COAL MINE RECLAMATION IN THE SOUTHERN APPALACHAINS: COSTS OF FORESTRY VERSUS HAYLAND/PASTURE[1]

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Abstract. The two most common options for post-mining land uses in the southern Appalachians are hayland/pasture or forestry. Hayland/pasture has become the predominant reclamation type due to strict regulation standards requiring quick and dense erosion control by herbaceous cover. Recently, more landowners have become interested in returning mined land to an economically valuable post-mining land use. Current research has provided the biological and technical information needed to reclaim mine lands to productive forest stands and achieve bond release. Cost information though has been lacking or variable at best. The purpose of this study was to understand the processes of reclamation for both forestry and hayland/pasture, and calculate detailed cost estimates for both reclamation types. Total costs of reclamation were determined using a cost-engineering method in conjunction with Office of Surface Mining Regulation and Enforcement bond-calculation worksheets. In all states analyzed, pasture reclamation was more costly on a per acre basis. In Ohio, reclamation costs differed by only $50 per acre between pasture and forestry reclamation. On the high end, reclamation costs differed by nearly $500 per acre for pasture versus forestry in West Virginia. Grading costs have the greatest impact on the difference between forestry and pasture reclamation. Forestry reclamation should involve only grading the site with one dozer pass to prevent compaction of minesoils which inhibits tree growth. Pasture reclamation requires more grading passes to prepare the seedbed, requiring four passes. Herbaceous seeding costs were higher for pasture reclamation due to higher application rates, but differences were not as substantial as the cost of grading. Fertilizer and lime costs were not substantively different between forestry and pasture reclamation. These cost estimates provide useful tools for mine operators and landowners to determine the most economical and suitable post-mining land use for their individual property.

Additional Key Words: Reforestation, Bond Calculation

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Introduction

Purpose of Study

The relative cost of forest versus hayland/pasture reclamation of surface mined lands in the Appalachian region has not been conclusively determined. Burger and Torbert (1990) claim that a forestry post-mining land use comprised of economically viable species requires little to no extra effort or expense after the beginning stages of reclamation. In contrast, Skousen (1989) claims that buying and planting of tree seedlings to provide a forestry post-mining land use is an added expense for the mine operator. In comparison, the reduced amount of grading and bulldozing work used in reforestation may offset the added expense of tree seedlings and planting, assuming the forestry reclamation approach is used during reclamation (Torbert et al., 1989).

Surface mine reclamation costs are not readily available in the current literature. When cost figures are available, a description or citation of what is included in these costs is often not given. Some cost figures do not differentiate between mining types, geographical area, or employment conditions. Whereas, most mine-reclamation costs are given on a per-acre basis, some are reported in per-ton, ton, or per-cubic yard measurements which exacerbate determining the reclamation cost for a particular site (Brooks 1979). This paper addresses component costs of surface coal mine-reclamation and factors that determine those costs.

Background

Prior to passage of the Surface Mining Control and Reclamation Act of 1977 (SMCRA), many attempts were made to reclaim mined land to forestry or hayland/pasture post-mining land uses. These attempts are documented by numerous experiments conducted throughout the mid 1930's and 40's. Although thousands of hectares of mined land became productive forest plantations or pastureland, many more acres were left un-reclaimed. As developments in mining technology intensified so too did the amount and area of disturbance caused by coal mining. Coal mining in the Appalachian mountains of the southeastern United States differed from mining in the mid-west. In the former, steep slopes and rough terrain caused enormous mud slides, while mine spoil eroded into Appalachian streams and rivers. This concern about stream health created a driving force for research in coal mine reclamation technology in the southern Appalachians (Plass 2000). In 1973 Congress enacted the "Seiberling Amendment" as a first attempt at achieving the goals now embodied in the SMCRA. This amendment imposed a tax on each ton of mined coal, with a higher tax on coal mined from surface mining operations as opposed to underground mines. This higher tax reflected an effort by Congress to attract companies to underground mining versus the more “visible” surface strip-mining operations (Goldstein and Smith, 1975). In 1966, Virginia enacted its first coal mining regulations and in 1977 President Jimmy Carter signed, Public Law #95-87, “The Surface Mine Control and Reclamation Act” (Plass 2000).

After passage of SMCRA many reclamation projects shifted from forestry to hayland/pasture due to the necessity of establishing grass and legume species immediately to a mined site to control erosion. Tree planting and survival was more difficult as these highly competitive herbaceous species quickly overtook the mine sites (Plass 2000). SMCRA states that mined land must be returned to its pre-mining land use or a higher and better use. Hayland/pasture was seen as a higher and better use due to the utility that could be theoretically gained from the grassland by grazing cattle or other livestock, or harvesting forage for sale.

Coal operators, too had little incentive to attempt reforestation, needing to extract the coal from a site and reclaim the area, thereby achieving bond release in the most timely and cost efficient manner. Tree planting was though to add risk to the bond release process due to the cost of planting seedlings and the risk of mortality. In the 1990’s these ideas began to change as more landowners became interested in forestry as a post-mining land use. Due to the rugged nature of most Appalachian property the land is valuable for little other use than forestry. Therefore landowners became increasingly interested in returning their mined land to a forestry post-mining land use so that future revenue could be gleaned from this land (Torbert and Burger, 2000).

The objectives of this study are to (1) document all the steps in the process of both forestry and hayland/pasture reclamation, (2) use a cost-engineering approach to determine unit costs for these processes, and (3) compare total costs of forest reclamation to those of hayland/pasture reclamation in the southern Appalachians.

Methods and Procedures

The geographic scope of this study is confined to the southern Appalachians including Kentucky, Maryland, Ohio, Pennsylvania, Tennessee, Virginia and West Virginia. These states are members of the Appalachian Regional Reforestation Initiative, which provides information on proper forestry reclamation techniques. To fulfill objective one, visits were made to the

Virginia Department of Mines, Minerals and Energy within the division of Mined Land Reclamation to review coal mine permits. These permits provided initial information regarding the processes of reclamation, as well as providing a sense of scale of mine lands in the southern Appalachians. Pertinent sections of the permits used included: Section 7.1 (Post-Mining Land Use), Section 9.3 (Soils), Section 9.4 (Revegetation), Section 10.1 (Operations Plan), Section 13.1 and 13.2 (Backfilling and Grading), and Section 19.1 (Bonding).

For hayland/pasture reclamation, the processes of reclamation include, backfilling/grading, seeding (herbaceous species), and addition of lime/fertilizer. Forest reclamation is similar, other than the added process of tree planting. Data for calculating grading costs were obtained from the 2006 *Caterpillar Performance Handbook* (Caterpillar 2006) and the 2000 *RS Means Heavy Construction Cost Data* (Chandler 2000). Herbaceous seeding prices were from four southeastern seed companies and the United States Department of Agriculture (USDA) national price data for 2006 (Agricultural Prices, 2006). Lime and fertilizer prices were also found using the USDA dataset. Tree seedling prices were obtained from the Department of Forestry/Division of Forestry state nursery seedling catalogs for each of the seven states analyzed. Tree planting was analyzed using both hand planting and machine planting costs as supplied by the 2005 publication of “Costs and Cost Trends for Forestry Practices in the South.” According to a study by Miller (1998), the most expensive part of reforestation is buying the planting stock and paying the tree planter. If available, this study found that mechanical planting was a cheap alternative to the more expensive option of hand planting seedlings. Cost savings were found using a machine planter due to the increased production of planting and less money being spent on labor wages. The rugged terrain and rocky soils of the Appalachians often limit the use of mechanical planters for eastern coal mine sites.

Grading

Using the Office of Surface Mining Reclamation and Enforcement 2005 *Handbook for the Calculation of Reclamation Bond Amounts*, per acre grading costs were developed (Equation 1). The cost framework is the same for both forestry and pasture with the end cost of grading for pasture reclamation being multiplied by four to represent the number of dozer passes recommended for pasture reclamation. Forestry reclamation grading cost is shown as the cost for one dozer pass since this number is most often cited in the literature.

(1)
$$\begin{bmatrix} \mathit{Adjusted\ Total} \\ \mathit{Grading\ Cost} \\ (\$/\mathit{acre})/\mathit{dozer\ pass} \end{bmatrix} = \begin{bmatrix} \mathit{Dozer\ Operating} \\ \mathit{Cost}\,(\$/\mathit{hour}) \end{bmatrix} \div \begin{bmatrix} \mathit{Net\ Hourly} \\ \mathrm{Pr}\mathit{oduction} \\ (\mathit{acre}/\mathit{hour}) \end{bmatrix}$$

The dozer-operating cost (Equation 2) is the cost of operating a bulldozer for one hour, taking into account factors such as maintenance, rental rates, and operator wage and fuel consumption. This cost must be adjusted to the specific locality by using location-adjustment factors provided in the RS Means Handbook (Chandler 2000).

(2)
$$\begin{array}{c}\text{Dozer}\\ \text{Operating Cost}\\ (\$/\text{hour})\end{array} = \left[\begin{array}{c}\text{Dozer Rental Rate}\\ (\$/\text{hour})\end{array} + \begin{array}{c}\text{Med. Equip}\\ \text{Worker Wage}\\ (\$/\text{hour})\end{array} + \begin{array}{c}\text{Dozer Fuel}\\ \text{Costs}\\ (\$/\text{hour})\end{array}\right] * (\text{Location Factor})$$

Dozer Rental Rate. The dozer rental rate was provided by the Caterpillar Performance Handbook (2006) for both D-4 and D-9 bulldozers. A monthly rental rate for a D-4 dozer was \$3,000 while a D-9 dozer was \$15,300 per month. Using a conversion factor of 160 hours per month, the monthly rental rate was converted to an hourly rental rate.

Labor. Medium equipment worker wage data were gathered from the RS Means Cost Data (Chandler 2000). The wage was reported as \$28.85 per hour for both the operator of a D-4 or D-9 bulldozer.

Fuel Costs. The Caterpillar Performance Handbook (2006) provided fuel consumption estimates for both D-4 and D-9 bulldozers performing light, medium, or high work. Light work includes finish grading, light maintenance, or road travel. This description best describes the work done during reclamation; therefore the average fuel consumption of a D-4 dozer performing light work is 2.75 gallons per hour, while a D-9 dozer consumes 10.5 gallons per hour. Average diesel fuel price for the United States was obtained from the U.S. Energy Information Administration (2006). The 2006 annual average was \$2.70 per gallon. The fuel cost is simply the bulldozer (D-4/D-9) hourly fuel consumption multiplied by the price per gallon of diesel fuel.

Location Factor. The cost of grading varies from state to state due to different working conditions and application scenarios. To account for this variation RS Means (2000) provides county adjustment factors for every state in the U.S. To obtain a state-wide location adjustment factor, county factors were averaged within each state. This factor is used to adjust the variables of dozer rental rate, worker wage and fuel costs.

Inflation Factor. Since the most recent version of RS Means Heavy Construction Cost Data available was from the year 2000, labor and rental rates needed to be adjusted for inflation. This was done using an inflation factor provided by Oregon State University (Sahr, 2005). The inflation factor for converting 2001 dollars to 2006 dollars was 0.848. Throughout this analysis, 2006 dollars were used since they were the most current available during the time of this project.

The second component of the total grading cost equation is the net hourly production factor (Equation 3).

$$(3)\quad \underset{\text{(acres/hour)}}{\text{Net Hourly Production}} = \underset{\text{(ac/hour)}}{\text{Hourly Production}} * \text{Operating Adjustment Factor}$$

Net Hourly Production. Net hourly production adjusts the hourly production to account for operator and efficiency factors. These factors affect productivity due to operator ability, weather conditions, and site conditions. To obtain net hourly production hourly production is multiplied by the three levels of operator adjustment factor.

Hourly Production. This is the amount of area a dozer can cover under ideal conditions in one hour. To calculate hourly production, average bulldozer speed is multiplied by the width of the dozer blade. The Caterpillar Handbook (2006) states that a D-9 dozer operates at an average speed of 2.4 mph in first gear while a D-4 dozer operates in first gear at an average speed of 2.8 mph. During grading, dozers tend to overlap a foot of area during subsequent passes. Therefore the effective blade width is the actual blade width minus the one foot of overlap. For most coal mine reclamation work, reclamation U-blades are used on the bulldozers. The actual width of the reclamation U-blade for a D-9 dozer is 17 feet, making the effective blade width 16 feet. A D-4 dozer reclamation U-blade has an actual width of 10.4 feet making the effective blade width 9.4 feet.

Operator Adjustment Factor. This factor accounts for eight variables which affect bulldozer productivity (Equation 4).

$$(4)\quad \text{Operator Adjustment Factor} = \text{Operator Factor} * \text{Material Factor} * \text{Efficiency Factor} * \text{Grade Factor} * \text{Weight Correction Factor} * \text{Production Method}$$

$$* \text{ Visibility Factor} * \text{Elevation Factor}$$

Operator Factor. This factor accounts for the variability found in machine operator abilities. The Caterpillar Handbook (2006) reports an excellent operator factor is 1, while a poor operator factor is 0.6. This analysis uses an average operator factor of 0.75.

Material Factor. This accounts for the difficulty of moving materials based on material composition. Values provided by The Caterpillar Handbook (2006) range from 0.6 for ripped/blasted rock, 0.8 for hard to cut or drift material, and 1.2 for loose stockpiled material. Torbert and Burger (2000) recommend for forestry reclamation that final graded material be end-dumped into place by trucks or other equipment to form a loose pile of material. Therefore this analysis will use 1.2 as the material factor.

Efficiency Factor. Bulldozer efficiency measures the amount of time the bulldozer is actually working during a 60 minute (1 hour) period. During a normal work hour, unknowns such as equipment repair, operator rest periods, inclement weather, or site inspection can cause equipment to not work an entire 60 minutes. Due to this the Caterpillar Handbook (2006) lists efficiency ratings based on the number of minutes worked out of a 60 minute period. A bulldozer working 50 minutes per hour has an efficiency factor of 0.83. This falls to 0.67 if the bulldozer is only productive for 40 minutes out of an hour. No efficiency factor is given for working an entire 60 minute period due to the inherent fact that during a day of work, at least some hours will not be full working hours with equipment running on the reclamation project. This analysis assumes bulldozers will be productive at a best case scenario of 50 minutes per hour and will use 0.83 as the efficiency factor.

Grade Factor. The grade factor accounts for changes in bulldozer speed as the site topography changes. When a bulldozer is traveling downhill (speed increases), the grade factor will be greater than 1; while traveling uphill (speed decreases), the grade factor is less than 1. To calculate a grade factor, slope estimates were first obtained from the Forest Service Northeastern Research Station (Prasad et al., 2006). Using the slope estimates a dozing factor for each state was determined.

Weight Correction Factor. This accounts for the differences in productivity due to load weights. For heavy, wet sand and gravel and a one-foot overlap, this factor is 0.91. Light shale has a correction factor of only 0.6. Torbert and Burger (2000) recommend using sandstone as the backfilled and graded material to provide optimal reclamation success. Sandstone has a weight correction factor of 0.6 and will be used for this analysis.

Production Method. This accounts for the dozing technique employed during reclamation. A single dozer will have a factor of 1. Slot dozing, used to move large quantities of dirt using the same path for each trip so spillage builds up along each side (Answers.com, 2008), incurs a factor of 1.2. Side-by-side dozing where two dozers work abreast with blade edges nearly touching (Engine Mechanics, 2008) has a production factor of 1.15. This analysis assumes a single dozer working alone, therefore making the production factor 1.

Visibility Factor. This factor accounts for productivity loss due to inclement conditions that reduce the operator's visibility. If dust, rain, snow, fog or darkness impairs visibility the factor is 0.8. This analysis assumes reclamation operations occur predominantly during favorable operating conditions that allow for normal visibility. The visibility factor will therefore be equal to 1.

Elevation Factor. This factor accounts for the difference in available horsepower due to changes in elevation. A D-9 dozer only has 85% horsepower when operating at elevations between 10,000 and 12,500 feet (Caterpillar, 2006). For a majority of the coal mining areas considered in this analysis in the southern Appalachians, elevation does not reach a height affecting horsepower availability. Therefore the elevation factor 1, indicating 100% horsepower is available during reclamation activities.

Fertilizer/Lime

Fertilizer and lime prices are from the USDA (Agricultural Prices, 2006) and adjusted for inflation and location. Labor costs for fertilizer application were given by RS Means (Chandler 2000) for a 12-inch tractor towed spreader (low), 8-inch tractor towed spreader (medium), and hyrdo-spreader (high). Labor costs for spreading lime are only given as one cost for mechanical spreading. Application rates of fertilizer and lime were found in Burger and Zipper (2002) and Daniels and Stewart (2000) for forestry and pasture reclamation, respectively. Forestry reclamation used either blended 19-19-19, blended 10-20-20, or a mix of ammonium nitrate and triple superphosphate fertilizers as Burger and Zipper (2002) recommended. Pasture reclamation used only three different application rates of ammonium nitrate mixed with one application rate of triple superphosphate (Daniels and Stewart, 2000).

Herbaceous Seeding

Herbaceous seeding is conducted for both forestry and pasture reclamation with differences in seed application rate and species used for the two reclamation types. This analysis reported herbaceous seeding cost by obtaining the price and application rate per seed type. Some seeding companies also blend seed mixtures to best suit the specific site. Cost estimates for these mixtures are highly variable and dependent upon site conditions and therefore were not used. Operators can obtain more precise herbaceous seeding cost estimates by contacting the company seeding the specific mine to determine if blended seed mixtures will be used and the cost of such mixtures. Burger and Zipper (2002) and Ashby and Vogel (1993) recommend a less competitive, lower seeding rate for forestry reclamation. Seed species and application rates (Table 1) for forestry reclamation were obtained from Burger and Zipper (2002). Pasture seed species and application rates (Table 2) came from Skousen and Zipper (1996).

Table 1: Forestry reclamation herbaceous seeding species and application rates (Burger and Zipper, 2002).

Species	(lbs/acre)
Perennial Ryegrass	10
Orchardgrass	5
Timothy	2
Foxtail Millet	5
Annual Rye	20
Birdsfoot Trefoil	5
Ladino Clover	3
White Clover	3
Weeping Lovegrass	2

Seed prices were obtained from DeBruyn Seed (DeBruynseed.com, 2007)), Outside Pride (Outsidepride.com, 2007), Seedland (Seedland.com, 2007), Stock Seed (stockseed.com, 2007), and USDA national average statistics (Agricultural Prices, 2006). Seed prices did not vary substantially among seed companies; the largest difference in herbaceous seeding costs depends on the application rate and type of labor. RS Means (Chandler 2000) provided three types of herbaceous seeding labor: push spreader (high), hyrdo-seeder (average), and tractor spreader (low), which are used in calculating seeding costs.

Table 2: Pasture reclamation herbaceous seeding species and application rates (Skousen and Zipper, 1996).

Species	lbs/ac
Kentucky Bluegrass	15-20
Smooth Brome	10-15
Tall Fescue	10-20
Weeping Lovegrass	2-5
Orchardgrass	10-20
Redtop	5-10
Perennial Ryegrass	10-15
Switchgrass	2-5
Timothy	5-10
Foxtail Millet	20-30

Tree Planting

Tree seedling prices were obtained from the Kentucky, Maryland, Ohio, Pennsylvania, Tennessee, Virginia, and West Virginia state nursery catalogs for the 2007-2008 growing season. Tree planting labor cost estimates were obtained from the 2005 Cost and Cost Trends for Forestry Practices in the South (Smidt et al., 2005). From this, a low hand-planting labor rate was used as well as a high machine-planting rate of for comparison. Although in certain conditions, machine planting may be a low cost option, this reference (Smidt et al. 2005), lists hand planting as the most cost effective option. Ashby and Vogel (1993) provide the recommended planting densities for reclaiming mine lands to a forestry post-mining land use to achieve bond release. The average number of trees per acre is multiplied by Department of Energy percentages of hardwood and softwood stand composition in the southern Appalachians (DOE, 2006). Hardwood and softwood seedling prices were averaged by state to calculate per acre tree planting costs. Burger et al (2002) in conjunction with the FRA developed a list of tree species most suitable to be planted in the southern Appalachians for a forestry post-mining land use (Table 3).

Table 3: Nurse and crop tree species recommended for forestry reclamation

Common Name	**Scientific Name**
Bristly Locust	*Robinia hispida var. fertilis*
Crab Apple	*Malus spp.*
Bicolor lespedeza	*Lespedeza bicolor*
Indigobush	*Amorpha fruticosa*
Dogwood	*Cornus florida*
Black Alder	*Alnus glutinosa*
Red Oak	*Quercus rubra*
Black Oak	*Quercus velutina*
White Oak	*Quercus alba*
Green Ash	*Fraxinus pennsylvanica*
White Ash	*Fraxinus americana*
Pignut Hickory	*Carya glabra*
Mockernut Hickory	*Carya alba*
Sugar Maple	*Acer saccharum*
Sycamore	*Platanus occidentalis*
Tulip Poplar	*Liriodendron tulipifera*
Black Cherry	*Prunus serotina*
White Pine	*Pinus strobes*

Results

Grading

Reforestation grading costs vary between $47.51 per acre and $193.25 per acre and are almost two times greater when using a D-9 bulldozer versus a D-4 bulldozer (Table 4). Hayland/pasture costs vary between $190.04 per acre and $773.00 per acre, and like reforestation nearly double when using a D-9 bulldozer rather than a D-4 (Table 5). Since four passes are required for pasture establishment, these grading costs are four time higher than those presented for reforestation.

Table 4: Per acre grading costs for forest reclamation (1 bulldozer pass).

	D-4	D-9
State	**Total Cost Grading-1 pass, avg ($/ac)**	**Total Cost Grading-1 pass, Avg ($/ac)**
Kentucky	63.52	120.16
Maryland	47.51	89.87
Ohio	52.21	98.76
Pennsylvania	61.93	117.15
Tennessee	53.21	100.65
Virginia	52.34	99.02
West Virginia	102.16	193.25

Table 5: Hayland/pasture grading reclamation costs (4 passes).

	D-4	D-9
State	**Total Cost Grading-4 passes, avg ($/ac)**	**Total Cost Grading-4 passes, avg ($/ac)**
Kentucky	254.07	480.64
Maryland	190.04	359.50
Ohio	208.82	395.03
Pennsylvania	247.71	468.60
Tennessee	212.83	402.61
Virginia	209.37	396.08
West Virginia	408.62	773.00

The greatest dozing cost difference is found in West Virginia, using a D-9 dozer under average conditions. This shows that pasture reclamation incurs a $773.00 per-acre grading cost while reforestation grading in West Virginia costs $193.25 per acre.

Fertilizer/Lime

Fertilizer application costs for forestry were nearly two percent lower than for pasture reclamation using an average application rate and average labor cost (Table 6). Lime application costs are the same for both forestry and pasture reclamation (Table 7).

Table 6: Per acre grading costs for pasture reclamation (4 bulldozer passes).

State	**Forestry Fertilizer Cost-AVG ($/ac)-med(L)**	**Pasture Fertilizer Cost-Avg N ($/ac)-med(L)**
Kentucky	59.62	112.09
Maryland	64.63	127.27
Ohio	65.48	119.77
Pennsylvania	69.48	132.12
Tennessee	56.60	109.07
Virginia	59.42	114.64
West Virginia	67.03	129.67

Table 7: Forestry and pasture reclamation fertilizer application costs ($/acre).

State	Limestone Cost-Avg ($/ac)
Kentucky	156.13
Maryland	163.61
Ohio	165.52
Pennsylvania	183.14
Tennessee	143.96
Virginia	155.66
West Virginia	173.28

Seeding

Herbaceous seeding costs (Table 8) differ between forestry and pasture by as little as $233 per acre in Virginia, and by as much as $285 per acre in Pennsylvania. The cost differences for seeding are due to the application rate and therefore are the same regardless of which labor rate is used. Again due to higher herbaceous seeding rates for pasture reclamation, this form of reclamation incurs a higher cost for every state analyzed.

Table 8: Limestone application costs for either forestry or pasture reclamation ($/acre).

	Forestry Seeding ($/ac)	Pasture Seeding ($/ac)	Difference ($/ac)
Kentucky	653.92	900.94	247.02
Maryland	662.39	912.59	250.2
Ohio	724.44	998.09	273.65
Pennsylvania	754.99	1040.17	285.18
Tennessee	596.23	821.46	225.23
Virginia	617.21	850.36	233.15
West Virginia	708.25	975.78	267.53

Tree Planting

Tree planting costs (Table 9) are shown for the average planting density and both the low and high seedling price for each state. For some states only one price is given, accounting for the null spaces. These cost estimates include the costs of purchasing seedlings and planting labor. Both hand and machine planting labor scenarios are given for comparison. Due to the rugged nature of the Appalachians it is assumed that hand planting is the technique most employed for reclamation plantings, although both hand and machine planting labor scenarios are included in the cost estimates for tree planting to aid in comparison.

Table 9: Tree planting costs ($/ac) for both hand and machine planted seedlings.

State	Total Planting Cost-Hand Planted-Low Price, Avg Density ($/ac)	Total Planting Cost-Hand Planted-High Price, Avg Density ($/ac)	Total Planting Cost-Machine Planted-Low price, avg density ($/ac)	Total Planting Cost-Machine Planted-High price, avg density ($/ac)
Kentucky	337.52	≠	582.58	≠
Maryland	314.74	496.03	563.59	744.87
Ohio	573.59	624.91	845.74	897.06
Pennsylvania	271.45	≠	555.08	≠
Tennessee	339.91	339.91	563.35	563.35
Virginia	352.33	486.63	583.37	717.66
West Virginia	418.95	452.49	486.03	718.56

Total Reclamation Costs

Total reclamation costs (Table 10) were calculated only using a D-9 dozer for grading and the average seeding, tree planting, and labor rates for both forestry and pasture reclamation. Ohio incurs the highest per-acre reclamation cost for a forestry post-mining land use, while West Virginia incurs the highest per-acre reclamation cost for hayland/pasture. A similar trend can be shown if total costs are calculated using the other grading, seeding, planting and labor scenarios.

Table 10: Total reclamation costs for forestry and pasture ($/acre).

	Forestry Reclamation ($/acre)	Pasture Reclamation ($/ac)	Difference ($/acre)
Kentucky	1327.35	1649.8	322.45
Maryland	1295.24	1562.97	267.73
Ohio	1627.79	1678.41	50.62
Pennsylvania	1396.21	1824.03	427.82
Tennessee	1237.35	1477.1	239.75
Virginia	1283.64	1516.74	233.1
West Virginia	1560.76	2051.73	490.97

In each state analyzed, pasture reclamation incurs the highest cost per acre. On the high end, the difference between the cost of pasture reclamation and forestry reclamation is $490.97 per acre in West Virginia. In comparison, in Ohio pasture reclamation incurs only a $50.62 per acre higher cost versus forestry reclamation.

Conclusions

Cost analyses show, grading costs exhibit the largest difference between forestry and hayland/pasture reclamation. For every state, grading costs were higher for pasture reclamation due to the increased number of bulldozer passes, more than offsetting the cost of tree seedlings and planting added to forestry reclamation. Herbaceous-seeding application also imparts a large cost to pasture reclamation due to the higher application rate. Lower seeding rates are used in forestry reclamation to prevent competitive herbaceous species from inhibiting tree growth. Fertilizer costs were nearly double for pasture reclamation as compared with forestry reclamation. This is due to a higher fertilizer application rate for pasture reclamation. A lower fertilizer application rate again aides in preventing competition from herbaceous species to the growth of tree seedlings.

Although many assumptions are made to calculate costs, especially the cost of grading, varying these factors (material, visibility, efficiency, elevation, etc.) does not substantially change the results. The same trends of Ohio incurring the highest cost for forestry reclamation and West Virginia incurring the highest cost for hayland/pasture reclamation are seen. These cost trends for Ohio and West Virginia are due to mainly topographic factors that are taken into consideration when using the RS Means location factor adjustment (Chandler 2000). Varying the above mentioned factors for each state would not change the final results and therefore one factor was used throughout the analysis. Factors that do impact the total costs of reclamation are total operator efficiency, labor method, and herbaceous seeding or tree planting application rate. When these factors are varied, especially if labor or application rate is increased, the total cost of reclamation increases for both forestry and hayland/pasture. Again though, under all scenarios analyzed, Ohio and West Virginia always incur the highest costs for forestry and hayland/pasture reclamation, respectively.

Cost estimates are important for coal operators due to the requirement of bonding. Reclamation performance bonds, which are based on projected costs, are required to insure the respective state agency can complete the reclamation if the mining company fails to do so as detailed in the reclamation plan. The performance bond is held by the state for a minimum of five years for both forestry and hayland/pasture reclamation while reclamation is ongoing. Bond is released in phases as certain steps in reclamation are completed and meet state agency inspection standards (DMME, 2005). Calculation of more precise bond amounts using accurate cost estimates can prevent operators from “over” bonding the permit area, thereby incurring greater opportunity costs due to the interest lost over the five-year bond period.

Accurate cost estimates also play a role in determining the post-mining land use for a particular site. Knowing that pasture reclamation may result in a higher cost for most areas, operators may choose to implement a forestry-reclamation approach more frequently. The factors analyzed can be manipulated to suit site-specific conditions that will provide even better cost estimates. These cost estimates can provide an important tool for mine operators to determine the best post-mining land use based on site conditions and costs.

Several other cost factors also may play a role in determining which post-mining land use is more economical. One factor currently being researched is the cost of cleaning sediment ponds for both forestry and pasture reclamation. Sediment ponds are required on surface mine sites prior to mining and must remain in place until all reclamation and drainage requirements are met. Many studies emphasized that forested landscapes decrease erosion due to higher infiltration rates versus non-forested landscapes, thereby decreasing sediment loads to ponds and requiring fewer cleanouts. This is a potentially large cost savings. Other costs such as deep tillage or ripping, pre-mine planning and consultant fees can also impact the total costs of reclamation. These costs are more site-specific and can be determined by the operator if needed.

One final note is that mine land reclamation is very site specific. Although this analysis has shown that in most states under ideal conditions pasture reclamation is more expensive, under variable conditions this may not always be the case. This project provides only initial reclamation cost estimates for forestry and pasture land in the southern Appalachians. This framework can provide mine operators and landowners the means to determine the most economically feasible post-mining land use option for their individual property.

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