FIELD ASSESSMENT OF MINE SITE QUALITY FOR ESTABLISHING HARDWOODS IN THE APPALACHIANS[1]

J. A. Burger, D. O. Mitchem, and D. A. Scott[2]

Abstract. In the past five years there has been a major resurgence in the hardwood timber and wood-using industries throughout the Appalachian coalfield region. Major forest companies are investing heavily in the Appalachian hardwood resource, and they are interested in reforestation of mined land with commercially valuable hardwoods. However, post-SMCRA reclamation creates sites that are difficult to reforest due to inappropriate mine spoil chemistry, excessive compaction, and competing ground cover vegetation. A study was installed across the three-state region of Virginia, West Virginia, and Kentucky to test the survival and growth of commercially valuable hardwoods across factorial gradients of mine spoil chemistry, grading intensity, and slope aspect. A total of 10 treatment blocks, each 1 ha in size, were installed over a 3-year period beginning in 1994. Tree survival and growth were measured across the study each year. Green ash survival and growth was relatively unaffected by the site factor gradients, but white oak was influenced by all gradients. Survival and growth was poorest and unacceptable on sites with southwest aspects and soils made up of compacted, finely textured alkaline parent material. Survival and growth of white oak was best on sites with northeastern aspects and loose soils made up of weathered sandstone spoil materials. Site mapping of forest site quality for site-specific species prescriptions appears to be a promising approach for successful reforestation of native hardwoods on mined land.

Additional Key Words: reforestation, tree planting, site quality

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Introduction

There is a renewed interest in restoring native hardwoods on surface-mined land. Hardwood timber and wood-using industries have resurged throughout the Appalachian coalfield region due to new solid wood product developments and demand for bleached papers and oriented strand board. Reforestation of mined land is also receiving more attention because intense, localized flooding has been partially attributed to forest clearing for surface mining, and because stream water quality generally decreases with decreasing forest cover in a watershed. Furthermore, reforestation with native tree species is preferred wildlife habitat, and native tree establishment minimizes the need, use and spread of exotic, invasive woody and herbaceous plant species.

Prior to the implementation of the Surface Mining Control and Reclamation Act of 1977, most surface-mined land in the mid-western and eastern coalfields was planted with trees (Plass and Powell, 1988). Research has shown that the majority of these mined sites are growing productive forests (Rodrigue and Burger, 2002a) (Fig. 1), and that good reforestation success and forest productivity were a function of planting trees in loose, good quality mine spoils without competing ground cover vegetation (Ashby, 1987).

Federal and state laws now require mine operators to re-grade mined sites to their approximate original contour, and to plant erosion-control ground covers to minimize soil movement (SMCRA, 1977). Current reclamation is generally detrimental to reforestation because the intensive grading associated with site preparation compacts mine soils, and commonly-used erosion control ground covers overtop and smother the small, planted tree seedlings (Burger, 1999). Moreover, "topsoil substitutes" from some layer of the overburden are commonly used instead of native topsoil layers (Torbert et al., 1990). These substitutes are often too alkaline and devoid of the facilitative microbial organisms needed for proper tree establishment and growth.

Because native hardwoods have had little chance of surviving typical post-SMCRA reclamation environments, we concentrated our initial reforestation research efforts on pines. Compared to most hardwoods, pine seedlings are widely available, inexpensive, relatively hardy, and easy to plant across a broad spectrum of compaction, rock type, and other site factors (Torbert et al., 1995). However, given the renewed interest in reforesting mined sites with native hardwoods, we are trying to understand species-specific site limitations and reclamation requirements in order to prescribe reclamation procedures that will allow their use and successful establishment. Our early studies of mine soil effects on the growth of pines (Torbert et al., 1988; Andrews et al., 1998), and our more recent studies on mine soil quality effects on hardwoods (Rodrigue and Burger, 2002a; Rodrigue and Burger, 2002b), show that forest site quality is primarily a function of soil parent material, degree of mine soil compaction, and slope aspect.

Figure 1. Dr. Clark Ashby, Professor Emeritus, Southern Illinois University, in a 55 year-old northern red oak stand growing on cast overburden (Photo by Jim Burger).

Given that a selected overburden invariably becomes a substitute for native topsoil on reclaimed sites, its physics, chemistry and biology will largely determine the success of planted trees. Torbert and co-workers (1990) have shown that weathered sandstone overburden is the best medium for new forests in lieu of native topsoil. The degree of mine soil compaction caused by surface grading and site preparation also influences tree performance, with survival and growth inversely proportional to degree of compaction (Torbert and Burger, 1990). The Appalachian hardwood forest is very diverse, with as many as 20 to 40 woody species occurring on a single hectare. Each species has a specific life history and set of site requirements, which means that ideal site conditions for one may be less than ideal for another (Burger and Zipper, 2002). Site factors that influence available water during the growing season, such as slope steepness and aspect, differentially affect the success of hardwood species. Furthermore, some are more tolerant of competition from other herbaceous and woody plants. To greater or lesser degrees, all these site factors can be managed during reclamation in order to better accommodate the needs of a variety of native tree species (Torbert et al., 1994).

In order to apply our knowledge of the effects of mine site factors on tree survival and growth, we need a straightforward, understandable procedure for classifying site quality for hardwood reforestation based on field criteria that can be measured and classified by reclamation practitioners. Accordingly, the objectives of this study were (1) to determine if field measures of mine spoil type, mine soil compaction, and site aspect could be classified based on their influence on survival and growth of different native hardwood tree species, and (2) to develop a species-specific site quality assessment system for mined sites that cover a spectrum of site conditions.

Methods And Procedures

Over a span of 3 years, 10 1-ha blocks of recently reclaimed mined land were planted to a variety of native hardwood species. The 10 sites were located across a three-state region that included southeastern Virginia, southern West Virginia, and eastern Kentucky. Sites were selected to cover a spectrum of three site factors previously determined to influence tree establishment: mine spoil type, degree of compaction, and slope aspect (Table 1). The site factors were rated from 1 to 5 along gradients of least (5) to most (1) desirable for native hardwood survival and growth. For example, the mine spoil gradient covered a spectrum of different visually-judged proportions of unweathered shale and weathered sandstone. The mine soil compaction gradient ranged from very loose to very compacted. It was estimated in the field based on the depth of penetration of a standard tile spade or “sharp-shooter”. The slope aspects varied from dry, hot southwest-facing slopes to moist, cool northeast-facing slopes. We evaluated the 10 sites by measuring the three site factors and rating them within one of five classes.

All sites were operationally prepared by different mine operators in the process of routine reclamation. In some cases, sites were hydroseeded with groundcover mixes chosen by the operator, and in some cases we sowed a mix that was shown to be compatible with tree establishment (Torbert et al., 1989). Sites were planted with eight hardwood species across a 3-year period, approximately three sites per year, until a total of 10 sites were completed. The oldest sites are 5 years, and the youngest sites are 3 years. Tree height, diameter, and survival were measured annually. The data collected after the third growing season for all sites were used for this analysis.

Table 1. Location, description and characterization of 10 reclaimed mined sites used in this study.

Site #	Location	Spoil Type SS:SiS* (ratio)	Compaction: Penetration Depth (cm)	Slope Aspect (degrees)
1	Inez, KY	50:50	50	180-270
2	Inez, KY	50:50	30	180-270
3	Inez, KY	50:50	30	0-90
4	Wise, VA	10:90	10	flat
5	Wise, VA	70:30	50	0-90
6	Inez, KY	70:30	50	0-90
7	Gilbert, WV	90:10	40	flat
8	Gilbert, WV	90:10	50	0-90
9	Leivasy, WV	90:10	40	180-270
10	Rainelle, WV	70:30	30	flat

*SS:SiS = sandstone:siltstone.

For this initial analysis, white oak and green ash were used as indicators of two different survival and growth strategies common among Appalachian hardwood species. White oak is a valuable commercial species harvested for quality sawtimber and veneer. It is a heavy-seeded species that is somewhat shade-tolerant and occurs late in a typical forest successional sequence. Its seed is commonly buried under existing stands in the forest litter by squirrels and blue jays.

After germinating, its shoot grows slowly while it builds an extensive root system. When a gap in the forest canopy occurs, the tree uses energy reserves stored in its disproportionately large root system to rapidly grow its shoot to capture a place in the gap. This species is characteristic of other heavy-seeded species such as other oaks, hickories, and walnuts that germinate close to the mother tree in existing forests.

Green ash is a fast-growing species harvested for hardwood pulp and chips for oriented-strand board. It is a light-seeded, shade-intolerant, early-successional species that is found across a broad range of natural sites. Its thousands of small seeds mature early and are dispersed by wind and birds. The seeds germinate quickly in disturbed areas during the same summer they are produced. Given that the species is widely dispersed, it tolerates a spectrum of site types and grows quickly in disturbed, open areas to ensure its place in the sun. This species is characteristic of other early-successional pioneering hardwoods such as American sycamore, black birch, red maple, and tulip poplar.

We hypothesized that the two species would react differently to the site factor gradients, and that their respective reaction would allow us to develop species-specific recommendations for different types of sites. Average survival and height values of green ash and white oak, measured on each of the 10 sites, were plotted as a function of three mine site factors: spoil type, degree of soil compaction, and direction of slope. These site factors were assessed on a 5-point scale (Fig. 2). The average of all site factor ratings was used as an estimate of overall site quality class (SQC). Survival and height were plotted as a function of overall SQC to compare the relative sensitivity of the two species on different sites, and to determine the efficacy of this relationship for prescribing species to sites of a given character.

Results And Discussion

Green ash, an early-successional pioneer species, was relatively unaffected by the site factor gradients (Figure 3 A, B, C). Survival ranged from 80 to 99% across the gradients of rock type, degree of compaction, and slope aspect. Lines were fit to the data to show general trends in survival along the gradients. The steeper the slope the greater the influence of an individual site factor on survival. White oak, a late-successional species poorly adapted to raw, early-successional environments, did not survive well (15 to 55%) and was more sensitive to all three site factors than green ash. Tree height was more variable than survival across the 10 sites (Figure 4 A, B, C), but most of the relationships were the same except for the response of green ash to rock type (Figure 4A). Green ash is better acclimated to the neutral soil reaction afforded by the shale soils, while white oak prefers the moderate acidity of weathered sandstone spoils.

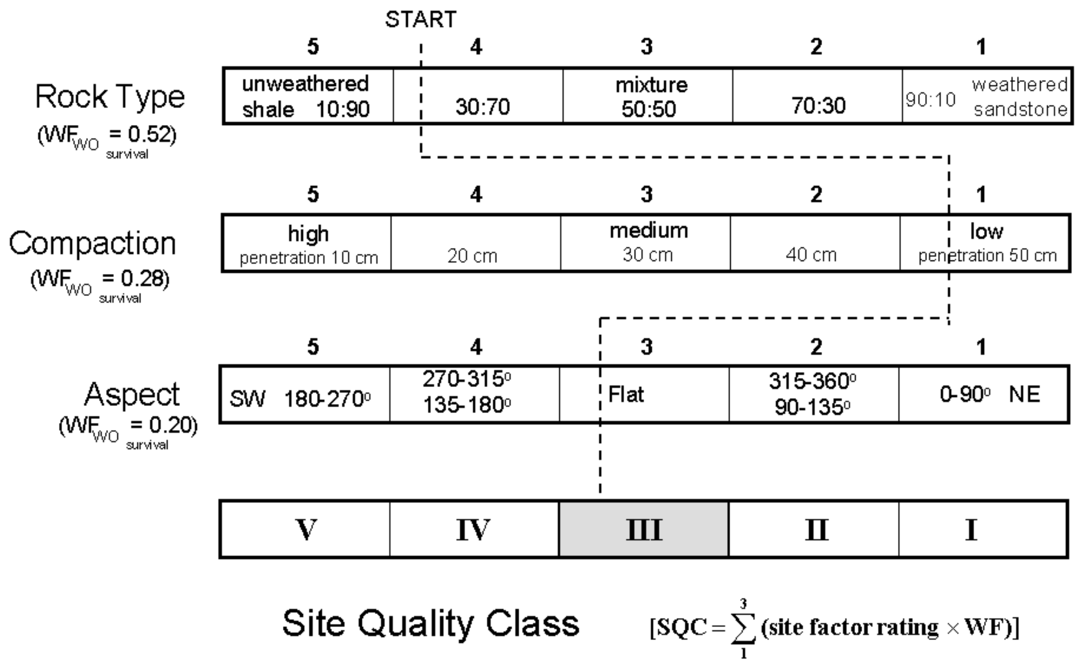


Figure 2. Site factor gradients used to determine overall mined site quality class (SQC).

To estimate the degree to which combined site factor ratings accounted for the variation in survival and growth of the two species, we calculated adjusted ratings for each factor for an overall average site quality class. Site factor ratings were adjusted by multiplying the rating by a weighting factor to account for its relative influence on survival or growth. We calculated the weighting factor by determining the sum of the slopes of the site factor regression lines (Figures 3 and 4) and calculating the relative contribution of each:

$$\mathbf{WF} = \frac{\mathbf{b}_{1_i}}{\sum_{1}^{i} \mathbf{b}_{1_i}}$$

Overall site quality class (SQC) for each site and species was then determined by:

SQC = (Rock type rating x WF) + (Compaction rating x WF) + (Aspect rating x WF).

An example of this calculation is illustrated in Figure 2.

Survival and height are shown as a function of SQC in Figure 5. Green ash survival and height were unaffected by overall site quality. No relationships are evident in the data. This finding is consistent with the life history and nature of green ash; it is an early-successional pioneer, tolerant of the range of site factors expressed in overall SQC. The implication for reclamation is that this species can be used across all mined site types with good establishment success, but it has little commercial value compared to white oak.

On the other hand, white oak survival was highly influenced ($p < 0.09$) by overall site quality (Figure 5A). Even on the best sites its survival was only around 50%. Again, this is consistent with the life history and nature of this conservative, late-successional species that normally regenerates from seed under an established forest, and in a soil environment with a rich diversity of organisms that facilitate belowground processes required for normal establishment and growth. The conditions of a Class I site, including a loose, weathered, sandy loam, moderately acid soil, on slopes with a cool, moist northeast aspect are the conditions under which white oak does the best in its natural habitat. A departure from these conditions causes a precipitous decline in survival (Figure 5A). White oak survival dropped an average of 10 % for each SQC. Our results show that survival of this species is suitable only on SQC I and II sites. White oak height response to SQC was also significant ($p < 0.07$); on Class I sites it grew an average of 10 cm yr^{-1}, but growth decreased by an average of 4.6 cm for each SQC (Figure 5B). It is clear that the combination of site factors expressed in SQC greatly influenced the survival and growth of this species. The implication for the use of white oak for mined land reclamation is that mined sites must be reclaimed in a way that accommodates this species, or the species must be carefully prescribed on selected sites, after the fact, in order to be successful.

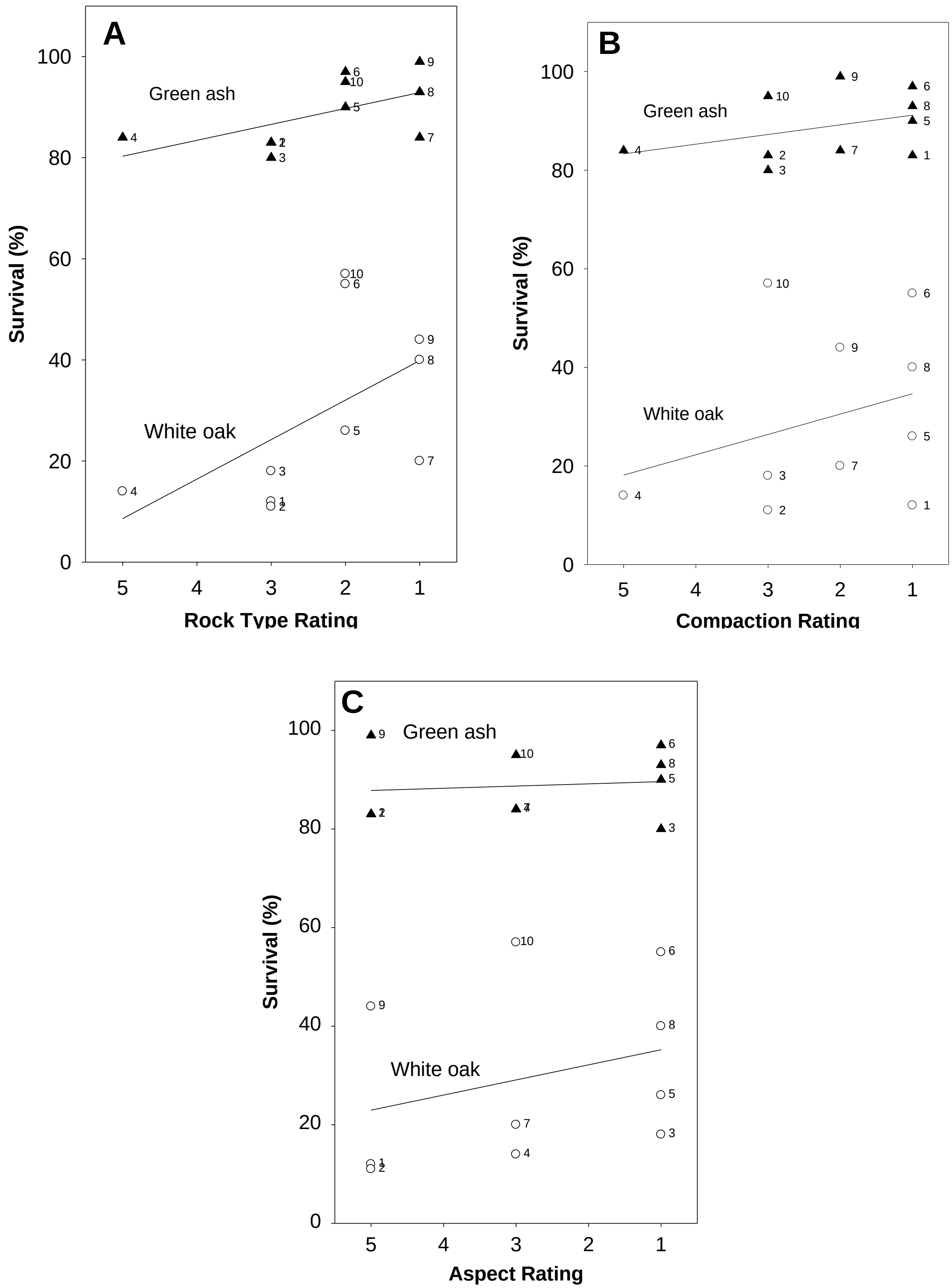


Figure 3. Survival of green ash and white oak on reclaimed mine sites across gradients of rock type, compaction, aspect, and ground cover.

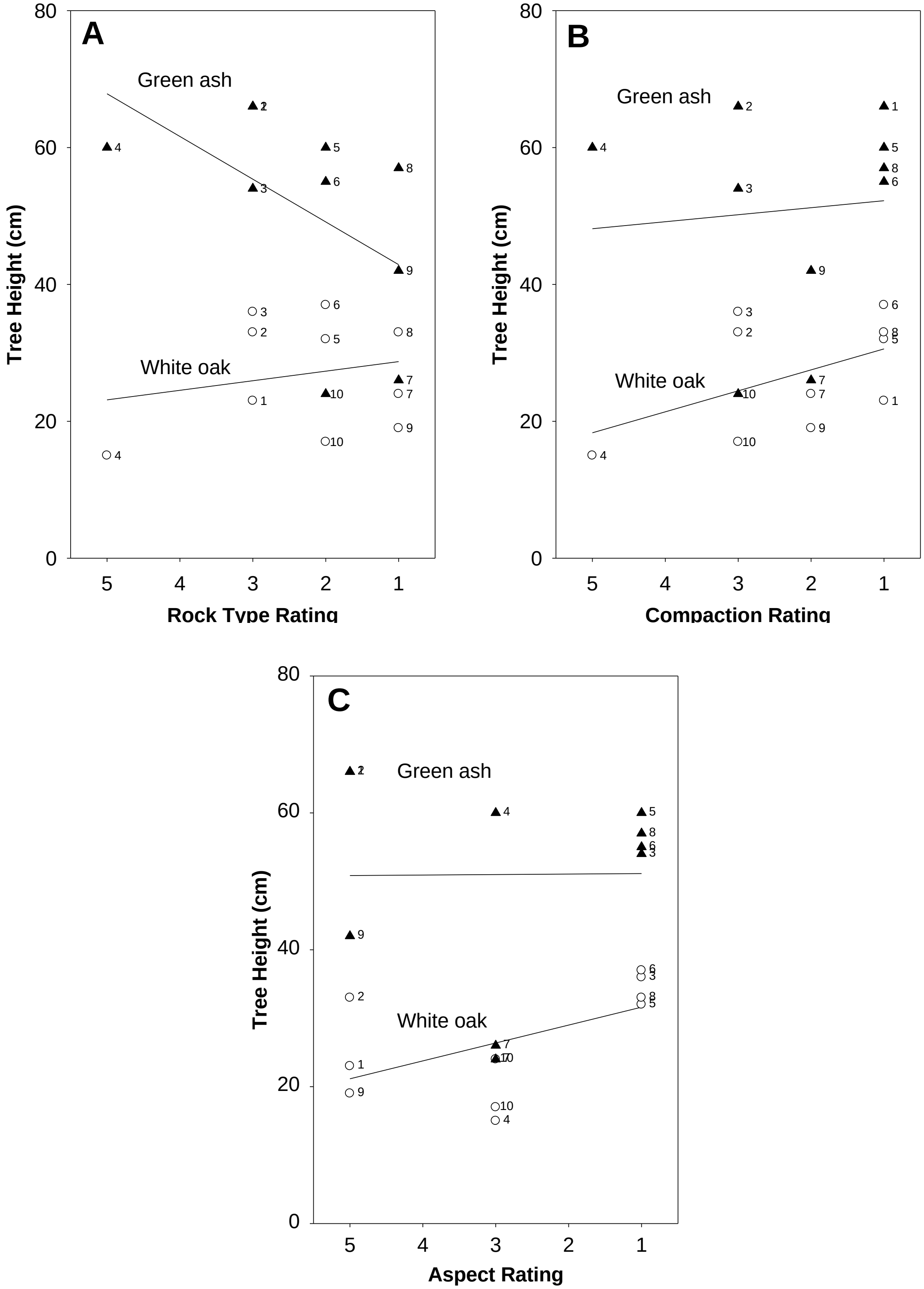
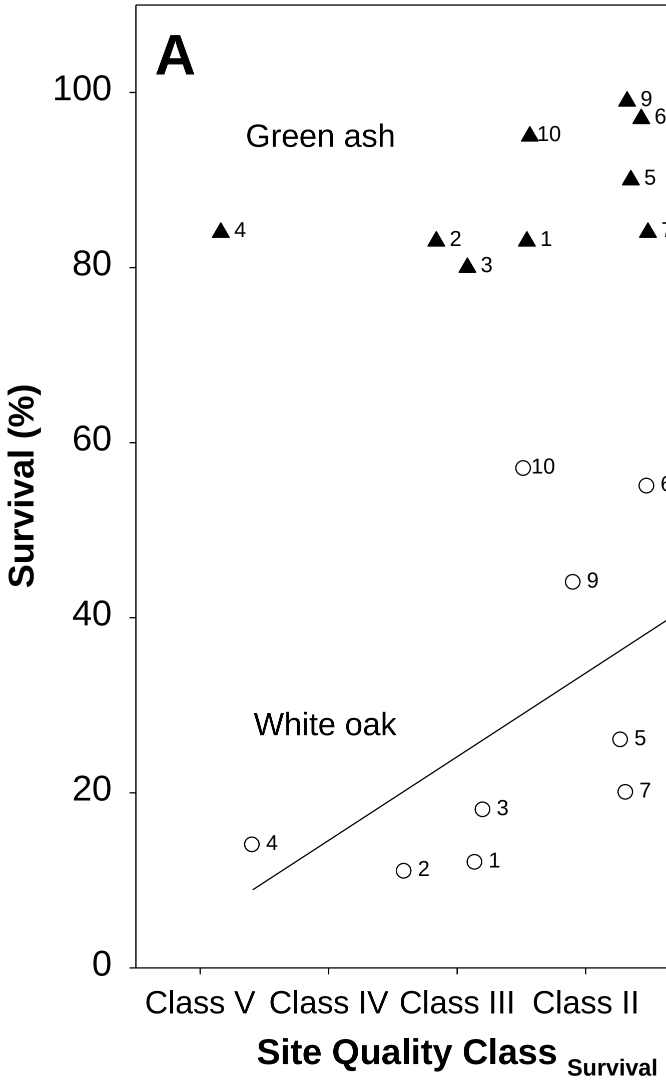


Figure 4. Height of green ash and white oak on reclaimed mine sites across gradient of rock type, compaction, aspect, and ground cover.


A
Green ash
White oak
Survival (%)
100
80
60
40
20
0
Class V
Class IV
Class III
Class II
Class I
Site Quality Class Survival
4
2
3
1
10
9
6
5
7
8

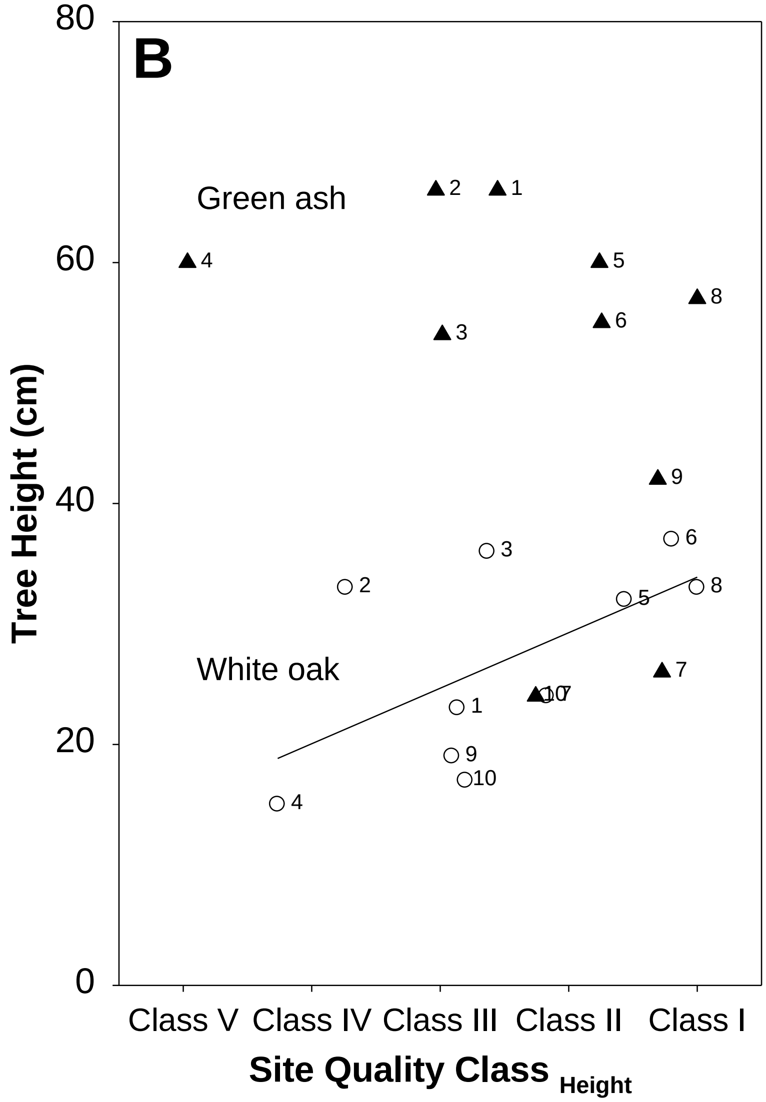


Figure 5. Survival and height of green ash and white oak as a function of site quality class.

Conclusions

Native Appalachian forests provide many benefits for landowners and surrounding communities. They produce valuable wood products, control flooding, increase water quality, provide habitat for wildlife, and sequester much of the carbon that is released to the atmosphere in the process of burning coal for power production. For 90% of all land mined in the Appalachian region, restoring the native forest and the values it provides is the most logical post-mining land use. Research and experience have shown that a combination of valuable, late-successional, native tree species can be planted to accelerate the return of native forest composition, productivity and value (Fig. 6). The key to this process is creating mine soils and sites with conditions similar to native soils and sites. However, a broad range in mine soil quality occurs after traditional mining and reclamation; some mine soils are suitable for native hardwoods, and others are not. For example, our data showed that green ash, a tolerant pioneering species, can survive and grow across a range of mined sites, while white oak, a more site-sensitive species, can only be used on certain mine soil types. Specifically, white oak survival will be unsatisfactory when the rock type rating is a 4 or 5, i.e., dominated by siltstone, due to the relative importance of rock type on white oak survival. White oak growth is affected more by compaction and aspect; highly compacted soils or southwestern aspects are incompatible with good growth.

Reclamation specialists need a straightforward way of classifying and mapping mined sites in order to make good silvicultural prescriptions. The results of this work show that rock type, soil compaction, and slope aspect are important site factors that should be used for assessing the suitability of mined sites for white oak and related species. Mapping site quality with our straightforward classification system should help improve species prescriptions, increase reforestation success, and ensure the development of valuable forests for present and future landowners. In order to be widely applicable, more work needs to be done to determine which species, if any, respond to site factors in a manner similar to other species. This information will allow us to develop a more general SQC rating system for groups of species based on silvics.

Figure 6. Example of successful hardwood reforestation on mined land (Photo by Rick Williams).

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