
Economics of Surface Mine Reforestation: Mine Operator and Landowner Perspectives

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Background

- Public Law 95-87, SMCRA 1977 mandates mined land reclaimed to a condition at least as productive as before mining
- Reclamation decision made by mine operator and regulator, who posts a performance bond to cover cost of reclamation in case of abandonment
- Landowner may be interested in land productivity, production/revenue, non-timber values from the reforested site; not necessarily consistent with mine operator incentives
- We examine reforestation decisions under a variety of site and economic conditions, as well as differences in reforestation incentives between mine operators and landowners

Mine Operator Perspective

- Incentives and considerations:
 - Establishment costs
 - Soil segregation C_S
 - Grading, forest site preparation, planting C_F
 - Foregone bond interest $r \times B$
 - Length of mining operation/reforestation t_M and t_F
 - Probability of establishment success $\rho(F)$
- Determine: establishment effort F (planting density, site prep intensity)
- Minimize expected discounted costs:

$$EC(F) = -C_S - C_F F e^{-rt_M} + \rho(F) \left[- \int_0^{t_M+t_F} r B e^{-rt} dt \right] + [1 - \rho(F)] \left[- \int_0^{t_M+t_F} r B e^{-rt} dt + EC_U e^{-r(t_M+t_F)} \right]$$

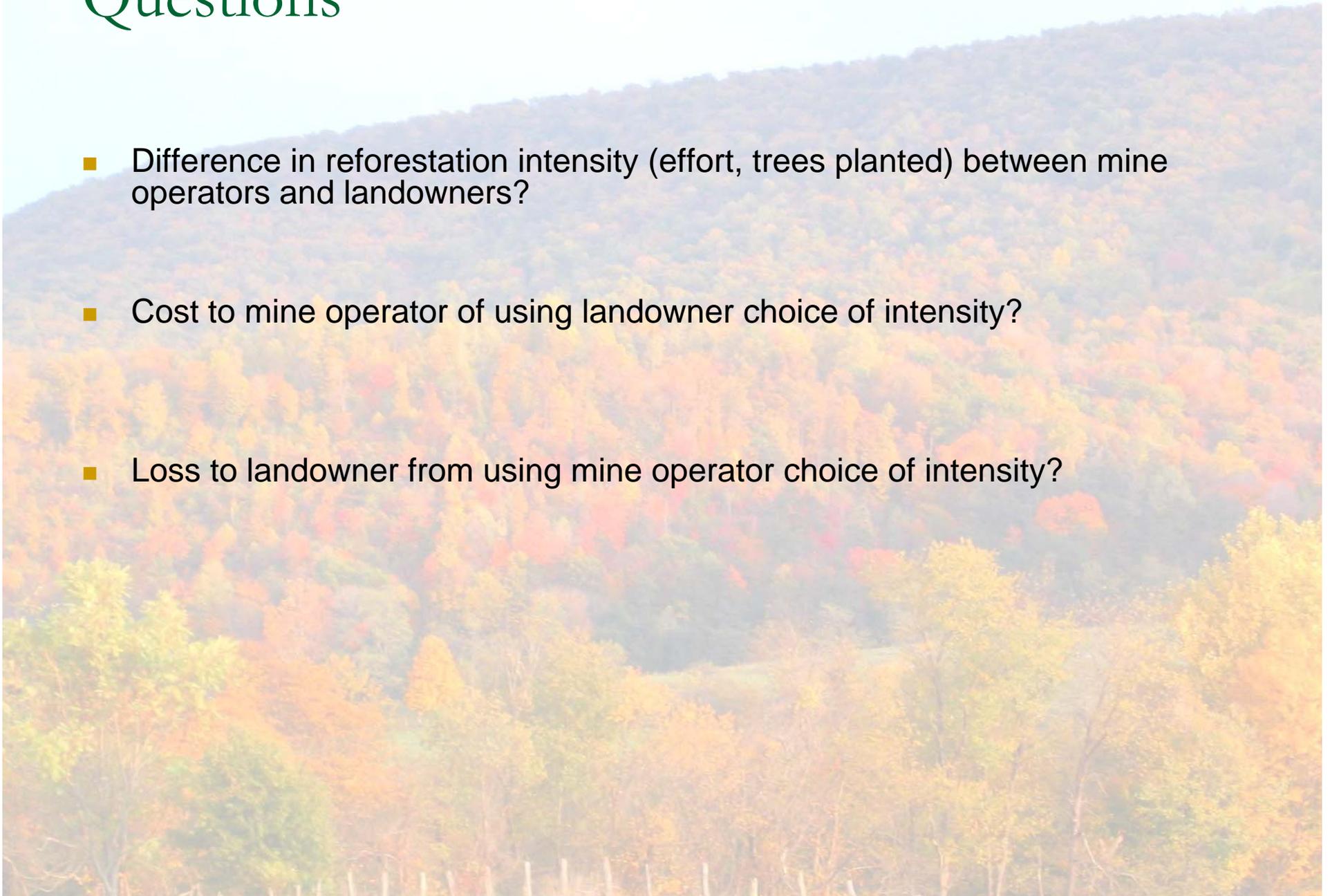
Landowner Perspective

- Considers land value; reflects productivity, management actions, timber revenues, non-timber values
 - $L_F(T, F)$
 - depends on management and site prep. intensity
- Mine operator pays establishment costs
- Maximize expected discounted land value:

$$EY_F(F, T) = \rho(F) \left[L_F(T, F) e^{-r(t_M + t_F)} \right] + [1 - \rho(F)] \left[EY_U e^{-r(t_M + t_F)} \right]$$

Questions

- Difference in reforestation intensity (effort, trees planted) between mine operators and landowners?
- Cost to mine operator of using landowner choice of intensity?
- Loss to landowner from using mine operator choice of intensity?



Simulations

- Establishment success probability – regen. plots across 3 states
- Volume growth estimated using tree growth data from 14 plots on mined sites
- Regen. effort composed of two parts: site prep intensity, trees planted
 - site prep:
 - low (weed control)
 - medium (weed control, soil compaction)
 - high (weed control, soil compaction, fertilization)
- Other conditions:
 - four site classes (65 -100 ft @ 50 years)
 - two stumpage price levels
 - three interest rates (3.5, 5.0, 7.5%)
 - two mining periods, 5 and 10 years
- For mine operator, calculate optimal *effort* (site prep. effort, trees planted)
- For landowner, calculate optimal *effort* and *management* (rotation length)

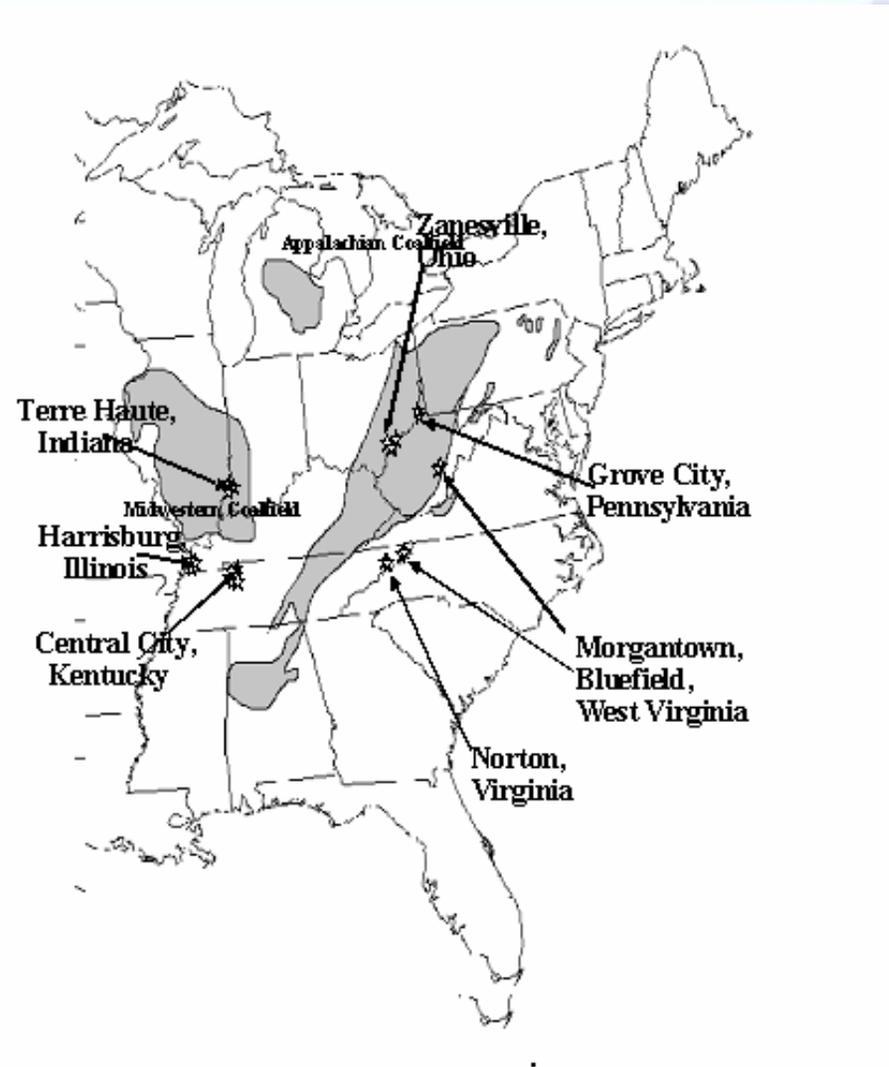
Establishment success

- Seedling survival rates across Ohio, Virginia, and West Virginia sites

intensity	treatment	mean	SD
low	weed control	0.58	0.2151
medium	weed control + tillage	0.65	0.2298
high	weed control+tillage+fertilize	0.41	0.2795

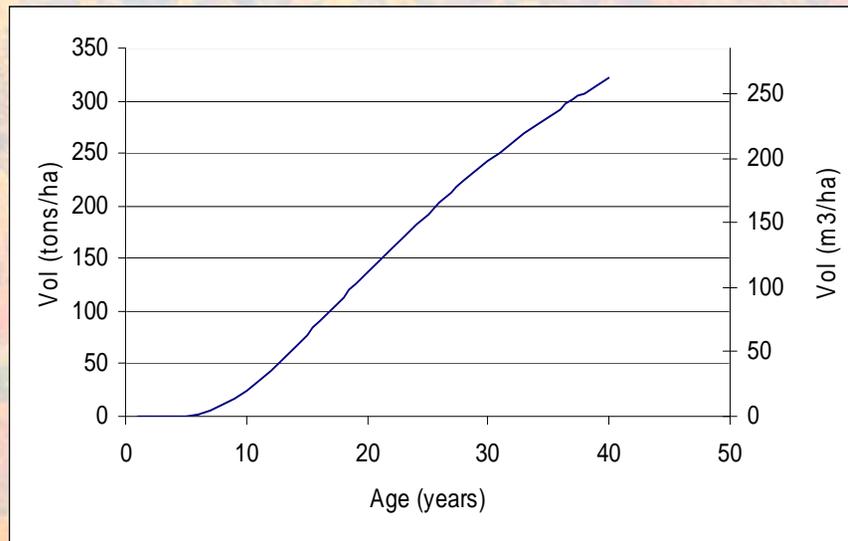
- Source: Casselman et al. 2006
- Used to determine probability of a given planting level achieving target TPA success level

Growth and yield—mined plot locations



Growth and yield

- Data source: Rodrigue 2001
- Volume = $\exp(5.4762 + .0161 \times SI - .0002 \times \text{density} - 38.7229/\text{age})$



Estimated costs

■ Reforestation:

Year	Activity	cost/acre	intensity
0	Weed control	\$44.31	High, medium, low
0	Ripping	\$121.40	High, medium
0	Fertilize	\$49.15	High
0	Lime	\$39.36	High
0	Seedlings (per tree)	\$0.0430	High, medium, low
0	Planting (per tree)	\$0.0848	High, medium, low
1	Weed control	\$29.03	High, medium, low

■ Other:

- Soil segregation \$200/ac
- Grading \$500/ac

Simulation Results—mine operator

- 5-year mining period (all sites)

int. rt.	intensity	trees/ac	expected cost/ac
3.5%	low	685	-\$948
5.0%	low	679	-\$957
7.5%	low	664	-\$957

- 10-year mining period (all sites)

int. rt.	intensity	trees/ac	expected cost/ac
3.5%	low	644	-\$892
5.0%	low	632	-\$876
7.5%	low	613	-\$834

Simulation Results—landowner

- 5-year mining period, 5% interest rate

site	high prices				low prices			
	intensity	TPA	rotation	value	intensity	TPA	rotation	value
1-good	med	754	23	\$860	med	752	23	\$734
2	med	752	23	\$703	med	750	23	\$599
3	med	745	23	\$438	med	740	24	\$364
4-poor	med	740	24	\$355	med	736	24	\$294

- 3.5% interest rate

site	high prices				low prices			
	intensity	TPA	rotation	value	intensity	TPA	rotation	value
1-good	med	719	25	\$1,753	med	718	25	\$1,496
2	med	717	25	\$1,434	med	714	26	\$1,222
3	med	709	26	\$899	med	706	26	\$747
4-poor	med	706	26	\$730	med	702	26	\$605

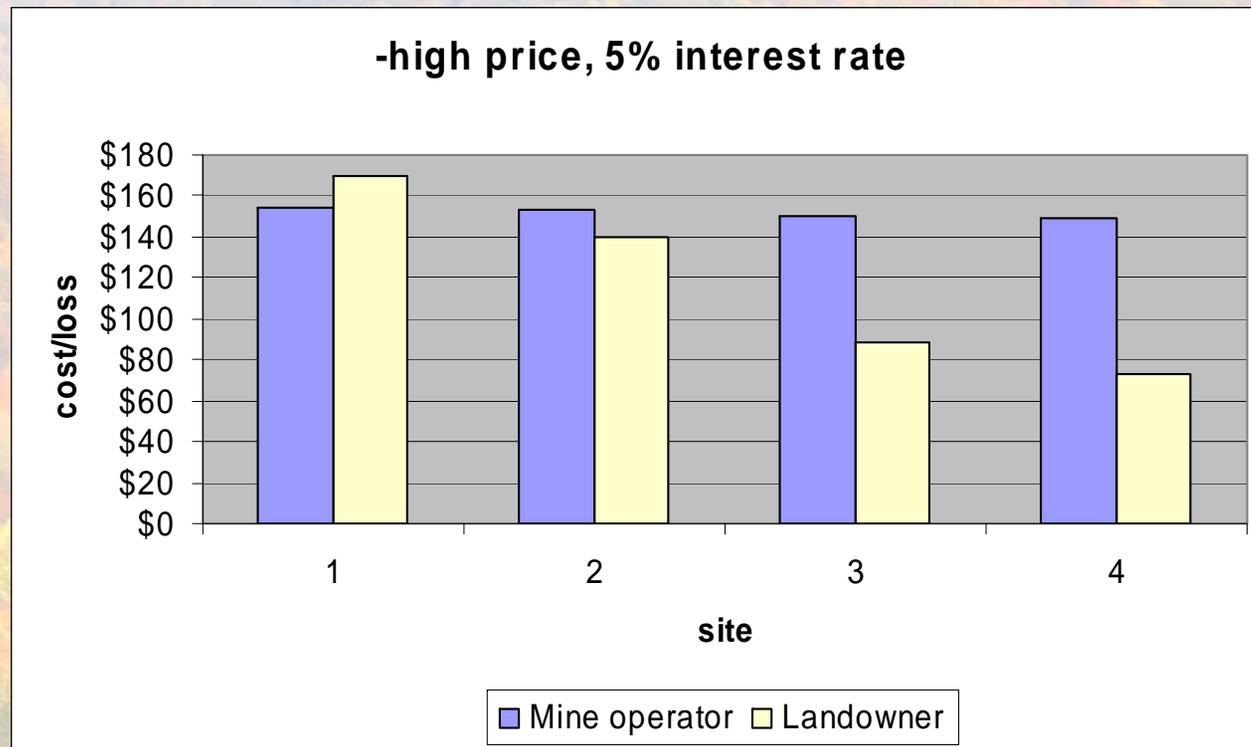
Simulation Results—landowner (cont.)

- 5-year mining period, 7.5% interest rate

site	high prices				low prices			
	intensity	TPA	rotation	value	intensity	TPA	rotation	value
1-good	med	795	20	\$330	med	793	20	\$281
2	med	792	20	\$269	med	789	20	\$228
3	med	784	21	\$166	med	780	21	\$137
4-poor	med	779	21	\$134	med	774	21	\$110

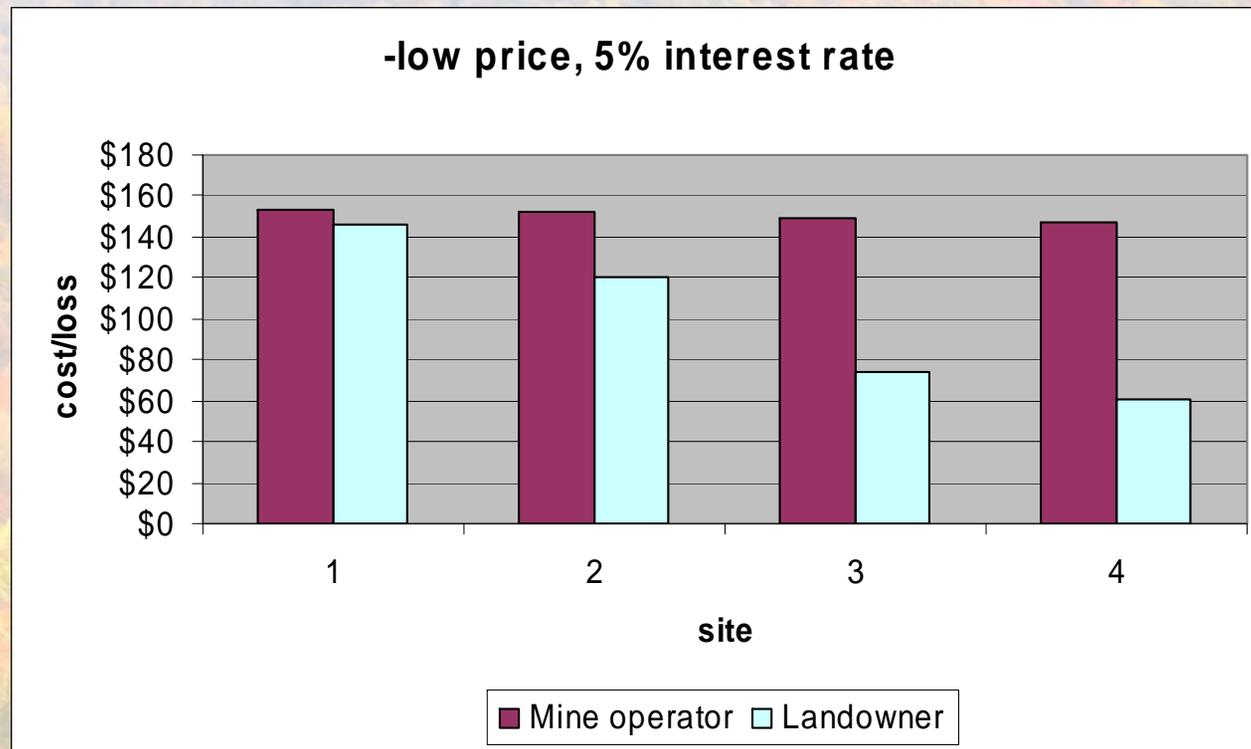
Simulation Results—potential costs/losses

- Additional mine operator costs at landowner optimum intensity
- v.
- Landowner losses at mine operator optimum intensity



Simulation Results—potential costs/losses

- Additional mine operator costs at landowner optimum intensity
- v.
- Landowner losses at mine operator optimum intensity



Conclusions

- Mine operators may opt for lower reforestation intensities than landowners (across all sites, prices, interest rates, mining periods)
- Mine operator reforestation intensity decisions weigh seedling establishment success (and bond release) against costs and interest on bond
- Landowner reforestation intensity decisions weigh seedling establishment success against density/growth effects
- May be substantial cost to mine operators for choosing optimal landowner intensity and substantial loss for landowner who are left with optimal mine operator choices
- Landowner “losses” sensitive to site condition, and mine operator costs may exceed owner losses in many cases

Simulation Results—landowner (cont.)

- 10-year mining period, 5% interest rate

site	high prices				low prices			
	intensity	TPA	rotation	value	intensity	TPA	rotation	value
1-good	med	754	23	\$674	med	752	23	\$575
2	med	752	23	\$551	med	750	23	\$469
3	med	745	23	\$343	med	740	23	\$285
4-poor	med	740	24	\$278	med	736	24	\$230

- 3.5% interest rate

site	high prices				low prices			
	intensity	TPA	rotation	value	intensity	TPA	rotation	value
1-good	med	719	25	\$1,476	med	718	25	\$1,260
2	med	717	25	\$1,207	med	714	26	\$1,029
3	med	709	26	\$757	med	706	26	\$629
4-poor	med	706	26	\$614	med	702	26	\$509

Simulation Results—landowner (cont.)

- 10-year mining period, 7.5% interest rate

site	high prices				low prices			
	intensity	TPA	rotation	value	intensity	TPA	rotation	value
1-good	med	795	20	\$230	med	793	20	\$196
2	med	792	20	\$187	med	789	20	\$159
3	med	784	21	\$116	med	780	21	\$96
4-poor	med	779	21	\$93	med	774	21	\$77

Simulation Results—potential losses

- Mine operator losses at landowner optimum—5 yr mining, 5% interest rt.

site	price	
	high	low
1-good	\$154	\$153
2	\$153	\$152
3	\$150	\$149
4-poor	\$149	\$147

- Landowner losses at mine operator optimum—5 yr mining, 5% interest rt.

site	price	
	high	low
1-good	\$170	\$146
2	\$140	\$120
3	\$89	\$75
4-poor	\$73	\$61

Simulation Results—potential losses (cont.)

- Mine operator losses at landowner optimum—5 yr mining, 3.5% interest rt.

site	price	
	high	low
1-good	\$132	\$132
2	\$132	\$131
3	\$130	\$129
4-poor	\$129	\$127

- Landowner losses at mine operator optimum—5 yr mining, 3.5% interest rt.

site	price	
	high	low
1-good	\$329	\$282
2	\$271	\$232
3	\$173	\$146
4-poor	\$143	\$119

Simulation Results—potential losses (cont.)

- Mine operator losses at landowner optimum—5 yr mining, 7.5% interest rt.

site	price	
	high	low
1-good	\$195	\$194
2	\$194	\$192
3	\$190	\$188
4-poor	\$187	\$185

- Landowner losses at mine operator optimum—5 yr mining, 7.5% interest rt.

site	price	
	high	low
1-good	\$73	\$62
2	\$60	\$51
3	\$38	\$32
4-poor	\$31	\$26