VALUE OF COMMERCIAL FORESTRY AS A POST-MINING LAND USE[1]

by

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Abstract: Forestry is becoming the preferred post-mining land use in the Appalachian region for the landowner as the value of forests becomes recognized. During the summer of 1996, a study was conducted in a white pine (*Pinus strobus* L.) plantation that was established in 1978 on a pre-SMCRA bench located in Wise County, Virginia. The objectives of this study were to illustrate the feasibility of commercial forestry as a post-mining land use, and to identify relationships between tree productivity and mine soil physical properties. The spoil was a deep, non-compacted, slightly-acid, weathered sandstone that had no topsoil applied. A timber inventory of the plantation showed that it was overstocked, therefore the plantation was thinned down to 20 m^2 ha^{-1} (90 ft^2 of basal area per acre). The average tree height was 14.3 m (47 ft), translating to a very high site index of 35 m (110 ft; base age 50), compared to site indices of 24 m (80 ft) and 18.3 m (60 ft) for adjacent undisturbed forest soils and post-SMCRA reclaimed mine soils, respectively. When these site indices were used to project tree growth for 30 years, the estimated timber per-acre value was \$3,480, \$1,755, and \$122 for the non-compacted mine soil, undisturbed forest soil, and typical post-SMCRA mine soil, respectively. The twenty-fold difference in the timber value between the non-compacted mine soil and the typical post-SMCRA mine soil represents a tremendous lost opportunity for most post-SMCRA sites that are not reclaimed for commercial forestry. The high productivity of the white pine plantation growing on the pre-SMCRA bench was attributed to low soil bulk density and a moderately-acid sandstone mine soil. Reclamation practices that result in these desirable soil properties need to be encouraged, so that restored forest land will be profitable for the landowner, meet society's needs, and meet the spirit and letter of the SMCRA.

Additional Key Words: reforestation, soil compaction, reclamation

Introduction

Commercial forestry is an attractive post-mining land use option because it provides multiple values for the landowner, including: (i) high-value wood products; (ii) wildlife habitat; (iii) recreational opportunities; (iv) enhanced water quality; and (v) environmental protection (Torbert et al. 1994). Research and anecdotal evidence suggests that reclaimed land can support productive forests when it has not been intensively graded or compacted (Ashby 1982). Conversely, our research has shown that reclaimed land that has been intensively graded and compacted cannot support productive forests (Torbert et al. 1994).

In the Appalachian region, most mined land since 1985 has been reclaimed for hayland/pasture, wildlife, or unmanaged forest land rather than commercial forestry (Zelenik and Skousen 1996; Burger and Torbert 1992). Reclaiming land for uses other than commercial forestry may have value; however, successional processes will insure that forests will eventually return to most reclaimed mined land, since the Appalachian region is naturally forested. Landowners can enjoy the benefits of commercial forestry on reclaimed mined land within comparatively few years (Figure 1) by following reclamation guidelines that facilitate productive forests, instead of waiting 120 years or more for nature to produce a commercially-viable forest. Figure 1 illustrates the approximate time required for a forest to reach commercial maturity after establishment by "default" (natural succession) on mined land reclaimed as hayland/pasture and then abandoned, a common scenario in the central Appalachians.

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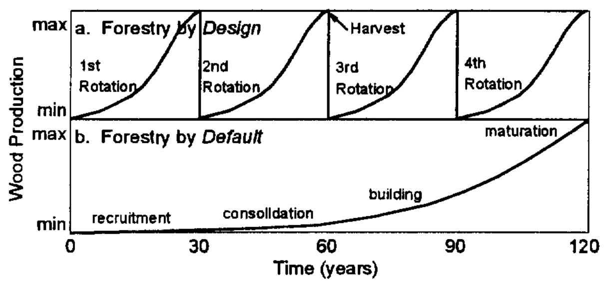

Figure 1. Generalization of the wood production opportunity on reclaimed mined land: a. managed commercial forestry (forestry by design); compared to (b) forest development via natural succession on unmanaged reclaimed land (forestry by default) in the central Appalachians.

Competitive grasses and legumes such as tall fescue (*Festuca arundinacea*) and sericea lespedeza (*Lespedeza cuneata*) may retard natural forest succession by 20 years or more, and compacted mine soils slow the facilitation processes commonly associated with forest succession (Ashby 1987; Williamson and Gray 1996). By contrast, reforestation procedures recommended by Burger and Torbert (1992) would result in a commercially-harvestable pine forest in 30 years.

The economic advantages of having land reclaimed with the purpose of growing productive forests are clear. With active management, productive forests may provide several commercial thinnings during the course of a rotation, which could provide early financial returns for the landowner. Intermediate stand treatments such as pruning of species like white pine result in more clear wood and usually increase the value of the stand at rotation age. Estimates indicate that pruning may increase yield return rates by 7 to 10 percent (Fight 1996).

However, traditional commercial forestry and practices like thinning and pruning that add additional value are viable options only when reclaimed land is successfully reforested. Successful establishment of commercial forests on mined land depends upon two critical factors: mine soil selection and construction, and a tree compatible ground cover. A tree-compatible ground cover (low stature and sparse cover) must be used to prevent trees from becoming shaded out before they become fully established. A suitable mine soil must be reclaimed in order to provide the soil attributes needed to ensure long-term forest productivity. Commercial forestry not only becomes possible, but it can be highly profitable when the two critical factors are properly addressed during reclamation.

Objectives

A research project was located on a pre-SMCRA bench on which a white pine plantation had been established in 1978 to demonstrate that commercial forestry is a viable option on reclaimed soil and that soil characteristics are paramount to developing a productive stand.

The specific objectives of this study were (1) to illustrate the feasibility and profitability of commercial forestry as a post-mining land use, and (2) to assess soil morphological and physical properties that determine white pine productivity on mine soils.

Methods

The study was conducted on a pre-SMCRA reclaimed contour mine located in Wise County, Virginia. In 1978, a white pine (*Pinus strobus* L.) plantation was established on the reclaimed bench. In 1996, a timber inventory was conducted to characterize the stand conditions and determine if the plantation needed to be thinned. The inventory showed that the plantation was overstocked (i.e. too many trees with not enough growing space per tree) (USDA Forest Service 1986), and required thinning (Table 1). The plantation was thinned to a desired level of stocking that would both maximize the growing space available for the remaining trees and prevent the invasion of other trees. In addition, the remaining trees were pruned to approximately 5 m (16.5 ft) to increase the future value of the sawtimber at final harvest.

Mine soil data were collected from 14 soil pits excavated to a depth of 1.0 to 1.5 m (3.3 to 5 ft) in order to determine the effects of soil morphological and physical properties on tree growth. The soil pits were located within the timber inventory plots. No bedrock or any other restrictive layer was encountered in any of the pits during pit excavation. Soil morphological characteristics (i.e., horizon depth, color, texture, structure, and roots) were described for each pit. Within each pit, intact soil cores were collected from each soil horizon and bulk density, total porosity, aeration and capillary porosity (i.e., macro- and micro-), and field capacity (% by volume) were measured from the soil cores (Am. Soc. Agron. 1965). Using these data, relationships between the soil properties and tree volume were explored using correlation analyses.

Results and Discussion

Stand Productivity

The average stand height was 14.3 m (47 ft), translating to a site index of 35 m (110 ft) for white pine (base age 50; i.e., a 50-year-old tree will be 110 feet tall), with site index being a measure of the site's ability to grow white pine. In southwestern Virginia, average site indices for undisturbed forest soils and post-SMCRA reclaimed mine soils are 24.4 m (80 ft) and 18.3 m (60 ft), respectively (Doolittle 1958, Torbert et al. 1994), indicating that the white pines growing on the pre-SMCRA reclaimed bench are exhibiting superior growth.

The stand basal area was 31 m^2 ha^{-1} (131 ft^2 $acre^{-1}$), which was considered to be overstocked for white pine. In order to reduce the stocking level, the stand was thinned to a basal area of 20 m^2 ha^{-1} (90 ft^2 $acre^{-1}$) (USDA Forest Service 1986). Cut and leave volumes are summarized in Table 1. The fact that this plantation required a thinning is significant because no other adjacent similar-age white pine plantation growing on post-SMCRA land was even close to this plantation's level of development and productivity.

Table 1. Initial stand data and thinning results for a 17-year-old white pine plantation growing on a reclaimed pre-SMCRA bench located in southwest Virginia.

Status	Basal Area per Acre (sq.ft.)	Volume per Acre (cu.ft.)	Stems per Acre
Cut	41	1346	318
Leave	90	3294	264
Total	131	4640	582

The measured site index for this white pine study, and the average site indices for typical reclaimed mine soils and undisturbed forest soils in this region (Doolittle 1958) were used to forecast standing volume at age 30 (Table 2). Based on these projections, the white pine plantation (non-compacted, sandstone, mine soil) would produce 32% more volume than average-quality undisturbed forest soils (Doolittle 1958), and approximately seven times the volume of the typical post-SMCRA reclaimed mine soil (Torbert et al. 1994). Projected total value for the white pine growing on the non-compacted, sandstone mine soil is $3,480 per acre, which would be twice the projected value of trees on average undisturbed Appalachian forest soils, and 28 times the projected value of the trees growing on average post-SMCRA reclaimed mine soils (Table 2). The difference in productivity and value between the typical reclaimed mine soil and the non-compacted, sandstone mine soil illustrates the tremendous lost opportunity when reclamation is not conducted with commercial forestry as the goal.

Soil Morphological Characterization

The parent material for the mine soil on the reclaimed bench was a partially-weathered, yellowish-brown, moderately-acid sandstone. Research has shown (Torbert et al. 1989) that this overburden material provides an excellent medium for trees because the majority of forest tree species in this region are adapted to soil pH's ranging between 5.0 and 5.5. Throughout the white pine plantation there was a well-defined O horizon overlying a shallow but well-defined A horizon. The A horizon texture ranged from sandy loam to loamy sand with granular structure. The C horizon was typically distinguished from the A based on a lighter color and a change to predominantly weak, subangular blocky structure. There was considerable variation in the C horizon due to occasional bands of coal, coal mixed with sandstone, and some intrusions of coal slurry. Purely based on observation, the decrease in coal content of the C horizon moving away from the high wall appeared to coincide with increased tree volume. Tree roots were observed throughout the soil profile in all soil pits; however, the majority of tree roots were concentrated in the A horizon.

Relationship Between Soil Physical Properties and Tree Growth

Bulk densities ranged from 1.00 to 1.25 g cm^{-3} in the A horizon, and from 0.96 to 1.44 g cm^{-3} in the C horizon (Table 3). These values are consistent with those reported by Zeleznik and Skousen (1996); they measured surface-soil bulk densities in the range of 1.07 to 1.22 g cm^{-3} for non-graded, non-compacted overburden that was supporting a closed-canopy, productive forest. Sufficiency curves developed for root growth as a function of bulk density show that for soils with sandy textures bulk density does not become restrictive until around 1.60 g cm^{-3} (Gale et al., 1991).

Table 2. The effects of soil type on white pine productivity and stand value after 30 years.

White Pine Site Type	Site Index (Base Age 50)	Standing Volume at Age 30 (cu.ft./acre)	Board Foot Volume at Age 30 (MBF*/acre)	Harvestable Wood Products	Harvest Price* ($/MBF)	Total Value ($/acre)
Projected Average Quality of a Post-SMCRA Reclaimed Mine Soil (Torbert et al. 1994)	60	1,020	6.1	Pulp	20	122
Average Quality of an Undisturbed Appalachian Forest Site (Doolittle 1958)	80	5,850	35.1	Small Sawtimber	50	1755
This Study Site	110	7,740	46.4	Large Sawtimber	75	3480

*MBF = thousand board feet

Table 3. Means and ranges of the mine soil A and C horizon physical properties measured on the study site.

Soil Horizon	Depth (cm)	Bulk Density (g/cm3)	Total Porosity (%)	Aeration Porosity (%)	Field Capacity (% by vol.)
A	5	1.11	57.9	32.6	20.1
(Range)	(2-8)	(1.00-1.25)	(52.8-62.2)	(24.4-42.5)	(16.1-23.9
C	>100	1.27	52.3	25.6	19.4
(Range)	(n/a)*	(0.96-1.44)	(45.8-63.7)	(17.3-40.9)	(15.3-25.5)

*Never reached bedrock.

A large part of the success of this white pine plantation can be attributed to the quality and depth of the mine soil. The excavated soil pits showed that the mine soil was > 1 m deep (~ 3 ft) with no obvious restricting layers (Table 3). Compaction caused during post-SMCRA mine soil construction can severely restrict tree growth because traffic pans commonly found in mine soils have densities greater than 1.7 g cm^{-3} (Torbert et al. 1994), a level that would severely limit root growth. Because the mine soil at this site showed no evidence of traffic pans or excess compaction, the low bulk densities combined with deep soil allowed the white pine roots fairly non-restricted access to a large soil volume. Mine soil rooting volume is a major determinant of forest productivity because a large mine soil volume means access to more water and nutrients. The low soil bulk densities and high productivity are consistent with the findings of Ashby et al. (1980) for mine soils in the central states; minimizing compaction during mine soil construction maximized tree growth.

Although the site was very productive overall, there were differences in tree volume within the site, with tree volumes ranging from 2.17 to 4.30 m^3. However, correlation analysis between tree volume and the soil physical properties revealed no meaningful relationships between tree volume and any soil physical properties (Table 4). There was a significant negative correlation between A horizon field capacity and tree volume; however, this relationship is most likely only statistical and not biologically meaningful because of the narrow range in A horizon field capacities. The lack of relationships between the soil physical properties and tree volume most likely indicates that the soil physical properties are non-limiting. Measured differences in tree volume may be explained by soil chemistry and/or possible unknown toxic effects of coal waste on tree growth. Soil chemical analyses and a study of mine soil chemistry effects on tree productivity is underway.

Table 4. Relationship between tree volume and mine soil physical properties.

Mine Soil Physical Property	Correlation Coefficient	P-value
A horizon		
Depth	0.087	0.438
Bulk Density	-0.307	0.743
Total Porosity	0.312	0.429
Aeration Porosity	0.421	0.200
Field Capacity	-0.772	0.002
C horizon		
Bulk Density	0.141	0.645
Total Porosity	-0.140	0.632
Aeration Porosity	-0.270	0.371
Field Capacity	0.358	0.210
Total Soil Field Capacity	0.160	0.586

Conclusions

The results of this study show that commercial forestry should be a viable and profitable post-mining land use. Comparing the volume of white pine growing on this deep, non-compacted, sandstone mine soil to that projected for an average post-SMCRA mine soil, standing volume is several times greater, and value is over 20 times greater due to the higher value of larger trees for solid wood products. White pine is a species with very high potential standing volumes. Hardwoods growing on comparable sites would carry lower volumes, but the same relative volumes and value among site qualities could be expected. Our results show that if soils are constructed of desirable material (e.g., weathered, moderately-acid sandstone) and compaction is minimized, mine soils are capable of wood production levels equivalent to, or exceeding the average for undisturbed soils in the region. These large differences in wood production on sites of different quality illustrate the need to encourage reclamation practices that promote tree growth so that restored forest land will be profitable for the landowner, meet society's needs, and meet the spirit and letter of the SMCRA.

Literature Cited

American Society of Agronomy. 1965. Methods of Soil Analysis (Vol. I), ASA Monograph 9. Madison, WI.

Ashby, W. C., C. A. Kolar, and N. F. Rogers. 1980. Results of 30-year-old plantations on surface mines in the central states. p. 99-107. In: Trees for Reclamation. USDA For.Serv.Tech. Rep. NE-61.

Ashby, W. C. 1982. Is good for trees good for corn? p. 15-18. In: C. A. Kolar and W. C. Ashby (ed.) Proc., 1982 Conf. On Postmining Productivity with Trees. Southern Illinois Univ., Carbondale.

Ashby, W. C. 1987. Forests. P. 89-108. In: W. R. Jordan III, M. E. Gilpin, and J. D. Aber (ed.). Restoration Ecology. Cambridge Univ. Press, New York.

Burger, J. A., and J. L. Torbert. 1992. Restoring forests on surface mined land. Virginia Cooperative Extension Publication 460-123. 16 pp.

Doolittle, W. T. 1958. Site index comparisons for several forest species in the Southern Appalachians. Soil Sci. Soc.Amer. Proc. 22:455-458. https://doi.org/10.2136/sssaj1958.03615995002200050023x

Fight, R. 1996.Pruning increases wood quality and potential profit. Temp. Agroforester 4(3):8.

Gale, M. R., D. F Grigal, and R. B. Harding. 1991. Soil productivity index: Predictions of site quality for white spruce plantations. Soil Sci. Soc. Am. J. 55:1701-1708. https://doi.org/10.2136/sssaj1991.03615995005500060033x

Torbert, J. L., T. Probert, J. A. Burger, and R. Gallimore. 1989. Creating productive forests on surface-mined land. Green lands 19(4):28-31.

Torbert, J. L., J. A. Burger, J. E. Johnson, and J. A. Andrews. 1994. Indices for indirect estimates of productivity of tree crops. OSM Coop. Agreement OR 996511 Final Report. Va. Polytechnic Inst. & State Univ., Blacksburg.

Torbert, J. L., Burger, J. A., and J. E. Johnson. 1994. Commercial Forestry as a post-mining land use. Virginia Cooperative Extension Publication 460-136. 6pp.

USDA Forest Service. 1986. Service Forester's Handbook. USDA For. Serv. Misc. Rep. SA-MR-10. Southern Region, State & Private Forestry, Atlanta, GA.

Williamson, D. L., and R. B. Gray. 1996. Evaluation of natural succession on reclaimed coal mine land in western Kentucky. p. 629-636. In: W. L. Daniels, J. A. Burger, and C. E. Zipper (ed.). Proc., 13th Ann. Mtg, Am. Soc. For Surface Mining and Reclamation. ASSMR, Princeton, WV. https://doi.org/10.21000/JASMR96010629

Zeleznik, J. D., and J. G. Skousen. 1996. Survival of three tree species on old reclaimed surface mines in Ohio. J. Environ. Qual. 25:1429-1435.

https://doi.org/10.2134/jeq1996.00472425002500060037x