THIRTEEN-YEAR HARDWOOD TREE PERFORMANCE ON A MIDWEST SURFACE MINE[1]

by

W.C. Ashby and C.A. Kolar[2]

Abstract. Black walnut *(Juglans nigra* L.), sweetgum *(Liquidambar styraciflua* L.), tuliptree *(Liriodendron tulipifera* L.), white oak *(Quercus alba* L.), bur oak *(Q. macrocarpa* Michx.), and pin oak *(Q. palustris* Muenchh.) seedlings were planted both fall 1980 and spring 1981 on mixed overburden strip-mining banks (ungraded), mixed overburden graded to approximate original contour (AOC) (graded), mixed overburden graded to AOC with 60 cm of replaced pre-mining surface soil materials (topsoil), and on old fields near the strip-mine (unmined). Black walnut and pin oak were also planted as seed, with a total of 6000 seedlings/seed spots in the study. Initial species field viability ranged from 86 to 100%. With one exception, after 3 growing seasons oak seedlings had 50% or greater survival. Survival was mostly lower after 3 years with some additional mortality by years 8 and 13. Height and diameter breast height were measured after 13 years. Survival and growth of trees planted fall or spring was similar overall with variable performance by species. Seedlings of several species on the ungraded site had over 50% survival after 13 years, with fewer trees where planted as seed. Mean height of all species combined was significantly greater on the ungraded than on any other site and was lowest on the topsoil site. The unmined sites had high variability in species survival and height. Better reclamation with trees resulted from a deep, well-drained rooting medium with minimal compaction and a mineral-rich surface soil including coarse fragments over 2 mm in size for long-term productivity.

Additional Key Words: coal mining, reclamation, reforestation, soil compaction, topsoil, height survival

Introduction

Our thesis is that mineland reclamation with trees in the midwest can and ought to be much more successful than it has been in the past 20 years. Only limited success with tree planting is now possible under regulatory interpretations of numerous state and federal laws, especially Public Law 95-87, The Surface Mining Control and Reclamation Act of 1977 (SMCRA), and administered by the Office of Surface Mining Reclamation and Enforcement (OSMRE). SMCRA and regulations promulgated by OSMRE have requirements cosmetic replacement of mined lands to presumed pre-mining soil conditions it commonly would be a blessing to change. The vast earth-moving processes of surface mining are not used to create renewed productive soils, vegetation, and environments.

Failure to construct suitable rooting media has been particularly true for lands permitted for tree planting and reforestation. OSMRE's and Illinois' administration of SMCRA contradicts the dominant land-use ethic from the times of earliest settlement in America of accepting new and better ways to meet human and other needs. In many countries, for example Germany and Australia reclamation practices are shaped to support the biological requirements of trees rather than to avoid notices of violations or lawsuits. Certainly there has not been a lack of research findings to justify regulatory acceptance of improved reclamation and ecological restoration practices.

We know of no instance in the Midwest where progressive reclamation methods have been used to implement SMCRA Sec. 515(b)(19): "establish on the regraded areas, and all other lands affected, a diverse, effective, and permanent vegetative cover of the same seasonal variety native to the area of land to be affected

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[2]W. Clark Ashby, Professor Emeritus and Visiting Research Professor, and Clay A. Kolar, former Researcher, Department of Plant Biology, Southern Illinois University at Carbondale, Carbondale, EL 62901-6509. This study was further supported by the Sahara Coal Company, Inc., Illinois Department of Conservation, National Mine Land Reclamation Center, and SIUC Coal Research Center.

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and capable of self regeneration and plant succession at least equal in extent of cover to the natural vegetation of the area; except, that introduced species may be used in the revegetation process where desirable and necessary to achieve the approved postmining land use plan".

The pre-law record of tree planting on mined lands in the Midwest had many notable and continuing successes (Den Uyl 1955, Limstrom 1960, Ashby *et al.* 1980, Larson and Vimmerstedt 1983). Trees planted after mining 50 years ago such as black walnut (see Table 1 for scientific nomenclature) are today among the finest stands of timber in a county (Ashby, 1996A). A few scattered barren areas from early reforestation failures, lavishly publicized by environmental activists, have gradually blended into surrounding wooded areas through natural revegetation processes or been successfully revegetated using new research findings of soil management and species selection.

SMCRA in 1977 mandated intensive grading of mined land to approximate original contour (AOC) and the replacement of surface soil layers. At that time it was known these restrictions would lead to lower survival and less growth of planted trees and hinder forest restoration, also mandated by SMCRA (Limstrom 1960, Chapman 1967, Geyer 1971). Since passage of SMCRA thousands of acres have been mined, reclaimed, and planted to trees in accordance with the directives of federal and state regulators. As expected by mining and research reclamation personnel, these plantings have commonly had limited success. Many hundreds of those acres have had to be replanted in hopes of bond release (personal communications from industry reclamation personnel).

Research on post-SMCRA reclamation plantings has documented soil compaction from grading and from other heavy machinery traffic as a major factor limiting tree growth after mining. Numerous papers have reported studies of minesoils including adverse effects of compaction on water and nutrient availability, soil aeration, and on soil strength affecting root system development (Smith *et al.* 1976, Bussler *et al.* 1984, Ashby *et al.* 1984, Ammons *et al.* 1985, Thurman *et al.* 1985, Josiah 1986, Vogel 1987). Even so, many persons inexperienced with tree planting on surface mines have blamed failure of post-SMCRA reclamation tree plantings on reasons other than excessive grading. Acceptance of the critical importance of a suitable rooting medium by the engineers, lawyers, environmental activists, and administrators who control reclamation practices is essential for successful growth of trees on mined lands. Something as simple as acceptance of reduced traffic by heavy machinery and incorporation of coarse fragments (rocks) to help bear the traffic load on the rooting medium would bring many benefits for growth of trees and other kinds of plants.

Table 1. Common and scientific names of species in the text with species codes in parentheses.

Habitat and common name	Scientific name
Lowland	
Sweetgum (sg)	*Liquidambar styraciflua* L.
Bur oak (bo)	*Quercus macrocarpa* Michx.
Pin oak (po) seed (posd)	*Quercus palustris* Muenchh.
Swamp white oak	Quercus bicolor Willd.
Ravine	
Black walnut (bw) seed (bwsd)	*Juglans nigra* L.
Tuliptree (tt)	*Liriodendron tulipifera L.*
Slope	
White oak (wo)	*Quercus alba L.*

A post-SMCRA limiting factor for establishment survival, and growth of many tree species has been the deleterious effect of replacing surface soils. A prevailing quasi-religious belief in benefits of 'topsoil" replacement in nearly all mining situations has proven to be erroneous. Another post SMCRA factor has been the differential effects of ground cover on tree performance (Raisanen 1982, Andersen *et al.* 1989, Ashby 1997). Even if these factors had been thought of pre-SMCRA, only in the past 20 years has research on their roles documented quantitatively their importance. Requiring densely planted ground cover for erosion control unfortunately has diverted needed attention from the causes of and alternative solutions for potential erosion problems on mined lands.

Our study focused on potential short- and long-term ecological and productivity consequences of planting trees on different types of post-mining rooting media. We report tree performance on unmined land and on mined land reclaimed to three differing legal standards in the history of mining. Our chief goal was to quantify to what extent tree survival and growth would be affected by various options in reconstructing surface-mined land. We were also interested in how other factors such as type of planting stock, season of planting, and choice of species affected tree performance on the four types of rooting medium.

Materials and Methods

This study was carried out on the Sahara Coal Company, Inc. surface Mine No. 6, west of Harrisburg in Saline Co., Illinois. The overburden was multi-layered with a total of about 4 m of surface unconsolidated material, 9 m of sandy shale layers, 3 m of limestone, and 1 m of sandstone overlying a 1.5 m bed of No. 6 coal. Mining in the 1971-1981 decade resulted in three as of sites: mined and ungraded, mined and graded, and mined and graded with a minimum of 60 cm of replaced surface soils. Surface soil replacement was started in 1980. Tree plots were established both fall 1980 and spring 1981 on the three kinds of mined land and on unmined old fields. Survival and/or growth were determined four times over the next 13 years.

The four sites differed in several ways:
Unmined—old fields near Mine No. 6. The soil types (Table 2) are listed as prime farmland by the regulatory authority. At the time of planting the ground cover was chiefly perennial herbs. Our plantings, along with

Table 2. Average height (m) and survival (%) for combined plots of six tree species on four rooting media at age 13 with fall or spring planting and both seedling and seed for two species. Umnined soil types from Miles and Weiss (1978).

	Rooting Medium							
	Upgraded		Graded		Unmined		Topsoil	
Species	Fall	Spr.	Fall	Spr.	Fall[a]	Spr.[b]	Fall	Spr.[c]
				Average Height (m)				
Sweetgum	7.3	7.1	3.2	5.2	4.8	6.5	5.8	3.9
Bur oak	4.7	4.5	4.0	3.7	2.4	2.0	3.8	3.4
Pin oak	5.5	5.7	2.8	2.9	-	3.2	2.5	2.7
Pin oak seed	4.8	4.4	2.6	2.4	0.5	2.3	1.9	-
Black walnut	4.5d	3.7	3.4d	3.0	-d	0.9	1.0d	1.5
Black walnut seed	3.9	5.3	3.5	3.4	-	2.6	0.90	0.9
Tuliptree	5.5	4.6	-	-	4.9	7.0	-	-
White oak	4.5	3.9e	2.4	3.4e	1.8	2.9e	2.9	3.5e
				Average Survival (%)				
Sweetgum	41	49	1	3	39	85	1	11
Bur oak	84	75	91	90	10	47	63	67
Pin oak	49	78	31	56	0	72	30	68
Pin oak seed	11	29	18	10	3	27	4	0
Black walnut	45d	57	53d	71	0d	19	25d	22
Black walnut seed	14	43	29	57	0	7	12	12
Tuliptree	41	42	0	0	69	11	0	0
White oak	63	40e	24	57e	15	41e	37	71e

aAquollic Hapludalfs, Alfisols--Hoyleton silt loam
bAeric Haplaquepts, Inceptisols--Banlic silt loam
cTree rows in each replicate plot had fewer than 50 trees and adjusted percent survival.
dSeedlings were fau-planted after being held in cold storage over the summer.
eMixed white and swamp white oak

volunteer trees, have now formed woodland canopies on parts of the plots on these sites.

Ungraded — graded mixed overburden overlying the Illinois No. 6 coal and classified as Orthents (Miles and Weiss 1978). Mining with a Marion 5761 power shovel from 1971 to 1973 under a substitution clause of a 196R Illinois law resulted in roughly parallel east-west banks or ridges averaging 6 m high with intervening valleys. The rooting medium was a mixture of soil fines from the pre-mining surface layers and of coarse fragments over 2 mm in size from lower layers in the overburden. This site had a loose, uncompacted, well-drained soil structure with no evident layer to impede movement of water and air or deep rooting and anchoring of trees. To the extent that these attributes were lacking in our other sites we could evaluate their effects on tree growth. Soil pH ranged from slightly one to slightly acidic with infrequent acidic microsites. Plant cover on the unseeded banks was mainly scattered annual or perennial herbaceous "weeds" with woody vines and a few pioneer trees locally.

Graded — mining was in the mid 1970's. This site had the same rooting medium mixture of soil fines and coarse fragments as the Ungraded site and was roughly leveled with a Bucyrus-Erie 1400 pullback dragline and then intensively graded to AOC using a Caterpillar D-8K crawler tractor with dozer blade. The rooting medium was typically highly compacted below about a 16-cm surface zone loosened by freezing and thawing and wetting and drying (Ashby *et aL* 1984). Perched water tables and standing water were found in scattered areas in winter-spring and after heavy summer and/or fall rains. The ground cover was chiefly a dense stand of tall fescue *(Festuca elatior [F. arundinacea]),* or locally orchardgrass *(Dactylis glonwrata),* that had taken over from an aeriauy-sown reclamation grass and legume pasture mixture.

Topsoil — sites mined from 1977 to 1980 and graded to AOC. Pre-mining Typic Fragiudalfs Alfisols were Hosmer silt loam--2 to 4 percent slope (prime farmland) and Hosmer silt loam--4 to 7 percent slope (high capability under Illinois regulations). In mining the surface 20 cm (designated topsoil by OSMRE) had been selectively removed by Caterpillar 327 pan scrapers ahead of the shovel in mining, stockpiled, and then replaced on graded areas behind the pit on top of a 40-cm layer of direct-hauled subsoil, and further graded with dozers. These sites had been fertilized and limed as needed to meet OSMRE regulations. They were typically highly compacted below about 16 cm. Perched water tables and standing water were found in scattered areas in winter-spring and after heavy rain. The ground cover was typically tall fescue from a reclamation pasture mix sown after mining.

Tree planting — Replicated plots with eight rows of tree seedling/seed spots were planted on the four sites both fall 1980 and spring 1981 to 50 trees per row. The spring 1981 topsoil site had fewer than 50 trees per row and survival percentages were adjusted accordingly. Spacing of rows and of seedlings/seed spots per row was 2.5 m with 6000 seedling/seed spots planted on a total of 16 plots.

Of the eight rows per plot six were planted to tree seedlings and a row each of black walnut and pin oak was planted also as seed. Bare-root seedlings were obtained from state nurseries in Illinois, or Indiana under a reciprocal species production agreement. Sometimes desired seedlings were not available from the state nurseries and they were bought from commercial nurseries reasonable close to southern Illinois. The oak bundles received from the state nurseries occasionally had stray seedlings of other species, and there were numerous unrecognized swamp white oak seedlings in the spring 1981 white oak bundle.

All seedlings when received were separated into basal stem caliper size classes with small and large seedlings discarded. Roots of seedlings were pruned as needed to avoid distortion when later placed in a planting-bar slit. A few times all seedlings in a nursery bundle were exceptionally tall and they were shoot-pruned as well for ease of handling and to balance size of shoot and root. A representative assortment of sizes of seedlings for planting per row per plot was placed with moist sphagnum moss in a bundle of 50 seedlings (plus 2 or more extra) and stored at 5° C until planted. Planting was with a planting bar (dibble), commonly in March/April or October/November. Each planting spot was marked for ease in locating later with a plastic, colored pot label.

Seed was collected in southern Illinois and either planted soon after collected, or stored in plastic bags with moist sphagnum at approximately *5° C* until planted. Usually two or three seed, depending on expected germination, were planted with a mattock at each seed spot in a hole 3 times the depth of the seed diameter, covered with soil tamped down by foot, and marked with a pot label.

In spring 1981 the contact herbicide glyphosate (Roundup) plus the pre-emergent herbicide simazine (Princep) was sprayed with a backpack sprayer to control ground cover in a 1.5 m circle around all trees planted fall 1980 and spring 1981. Trees were well-shielded while the ground cover was sprayed. The herbicides were highly effective in eliminating plant cover on the planting spots in 1981. By 1983 the surrounding vegetation had re-grown on many spots, and by 1988 few spots still showed reduced cover from the herbicide treatment.

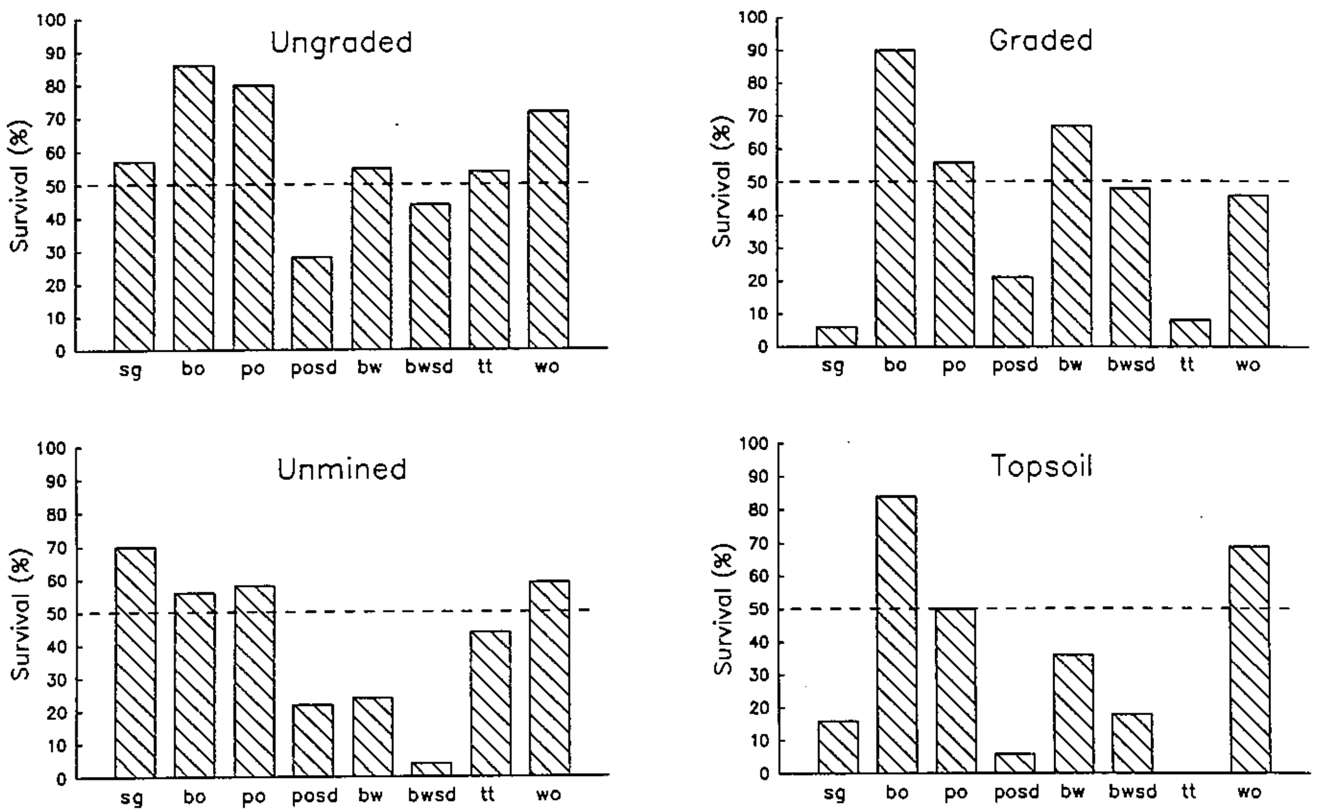

Figure 1. Average survival after 3 growing seasons for combined plots planted fall 1980 and spring 1981 on the 4 sites with 8 species/planting types each. Percent survival above the horizontal dashed line would meet current bond release standards. See Table 1 for species codes.

All planting spots with a living tree(s) were counted after 1, 3, 8, and 13 growing seasons. If a seed spot had multiple seedlings, all but one were clipped off at ground level the first year. After 13 years tree heights were measured with a telescoping fiberglass measuring pole or, if too tall for use of the pole, by climbing the tree or with a Haga altimeter. Diameter breast height (DBH) was measured as well for trees 1.4 m height or taller.

Tree counts and averaged heights of a few species on unmined plots may be in error by a tree or two because a row was blurred by invasion of volunteer trees of the same species from surrounding stands. Trees were missing or had been damaged on some plots from tree theft (most often sweetgum), off-road vehicles, powerhne or field operations, or errant mowing.

Data processing and analyses were carried out with an IBM PC using ABSTAFM and SigmaPlotrm software. Our treatments were qualitative that differed in Icind of site rather than quantitative (Mize and Schultz 1985). The data were handled in several ways. Average heights and percent survival were tabulated or graphed for each species, rooting median, and/or planting season. A ranking of height by rooting medium was further tabulated. Multiple comparison statistical procedures were not carried out for these tabulations. Coefficients were calculated to correlate height or DBH, of trees planted in fall 1980 and spring 1981. ANOVA was caffied out for comparisons of height by season within sites, and for comparisons of height, and of DBH, among sites.

Results

Greatest first-year establishment an estimate of planting stock viability, ranged from 86 to 88% for black walnut and tulip tree and from 96 to 100% for the other species/planting stocks in summer 1981. Some black walnut seed may he dormant for a year. Mixed overburden minesoil, ungraded or graded, 6 tended to have the greatest third-year percent survival, with the exception of sweetgum on the unmined (Fig. 1). All oaks, except not quite for white oak on the graded site, had sufficient percent survival on all sites to meet a 450 trees per acre bond release standard for a forest products land use in Illinois when planted at customary spacings to give 900 trees per acre.

Mortality of the several species varied from year 3 to year 13 (Fig. 1, Table 2). Oak seedlings also after 13 years consistently had relatively high survival. Survival of pin oak and black walnut continued to be greater when planted as seedlings than as seed. Tree-form of all species on the ungraded site was typically much higher quality than on the graded or topsoil sites. Swamp white and bur oak trees, younger than reported minimum seed-bearing ages (Burns and Honkala 1990), commonly had acorns. Seed was found occasionally on pin oak and black walnut.

Height growth of trees planted in fall 1980 and spring 1981 was relatively the same after 13 years (correlation coefficient r=0.81), with few exceptions (Table 2). No statistically significant differences in height of trees planted fall and spring were found from ANOVA for site or for all sites combined. The overall correlation coefficient for DBH of trees planted fall 1980 and spring 1981 was r=0.49. Some trees after 13 years were not 1.4 m in height for DBH measurement. Height/diameter relationships were not consistent within and between species.

In an observational ranking of height by rooting medium, within-species heights combined ranked lowest on the topsoil sites and only tulip tree was not tallest on the ungraded sites (Table 3). Neither black walnut from seedlings nor from seed was observed consistently to out-perform the other in height. Black walnut trees from seedlings held over summer in cold storage and fall-planted grew about the same as those spring-planted.

A comparison of all tree rows combined using ANOVA showed differences among sites in height growth (p=0.0001) and in DBH (p=0.0079).

Height	DF	Mean Sq.
Sites	3	15.2
Residual	52	1.9
Total	55	

Conservative Sheffe-test comparisons between sites showed that height growth of tree rows on the ungraded site was greater than on any other site after 13 years (Table 4). DBH of tree rows on the ungraded site was greater than on the unmined reference sites.

Discussion

An important issue in deciding how best to construct a rooting medium after surface mining is whether different kinds of trees are alle or unlike in their responses to post-mining soil conditions. The species selected for our study were representative of three natural ecological habitats, termed "sites" by foresters. Sweetgum and bur oak, found also on other habitats elsewhere, and pin oak are typically restricted to lowlands in southern Illinois (Bums and Honkala 1990, Ashby and Kelting 1963). Black walnut and tulip tree are characteristic of ravines and white oak of slopes (Table 1).

These several species responded differently to the 4 as of rooting medium. Grading, however, limited tree growth both of those species that naturally grow on soils with fragipans or other restrictive layers and of black walnut and tulip tree native to well-drained soils. Trees tended to perform better on the less-segregated graded minesoils with the exception of the white oak mixed with swamp white oak in the spring 1981 plots where the swamp white oak, adapted to poorly drained soils, outperformed the white oak. Half of our study species tended to grow better on the old fields and another half on replaced topsoil.

That no species had first rank for height growth on replaced soils of the topsoil site was not unexpected. Studies of four-year-old black walnut trees planted on the study sites showed both the graded and topsoil sites to be compacted with severely limited root growth (Josiah 1986). Black walnut survival and growth were greatly increased by soil ripping on near-by graded plots (Ashby 1996B). Restncted height growth of all species on the topsoil site has become more evident over time. These

Table 3. Observational ranking of rooting media for average tree height by species. Greatest tree height within species is ranked 1, and least is ranked 4.

	Ranking and Rooting Medium			
	1	2	3	4
Species	Ungraded	Graded	Unmined	Topsoil
Sweetgum	1	3	2	4
Bur oak	1	2	4	3
Pin oak	1	3	2	4
Black walnut	1	2	4	3
Black walnut seed	1	2	3	4
Tuliptree	2	-	1	-
White oak	1	3	4	2
Mean	1.1	2.1	2.9	3.0

Table 4. Mean height and DBH of all trees on each rooting medium.

Rooting Medium	Height* (m)	DBH* (cm)
Upgraded	5.0a	6.2a
Graded	3.3b	5.1a
Unmined	3.2b	4.1b
Topsoil	2.7b	4.4a

*Heights (or DBHS) with the same letter were not different in Scheffe-test comparisons at p=0.05.

plots had been both graded and subject to additional soil compaction by pan scrapers and tractor dozers during topsoil-replacing operations. Other factors such as ground cover likely affected tree performance. To what extent the longer-term tree performance on the topsoil or graded sites was affected by seeded ground cover species compared to the ground covers of the ungraded or unmined sites was difficult to assess. Herbicide spraying presumably lessened the differences for the first years.

A reason some people have insisted on replacing topsoil could be an assumption that it is relatively uniform and predictable while minesoils in turn have been thought of as highly variable. Variability is a matter of scale. On a large scale each of our sites was relatively consistent in its features with random small-scale heterogeneity. We observed site variability with replaced surface soils equal to or greater than the variability found in a mixed overburden rooting medium. Plant response likewise was variable on the topsoil sites.

An unexpected result of our studies was a lack of evidently useful information for reclamation with trees from the old-field, reference plots. Relative height ranking was more variable there than on other sites. Information on or justification of the value of reference areas is needed.

A largely uncontrollable factor for reclamation with trees is possible animal damage. The lower establishment/survival of pin oak from seed than seedlings was likely caused in part by pilfering of seed by animals. In some places the plastic pot labels only marked empty holes where pin oak seed had been planted. Such holes were not often found at the planting spots with the much larger walnut seed. Walnut saplings, however, were a favorite target for deer buck rub. Seventy-six percent of young walnut trees on a topsoil plot were damaged from October 1988 to April

1989. Deer damage may be affected by the kind of surrounding vegetation.

Our data reported here are a portion of data from a much larger series of tree plantings on the four rooting media at Mine No. 6 planted fall and spring from 1978 to 1982 and totaling over 70,000 experimental trees of 25 tree species planted one or more years. These plantings are available (with permission) as a resource for qualified persons who later may wish to study longer-term tree growth on our plots. The full data base to date on PC computer disks has been deposited at the Coal Research Center, Southern Illinois University at Carbondale, and is included in Ashby *et al.* (1995). The data that are the basis for this paper are representative of data from the larger study.

Conclusions

Mixed overburden (spoil) at the Sahara mine proved to be a very suitable rooting medium for tree growth, likely superior to native soils for many tree species if not excessively graded.

Mixed overburden sites with high productivity for tree growth and forest restoration created by surface mining in former years should not be dismissed as irrelevant because reclamation regulations have long since disallowed the "old ungraded spoil banks". High quality forest sites are always relevant. Incorporating site characteristics identified through research and experience as contributing to optimum tree growth and forest restoration, no matter what type of post-mining landscape is being created, should be a logical and desirable goal in reclamation. This approach has enhanced reclamation success for reforestation in other countries and has long been promoted by experienced reclamation research persons in this country.

We were surprised by the relatively good performance of several species on the graded site, in contrast to evaluations after 3 or 8 years. A reason for evident improvement may be weathering of coarse fragments that enhanced deeper rooting. Coarse fragments in the soil likely reduced the initially adverse effects of grading and/or compensated for them by providing discontinuities in the compacted soil matrix. Larger trees may have relatively greater drought tolerance and better utilization of an otherwise favorable rooting medium.

In contrast to the expectations of some people from SMCRA, the additional site preparation of segregating and replacing the pre-mining surface soil layers did not lead to an increase in tree growth or accelerated forest development 13 years after establishment. Tree growth on the topsoil site was not evidently becoming relatively better over time. Tree numbers alone are a poor indication of site quality. Later percent survival could not well be predicted from initial establishment rates.

The midwest coal areas have had 20 years of reclamation regulations that limited forest restoration programs mandated under SMCRA. It is past time for the regulatory authorities to institute realistic and meaningful requirements for site preparation of areas in the Midwest designated for trees.

Recommendations

One practical recommendation from our findings is to reduce soil compaction during site preparation to the greatest extent possible. Dozer operators should be trained and instructed to make fewer passes over an area. Grading to parking-lot standards damages the environment and limits revegetation. Residual surface roughness should not only be permitted but encouraged to help hold water, lessen erosion, and enhance biodiversity (Torbert and Burger 1993). AOC needs to be re-evaluated. Close interpretation and adherence to AOC for many coal mining regions clearly limits gaining highly productive post-mining land for forestation. By limiting the land types most productive for forestation, we lose many desirable reclamation options that could be optimized by having diversified landscapes. More consideration should be given in coal-mining regions that typically have poor surface soils and/or steep slopes to a nontoxic mixed overburden as the final surface material, particularly on areas designated for trees including slopes along ramps or inal cuts. Coarse fragments in the rooting medium should not usually be viewed as undesirable since their presence improves water movement, helps in erosion control and enhances nutrient supply (Ashby *et aL* 1984).

For the species in our study, using seed versus seedlings, holding seedlings over summer in cold storage before fall planting, and planting both fall and spring can contribute to management of successful reclamation tree planting programs. Animal control efforts such as deer himting permits, mouse poisoning, and/or mowing of strips before seed planting for greater predator success should be implemented where feasible.

Our most important finding was to realize how well these tree species performed after 13 growing seasons on a suitable rooting medium, the ungraded site.

Tree growth now accepted as satisfactory, or even good, on other post-SMCRA sites need not to be a poor substitute for potential growth on mined land. SMCRA should properly be bnplemented in such a manner that better tree growth can be gained with less input of energy and resources and greater long-term productivity.

Literature Cited

Ammons, J.T., T.A. Keeney, and R.M. Smith. 1985. Minesoil properties affecting rootgrowth. pp. 111-126 In: Proceedings Better Reclamation with Trees Conference. Carbondale, Illinois.

Andersen, C.P., B.H. Bussler, W.R. Chaney, P.E. Pope and W.R. Byrnes. 1989. Concurrent establishment of ground cover and hardwood trees on reclaimed mined land and unmined reference sites. Forest Ecology and Management 28:81-99.
https://doi.org/10.1016/0378-1127(89)90062-5

Ashby, W.C. 1996A. Growth of hardwoods and conifers after 47 years on coal mine soils in southern Illinois. Tree Planters' Notes 47(l):24-29.

Ashby, W.C. 1996B. Red oak and black walnut growth increased with minesoil ripping. International Journal of Surface Mining, Reclamation and Environment 10 (1996):113-116.
https://doi.org/10.1080/09208119608964813

Ashby, W.C. 1997. Soil ripping and herbicides enhance tree and shrub restoration on stripmines. Restoration Ecology:5(2)169-177.
https://doi.org/10.1046/j.1526-100X.1997.09720.x

Ashby, W.C. and R.W. Kelting. 1963. Vegetation of the Pine Hills Field Station in Southwestern Illinois. Transactions of the Illinois State Academy of Science 56(4):188-201

Ashby, W.C., C.A. Kolar, G.R. Philo, and C.A. Huetteman. 1995. Database of reclamation with trees in southern Illinois, 1978-1993. Coal Research Center, Southern Illinois University at Carbondale. 47 p.

Ashby, W.C., C.A. Kolar, and N.F. Rogers. 1980. Results of 30-year-old plantations on surface mines in the Central States. pp. 99-107 In: USDA Forest Service General Technical Report NE-61, Broomall, PA.

Ashby, W.C., W.G. Vogel, C.A. Kolar and G.R. Philo. 1984. Productivity of stony soils on strip mines. pp. 31-44 In: Erosion and Productivity of Soils Containing Rock Fragments, Soil Science Society of America, Madison, WI.

Burns, R.M. and Honkala, B.H., technical coordinators. 1990. Silvics of North America: 2. Hardwoods. Agriculture Handbook 654. Forest Service, United States Department of Agriculture, Washington, D.C. 877 p.

Bussler, B.H., W.R. Byrnes, P.E. Pope, and W.R. Chaney. 1984. Properties of minesoil reclaimed for forest land use. Soil Science @nciety of America Journal 49(l)-179-194.

Chapman, A.G. 1967. How stripland grading affects tree survival and growth. Southern Illinois University, School of Agriculture. Publication No. 29. 34 p.

DenUyl, D. 1955. Hardwood tree planting experiments on strip none spoil banks of Indiana. Bulletin 619. Purdue University Agricultural Experiment Station. 16 p.

Geyer, W.A. 1971. Tiinber growth on graded and ungraded strip-mine spoil banks in southeast Kansas. Transactions Kansas Academy of Science 74:318-324.

Josiah, S. J. 1986. The effects of minesoil construction techniques and ripping on the long term survival and growth of black walnut. pp. 183-193 In: Proceedings American Society for Surface Mining and Reclamation National Meeting. Princeton, WV.
https://doi.org/10.21000/JASMR86010183

Larson, M. M. and J. P. Vimmerstedt. 1983. Evaluation of 30-year-old plantations on stripmined land in east central Ohio. Ohio Agricultural Research and Development Center Research Bulletin 1149. Wooster, OH. 20 p.

Limstrom, G. A. 1960. Forestation of strip-mined land in the central states. USDA Agriculture Handbook No. 166. 74 p.

Miles, C. and B. Weiss. 1978. Soil Survey of Saline County, Illinois. USDA Soil Conservation Service and Forest Service. Washington, DC. 94 pp. plus maps.

Mize, C.W. and R.D. Schultz. 1985. Comparing treaunent means correctly and appropriately. Can. J. For. Res. 15:1142-1148.
https://doi.org/10.1139/x85-185

Raisanen, D.L. 1982. Survival of selected tree species on sites reclaimed to various reclamation standards. pp. 92-102 In: 1982 Seminar: Post-Mining Productivity with Trees. Carbondale: Southern Illinois University.

Smith, R.M., A.A. Sobek, T. Arkle, Jr., J.C. Sencindiver, and J.R. Freeman. 1976. Extensive overburden Potentials for soil and water quality. EPA-600/2-76-184. U.S. Environmental Protection Agency, Industrial Environmental Research Laboratory. Cincinnati, OH. 311 p.

Thurman, N.C., J.C. Sencindiver, J.T. Ammons, and D.C. Adamo. 1985. Physical properties of minesoids and their effects on root growth. pp. 194-208 In: Proceedings Bener Reclamation with Trees Conference. Carbondale: Southern Illinois University.

Torbert, J.L. and J.A. Burger. 1993. Commercial forest land as a postmining land-use: A win-win-win opportunity for coal operators, landowners, and society in the central Appalachians. pp. 732-737 In: Proceedings American Society for S@ce Mining and Reclamation National Meeting. Princeton, WV.
https://doi.org/10.21000/JASMR93020732
Vogel, W. G. 1987. A manual for training reclamation inspectors in the fundamentals of soils and revegetation. Soil and Water Conservation Society, Ankeny, IA. 178 p.