From Forest Nursery Notes, Winter 2011

75. Private and social costs of surface mine reforestation performance criteria.
Sullivan, J. and Amacher, G. S. Environmental Management 45:311-319. 2010.

Environmental Management (2010) 45:311–319
DOI 10.1007/s00267-009-9395-4

Private and Social Costs of Surface Mine Reforestation Performance Criteria

Jay Sullivan · Gregory S. Amacher

Received: 7 April 2009 / Accepted: 7 October 2009 / Published online: 5 December 2009

Abstract We study the potentially unnecessary costs imposed by strict performance standards for forest restoration of surface coal mines in the Appalachian region under the Surface Mining Control and Reclamation Act of 1977 (SMCRA) that can vary widely across states. Both the unnecessary private costs to the mine operator and costs to society (social costs) are reported for two performance standards, a ground cover requirement, and a seedling survival target. These standards are examined using numerical analyses under a range of site productivity class and market conditions. We show that a strict (90%) ground cover standard may produce an unnecessary private cost of more than \$700/ha and a social cost ranging from \$428/ha to \$710/ha, as compared with a 70% standard. A strict tree survival standard of 1235 trees/ha, as compared with the more typical 1087 trees/ha standard, may produce an unnecessary private cost of approximately \$200/ha, and a social cost in the range of \$120 to \$208/ha. We conclude that strict performance standards may impose substantial unnecessary private costs and social costs, that strict performance standards may be discouraging the choice of forestry as a post-mining land use, and that opportunities exist for reform of reforestation performance standards. Our study provides a basis for evaluating tradeoffs between regulatory efficiency and optimal reforestation effort.

Keywords Mine reclamation · Regulation reform · Forest land value · Ground cover · Tree seedling survival · Post mining land use

Introduction

The Surface Mining Control and Reclamation Act of 1977 (SMCRA) requires that land on which surface coal mining operations in the United States are conducted be restored "to a condition capable of supporting the uses which it was capable of supporting prior to any mining, or higher or better uses" [Section 515 (b) (2)]. Though "higher or better uses" remain undefined in the law or by regulatory authorities, economic development opportunities for mined land are scarce in many rural areas such as the Appalachian coal region, and thus the most practical post-mining land use choices are either forestland or hayland/pasture. Since its enactment in 1977, the majority of mined land reclaimed in the region under SMCRA has been classified as hayland/pasture (Ford 2004; Isabell 2004).

The surface mine permit process begins with the determination of a post-mining land use (e.g., hayland/pasture, commercial forestry or non-commercial forestry), the choice of which must be consistent with surface owner plans, according to section 508 of SMCRA. In typical practice the choice is yielded to the mine operator who applies for the mining permit, which requires declaration of the post-mining land use, development of a reclamation plan, and posting of a performance bond. Following active mine operations on the site, available overburden is used to return the land to the approximate original contour. Topsoil, or the best available substitute material, is replaced and graded, and then stabilized through ground cover establishment. The first and second phases of bond release occur following successful

J. Sullivan (✉) · G. S. Amacher
Virginia Polytechnic Institute and State University, Forestry,
310 Cheatham Hall, Blacksburg, VA 24061, USA
e-mail: jsulliv@vt.edu

G. S. Amacher
e-mail: gamacher@vt.edu

grading and ground cover establishment, respectively, if the results are judged to be successful according to regulatory standards.

State-specific regulations specify performance standards that typically depend upon the permitted post-mine use. In the case of forest reclamation, which we examine, trees are planted, and following a prescribed liability period, judged as successful or unsuccessful. If successful, a final portion of the bond is released, but if judged to be unsuccessful, the site must be remediated, and the liability period is extended through another attempt at tree establishment. This process continues until final bond release has been achieved. The threat of losing future permit opportunities due to failed reclamation almost guarantees that mine operators continue to reclaim until successful, unless the mining firm ceases to be a business entity.

A key part of the reclamation process is the set of performance standards by which successful reforestation is judged. State regulators determine what constitutes successful reclamation, and these standards differ considerably across states. The fact that performance standards differ appreciably across states for no apparent reason begs the question of what the effects of more stringent or less stringent regulations are on the costs to reclaim land for both society and mine operators. Among the most critical performance standards are the percent of ground cover and number of surviving tree seedlings required for reclamation to be deemed successful. These are especially important for reclamation to forests, with both factors having a profound impact on the probability of meeting the seedling survival standard, as well as influencing the growth of surviving trees (Burger and others 2008a, b; Skousen and King 2004). Interest in the question of ground cover has arisen recently in Virginia and Tennessee. In Virginia, a previous standard requiring 90% ground cover for bond release, a standard tougher than any other state in the Appalachian coal region, was recently relaxed. In Tennessee, a "non-primacy" state that relies on federal performance standards with no state requirements of its own, the absolute 70% federal standard was also modified recently to specify simply a ground cover level necessary to control erosion.

While reclamation standards provide ease of enforcement and assure at least some minimum site stability on surface mined land, if a required performance standard is beyond that necessary to meet the protection need, it may place an avoidable economic burden on mine operators who thereby incur an unnecessary "private cost" of the performance standard. This unnecessary "private cost" might be incurred by the mine operator when, for example, a strict ground cover standard requires planting excessive herbaceous vegetation that provides little additional site stability, yet generates additional costs and may even inhibit tree establishment that can delay and further increase expected costs of achieving full bond release on a site. In addition to potentially imposing an unnecessary private cost, a strict performance standard also may not be in the best interest of society as a whole that would gain from timely forest establishment, and the consequent market-based and nonmarket benefits that would result. The reduced benefits to society resulting from the unnecessarily strict standard are referred to as "social costs." Though not necessarily providing definitive evidence, differing performance standards across states in the Appalachian region suggests that unnecessary private and social costs may be occurring.

In this article, we seek to understand and estimate the magnitude of potentially unnecessary private and social costs of forest reclamation performance standards on surface mine lands. Our cost analysis is based on the so-called Forest Reclamation Approach (FRA), which has been developed under the Appalachian Regional Reforestation Initiative (Angel and others 2005) to promote forest establishment on surface mined lands.[1] We examine both mine operator and public decision-maker/regulator perspectives and estimate the magnitude of private and social costs of strict performance standards for reforestation in the eastern Appalachian coal mining region. Our results will provide a basis for understanding and evaluating tradeoffs between regulatory efficiency and optimal reforestation effort on surface mine lands.

There are few formal economic studies concerning SMCRA mine-land reclamation, with exceptions being Sullivan and Amacher (2009), Gerard (2000), Erickson (1995), and Sullivan and others (2006). Sullivan and Amacher examine the gap between public and private reclamation effort, and associated social costs, under various bonding schemes. Erickson discusses how reclamation bond programs are applied throughout the World, drawing parallels between US, Canadian, and Australian cases. Gerard (2000) presents a model of the reclamation default decision for a mine operator, but he does not analyze the issue of bonding or the social costs inherent in private and public decision making. Sullivan and others (2006) examine the net present value of reclaiming to various forest types, but they do not examine bonding or social costs of mine operator private decisions. None of this work has considered the design of performance standards as we do here.

The remainder of the article is structured as follows. First, we examine a simple model that elaborates the

[1] The FRA is a five step process that involves: (1) creating a suitable rooting medium for good tree growth, (2) loosely grading the topsoil or topsoil substitute, (3) using tree-compatible ground covers, (4) planting both early successional trees for wildlife and soil stability and commercially valuable crop trees, and (5) using proper tree planting techniques (Burger and others 2005).

relationships between regulatory standards, and unnecessary private and social costs. Second, we construct a simulation based on this theory to assess the magnitudes of these costs and the efficacy of more or less stringent performance standards. Finally, we offer our conclusions.

Reclamation Standards, Decisions, and Costs

In reclaiming a surface coal mine to forest, we assume, following Sullivan and Amacher (2009), that a mine operator's objective is to minimize the expected costs of reforestation while meeting performance standards, thereby achieving bond release. Of course, forest reclamation costs must recognize effort expended in stabilizing/grading the site, establishing a suitable herbaceous ground cover, and planting and establishing tree seedlings. However, from a financial perspective, reclamation costs also must recognize the opportunity costs (foregone interest) of the performance bond, as well as the probability of failed reforestation/bond release and subsequent cost of remediation, both of which will raise expected costs. As mentioned previously, our cost estimates are based upon the FRA, in which limited grading to maintain a loose planting surface results in reduced costs compared with the conventional reclamation practice of multiple-pass grading. Determining the best decisions from an operator perspective requires weighing the tradeoff between higher initial cash outlays and a high probability of successful reforestation and consequent bond release verses lower initial outlays with a lower probability of early bond release. From this discussion, the mine operator's expected costs of reforestation $\mathrm{EC_{MO}}(F, \bar{S})$ are:

$$\mathrm{EC_{MO}}(F, \bar{S}) = C_{\mathrm{G}}\delta^{t_{\mathrm{M}}} + c_{\mathrm{F}}F\delta^{t_{\mathrm{M}}} + \int_{0}^{t_{\mathrm{M}}+t_{\mathrm{F}}} rB\delta^{t}\,\mathrm{d}t + [1-\rho(F, \bar{S})]\mathrm{EC}_2\delta^{(t_{\mathrm{M}}+t_{\mathrm{F}})} \quad (1)$$

where F is vegetation establishment effort, $\bar{S}$ is the imposed performance standard, C_{G} is the total cost of grading the site,[2] and c_{F} is the unit cost of establishing vegetation (e.g., herbaceous ground cover and hand planting trees). The (exogenous) performance bond is denoted as B, and $\rho(F, \bar{S})$ is the probability of successful bond release. Mining and reforestation time periods are represented by t_{M} and t_{F}, respectively, r is the interest rate, and δ is a discount factor (i.e., $\delta = e^{-r}$). At the reclamation stage of an overall mining operation, previous costs of mining are unrecoverable, often referred to as "sunk" costs, and thus they do not factor into current reclamation decisions.

In the event of unsuccessful bond release in the initial attempt, the process is repeated, and EC_2 represents the expected cost of the next forest establishment attempt:

$$\mathrm{EC}_2(F, \bar{S}) = c_{\mathrm{F}}F + \int_{t_{\mathrm{M}}+t_{\mathrm{F}}}^{t_{\mathrm{M}}+2t_{\mathrm{F}}} rB\delta^{t}\,\mathrm{d}t + [1-\rho(F, \bar{S})]\mathrm{EC}_3\delta^{t_{\mathrm{F}}}$$

Likewise, EC_3 represents the expected cost of the third attempt in the event that the second attempt fails, and the process repeats until final bond release is achieved.

Under reform in a performance standard that is fixed by regulation, the expected cost-minimizing level of forest establishment effort F can be determined for the initial standard. The unnecessary private cost $\mathrm{PC}(F^{\bar{S}''}, \bar{S}'')$ of a more stringent standard is then simply the difference between minimized costs under the lower performance standard and minimized costs with the more restrictive standard:

$$\mathrm{PC}(F^{\bar{S}''}, \bar{S}'') = \mathrm{EC_{MO}}(F^{\bar{S}''}, \bar{S}'') - \mathrm{EC_{MO}}(F^{\bar{S}'}, \bar{S}') > 0 \quad (2)$$

where $\bar{S}'$ and $\bar{S}''$ are less restrictive and more restrictive performance standards, respectively, and $F^{\bar{S}'}$ and $F^{\bar{S}''}$ are the cost-minimizing levels of forest establishment effort under each instrument. We anticipate the cost-minimizing level of forest establishment effort to increase with performance standard level, or: $\partial F^{\bar{S}}/\partial \bar{S} > 0$.

Sullivan and Amacher (2009) also consider a public decision-maker, acting in the best interest of society, who seeks to maximize the expected net social benefit of reclamation. Costs recognized by the public decision-maker also include costs of grading the site, establishing a suitable herbaceous ground cover, the costs of planting and establishing tree seedlings, the risk of failed reforestation efforts, and subsequent cost of remediation. However, the bond opportunity cost is not included, and in this case there is a new term representing the expected land value for the eventual reclaimed mine site. This land value capitalizes all future timber and non-timber values that arise once reclamation is complete. Expected net social benefits $\mathrm{ES_F}(F, \bar{S}, T)$ are therefore a modification of (1),

$$\begin{aligned}\mathrm{ES_F}(F, \bar{S}, T) = &- C_{\mathrm{G}}\delta^{t_{\mathrm{M}}} - c_{\mathrm{F}}F\delta^{t_{\mathrm{M}}} \\ &+ \rho(F, \bar{S})L_{\mathrm{F}}(F, T)\delta^{(t_{\mathrm{M}}+t_{\mathrm{F}})} \\ &+ [1-\rho(F, \bar{S})]\mathrm{ES}_2 \end{aligned} \quad (3)$$

where $L_{\mathrm{F}}(F, T)$ is the forest value upon establishment (i.e., the present net value of current and future stands, including non-timber benefits), and T represents the management regime of the established forest (e.g., rotation length and thinning schedule). ES_2 is expected benefit of the next

[2] Our cost of stabilizing and grading the site (C_{G}) includes the first two steps of the FRA process: (1) creating a suitable growth medium, and (2) loosely grading the topsoil or topsoil substitute. Costs of establishing ground cover and tree planting are included in c_{F}, with the level of effort in these activities (or F) being determined by the mine operator.

forest establishment attempt in the event of unsuccessful establishment in the first attempt:

$$\mathrm{ES}_2(F,\bar{S},T) = -c_F F\delta^{(t_M+t_F)} + \rho(F,\bar{S})L_F(F,T)\delta^{(t_M+2t_F)} + [1-\rho(F,\bar{S})]\mathrm{ES}_3$$

Determining the best decisions from the public decision maker's perspective requires evaluating the tradeoff between immediate cost, probability of successful reforestation, and the effect on the value of the established forest. We would not expect this future forest land value to be of much interest to the mine operator. Hence, with the mine operator typically in charge of establishing the reclamation plan within restrictions imposed by regulations, as discussed previously, we would not expect identical reforestation decisions between the public decision maker and the mine operator, even though they meet the same ground cover standard.

Continuing with an idea of reform in the performance standard, the social cost of a more stringent standard is therefore the difference between the social benefit (3) obtainable under the less restrictive performance standard and the social benefit under the most restrictive performance standard, in both cases using mine operator choices of F, or:

$$\mathrm{SC}(F^{\bar{S}''},\bar{S}'',T^{\bar{S}''}) = \mathrm{ES}_F(F^{\bar{S}'},\bar{S}',T^{\bar{S}'}) - \mathrm{ES}_F(F^{\bar{S}''},\bar{S}'',T^{\bar{S}''}) > 0 \qquad (4)$$

where $F^{\bar{S}'}$ and $F^{\bar{S}''}$ are the mine operator decisions regarding tree planting effort under the two levels of performance standards, and $T^{\bar{S}'}$ and $T^{\bar{S}''}$ are net social benefit-maximizing management decisions for the established forest under the less restrictive and more restrictive standards, respectively. These forest management decisions are influenced by the choice of forest establishment effort F, and hence by the reclamation performance standard, although the sign of $\partial T^{\bar{S}}/\partial\bar{S}$ is indeterminate except through numerical analysis.

Numerical Analysis of Performance Criteria Reform

Our empirical analysis focuses specifically on the unnecessary private and social costs of two different forest reclamation performance standards: (1) a more stringent ground cover requirement enforced until recently in Virginia, where 90% ground cover was required for phase 2 bond release as compared to 70% ground cover requirements found elsewhere in the Appalachian region, and (2) a tree seedling survival requirement of 1235 trees/ha (500 trees per acre) for phase 3 bond release in West Virginia compared with a less stringent, but more typical, 1087 trees/ha (440 trees per acre) requirement. Other similar performance standard disparities exist across states, but these examples serve to illustrate the potential that exists for reducing private and social costs through targeted regulatory reform.

A numerical estimation of reforestation costs begins with an examination of optimal mine operator choices, in cases of more and less stringent standards. These choices then determine unnecessary private costs (Eq. 2) and social costs (Eq. 4) that could be mitigated by regulation reform. Information necessary for our estimation includes reclamation costs, performance bonding practices, seedling survival and forest growth as a function of reclamation activities, and forest product and service values.

Forest reclamation costs were estimated recently for the Appalachian coal region by Baker (2008), who found that average costs for forest reclamation varies from approximately \$3600 to \$4700/ha across six states in the region. Costs used in our study include grading, hydro-seeding to establish herbaceous ground cover, and tree planting (Table 1).

For our analysis, the performance bond level is assumed to be based upon anticipated reclamation costs. A variety of alternative financial security schemes are available under the regulations, but the cost-based bond is available to operators of all sizes and best represents the conceptual purpose of bonding; i.e., to ensure that funds exist to reclaim the site to the permitted post-mine use in the event that the operator fails to do so. In addition to the direct layout of the bond itself, an opportunity cost of foregone interest on the bond is calculated over the period from permit approval, through the active mining period, and until full bond release is achieved. We must also account for the fact that bond release is phased, with the first portion being returned when grading is completed (phase one), the second portion being returned when ground cover is established (phase two), and the final portion being returned when trees are judged to be successfully established (phase three). Bond release phases vary by state, but we use a typical allocation of 60% returned following phase one, 25% being returned following phase two, and the remaining 15% being returned after phase three (Baker 2008).

Table 1 Estimated costs of forest reclamation, Virginia

Activity	Unit cost (low–high)
Grading	\$245–299/ha per pass[a]
Hydroseeding	\$2616–2744/ha[b]
Planting	\$0.29–2.77/seedling[c]

Source: Baker 2008

[a] Difference based on equipment used: D9 vs. D11 bulldozer

[b] Difference based on fertilizer blend; and includes lime, mulch, seed, and labor

[c] Includes seedlings and labor, and differences come primarily from state seedling prices

Seedling survival associated with varying levels of herbaceous ground cover is used to determine the probability of successful phase three bond release and is based on Skousen and King (2004) and Burger and others (2008a, b). Using data from these studies, the probability of the tree establishment standard being achieved is determined as a function of ground cover and seedling planting density. When the tree establishment standard is not achieved, replanting of failed areas is assumed to take place at the same density as the original area.

Considering future forest land value, an important component of the public decision-maker/regulator decision process, we use the Hartman (1976) concept of bare land value $L(F,T)$ that is based upon the net present value of future site benefits (timber and non-timber) and costs,

$$L(F,T) = \frac{pQ(F,T)\delta^T - c_{\mathrm{mh}}F\delta^T + \int_0^T A(t)\delta^t\,\mathrm{d}t}{1-\delta^T} \tag{5}$$

where $Q(F, T)$ is the timber yield per hectare at harvest, as a function of reforestation intensity F and rotation length T in future rotations, p is the stumpage price of mixed hardwood timber, c_{mh} is the unit cost of mixed hardwood reforestation effort in future rotations, and $A(t)$ is the non-timber forest benefit per hectare at stand age t.

Estimation of land value requires projection of future timber volumes, forest product prices, and non-timber benefits associated with forest establishment that occurs through the reclamation process. Timber volume is estimated using a growth model for mixed Appalachian hardwoods developed using inventory data from reclaimed mined sites across the region (Sullivan and others 2006). This growth model is sensitive to site quality, stand density, and stand age, and uses forest inventory data from a study of fourteen planted forest sites on reclaimed mine land across seven states, in mid-western and eastern U.S. coalfields (Rodrigue 2001). These fourteen sites, each with an average size of 2.5 ha of uniform and contiguous forest cover, range from 20 to 55 years old, and cover a broad spectrum of mine spoil types. Five site quality classes are considered in our forest growth calculations, and hence in our social cost simulations, ranging from a highest quality class (class I) of 30 m of tree growth at a 50 year white oak base age to a lowest quality class (class V) of 14 feet at the base age of 50 years.

Both low and high price assumptions are considered in the land value calculations. Low prices are based on 2008 Timber Mart-South third quarter standing timber prices for mixed hardwoods in the mountains of Virginia, and high prices are derived from the 2008 Pennsylvania Woodlands third quarter timber market report, with these two locations representing the relative extremes of the timber market in the Appalachian mine region.

Alternative rates of return of 3.5, 5, and 7.5% are considered to reflect the opportunity cost of money expended in mine reclamation. A 5% discount rate is a common baseline for reforestation analyses. Further, we assume a five-year mining period prior to the commencement of reclamation activities, which is representative of a relatively large mining operation in our study region (a sensitivity analysis, available upon request, confirmed that this is not a restrictive assumption). In addition, we assume a reclamation "liability" period of five years, which is common practice in the region.

For non-timber forest benefits, we use function in which benefits vary over age of the trees according to: $A(t) = a_1 t e^{a_2 t}$, where a_1, a_2 are the parameters that define intercept and curvature, respectively. This function has been used recently in forest-based simulations (Swallow and Wear 1993; Swallow and others 1990, 1997; Amacher and others 2005; Sullivan and Amacher 2009) and accounts for between \$20 and \$30 of valued added to land value per hectare over the range of our optimal rotation lengths**.** The parameters of this function were calibrated to achieve an annual stream of values that are similar to those presented in Wear and Greis (2002) for U.S. Southeastern forests.

The numerical analysis proceeds in the following steps: (1) expected cost minimizing choice of tree planting intensity is determined for the mine operator (Eq. 1) under each scenario regarding herbaceous ground cover density and discount rate; (2) land value-maximizing rotation length and planting intensity on future forest rotations (Eq. 5) are determined for the public decision-maker under each scenario defined by herbaceous ground cover density, site quality, timber price level, and discount rate; and (3) expected net public benefit maximizing management of first forest rotation is determined (Eq. 3) for each scenario using the mine operator choice of tree planting intensity[3] (from step 1 above) and optimal future rotation management (from step 2 above). Unnecessary private cost to the mine operator (Eq. 2) is estimated by comparing minimized cost in step 1) across lower and higher ground cover performance standards. Social cost (Eq. 4) is estimated by comparing maximized net public benefits from step 3) between lower and higher ground cover standards.

Operator Choices and Unnecessary Private Costs

Beginning with mine operator choice of tree planting density, our simulations show how this choice is influenced

[3] Mine operator choice of planting density is used in social cost calculations, because we assume that planting intensity is chosen by the operator, and in maximizing public benefits the public decision-maker would only make forest management decisions, such as rotation length and future rotation tree stocking levels.

by both ground cover density and tree survival standards for a range of discount rates (Table 2). In general, optimal tree planting density increases as the ground cover and seedling survival standards become more stringent, and higher discount rates are associated with lower planting densities for any given performance standard. Given a documented inverse relationship between ground cover and probability of seedling survival (Skousen and King 2004; Burger and others 2008a, b), a more strict ground cover standard leads to greater planting densities to avoid reductions in the chance of successful tree establishment, and hence to avoid delayed bond release. Similarly, a more stringent tree survival standard leads to a higher optimal planting density for a given discount rate. As expected, the higher opportunity cost of forest establishment expenditures associated with a higher discount rate leads to a reduction in tree planting density, and consequently, acceptance of greater risk of tree establishment failure.

Based on mine operator-selected planting density, we calculate the unnecessary private costs associated with the more stringent performance standards (Table 3). These unnecessary private costs occur as a result of initial planting cost differences across standards, as well as expected future costs that are driven by differences in the probability of attaining successful bond release associated with each performance standard scenario. According to our findings, a 90% ground cover standard may impose a substantial unnecessary private cost of more than \$700/ha, as compared with a 70% standard, depending upon the discount rate. With the recent regulatory change occurring in Virginia to reduce required ground cover density from 90% for phase two bond release to 70% of vegetative stocking on a representative reference area, the consequent private cost savings may provide an important incentive for encouraging mine operators to choose reforestation of surface mine lands that would otherwise have been reclaimed to hayland/pasture, foregoing potentially valuable land rents. A strict tree survival standard of 1235 trees/ha, as compared with the more typical 1087 trees/ha standard, may result in a somewhat smaller private cost than the strict ground cover standard, in the vicinity of \$200/ha, but it still may impose a substantial private disincentive for reforestation.

It should be noted that our private choice and private cost results are invariant to forest site quality and timber price scenarios. Timber price is relevant to the value of the established and future forests, primarily, and these are not components of the mine operator's costs for reasons discussed earlier. Further, the field studies upon which we base our empirical analyses do not find forest site quality class to be a fundamental factor in the probability of seedling survival, and hence, it does not factor into our results. If a relationship between site quality and forest establishment were to be found and documented, then it could be incorporated easily into our model.

Table 2 Simulated mine operator choice of tree planting density for forest reclamation (trees per hectare shown)

	Discount rate		
	3.5%	5%	7.5%
Performance standard			
Ground cover[a]			
>90% of full cover	2056	2004	1398
>70% of full cover	1920	1875	1341
Seedling survival[b]			
>1235 trees/ha	2161	2103	1521
>1087 trees/ha	1920	1875	1341

[a] Ground cover standard is evaluated with the tree survival standard set at 1087 trees/ha

[b] Seedling survival standard is evaluated using a 70% ground cover establishment

Table 3 Unnecessary private cost[a] of strict forest reclamation performance standards (dollars per hectare shown)

	Discount rate		
	3.5%	5%	7.5%
Performance standard			
Ground cover			
>90% compared with >70% cover	736.35	731.93	688.70
Seedling survival			
>1235 compared with >1087 trees/ha	232.54	226.34	180.58

[a] Unnecessary private cost is the difference between minimized mine operator costs under the lower performance standard and minimized mine operator costs with the more restrictive standard

Public Choices and Social Costs

Public decision-maker choices regarding the reclaimed forest may be only slightly influenced by performance standards, as indicated by our findings concerning rotation length (Table 4). As expected, rotation choice is inversely related to site quality and timber price under any given performance standard. More relevant to the issue of the performance standard is the overall slight increase in chosen rotation length for more stringent performance standards, except for a few cases at the lowest (3.5%) interest rate for the ground cover analysis. In our typical case, mine operator choice of planting density under a strict performance standard alters volume growth of the established forest in such a way as to delay financial maturity of the stand, and the public decision-maker choice of rotation length is correspondingly extended. The increase in rotation length associated with the more stringent seedling

Table 4 Simulated public decision-maker choice of initial rotation length of reclaimed forest using mine operator choice of planting density (rotation length shown in years)

Site class[a]	3.5% Discount rate		5% Discount rate		7.5% Discount rate	
	High prices	Low prices	High prices	Low prices	High prices	Low prices
>90% Ground cover standard[b]						
I	52.8	58.0	46.5	51.0	40.7	44.8
II	53.2	58.6	46.8	51.4	41.0	45.2
III	65.8	71.9	58.1	63.1	51.4	55.9
IV	66.8	73.4	58.8	64.1	52.0	56.7
V	67.9	75.2	59.6	65.4	52.6	57.6
>70% Ground cover standard[b]						
I	53.1	58.0	46.4	50.6	40.4	44.3
II	53.5	58.5	46.7	51.0	40.7	44.6
III	65.6	71.3	57.7	62.4	51.0	55.2
IV	66.6	72.7	58.4	63.5	51.6	56.1
V	67.6	74.4	59.2	64.7	52.2	57.0
>1235 Seedlings/ha survival standard[c]						
I	53.1	58.0	46.4	50.7	40.5	44.4
II	53.5	58.5	46.7	51.1	40.7	44.7
III	65.7	71.4	57.8	62.5	51.1	55.3
IV	66.6	72.9	58.5	63.6	51.7	56.2
V	67.7	74.6	59.3	64.8	52.3	57.2
>1087 Seedlings/ha survival standard[c]						
I	53.1	58.0	46.4	50.6	40.4	44.3
II	53.5	58.5	46.7	51.0	40.7	44.6
III	65.6	71.3	57.7	62.4	51.0	55.2
IV	66.6	72.7	58.4	63.5	51.6	56.1
V	67.6	74.4	59.2	64.7	52.2	57.0

[a] Site class represents growth potential, ranging from 30 m of white oak height growth after 50 years on site I land to 14 m of height growth on site V land

[b] Ground cover standard is evaluated with the tree survival standard set at 1087 trees/ha

[c] Seedling survival standard is evaluated using a 70% ground cover establishment

Table 5 Social cost[a] of strict forest reclamation performance standards (dollars per hectare shown)

Site class[b]	3.5% Discount rate		5% Discount rate		7.5% Discount rate	
	High prices	Low prices	High prices	Low prices	High prices	Low prices
>90% Ground cover compared with >70% cover						
I	710.33	664.31	577.31	556.87	439.41	434.39
II	695.96	654.93	571.31	553.10	438.07	433.60
III	648.55	623.73	548.10	538.55	431.85	429.98
IV	632.74	613.50	542.38	535.00	430.83	429.38
V	619.66	605.05	537.66	532.07	429.99	428.89
>1235 Seedlings/ha survival compared with >1087 seedlings/ha						
I	208.92	200.80	178.21	174.06	121.62	120.81
II	207.49	199.88	177.51	173.63	121.50	120.74
III	199.88	195.03	173.13	170.99	120.52	120.18
IV	198.23	193.97	172.43	170.56	120.41	120.12
V	196.78	193.02	171.82	170.18	120.32	120.06

[a] Social cost is the difference between the social benefit obtainable under the less restrictive performance standard and the social benefit under the most restrictive performance standard

[b] Site class represents growth potential, ranging from 30 m of white oak height growth after 50 years on site I land to 14 m of height growth on site V land

survival standard is less than that found for the more stringent ground cover standard, indicating a greater impact of the ground cover standard on reclamation.

Social costs, again calculated as the difference between public benefits of the less restrictive and more restrictive performance standards (Eq. 4), vary from \$428/ha to \$710/ha for the strict ground cover and from \$120/ha to \$208 for the seedling survival standard (Table 5). Social cost decreases as site quality and timber price declines, given that less potential forest value is at stake. As with private costs, social costs are substantially greater for the strict ground cover standard for any combination of site, interest rate, and price. This finding reflects a greater stringency of the ground cover standard compared with the tree survival standard.

Across all site classes and price levels, social costs fall below private cost for each corresponding performance standard. Although social cost does incorporate future forest values, which private cost does not recognize, social cost does not incorporate opportunity costs of the performance bond faced by the mine operator. The magnitude of opportunity costs apparently makes changes in the performance criteria more critical to expected private outcomes than to social desirability. We should note that we have not included in our social costs the potential benefits that more stringent performance standards might bring in terms of reduced erosion and possibly greater guarantee of stabilized slopes in the short run until the forest is fully established. This omission might raise concern that a relaxed performance standard might not provide sufficient protection. However, we find no evidence in the literature of a quantifiable relationship between performance standards and negative environmental outcomes over the range of standards that we consider. Further, in our analysis, we compare the strict performance standards only to those that are more typical across the region, and do not advocate eliminating the standards altogether, or reducing them to a point below which efficacy of the standard might be questionable.

Conclusions

Our analysis supports at least three conclusions concerning reforms in performance standards for forestry reclamation of surface mines. First, our results show that strict standards may in some cases impose substantial unnecessary private and social costs, and a relaxation of these standards might benefit both mine operators and society. For example, Virginia's recent relaxation of a 90% ground cover standard to a 70% standard may save operators more than $700/ha, and yield benefits to society of nearly the same magnitude. Both private operators and public decision-makers might be interested in reducing these costs where practical. Although our analysis emphasizes potential monetary costs, we do not want to overlook that strict performance standards may be imposing environmental costs where the relaxation of ground cover and survival standards could allow more rapid forest succession and greater species diversity than may be found under the strict standards (Groninger and others 2007).

Second, given that it is the mine operator who typically makes the post-mining land-use decision, our results regarding private costs suggest that strict performance standards may not encourage the selection of forestry as post-mining use. This finding is important where ever forest use is deemed socially more valuable than hayland/pasture, and therefore is socially desirable to encourage. Strict standards impose additional costs on private operators of planting trees directly, but also impose costs indirectly by reducing the probability of successful forest establishment for any given tree planting density, which subsequently entails additional mitigation and opportunity costs. Multiplied across hundreds of thousands of hectares of land under original permits, as well as abandoned mine lands available for re-mining, these private costs may have important implications for post mining land use in the Appalachian region. In addition, concern has been expressed that many thousands of hectares that previously were reclaimed to hayland/pasture under SMCRA have been left unmanaged when they could have been reclaimed to a more productive forest condition (e.g., Burger and Zipper 2009), perhaps for this very reason.

Finally, although we do not incorporate the erosion and slope stabilizing benefits of strict performance standards, our results suggest that opportunities may exist to consider reform in performance standards nonetheless. A reexamination is perhaps especially appropriate where standards in one state are out of line with those in states with similar conditions, possibly indicating that private and social costs could be reduced without imposing undue environmental risks. As we have shown, designing optimal forest reclamation policies requires an understanding of both the costs and benefits of performance standards, over a full range of site conditions, but also the potential administrative costs of a policy change.

References

Amacher G, Malik A, Haight R (2005) Don't get burned: the importance of fire prevention in forest management. Land Economics 81(2):284–302

Angel P, Davis V, Burger J, Graves D, Zipper C (2005). The Appalachian Regional Reforestation Initiative. Forest Reclamation Advisory Number 1, 2 pp

Baker KL (2008) Costs of reclamation on southern Appalachian coal mines: a cost-effectiveness analysis for reforestation versus hayland/pasture reclamation. M.S. thesis. Department of Forestry. Virginia Polytechnic Institute and State University, 103 pp

Burger JA, Zipper CE (2009) Restoring the value of forests on reclaimed mined land. Virginia Cooperative Extension Publication Number 460-138

Burger J, Graves D, Angel P, Davis V, Zipper C (2005). The forestry reclamation approach. Appalachian Regional Reforestation Initiative. Forest Reclamation Advisory Number 2, 4 pp

Burger JA, Mitchem DO, Zipper CE, Williams R (2008a) Hardwood reforestation for phase III bond release: need for reduced ground cover. In: Proceedings, 2008 national meeting of the American society of mining and reclamation

Burger JA, Zipper CE, Skousen J (2008b) Establishing ground cover for forested post-mining land uses. Virginia Cooperative Extension Publication Number 460-124

Erickson D (1995) Policies for the planning and reclamation of coal-mined landscapes: an international comparison. Journal of Environmental Planning and Management 38(4):453–467

Ford V (2004) Biological and economic hurdles to private forest ownership of reclaimed strip mines. In: Proceedings of the American society of mining and reclamation, April 18–24, Morgantown, WV

Gerard D (2000) The law and economics of reclamation bonds. Resources Policy 26:189–197

Groninger J, Skousen J, Angel P, Barton C, Burger J, Zipper C (2007) Mine reclamation practices to enhance forest development through natural succession. Appalachian Regional Reforestation Initiative, Forest Reclamation Advisory Number 5, 5 pp

Hartman R (1976) The harvesting decision when a standing forest has value. Economic Inquiry XIV:52–58

Isabell M (2004) Forestry: a practical use for surface mining? In: Proceedings of the American society of mining and reclamation, April 18–24, Morgantown, WV

Rodrigue JA (2001) Woody species diversity, forest and site productivity, stumpage value, and carbon sequestration of forests on mined lands reclaimed prior to the passage of the Surface Mining Control and Reclamation Act of 1977. M.S. Thesis. Virginia Polytechnic Institute and State University

Skousen J, King J (2004) Tree survival on mountaintop mines in Southern West Virginia. West Virginia University Extension Service, 5 pp

Sullivan J, Amacher GS (2009) Social costs of mine-land reclamation. Land Economics 85(4):712–726

Sullivan J, Aggett J, Amacher G, Burger J (2006) Financial viability of reforesting reclaimed surface mined lands, the burden of site conversion costs, and carbon payments as reforestation incentives. Resources Policy 30:247–258

Swallow S, Wear D (1993) Spatial interactions in multiple-use forestry and substitution and wealth effects for the single stand. Journal of Environmental Economics and Management 25(2):103–120

Swallow S, Parks P, Wear D (1990) Policy-relevant nonconvexities in the production of multiple forest benefits. Journal of Environmental Economics and Management 19(2):264–280

Swallow S, Talukdar P, Wear D (1997) Spatial and temporal specialization in forest ecosystem management under sole ownership. American Journal of Agricultural Economics 79(2):311–326

Wear D, Greis J (2002) Southern Forest Resource Assessment. General Technical Report SRS-53. U.S. Department of Agriculture, Forest Service, Southern Research Station, Asheville, NC