		0.000000
1	6	Compact	AR	80		0.000000
2	1	Loose	AR	80		0.000000
2	2	Loose	Con	80		0.000000
2	3	Loose	TC	80		0.000000
2	5	Compact	Con	80		0.000000
2	6	Compact	TC	80		0.000000
2	7	Compact	AR	80		0.000000

3	1	Loose	TC	80	0.000000
3	2	Loose	AR	80	0.000000
3	3	Loose	Con	80	0.000000
3	4	Compact	Con	80	0.000000
3	5	Compact	TC	80	0.000000
3	6	Compact	AR	80	0.000000
1	1	Loose	AR	81	0.000000
1	2	Loose	Con	81	0.000000
1	3	Loose	TC	81	0.000000
1	4	Compact	Con	81	0.000000
1	5	Compact	TC	81	0.250000
1	6	Compact	AR	81	0.000000
2	1	Loose	AR	81	0.000000
2	2	Loose	Con	81	0.000000
2	3	Loose	TC	81	0.000000
2	5	Compact	Con	81	0.000000
2	6	Compact	TC	81	0.000000
2	7	Compact	AR	81	0.000000
3	1	Loose	TC	81	0.000000
3	2	Loose	AR	81	0.000000
3	3	Loose	Con	81	0.000000
3	4	Compact	Con	81	0.000000
3	5	Compact	TC	81	0.000000
3	6	Compact	AR	81	0.000000

Table A.11. Simpson's and Shannon's Diversity Indices by plot.

Block	Grading	Groundcover	Simpson's DI	Shannon's DI
1	Compact	AR	0.44	1.01
1	Compact	Con	0.58	0.98
1	Compact	TC	0.59	1.10
1	Loose	AR	0.72	1.71
1	Loose	Con	0.71	1.57
1	Loose	TC	0.66	1.28
2	Compact	AR	0.57	1.24
2	Compact	Con	0.66	1.28
2	Compact	TC	0.72	1.59
2	Loose	AR	0.76	1.90
2	Loose	Con	0.66	1.21
2	Loose	TC	0.74	1.59
3	Compact	AR	0.81	1.97
3	Compact	Con	0.66	1.23
3	Compact	TC	0.64	1.09
3	Loose	AR	0.77	1.94
3	Loose	Con	0.66	1.23
3	Loose	TC	0.66	1.22

Table A.12. Partitioned diversity values used to make figures II.11a – 11f.

Herbaceaous Species Richness

	Native	Alien	Volunteer	Planted
Loose	4	8	7	6
Smooth	3	7	6	5
AR	8	8	11	5
Con	2	8	3	6
TC	3	7	4	5
Total	4	8	7	6

Groundcover %

	Native	Alien	Volunteer	Planted
Loose	1.6	54.9	4.1	52.4
Smooth	1.4	60.5	5.4	56.5
AR	3.3	34.7	6.7	31.2
Con	0.2	75.1	1.2	74.1
TC	1	63.4	6.4	58.1
Total	1.5	57.7	4.8	54.5

Shannon's Diversity Index

	Native	Alien	Volunteer	Planted
Loose	0.21	1.31	0.38	1.15
Smooth	0.17	1.11	0.38	0.89
AR	0.41	1.22	0.68	0.94
Con	0.03	1.22	0.08	1.17
TC	0.13	1.19	0.36	0.95
Total	0.19	1.21	0.38	1.02

Table A.13. Plot corner coordinates, corner positions oriented by standing at the bottom of a plot looking upslope, assume degrees and minutes in rows in which they are not shown are the same as in the nearest row above which does present them, all corners are marked on the ground with rebar stakes covered with 3 ft tall white PVC pipe wrapped with yellow flagging.

Block	**Plot Number**	**Corner Position**	**Latitude**	**Longitude**
1 RR	1	Upper Right	N 37°00'19.9"	W 82°42'57.8"
1 RR	1	Upper Left	19.0"	58.9"
1 RR	1	Lower Left	16.8"	56.7"
1 RR	1	Lower Right	18.1"	56.0"
1 RR	2	Upper Right	21.0"	56.8"
1 RR	2	Lower Right	19.0"	55.3"
1 RR	3	Lower Right	20.0"	54.0"
1 RR	3	Upper Right	21.7"	55.5"
1 RR	4	Upper Right	22.1”	53.1”
1 RR	5	Upper Right	22.3”	49.6”
1 RR	4	Lower Right	20.5”	52.2”
1 RR	5	Lower Right	20.7”	49.9”
1 RR	6	Lower Left	21.6”	42.6”
1 RR	6	Lower Right	23.1”	38.9”
1 RR	6	Upper Right	24.9”	39.0”
2 PR	3	Upper Right	30.4"	56.8"
2 PR	2	Upper Right	28.5"	57.0"
2 PR	2	Lower Right	27.7"	51.4"
2 PR	3	Lower Right	30.0"	52.1"
2 PR	1	Lower Right	25.9"	50.9"
2 PR	1	Upper Right	26.5"	57.2"
2 PR	1	Upper Left	24.7"	58.0"
2 PR	1	Lower Left	24.1"	51.4"
2 PR	5	Upper Right	33.5”	0.2”
2 PR	5	Lower Right	35.9”	41’56.4”
2 PR	5	Lower Left	34.3”	54.1”
2 PR	5	Upper Left	32.3”	58.3”
2 PR	6	Lower Right	37.1”	58.0”
2 PR	6	Upper Right	34.4”	42’02.3”
2 PR	7	Lower Right	38.9”	0.2”
2 PR	7	Upper Right	36.1”	3.9”
3 CR	3	Lower Left	1'29.1"	11'05.6"
3 CR	2	Lower Left	30.2"	4.5"
3 CR	1	Lower Left	32.0"	2.1"
3 CR	1	Lower Right	33.7"	10'59.4"
3 CR	1	Upper Right	35.9"	11'02.2"
3 CR	2	Upper Right	34.6"	5.3"
3 CR	3	Upper Right	32.8"	7.6"
3 CR	3	Upper Left	31.1"	7.7"

3 CR	4	Lower Left	0.9”	7.8”
3 CR	4	Lower Right	28.9”	5.8”
3 CR	4	Upper Right	30.8”	7.9”
3 CR	5	Lower Left	0.3”	10.2”
3 CR	5	Upper Right	30.3”	8.9”
3 CR	6	Lower Left	27.2”	12.7”
3 CR	6	Upper Right	30.0”	10.4”
3 CR	6	Upper Left	29.2”	12.2”

Table A.14. Woody plot center coordinates, assume degrees and minutes in rows in which they are not shown are the same as in the nearest row above which does present them, all corners are marked on the ground with rebar stakes covered with 3 ft tall white PVC pipe wrapped with orange flagging.

Block	Treatment Plot	Woody Plot	Latitude	Longitude
1 RR	1	1	N37˚00'19.0"	W82˚42'58.1"
1 RR	1	2	19.1"	57.6"
1 RR	1	3	18.6"	57.9"
1 RR	1	4	18.8"	57.2"
1 RR	1	5	18.3"	57.2"
1 RR	2	1	19.6"	57.2"
1 RR	2	2	19.7"	56.6"
1 RR	2	3	19.1"	56.7"
1 RR	2	4	19.3"	56.2"
1 RR	2	5	18.8"	56.1"
1 RR	3	1	21.2"	56.3"
1 RR	3	2	21.1"	55.6"
1 RR	3	3	20.6"	55.8"
1 RR	3	4	20.7"	55.3"
1 RR	3	5	20.0"	55.6"
1 RR	4	1	21.5"	54.3"
1 RR	4	2	21.3"	53.4"
1 RR	4	3	20.9"	54.2"
1 RR	4	4	20.9"	53.2"
1 RR	4	5	20.5"	54.2"
1 RR	5	1	21.9"	52.4"
1 RR	5	2	21.9"	51.4"
1 RR	5	3	21.5"	51.8"
1 RR	5	4	21.3"	51.1"
1 RR	5	5	20.9"	52.1"
1 RR	6	1	24.2"	42.7"
1 RR	6	2	24.3"	40.9"
1 RR	6	3	23.6"	41.9"
1 RR	6	4	23.7"	40.0"
1 RR	6	5	22.5"	42.3"
2 PR	1	1	24.8"	41'56.8"
2 PR	1	2	25.3"	54.8"
2 PR	1	3	24.6"	53.4"
2 PR	1	4	25.0"	52.2"
2 PR	1	5	24.4"	51.7"
2 PR	2	1	26.7"	56.6"
2 PR	2	2	27.7"	55.2"
2 PR	2	3	26.8"	54.0"

2 PR	2	4	27.5"	53.0"
2 PR	2	5	26.3"	51.6"
2 PR	3	1	29.2"	56.3"
2 PR	3	2	29.7"	55.4"
2 PR	3	3	29.0"	54.4"
2 PR	3	4	29.8"	53.4"
2 PR	3	5	29.3"	52.8"
2 PR	5	1	32.7"	58.3"
2 PR	5	2	33.7"	58.7"
2 PR	5	3	33.5"	57.5"
2 PR	5	4	34.6"	57.6"
2 PR	5	5	34.4"	56.3"
2 PR	6	1	34.3"	59.8"
2 PR	6	2	35.2"	59.4"
2 PR	6	3	34.9"	58.5"
2 PR	6	4	36.0"	58.3"
2 PR	6	5	35.9"	57.2"
2 PR	7	1	35.1"	42'02.3"
2 PR	7	2	36.0"	2.1"
2 PR	7	3	35.9"	0.8"
2 PR	7	4	37.1"	1.2"
2 PR	7	5	36.9"	41'59.7"
3 CR	1	1	1'34.6"	11'03.7"
3 CR	1	2	35.0"	1.5"
3 CR	1	3	33.5"	2.3"
3 CR	1	4	33.9"	1.0"
3 CR	1	5	32.5"	1.9"
3 CR	2	1	33.0"	7.0"
3 CR	2	2	33.3"	4.7"
3 CR	2	3	31.8"	5.4"
3 CR	2	4	32.1"	3.5"
3 CR	2	5	31.0"	4.3"
3 CR	3	1	30.9"	7.2"
3 CR	3	2	30.6"	6.8"
3 CR	3	3	30.1"	6.3"
3 CR	3	4	30.0"	5.4"
3 CR	3	5	29.4"	5.6"
3 CR	4	1	30.2"	8.4"
3 CR	4	2	30.1"	7.4"
3 CR	4	3	29.1"	8.1"
3 CR	4	4	29.1"	6.8"
3 CR	4	5	28.6"	7.5"
3 CR	5	1	29.4"	9.9"

3 CR	5	2	28.9"	9.1"
3 CR	5	3	28.4"	9.5"
3 CR	5	4	28.2"	8.8"
3 CR	5	5	27.6"	9.7"
3 CR	6	1	27.6"	11.8"
3 CR	6	2	27.9"	10.9"
3 CR	6	3	28.2"	11.8"
3 CR	6	4	28.9"	10.8"
3 CR	6	5	29.0"	11.3"

APPENDIX B

Data Tables for:

CHAPTER III. DEEP RIPPING, FERTILIZATION, TREE SPECIES AND SITE EFFESCTS ON REHABILITATION OF UNUSED RECLAIMED MINED LANDS FOR FORESTRY

Table B.1. Fall 2007 data summary following 4 years of growth and mortality; treatments (Treat) are 1: weed control, 2: weed control with subsoil ripping and 3: weed control with subsoil ripping and fertilization; Survival (Surv) is number of trees living divided by number originally planted; Biomass Index (BI) is in cm^3 calculated as (ground-line diameter)^2 x height.

Species	State	Treat	Block	Living	Planted	Surv	BI $Tree^{-1}$	BI Ha^{-1}
EWP	OH	1	1	22	45	0.49	121.7	66935
EWP	OH	1	2	26	51	0.51	182.9	118880
EWP	OH	1	3	0	43	0	0	0
EWP	OH	2	1	16	51	0.31	36.3	14517.5
EWP	OH	2	2	2	52	0.04	26.1	1302.5
EWP	OH	2	3	7	58	0.12	26.2	4577.5
EWP	OH	3	1	12	48	0.25	9.3	2785
EWP	OH	3	2	9	49	0.18	12.7	2855
EWP	OH	3	3	6	50	0.12	20.1	3012.5
EWP	VA	1	1	35	54	0.65	333.3	291650
EWP	VA	1	2	17	49	0.35	358.5	152370
EWP	VA	1	3	30	61	0.49	92.6	69427.5
EWP	VA	2	1	49	54	0.91	790	967742.5
EWP	VA	2	2	25	47	0.53	177.7	111045
EWP	VA	2	3	46	53	0.87	267.8	307922.5
EWP	VA	3	1	43	54	0.8	420.7	452202.5
EWP	VA	3	2	7	60	0.12	167.8	29360
EWP	VA	3	3	33	53	0.62	325.1	268202.5
EWP	WV	1	1	22	47	0.47	185.7	102120
EWP	WV	1	2	9	50	0.18	315.7	71032.5
EWP	WV	1	3	14	49	0.29	198	69307.5
EWP	WV	2	1	36	58	0.62	683.2	614852.5
EWP	WV	2	2	26	47	0.55	348.3	226367.5
EWP	WV	2	3	32	49	0.65	781.9	625507.5
EWP	WV	3	1	20	50	0.4	360.3	180157.5
EWP	WV	3	2	9	49	0.18	103.6	23300
EWP	WV	3	3	41	61	0.67	611.2	626445
HP	OH	1	1	32	55	0.58	1648.6	1318875
HP	OH	1	2	31	49	0.63	1556.7	1206443
HP	OH	1	3	11	48	0.23	64.7	17790

HP	OH	2	1	33	48	0.69	9899.1	8166765
HP	OH	2	2	36	45	0.8	1706.5	1535810
HP	OH	2	3	7	44	0.16	998.3	174700
HP	OH	3	1	18	47	0.38	13074.7	5883608
HP	OH	3	2	17	46	0.37	7784	3308200
HP	OH	3	3	1	57	0.02	1541.8	38545
HP	VA	1	1	39	50	0.78	6219.3	6063790
HP	VA	1	2	37	57	0.65	3347.7	3096628
HP	VA	1	3	40	43	0.93	5924.6	5924560
HP	VA	2	1	46	58	0.79	4679.1	5380973
HP	VA	2	2	52	66	0.79	10160.9	13209233
HP	VA	2	3	43	49	0.88	20580.7	22124220
HP	VA	3	1	41	59	0.69	11539.9	11828413
HP	VA	3	2	55	60	0.92	12893.6	17728683
HP	VA	3	3	47	51	0.92	8309.2	9763270
HP	WV	1	1	13	42	0.31	540.7	175717.5
HP	WV	1	2	10	49	0.2	4180.7	1045170
HP	WV	1	3	7	47	0.15	12.1	2110
HP	WV	2	1	40	51	0.78	34145.9	34145933
HP	WV	2	2	29	59	0.49	32276.6	23400565
HP	WV	2	3	32	53	0.6	15056.2	12044985
HP	WV	3	1	30	56	0.54	26695	20021223
HP	WV	3	2	24	57	0.42	31268.4	18761043
HP	WV	3	3	9	50	0.18	4549.8	1023705
MH	OH	1	1	32	44	0.73	57.6	46115
MH	OH	1	2	22	51	0.43	41.2	22650
MH	OH	1	3	13	44	0.3	2.9	937.5
MH	OH	2	1	40	48	0.83	97.8	97777.5
MH	OH	2	2	31	53	0.58	11.5	8877.5
MH	OH	2	3	35	52	0.67	66.8	58442.5
MH	OH	3	1	27	48	0.56	18.2	12312.5
MH	OH	3	2	16	54	0.3	27.4	10967.5
MH	OH	3	3	32	54	0.59	19.3	15402.5
MH	VA	1	1	44	50	0.88	286.8	315520
MH	VA	1	2	7	65	0.11	56.2	9827.5
MH	VA	1	3	33	57	0.58	658.8	543515
MH	VA	2	1	43	50	0.86	180.4	193917.5
MH	VA	2	2	44	56	0.79	261.6	287750
MH	VA	2	3	42	51	0.82	111.6	117147.5
MH	VA	3	1	43	45	0.96	606.8	652270
MH	VA	3	2	29	50	0.58	323.2	234332.5
MH	VA	3	3	50	60	0.83	34.8	43437.5
MH	WV	1	1	20	48	0.42	28.9	14470

MH	WV	1	2	16	49	0.33	40.8	16327.5
MH	WV	1	3	15	46	0.33	24.4	9140
MH	WV	2	1	44	50	0.88	163.6	180007.5
MH	WV	2	2	29	52	0.56	47.2	34192.5
MH	WV	2	3	44	57	0.77	240.4	264477.5
MH	WV	3	1	36	47	0.77	137.9	124110
MH	WV	3	2	38	49	0.78	128.3	121895
MH	WV	3	3	43	52	0.83	38.2	41112.5

Table B.2. Fall 2008 data summary following 5 years of growth and mortality; treatments (Treat) are 1: weed control, 2: weed control with subsoil ripping and 3: weed control with subsoil ripping and fertilization; Survival (Surv) is number of trees living divided by number originally planted; Biomass Index (BI) is in cm^3 calculated as $(\text{ground-line diameter})^2$ x height, data highlighted in gray were imputed according to description in attached manuscript because of being destroyed by re-mining in 2008; data imputed for destroyed plots as described in manuscript is highlighted in gray.

Species	State	Treat	Block	Living	Planted	Surv	BI Tree^{-1}	BI Ha^{-1}
EWP	OH	1	1	20	45	0.44	368.7	218196.7
EWP	OH	1	2	20	51	0.4	458.7	246780.6
EWP	OH	1	3	0	43	0	0	0
EWP	OH	2	1	14	51	0.28	108.1	40710.5
EWP	OH	2	2	1	52	0.02	99.7	26827.4
EWP	OH	2	3	7	58	0.12	81.6	13170.2
EWP	OH	3	1	11	48	0.22	17.6	5207.8
EWP	OH	3	2	6	49	0.12	13.5	2178.9
EWP	OH	3	3	5	50	0.1	74.1	9966.5
EWP	VA	1	1	35	54	0.65	840.4	734719.7
EWP	VA	1	2	17	49	0.35	980.6	461617.5
EWP	VA	1	3	30	61	0.49	243.4	160412.8
EWP	VA	2	1	49	54	0.91	2274.4	2783752
EWP	VA	2	2	30	47	0.64	356.9	307219.5
EWP	VA	2	3	46	53	0.87	709.4	830104.4
EWP	VA	3	1	41	54	0.76	1437.8	1469719
EWP	VA	3	2	6	60	0.1	187.5	25218.8
EWP	VA	3	3	31	53	0.59	737.3	585084.4
EWP	WV	1	1	22	47	0.47	562.1	355331.5
EWP	WV	1	2	9	50	0.18	881	213290.1
EWP	WV	1	3	14	49	0.28	341.9	128759.5
EWP	WV	2	1	35	58	0.61	2804.3	2300788
EWP	WV	2	2	26	47	0.55	972.7	719554.8
EWP	WV	2	3	34	49	0.69	2389.4	2217483
EWP	WV	3	1	22	50	0.44	1083	640919.4
EWP	WV	3	2	7	49	0.14	140.6	26475
EWP	WV	3	3	43	61	0.71	2702.7	2580943
HP	OH	1	1	30	55	0.55	3019.8	2233897
HP	OH	1	2	30	49	0.61	2712.9	2225799
HP	OH	1	3	11	48	0.23	318.5	98528
HP	OH	2	1	33	48	0.69	19666.3	18251310
HP	OH	2	2	37	45	0.82	2321.6	2560493
HP	OH	2	3	6	44	0.13	1816.7	317650
HP	OH	3	1	18	47	0.38	22366	11431263

HP	OH	3	2	17	46	0.37	18242.9	9078579
HP	OH	3	3	1	57	0.02	261.2	7026.3
HP	VA	1	1	37	50	0.74	12111.7	12054775
HP	VA	1	2	35	57	0.61	4608	3780634
HP	VA	1	3	31	43	0.71	17475	16687751
HP	VA	2	1	46	58	0.79	8208.2	8721623
HP	VA	2	2	55	66	0.83	19044.2	21259993
HP	VA	2	3	44	49	0.9	48793.8	59064895
HP	VA	3	1	34	59	0.58	40274.3	31417981
HP	VA	3	2	44	60	0.73	27820	27315067
HP	VA	3	3	39	51	0.76	17567.3	17957294
HP	WV	1	1	10	42	0.24	1393.6	449854.1
HP	WV	1	2	8	49	0.16	11062.2	2380585
HP	WV	1	3	1	47	0.02	1.7	46
HP	WV	2	1	39	51	0.77	70120.7	72620503
HP	WV	2	2	28	59	0.47	46669.6	29502188
HP	WV	2	3	34	53	0.65	28623.7	25024270
HP	WV	3	1	31	56	0.55	61298.3	45345417
HP	WV	3	2	22	57	0.39	41190.1	21606267
HP	WV	3	3	9	50	0.17	6043.3	1381801
MH	OH	1	1	28	44	0.64	160.6	138244.5
MH	OH	1	2	22	51	0.43	50.9	29438
MH	OH	1	3	16	44	0.36	3	1452.6
MH	OH	2	1	40	48	0.83	153	170801.6
MH	OH	2	2	31	53	0.58	11.9	9283.2
MH	OH	2	3	38	52	0.73	91.6	89937.5
MH	OH	3	1	26	48	0.54	30.1	21861.6
MH	OH	3	2	18	54	0.33	25.3	11229.4
MH	OH	3	3	29	54	0.54	76.4	55489.3
MH	VA	1	1	48	50	0.96	398.5	514543.2
MH	VA	1	2	10	65	0.15	82.7	16684.7
MH	VA	1	3	39	57	0.68	484.9	443489.5
MH	VA	2	1	43	50	0.86	290.6	336137
MH	VA	2	2	48	56	0.86	434.3	502354.8
MH	VA	2	3	44	51	0.86	182.6	211213.4
MH	VA	3	1	45	45	1	945	1271025
MH	VA	3	2	30	50	0.6	575.7	464589.9
MH	VA	3	3	50	60	0.83	579.9	647371.4
MH	WV	1	1	17	48	0.36	193.1	93499
MH	WV	1	2	7	49	0.14	42.3	7965.1
MH	WV	1	3	7	46	0.16	35.3	7596.6
MH	WV	2	1	42	50	0.83	102.5	114425.9
MH	WV	2	2	19	52	0.37	69.7	34686.2

MH	WV	2	3	29	57	0.51	490.6	336527.1
MH	WV	3	1	36	47	0.76	155.3	158747.7
MH	WV	3	2	37	49	0.75	145.8	147075.8
MH	WV	3	3	38	52	0.73	57.1	56063.6

Table B.3. Fall 2008 data summary of mixed hardwood planting treatments with results by individual species following 5 years of growth and mortality; treatments (Treat) are 1: weed control, 2: weed control with subsoil ripping and 3: weed control with subsoil ripping and fertilization; Survival (Surv) is number of trees living divided by number originally planted; Biomass Index (BI) is in cm^3 calculated as (ground-line diameter)^2 x height; tree species are: bh: bitternut hickory, bo: black oak, co: chestnut oak, dw: flowering dogwood, haw: Washington hawthorn, rb: redbud, rm: red maple, ro: northern red oak, sm: sugar maple, so: scarlet oak, tp: tulip-poplar, wa: white ash, wo: white oak; data highlighted in gray were imputed according to description in attached manuscript because of being destroyed by re-mining in 2008.

St.	**Bl.**	**Plt**	**Treat**	**Species**	**Planted**	**Living**	**Ht mm**	**Gld mm**	**Surv**	**BI Tree^{-1}**
OH	1	9	1	bh	1	0	.	.	0.00	.
OH	1	9	1	bo	2	2	210	5	1.00	5
OH	1	9	1	co	9	9	656	12	1.00	94
OH	1	9	1	dw	.	.	.	.	.	.
OH	1	9	1	haw	4	3	877	10	0.75	88
OH	1	9	1	rb	1	0	.	.	0.00	.
OH	1	9	1	rm	.	.	.	.	.	.
OH	1	9	1	ro	22	13	354	8	0.59	23
OH	1	9	1	sm	3	0	.	.	0.00	.
OH	1	9	1	so	.	.	.	.	.	.
OH	1	9	1	tp	2	2	1120	31	1.00	1076
OH	1	9	1	wa	.	.	.	.	.	.
OH	1	9	1	wo	.	.	.	.	.	.
OH	1	6	2	bh	3	2	195	5	0.67	5
OH	1	6	2	bo	4	3	220	6	0.75	8
OH	1	6	2	co	7	6	328	10	0.86	33
OH	1	6	2	dw	4	2	580	8	0.50	37
OH	1	6	2	haw	5	5	560	11	1.00	68
OH	1	6	2	rb	2	2	495	14	1.00	97
OH	1	6	2	rm	.	.	.	.	.	.
OH	1	6	2	ro	13	12	221	6	0.92	8
OH	1	6	2	sm	.	.	.	.	.	.
OH	1	6	2	so	2	1	130	5	0.50	3
OH	1	6	2	tp	8	7	809	25	0.88	506
OH	1	6	2	wa	.	.	.	.	.	.
OH	1	6	2	wo	.	.	.	.	.	.
OH	1	2	3	bh	.	.	.	.	.	.
OH	1	2	3	bo	3	1	470	11	0.33	57
OH	1	2	3	co	1	1	520	9	1.00	42
OH	1	2	3	dw	.	.	.	.	.	.
OH	1	2	3	haw	.	.	.	.	.	.
OH	1	2	3	rb	.	.	.	.	.	.
OH	1	2	3	rm	.	.	.	.	.	.
OH	1	2	3	ro	37	21	310	6	0.57	11
OH	1	2	3	sm	4	2	170	7	0.50	8

OH	1	2	3	so	2	1	800	20	0.50	320
OH	1	2	3	tp	1	0	.	.	0.00	.
OH	1	2	3	wa	.	.	.	.	.	.
OH	1	2	3	wo	.	.	.	.	.	.
OH	2	2	1	bh	1	0	.	.	0.00	.
OH	2	2	1	bo	3	3	230	6	1.00	8
OH	2	2	1	co	1	1	540	13	1.00	91
OH	2	2	1	dw	.	.	.	.	.	.
OH	2	2	1	haw	5	5	648	15	1.00	146
OH	2	2	1	rb	1	1	740	8	1.00	47
OH	2	2	1	rm	.	.	.	.	.	.
OH	2	2	1	ro	34	10	300	7	0.29	15
OH	2	2	1	sm	2	1	170	2	0.50	1
OH	2	2	1	so	1	1	110	2	1.00	0
OH	2	2	1	tp	3	0	.	.	0.00	.
OH	2	2	1	wa	.	.	.	.	.	.
OH	2	2	1	wo	.	.	.	.	.	.
OH	2	8	2	bh	.	.	.	.	.	.
OH	2	8	2	bo	.	.	.	.	.	.
OH	2	8	2	co	1	0	.	.	0.00	.
OH	2	8	2	dw	.	.	.	.	.	.
OH	2	8	2	haw	1	1	260	8	1.00	17
OH	2	8	2	rb	.	.	.	.	.	.
OH	2	8	2	rm	.	.	.	.	.	.
OH	2	8	2	ro	50	28	274	5	0.56	7
OH	2	8	2	sm	1	1	120	1	1.00	0
OH	2	8	2	so	.	.	.	.	.	.
OH	2	8	2	tp	.	.	.	.	.	.
OH	2	8	2	wa	.	.	.	.	.	.
OH	2	8	2	wo	.	.	.	.	.	.
OH	2	3	3	bh	1	1	160	5	1.00	4
OH	2	3	3	bo	1	0	.	.	0.00	.
OH	2	3	3	co	.	.	.	.	.	.
OH	2	3	3	dw	.	.	.	.	.	.
OH	2	3	3	haw	.	.	.	.	.	.
OH	2	3	3	rb	.	.	.	.	.	.
OH	2	3	3	rm	.	.	.	.	.	.
OH	2	3	3	ro	52	17	317	8	0.33	20
OH	2	3	3	sm	.	.	.	.	.	.
OH	2	3	3	so	.	.	.	.	.	.
OH	2	3	3	tp	.	.	.	.	.	.
OH	2	3	3	wa	.	.	.	.	.	.
OH	2	3	3	wo	.	.	.	.	.	.
OH	3	2	1	bh	2	1	160	2	0.50	1
OH	3	2	1	bo	.	.	.	.	.	.
OH	3	2	1	co	2	2	205	4	1.00	3

OH	3	2	1	dw	.	.	.	.	.	.
OH	3	2	1	haw	1	1	430	4	1.00	7
OH	3	2	1	rb	1	0	.	.	0.00	.
OH	3	2	1	rm	.	.	.	.	.	.
OH	3	2	1	ro	37	12	160	3	0.32	1
OH	3	2	1	sm	1	0	.	.	0.00	.
OH	3	2	1	so	.	.	.	.	.	.
OH	3	2	1	tp	.	.	.	.	.	.
OH	3	2	1	wa	.	.	.	.	.	.
OH	3	2	1	wo	.	.	.	.	.	.
OH	3	9	2	bh	8	7	330	6	0.88	12
OH	3	9	2	bo	3	1	80	2	0.33	0
OH	3	9	2	co	3	2	485	12	0.67	70
OH	3	9	2	dw	1	1	650	8	1.00	42
OH	3	9	2	haw	1	0	.	.	0.00	.
OH	3	9	2	rb	5	4	1025	17	0.80	296
OH	3	9	2	rm	.	.	.	.	.	.
OH	3	9	2	ro	29	21	474	10	0.72	47
OH	3	9	2	sm	1	1	410	7	1.00	20
OH	3	9	2	so	1	0	.	.	0.00	.
OH	3	9	2	tp	.	.	.	.	.	.
OH	3	9	2	wa	.	.	.	.	.	.
OH	3	9	2	wo	.	.	.	.	.	.
OH	3	7	3	bh	.	.	.	.	.	.
OH	3	7	3	bo	2	1	120	4	0.50	2
OH	3	7	3	co	2	1	650	9	0.50	53
OH	3	7	3	dw	.	.	.	.	.	.
OH	3	7	3	haw	.	.	.	.	.	.
OH	3	7	3	rb	.	.	.	.	.	.
OH	3	7	3	rm	.	.	.	.	.	.
OH	3	7	3	ro	50	25	331	10	0.50	33
OH	3	7	3	sm	.	.	.	.	.	.
OH	3	7	3	so	.	.	.	.	.	.
OH	3	7	3	tp	.	.	.	.	.	.
OH	3	7	3	wa	.	.	.	.	.	.
OH	3	7	3	wo	.	.	.	.	.	.
VA	1	2	1	bh	6	6	201	6	1.00	7
VA	1	2	1	bo	.	.	.	.	.	.
VA	1	2	1	co	.	.	.	.	.	.
VA	1	2	1	dw	1	1	355	12	1.00	51
VA	1	2	1	haw	11	11	1080	25	1.00	675
VA	1	2	1	rb	.	.	.	.	.	.
VA	1	2	1	rm	.	.	.	.	.	.
VA	1	2	1	ro	10	6	602	12	0.60	87
VA	1	2	1	sm	3	3	365	10	1.00	37
VA	1	2	1	so	.	.	.	.	.	.

VA	1	2	1	tp	2	2	1434	37	1.00	1963
VA	1	2	1	wa	4	4	963	24	1.00	555
VA	1	2	1	wo	13	13	360	12	1.00	52
VA	1	6	2	bh	4	4	202	9	1.00	16
VA	1	6	2	bo	.	.	.	.	.	.
VA	1	6	2	co	.	.	.	.	.	.
VA	1	6	2	dw	5	5	543	12	1.00	78
VA	1	6	2	haw	7	7	829	22	1.00	401
VA	1	6	2	rb	.	.	.	.	.	.
VA	1	6	2	rm	.	.	.	.	.	.
VA	1	6	2	ro	13	8	644	16	0.62	165
VA	1	6	2	sm	2	2	724	12	1.00	104
VA	1	6	2	so	.	.	.	.	.	.
VA	1	6	2	tp	5	4	936	23	0.80	495
VA	1	6	2	wa	4	3	1174	30	0.75	1057
VA	1	6	2	wo	10	9	521	16	0.90	133
VA	1	8	3	bh	4	4	914	21	1.00	403
VA	1	8	3	bo	.	.	.	.	.	.
VA	1	8	3	co	.	.	.	.	.	.
VA	1	8	3	dw	4	4	585	13	1.00	99
VA	1	8	3	haw	4	4	1185	27	1.00	864
VA	1	8	3	rb	.	.	.	.	.	.
VA	1	8	3	rm	.	.	.	.	.	.
VA	1	8	3	ro	8	8	746	21	1.00	329
VA	1	8	3	sm	6	5	836	17	0.83	242
VA	1	8	3	so	.	.	.	.	.	.
VA	1	8	3	tp	3	3	758	26	1.00	512
VA	1	8	3	wa	11	11	1435	35	1.00	1758
VA	1	8	3	wo	5	6	787	24	1.20	453
VA	2	8	1	bh	.	.	.	.	.	.
VA	2	8	1	bo	.	.	.	.	.	.
VA	2	8	1	co	.	.	.	.	.	.
VA	2	8	1	dw	.	.	.	.	.	.
VA	2	8	1	haw	3	2	548	14	0.67	107
VA	2	8	1	rb	2	2	130	8	1.00	8
VA	2	8	1	rm	.	.	.	.	.	.
VA	2	8	1	ro	49	1	113	3	0.02	1
VA	2	8	1	sm	2	0	.	.	0.00	.
VA	2	8	1	so	.	.	.	.	.	.
VA	2	8	1	tp	2	0	.	.	0.00	.
VA	2	8	1	wa	4	3	421	14	0.75	83
VA	2	8	1	wo	3	1	356	11	0.33	43
VA	2	1	2	bh	4	2	331	6	0.50	12
VA	2	1	2	bo	.	.	.	.	.	.
VA	2	1	2	co	.	.	.	.	.	.
VA	2	1	2	dw	3	3	412	12	1.00	59

VA	2	1	2	haw	3	3	1330	31	1.00	1278
VA	2	1	2	rb	3	3	669	20	1.00	268
VA	2	1	2	rm	.	.	.	.	.	.
VA	2	1	2	ro	18	9	442	12	0.50	64
VA	2	1	2	sm	9	8	347	9	0.89	28
VA	2	1	2	so	.	.	.	.	.	.
VA	2	1	2	tp	4	4	877	23	1.00	464
VA	2	1	2	wa	6	6	1026	28	1.00	804
VA	2	1	2	wo	6	6	392	14	1.00	77
VA	2	4	3	bh	3	1	221	6	0.33	8
VA	2	4	3	bo	1	1	584	14	1.00	114
VA	2	4	3	co	.	.	.	.	.	.
VA	2	4	3	dw	1	1	584	14	1.00	114
VA	2	4	3	haw	2	2	1128	35	1.00	1382
VA	2	4	3	rb	4	4	1092	35	1.00	1338
VA	2	4	3	rm	.	.	.	.	.	.
VA	2	4	3	ro	28	10	353	9	0.36	29
VA	2	4	3	sm	2	2	291	8	1.00	19
VA	2	4	3	so	.	.	.	.	.	.
VA	2	4	3	tp	2	1	732	17	0.50	212
VA	2	4	3	wa	5	6	949	27	1.20	692
VA	2	4	3	wo	3	3	509	17	1.00	147
VA	3	4	1	bh	2	0	.	.	0.00	.
VA	3	4	1	bo	.	.	.	.	.	.
VA	3	4	1	co	.	.	.	.	.	.
VA	3	4	1	dw	.	.	.	.	.	.
VA	3	4	1	haw	3	2	410	10	0.67	41
VA	3	4	1	rb	3	2	290	10	0.67	29
VA	3	4	1	rm	.	.	.	.	.	.
VA	3	4	1	ro	21	4	170	5	0.19	4
VA	3	4	1	sm	5	2	180	6	0.40	6
VA	3	4	1	so	.	.	.	.	.	.
VA	3	4	1	tp	6	6	983	23	1.00	520
VA	3	4	1	wa	11	9	661	17	0.82	191
VA	3	4	1	wo	6	4	133	5	0.67	3
VA	3	2	2	bh	2	1	50	2	0.50	0
VA	3	2	2	bo	.	.	.	.	.	.
VA	3	2	2	co	.	.	.	.	.	.
VA	3	2	2	dw	3	3	780	14	1.00	153
VA	3	2	2	haw	3	3	820	17	1.00	237
VA	3	2	2	rb	.	.	.	.	.	.
VA	3	2	2	rm	.	.	.	.	.	.
VA	3	2	2	ro	15	8	490	12	0.53	71
VA	3	2	2	sm	7	7	990	34	1.00	1144
VA	3	2	2	so	.	.	.	.	.	.
VA	3	2	2	tp	9	8	720	14	0.89	141

VA	3	2	2	wa	4	4	840	24	1.00	484
VA	3	2	2	wo	8	7	370	13	0.88	63
VA	3	7	3	bh	3	1	440	10	0.33	44
VA	3	7	3	bo	.	.	.	.	.	.
VA	3	7	3	co	.	.	.	.	.	.
VA	3	7	3	dw	1	1	475	10	1.00	48
VA	3	7	3	haw	5	5	1278	26	1.00	864
VA	3	7	3	rb	1	0	.	.	0.00	.
VA	3	7	3	rm	.	.	.	.	.	.
VA	3	7	3	ro	23	18	517	15	0.78	116
VA	3	7	3	sm	6	6	718	14	1.00	141
VA	3	7	3	so	.	.	.	.	.	.
VA	3	7	3	tp	6	6	1030	29	1.00	866
VA	3	7	3	wa	4	4	1463	39	1.00	2225
VA	3	7	3	wo	11	9	620	14	0.82	122
WV	1	3	1	bh	1	1	42	60	1.00	151
WV	1	3	1	bo	.	.	.	.	.	.
WV	1	3	1	co	.	.	.	.	.	.
WV	1	3	1	dw	.	.	.	.	.	.
WV	1	3	1	haw	.	.	.	.	.	.
WV	1	3	1	rb	1	1	42	60	1.00	151
WV	1	3	1	rm	2	1	15	1	0.50	0
WV	1	3	1	ro	27	5	84	5	0.19	2
WV	1	3	1	sm	8	2	210	46	0.25	444
WV	1	3	1	so	.	.	.	.	.	.
WV	1	3	1	tp	.	.	.	.	.	.
WV	1	3	1	wa	10	8	320	13	0.80	54
WV	1	3	1	wo	.	.	.	.	.	.
WV	1	7	2	bh	.	.	.	.	.	.
WV	1	7	2	bo	.	.	.	.	.	.
WV	1	7	2	co	.	.	.	.	.	.
WV	1	7	2	dw	3	3	403	7	1.00	20
WV	1	7	2	haw	5	4	928	7	0.80	45
WV	1	7	2	rb	4	3	119	14	0.75	23
WV	1	7	2	rm	7	6	660	12	0.86	95
WV	1	7	2	ro	10	7	423	7	0.70	21
WV	1	7	2	sm	4	4	460	7	1.00	23
WV	1	7	2	so	.	.	.	.	.	.
WV	1	7	2	tp	9	8	750	6	0.89	27
WV	1	7	2	wa	8	8	975	10	1.00	98
WV	1	7	2	wo	.	.	.	.	.	.
WV	1	2	3	bh	.	.	.	.	.	.
WV	1	2	3	bo	.	.	.	.	.	.
WV	1	2	3	co	.	.	.	.	.	.
WV	1	2	3	dw	1	1	190	17	1.00	55
WV	1	2	3	haw	2	2	465	18	1.00	151

WV	1	2	3	rb	.	.	.	.	.	.
WV	1	2	3	rm	11	10	352	12	0.91	51
WV	1	2	3	ro	27	15	261	10	0.56	26
WV	1	2	3	sm	.	.	.	.	.	.
WV	1	2	3	so	.	.	.	.	.	.
WV	1	2	3	tp	.	.	.	.	.	.
WV	1	2	3	wa	6	7	779	24	1.17	449
WV	1	2	3	wo	6	7	779	24	1.17	449
WV	2	7	1	bh	6	2	535	13	0.33	90
WV	2	7	1	bo	.	.	.	.	.	.
WV	2	7	1	co	.	.	.	.	.	.
WV	2	7	1	dw	.	.	.	.	.	.
WV	2	7	1	haw	6	2	535	13	0.33	90
WV	2	7	1	rb	.	.	.	.	.	.
WV	2	7	1	rm	9	0	.	.	0.00	.
WV	2	7	1	ro	26	4	153	5	0.15	4
WV	2	7	1	sm	2	0	.	.	0.00	.
WV	2	7	1	so	.	.	.	.	.	.
WV	2	7	1	tp	2	0	.	.	0.00	.
WV	2	7	1	wa	4	1	470	13	0.25	79
WV	2	7	1	wo	.	.	.	.	.	.
WV	2	3	2	bh	.	.	.	.	.	.
WV	2	3	2	bo	.	.	.	.	.	.
WV	2	3	2	co	.	.	.	.	.	.
WV	2	3	2	dw	3	0	.	.	0.00	.
WV	2	3	2	haw	.	.	.	.	.	.
WV	2	3	2	rb	1	0	.	.	0.00	.
WV	2	3	2	rm	8	3	220	3	0.38	2
WV	2	3	2	ro	21	8	390	8	0.38	25
WV	2	3	2	sm	5	1	220	3	0.20	2
WV	2	3	2	so	.	.	.	.	.	.
WV	2	3	2	tp	8	2	425	9	0.25	34
WV	2	3	2	wa	6	5	594	14	0.83	116
WV	2	3	2	wo	.	.	.	.	.	.
WV	2	5	3	bh	.	.	.	.	.	.
WV	2	5	3	bo	.	.	.	.	.	.
WV	2	5	3	co	.	.	.	.	.	.
WV	2	5	3	dw	.	.	.	.	.	.
WV	2	5	3	haw	.	.	.	.	.	.
WV	2	5	3	rb	3	2	1085	15	0.67	244
WV	2	5	3	rm	11	11	315	7	1.00	15
WV	2	5	3	ro	25	15	484	12	0.60	70
WV	2	5	3	sm	3	3	393	13	1.00	66
WV	2	5	3	so	.	.	.	.	.	.
WV	2	5	3	tp	2	1	640	15	0.50	144
WV	2	5	3	wa	5	4	803	24	0.80	463

WV	2	5	3	wo	.	.	.	.	.	.
WV	3	2	1	bh	.	.	.	.	.	.
WV	3	2	1	bo	.	.	.	.	.	.
WV	3	2	1	co	.	.	.	.	.	.
WV	3	2	1	dw	.	.	.	.	.	.
WV	3	2	1	haw	1	1	620	13	1.00	105
WV	3	2	1	rb	2	2	130	2	1.00	1
WV	3	2	1	rm	5	0	.	.	0.00	.
WV	3	2	1	ro	25	1	360	12	0.04	52
WV	3	2	1	sm	4	0	.	.	0.00	.
WV	3	2	1	so	.	.	.	.	.	.
WV	3	2	1	tp	3	1	220	5	0.33	6
WV	3	2	1	wa	6	2	280	9	0.33	23
WV	3	2	1	wo	.	.	.	.	.	.
WV	3	7	2	bh	.	.	.	.	.	.
WV	3	7	2	bo	.	.	.	.	.	.
WV	3	7	2	co	.	.	.	.	.	.
WV	3	7	2	dw	3	2	250	4	0.67	4
WV	3	7	2	haw	.	.	.	.	.	.
WV	3	7	2	rb	3	2	355	5	0.67	9
WV	3	7	2	rm	12	7	301	6	0.58	11
WV	3	7	2	ro	20	11	201	6	0.55	7
WV	3	7	2	sm	5	3	163	4	0.60	3
WV	3	7	2	so	.	.	.	.	.	.
WV	3	7	2	tp	11	2	455	8	0.18	29
WV	3	7	2	wa	2	1	260	5	0.50	7
WV	3	7	2	wo	.	.	.	.	.	.
WV	3	4	3	bh	1	1	590	19	1.00	213
WV	3	4	3	bo	1	1	370	6	1.00	13
WV	3	4	3	co	.	.	.	.	.	.
WV	3	4	3	dw	.	.	.	.	.	.
WV	3	4	3	haw	1	1	590	19	1.00	213
WV	3	4	3	rb	1	1	370	6	1.00	13
WV	3	4	3	rm	3	3	270	4	1.00	4
WV	3	4	3	ro	33	21	340	8	0.64	22
WV	3	4	3	sm	3	3	323	3	1.00	3
WV	3	4	3	so	.	.	.	.	.	.
WV	3	4	3	tp	.	.	.	.	.	.
WV	3	4	3	wa	11	9	534	12	0.82	77
WV	3	4	3	wo	.	.	.	.	.	.

APPENDIX C

Data Tables for:

CHAPTER IV. RESTORING AMERICAN CHESTNUT ON MINED LANDS UNDER THE FORESTRY RECLAMATION APPROACH

Table C.1. Plot summaries of cumulative chestnut survival and height by groundcover type and breeding generation for the 2008 groundcover trial experiment.

Block	Plot Groundcover Type	Generation	Dead	Alive	Total	Survival	Ht (mm)
1	Conventional 2	Chinese	1	10	11	0.91	408
1	Conventional 2	B1F3	3	12	15	0.80	343
1	Conventional 2	B2F3	12	3	15	0.20	304
1	Conventional 2	B3F2	6	5	11	0.45	282
1	Conventional 2	American	5	1	6	0.17	80
1	Conventional 2	American	2	5	7	0.71	204
1	Conventional 2	Unknown	2	9	11	0.82	287
1	Annual Rye 1	Chinese	0	9	9	1.00	371
1	Annual Rye 1	B1F4	0	5	5	1.00	336
1	Annual Rye 1	B2F4	2	4	6	0.67	250
1	Annual Rye 1	B3F3	0	6	6	1.00	268
1	Annual Rye 1	American	1	3	4	0.75	185
1	Annual Rye 1	American	1	2	3	0.67	253
1	Annual Rye 1	Unknown	11	18	29	0.62	360
1	Tree Compatible 3	Chinese	2	8	10	0.80	446
1	Tree Compatible 3	B1F4	3	8	11	0.73	412
1	Tree Compatible 3	B2F4	6	4	10	0.40	241
1	Tree Compatible 3	B3F3	4	8	12	0.67	346
1	Tree Compatible 3	American	3	4	7	0.57	344
1	Tree Compatible 3	American	1	3	4	0.75	276
1	Tree Compatible 3	Unknown	6	13	19	0.68	445
2	Conventional 2	Chinese	5	18	23	0.78	291
2	Conventional 2	B1F4	5	12	17	0.71	239
2	Conventional 2	B2F4	8	8	16	0.50	204
2	Conventional 2	B3F3	7	10	17	0.59	205
2	Conventional 2	American	2	8	10	0.80	177
2	Conventional 2	American	1	6	7	0.86	179
2	Conventional 2	Unknown	1	0	1	0.00	0
2	Annual Rye 1	Chinese	0	8	8	1.00	311
2	Annual Rye 1	B1F4	1	11	12	0.92	338
2	Annual Rye 1	B2F4	3	8	11	0.73	275
2	Annual Rye 1	B3F3	2	8	10	0.80	215
2	Annual Rye 1	American	1	4	5	0.80	279
2	Annual Rye 1	American	0	4	4	1.00	294

2	Annual Rye 1	Unknown	1	0	1	0.00	0
2	Tree Compatible 3	Chinese	1	14	15	0.93	329
2	Tree Compatible 3	B1F4	3	10	13	0.77	375
2	Tree Compatible 3	B2F4	6	9	15	0.60	238
2	Tree Compatible 3	B3F3	0	14	14	1.00	260
2	Tree Compatible 3	American	0	6	6	1.00	204
2	Tree Compatible 3	American	1	6	7	0.86	292
2	Tree Compatible 3	Unknown	1	3	4	0.75	230
3	Conventional 3	Chinese	6	9	15	0.60	414
3	Conventional 3	B1F4	9	5	14	0.36	349
3	Conventional 3	B2F4	9	4	13	0.31	252
3	Conventional 3	B3F3	10	4	14	0.29	289
3	Conventional 3	American	4	3	7	0.43	294
3	Conventional 3	American	5	1	6	0.17	150
3	Annual Rye 2	Chinese	1	9	10	0.90	412
3	Annual Rye 2	B1F4	2	8	10	0.80	456
3	Annual Rye 2	B2F4	4	6	10	0.60	495
3	Annual Rye 2	B3F3	2	6	8	0.75	378
3	Annual Rye 2	American	2	3	5	0.60	364
3	Annual Rye 2	American	3	1	4	0.25	177
3	Annual Rye 2	Unknown	2	0	2	0.00	0
3	Tree Compatible 1	Chinese	8	12	20	0.60	371
3	Tree Compatible 1	B1F5	10	10	20	0.50	322
3	Tree Compatible 1	B2F5	14	6	20	0.30	198
3	Tree Compatible 1	B3F4	15	6	21	0.29	242
3	Tree Compatible 1	American	7	1	8	0.13	270
3	Tree Compatible 1	American	11	0	11	0.00	0
3	Tree Compatible 1	Unknown	4	1	5	0.20	352

Table C.2. Plot summaries of cumulative chestnut height and survival by planting method and breeding generation for the 2008 planting method experiment.

Block	Generation	Planting Method	Height (mm)	Survival
1	American	Direct Seeding	340	0.67
1	American	Bare Root Seedling	569	0.89
1	B1F3	Direct Seeding	223	0.78
1	B1F3	Bare Root Seedling	267	0.89
1	B2F3	Direct Seeding	261	0.44
1	B2F3	Bare Root Seedling	246	0.56
1	B3F2	Direct Seeding	198	0.67
1	B3F2	Bare Root Seedling	194	0.33
1	Chinese	Direct Seeding	586	0.78
1	Chinese	Bare Root Seedling	798	0.89
1	American	Direct Seeding	336	0.78
1	American	Bare Root Seedling	566	1.00
1	B1F3	Direct Seeding	266	0.67
1	B1F3	Bare Root Seedling	363	0.56
1	B2F3	Direct Seeding	375	0.78
1	B2F3	Bare Root Seedling	361	0.89
1	B3F2	Direct Seeding	367	0.67
1	B3F2	Bare Root Seedling	216	0.56
1	Chinese	Direct Seeding	592	0.78
1	Chinese	Bare Root Seedling	927	0.89
2	American	Direct Seeding	300	0.83
2	American	Bare Root Seedling	552	1.00
2	B1F3	Direct Seeding	226	0.50
2	B1F3	Bare Root Seedling	388	1.00
2	B2F3	Direct Seeding	248	0.50
2	B2F3	Bare Root Seedling	292	0.83
2	B3F2	Direct Seeding	205	0.50
2	B3F2	Bare Root Seedling	273	1.00
2	Chinese	Direct Seeding	504	0.83
2	Chinese	Bare Root Seedling	1174	1.00
2	American	Direct Seeding	267	0.67
2	American	Bare Root Seedling	649	1.00
2	B1F3	Direct Seeding	237	0.50
2	B1F3	Bare Root Seedling	333	1.00
2	B2F3	Direct Seeding	318	0.33
2	B2F3	Bare Root Seedling	293	0.83
2	B3F2	Direct Seeding	0	0.00
2	B3F2	Bare Root Seedling	241	0.67
2	Chinese	Direct Seeding	411	0.50
2	Chinese	Bare Root Seedling	723	1.00
2	American	Direct Seeding	335	0.33
2	American	Bare Root Seedling	479	1.00
2	B1F3	Direct Seeding	310	0.67

2	B1F3	Bare Root Seedling	362	1.00
2	B2F3	Direct Seeding	293	0.83
2	B2F3	Bare Root Seedling	272	0.67
2	B3F2	Direct Seeding	393	0.83
2	B3F2	Bare Root Seedling	189	0.83
2	Chinese	Direct Seeding	577	1.00
2	Chinese	Bare Root Seedling	1140	1.00
3	American	Direct Seeding	373	1.00
3	American	Bare Root Seedling	535	1.00
3	B1F3	Direct Seeding	263	1.00
3	B1F3	Bare Root Seedling	305	1.00
3	B2F3	Direct Seeding	391	1.00
3	B2F3	Bare Root Seedling	409	1.00
3	B3F2	Direct Seeding	388	1.00
3	B3F2	Bare Root Seedling	270	0.83
3	Chinese	Direct Seeding	579	0.83
3	Chinese	Bare Root Seedling	1016	1.00
3	American	Direct Seeding	366	1.00
3	American	Bare Root Seedling	494	1.00
3	B1F3	Direct Seeding	383	1.00
3	B1F3	Bare Root Seedling	340	1.00
3	B2F3	Direct Seeding	303	0.83
3	B2F3	Bare Root Seedling	238	0.83
3	B3F2	Direct Seeding	333	1.00
3	B3F2	Bare Root Seedling	262	0.86
3	Chinese	Direct Seeding	538	1.00
3	Chinese	Bare Root Seedling	751	0.83
3	American	Direct Seeding	311	1.00
3	American	Bare Root Seedling	549	1.00
3	B1F3	Direct Seeding	302	1.00
3	B1F3	Bare Root Seedling	384	0.83
3	B2F3	Direct Seeding	322	0.67
3	B2F3	Bare Root Seedling	226	0.67
3	B3F2	Direct Seeding	369	1.00
3	B3F2	Bare Root Seedling	291	0.83
3	Chinese	Direct Seeding	541	1.00
3	Chinese	Bare Root Seedling	1147	1.00
4	American	Direct Seeding	348	0.67
4	American	Bare Root Seedling	400	0.83
4	B1F3	Direct Seeding	265	0.83
4	B1F3	Bare Root Seedling	407	0.83
4	B2F3	Direct Seeding	229	1.00
4	B2F3	Bare Root Seedling	384	0.33
4	B3F2	Direct Seeding	341	1.00
4	B3F2	Bare Root Seedling	288	1.00
4	Chinese	Direct Seeding	580	1.00

4	Chinese	Bare Root Seedling	826	1.00
4	American	Direct Seeding	333	0.67
4	American	Bare Root Seedling	545	1.00
4	B1F3	Direct Seeding	298	1.00
4	B1F3	Bare Root Seedling	304	1.00
4	B2F3	Direct Seeding	246	0.67
4	B2F3	Bare Root Seedling	218	0.50
4	B3F2	Direct Seeding	329	0.83
4	B3F2	Bare Root Seedling	253	0.33
4	Chinese	Direct Seeding	492	0.83
4	Chinese	Bare Root Seedling	944	0.67
4	American	Direct Seeding	363	0.83
4	American	Bare Root Seedling	489	1.00
4	B1F3	Direct Seeding	353	0.83
4	B1F3	Bare Root Seedling	238	0.67
4	B2F3	Direct Seeding	148	0.17
4	B2F3	Bare Root Seedling	245	0.17
4	B3F2	Direct Seeding	328	0.67
4	B3F2	Bare Root Seedling	287	0.67
4	Chinese	Direct Seeding	516	0.83
4	Chinese	Bare Root Seedling	918	0.83

Table C.3. Soil characteristics for each block of the 2008 and 2009 Chestnut studies (Blocks as follows: 2008: 1 RR = Red River Coal Site, 2 PR = Powell River Site, 3 CR = Carrie Ridge Site; 2009: 1 OF = Over FRA B1 Site, 2 CF = Cliff Face Site, 3 BH = Brown Hill Site and 4 PR = Powell River Project Site).

	2008 Study			**2009 Study**			
Blocks:	**1 RR**	**2 PR**	**3 CR**	**1 OF**	**2 CF**	**3 BH**	**4PR**
Coarse Framents %	50	66	61	53	64	40	40
Brown Sandstone %	44	23	50	50	53	98	93
Gray Sandstone %	40	28	15	25	44	0	3
Siltstone %	15	43	35	20	1	0	3
Shale %	0	2	0	0	0	0	0
Coal %	1	4	0	5	3	1	1
Fine Fraction %	50	34	39	47	36	60	60
Sand %	51	43	55	36	45	55	39
Silt %	23	29	25	33	28	23	33
Clay %	25	28	20	31	27	22	29
Soil Texture	SCL	CL	SL	CL	L	SCL	CL
CNS Total Carbon %	1.4	2.9	0.5	2.1	2.3	0.6	3.8
CNS Total Nitrogen %	0.05	0.09	0.03	0.08	0.08	0.03	0.16
CNS C:N Ratio	28	33	16	26	29	19	22
Baseline Ammonium (KCl extract) ppm	2.67	1.32	1.47	1.14	1.12	0.87	5.00
Baseline Nitrate (KCl extract) ppm	4.40	2.58	1.13	0.00	0.10	0.00	1.46
Anaerobic 8-days Ammonium (KCl) ppm	7.41	3.08	1.62	2.49	4.41	1.25	112.97
ICP (NH4OAc) Al ppm	1.8	10.4	1.0	1.8	1.3	7.5	1.3
ICP (NH4OAc) Ca ppm	1103	1616	868	407	630	39	3142
ICP (NH4OAc) K ppm	298	301	280	79	69	60	105
ICP (NH4OAc) Mg ppm	278	306	219	206	195	34	194
ICP (NH4OAc) Na ppm	17.6	12.2	11.4	1.8	2.2	0.4	3.6
(NH4OAc) CEC $cmol_{q+}$ kg^{-1}	8.7	11.6	6.9	4.0	5.0	0.7	17.6
(NH4OAc) Base Saturation %	100%	99%	100%	99%	100%	89%	100%
ICP (NaHCO3) P ppm	6.9	4.0	8.6	4.5	10.0	3.4	6.4
ICP (Mehlich 1) P ppm	43	62	43	22	30	3	7
ICP (Mehlich 1) K ppm	62	66	48	60	59	51	60
ICP (Mehlich 1) Ca ppm	1039	1774	928	426	624	110	2720
ICP (Mehlich 1) Mg ppm	255	392	278	181	180	44	167
ICP (Mehlich 1) Zn ppm	3.1	4.3	1.9	4.4	3.7	1.1	1
ICP (Mehlich 1) Mn ppm	49	99	43	31	31	15	22
ICP (Mehlich 1) Cu ppm	2.2	3.2	1.8	4.8	3.1	1.4	0.7
ICP (Mehlich 1) Fe ppm	71	100	52	61	68	22	19
ICP (Mehlich 1) B ppm	0.1	0.1	0.1	0.1	0.1	0.1	0.2
(Mehlich 1) CEC $cmol_{q+}$ kg^{-1}	8.0	12.2	7.1	7.1	6.2	4.5	15.2
(Mehlich 1) Base Saturation %	93%	100%	100%	54%	75%	24%	98%

pH (1:1 Soil:Water)	5.72	7.44	6.89	4.85	5.62	4.90	7.30
Organic Matter % (LOI 360°C)	1.3	1.8	0.9	2.2	1.7	1.4	3.9
Soluble Salts ppm (1:2 Soil:Water)	572	316	60	84	120	38	128

Table C.4. Plot corner coordinates for the 2008 Chestnut Groundcover study, corner positions oriented by standing at the bottom of a plot looking upslope, assume degrees and minutes in rows in which they are not shown are the same as in the nearest row above which does present them, all corners are marked on the ground with rebar stakes covered with 3 ft tall white PVC pipe wrapped with yellow flagging.

Block	Plot Number	Corner Position	Latitude	Longitude
1 RR	1	Upper Right	N 37°00'19.9"	W 82°42'57.8"
1 RR	1	Upper Left	19.0"	58.9"
1 RR	1	Lower Left	16.8"	56.7"
1 RR	1	Lower Right	18.1"	56.0"
1 RR	2	Upper Right	21.0"	56.8"
1 RR	2	Lower Right	19.0"	55.3"
1 RR	3	Lower Right	20.0"	54.0"
1 RR	3	Upper Right	21.7"	55.5"
2 PR	3	Upper Right	30.4"	56.8"
2 PR	2	Upper Right	28.5"	57.0"
2 PR	2	Lower Right	27.7"	51.4"
2 PR	3	Lower Right	30.0"	52.1"
2 PR	1	Lower Right	25.9"	50.9"
2 PR	1	Upper Right	26.5"	57.2"
2 PR	1	Upper Left	24.7"	58.0"
2 PR	1	Lower Left	24.1"	51.4"
3 CR	3	Lower Left	1'29.1"	11'05.6"
3 CR	2	Lower Left	30.2"	4.5"
3 CR	1	Lower Left	32.0"	2.1"
3 CR	1	Lower Right	33.7"	10'59.4"
3 CR	1	Upper Right	35.9"	11'02.2"
3 CR	2	Upper Right	34.6"	5.3"
3 CR	3	Upper Right	32.8"	7.6"
3 CR	3	Upper Left	31.1"	7.7"

Table C.5. Plot corner coordinates for the 2009 Chestnut Planting Method study, corner positions oriented by standing at the bottom of a plot looking upslope or standing with your back to the coal haul road nearest to the block and facing the middle of the nearest long side of the block the case of Block 4 PR, assume degrees and minutes in rows in which they are not shown are the same as in the nearest row above which does present them, all corners are marked on the ground with rebar stakes covered with 3 ft tall white PVC pipe wrapped with yellow flagging.

Block	Plot Number	Corner Position	Latitude	Longitude
1 OF	1	Lower Left	N 37°00'28.8"	W 82°43'01.0"
1 OF	2	Lower Left	29.6"	0.6"
1 OF	2	Lower Right	30.0"	42'59.7"
1 OF	2	Upper Right	31.0"	43'00.6"
1 OF	2	Upper Left	30.4"	1.4"
1 OF	1	Upper Left	29.9"	2.2"
2 CF	1	Lower Left	N 36°59'38.7"	W 82°42'11.5"
2 CF	2	Lower Left	39.3"	10.8"
2 CF	3	Lower Left	39.8"	10.1"
2 CF	3	Lower Right	40.3"	9.4"
2 CF	3	Upper Right	40.9"	10.1"
2 CF	3	Upper Left	40.4"	11.0"
2 CF	2	Upper Left	40.0"	11.6"
2 CF	1	Upper Left	39.3"	12.3"
3 BH	3	Lower Right	37.0"	41'54.4"
3 BH	2	Lower Right	36.8"	53.5"
3 BH	1	Lower Right	36.6"	52.5"
3 BH	1	Lower Left	36.1"	51.8"
3 BH	1	Upper Left	35.4"	52.6"
3 BH	1	Upper Right	35.8"	53.1"
3 BH	2	Upper Right	36.0"	53.8"
3 BH	3	Upper Right	36.1"	54.6"
4 PR	1	Lower Left	N 37°00'44.4"	41'01.1"
4 PR	1	Lower Right	44.3"	2.2"
4 PR	2	Lower Right	44.0"	3.1"
4 PR	3	Lower Right	44.0"	3.9"
4 PR	3	Upper Right	43.0"	3.8"
4 PR	2	Upper Right	43.1"	2.9"
4 PR	1	Upper Right	43.2"	1.9"
4 PR	1	Upper Left	43.4"	1.0"