FORESTRY AS AN END USE FOR RECLAIMED MINES: SOME CONSIDERATIONS.[1]

Mike Curran, Ph.D., P.Ag.[2] and Chuck Bulmer, Ph.D., P.Ag.[3]

ABSTRACT

Sometimes forestry is identified as an end use during mine reclamation planning. This is desirable and is feasible under some conditions. This paper provides some information from our perspective as soil scientists working on forest soil rehabilitation. Resource values such as wildlife and biodiversity figure prominently in forest planning, as does the desire to mimic natural disturbance processes to create a range of natural habitat conditions. Good stewardship of the soil resource is required to create and sustain all of these conditions. Because the "undisturbed" forest land base is under heavy pressure to provide a balance of resource values, one option is to create or maintain some of the non-timber habitat types during mine reclamation. Such an approach might free up more of the naturally productive, "undisturbed" sites for timber production while maintaining an appropriate balance of habitat types in a given area. However, timber production is still a highly desirable end use for mine areas and consideration should be given to topsoil handling, natural disturbance regimes and current harvest scheduling. Rehabilitated areas should be reforested using the same seed and stock standards as for forestry, with local native species and in landscape patterns similar to the undisturbed areas. Depending on the state of harvesting in the surrounding area, production from the mined areas should be fit into the overall harvesting schedule in the local area, to help maintain a balance of serai (age) stages. In summary, commercial trees are likely to grow on many sites, provided some form of topsoil is provided.

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[1] Paper presented at BC Land Reclamation Conference, September 1999, Kamloops.

[2] Research Soil Scientist and Acting Forest Sciences Manager, BC Ministry of Forests, Nelson Forest Region, Nelson, BC, (250) 354-6274, http://www.for.gov.bc.ca/nelson/research/homepage.htm.

[3] Soil Restoration Ecologist, BC Ministry of Forests, Research Branch, Kalamalka Research Station, Vernon, BC, (250) 260-4765.

INTRODUCTION

In a number of Forest Districts in BC, mines occupy a significant portion of the land base and consideration or commitments have been made for restoring forest productivity to these areas. BC Forest Districts have been divided into Landscape Units ranging in size from about 10,000 to 100,000 ha. Larger mines can significantly influence the distribution of forest habitats in these units. Restoring forest productivity on mined lands is beneficial because it has the potential to increase the amount of timber available for harvest in British Columbia, and also provides opportunities to enhance non-timber resources. The intent of this paper is not to provide exhaustive information on Ministry of Forests policy or the practice of growing trees, but to provide some information from our perspective as soil scientists working for the Ministry. Further information is available through the references, local district or regional offices, or the authors.

Resource and Soil Consideration

Resource Considerations

The multiple ecological and social roles of trees should be considered in the reclamation process. Trees and woody debris provide the food and shelter requirements for small mammals and birds, supporting a complex food web. Trees are an important part of the global carbon cycle, sequestering large amounts of carbon and helping to compensate for the burning of fossil fuels. Forest product exports continue to be one of the largest economic sectors of our province. The scenic quality of beautiful BC is composed largely of forested landscapes.

Resource values such as wildlife and biodiversity figure prominently in forest planning, as does the de/ire to mimic natural disturbance processes to create a range of natural habitat conditions. Some of these habitat conditions are conducive to production of commercial forest, others are essential for maintenance of wildlife habitat/corridors and fisheries and water quality. All should include good stewardship of the soil resource. Because the undisturbed forest land base is under heavy pressure to provide a balance of these resource values, it may also be desirable to create or maintain some of these other habitat types as end uses of reclaimed land. In some cases, creation of wildlife habitat may free up more undisturbed sites for timber production.

Soil Considerations

To restore productive forests on disturbed lands requires consideration of a number of factors in the tree growing environment. These include: soil moisture storage, temperature, seasonal water deficit, texture, organic matter, freedom from toxic substances, and rooting depth (50 cm desired, to provide for wind firmness and access to soil moisture reserves). These and other factors affect numerous processes controlling tree survival and growth (Bulmer, 1998).

The fertile topsoil layer, including the forest floor, contains much of the site organic matter, biocycled (limiting) nutrients, and beneficial organisms. Many of the organisms that inhabit topsoil have not been identified, and the processes involved in nutrient cycling are still not fully understood. Efforts should be made to salvage this topsoil layer separately (e.g., the top 30 cm) and ensure an adequate amount is spread back on sites intended for forest production - this is "free" fertilizer, which, along with the establishment of appropriate plants, is an essential part of a self-sustaining ecosystem. In addition, coarse woody debris is considered beneficial to soil fertility and productivity. Much of the natural forest floor is derived from rotting wood. During reclamation, efforts should also be made to spread some coarse woody debris on sites intended for timber production.

A number of questions should be asked about the native soil. Successful forest production can be expected when we use topsoil that is not mixed with unfavourable subsoils, in combination with vegetation and tree species that are adapted to the site. Consider the topographic and soil conditions that are most productive prior to mining - these are the ones to recreate during reclamation. The Ministry of Forests has a number of soil disturbance hazard keys that may be helpful in considering soil conditions most conducive to rehabilitation. These would include soils with Low to High hazards for Compaction and Soil Displacement. In some cases, it may be possible to reclaim soils with Very High by using special handling or tillage technique. Soil compaction is considered a long-lived problem and should be avoided.

Based on our experience with smaller disturbance types likes skid roads and landings, best tree growth occurs when topsoil is replaced. For example, on skid roads, Dykstra and Curran (1999) concluded that reduced growth of trees growing on the rehabilitated trail area were partly due to topsoil being mixed with unfavourable subsoil, while better growth on the berm area was partly due to topsoil being still intact in that location (Figure 1). Similarly, Bulmer and Curran (1999) found less growth on the excavated portion of ripped landings than the fill area that contained the topsoil (Figure 2). Subsoils of particular concern are high pH (calcareous) soils that are commonly found in the southern Rocky Mountains, and still prevalent further north. In a summary of calcareous soils, Kishchuk et al. (1999) reported on preliminary data that demonstrated reduced tree growth on native soils that were shallower to calcareous subsoils (e.g., less than 40 cm for one lodgepole pine study site; Table 1). Therefore, even with our smaller, and sometimes very narrow disturbances, we are still very concerned about the topsoil when rehabilitating forest sites.

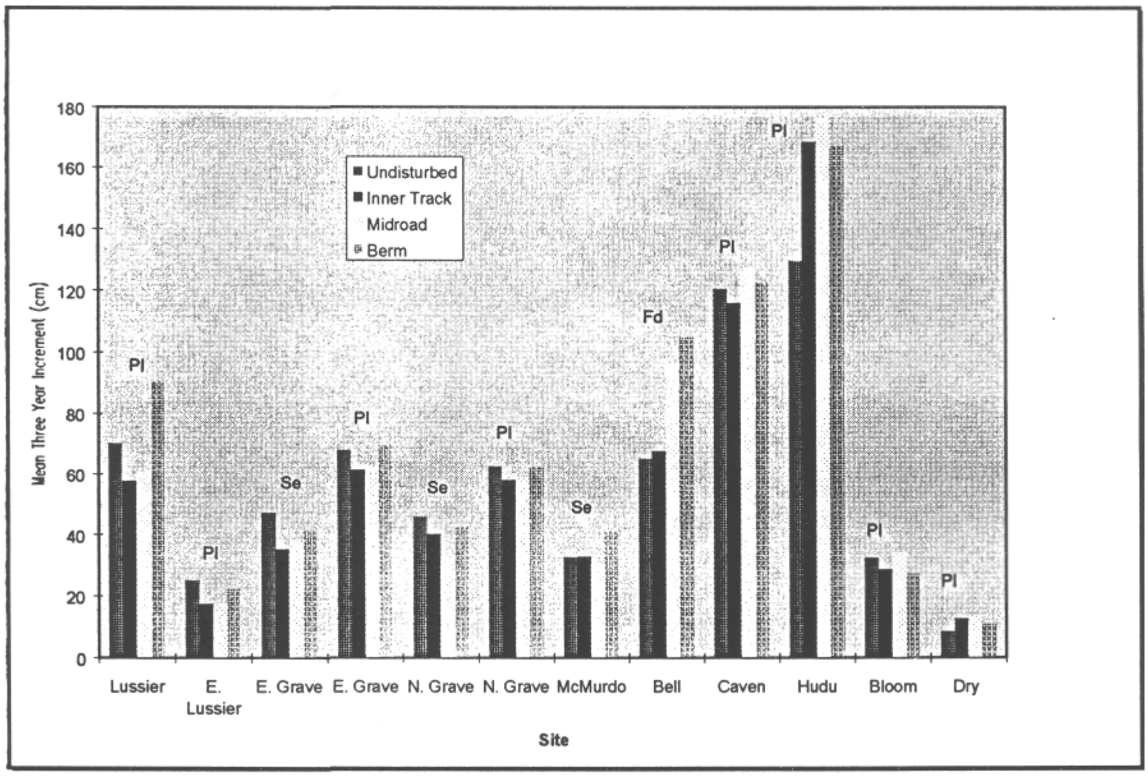

Figure 1. Three-year height increment on rehabilitated skid roads at 1996 block height, all blocks and species studied (Pl = lodgepole pine; Se = Engelmann spruce; from Dykstra and Curran, 1999). Lussier block is calcareous at 12 cm; data order is U (undisturbed), I (inner track), M (midroad), and B (berm).

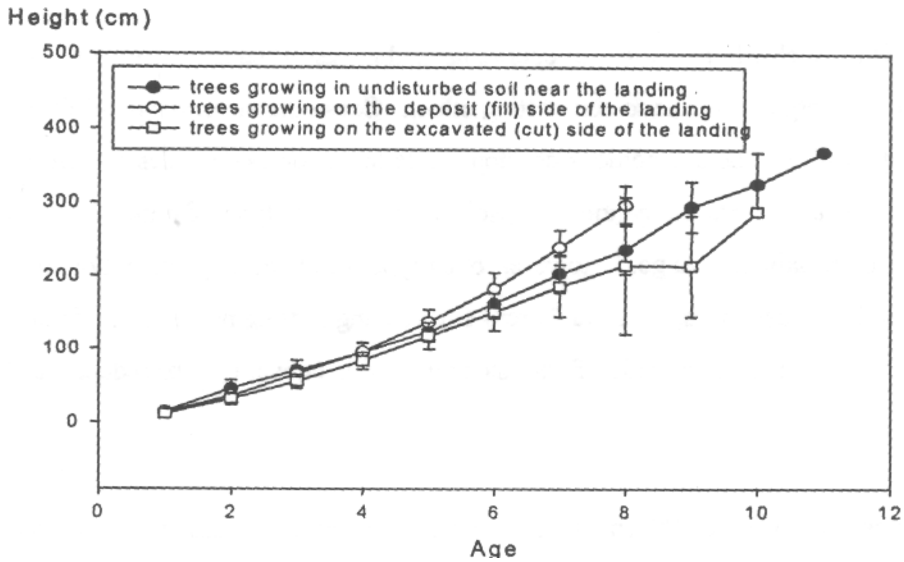

Figure 2. Caven 1 landing. Relative to the trees growing in undisturbed soil, growth rates for lodgepole pine are slightly better for the deposit portion of the landing, and slightly worse for trees growing in the excavated portion of the landing. Error bars represent the 95 percent confidence interval (from Bulmer and Curran, 1999).

Depth to Carbonates	Good Provenances*		Medium Provenances		Poor Provenances	
	Height (cm)	Diameter (mm)	Height (cm)	Diameter (mm)	Height (cm)	Diameter (mm)
< 40 cm	650 ± 24	94 ± 4	589 ± 27	79 ± 5	382 ± 27	58 ± 5
> 40 cm	752 ± 48	102 ± 9	649 ± 34	96 ± 6	465 ± 34	68 ± 6

(Based on 20-year growth and survival of 5 provenances in each category.)

Table 1. Height and diameter of lodgepole pine in the presence or absence of carbonates at Lussier River within the Invermere Pilot Study area (from Kishchuk et al. 1999).

The topsoil layer needs to be clearly identified for operations and is best when not stored for long. Storage changes the populations of organisms due to composting effect. Considerable amounts of nitrogen can be lost due to denitrification if anaerobic conditions develop inside larger or wetter piles of soil and organic matter. Opportunities for immediate utilization of topsoil depend on the type of mine, with strip mining being most conducive to "reclaim as you go." However, other types of mines may present opportunities for topsoil use, such as the first waste piles, dams, and areas surrounding settling ponds, etc. If immediate use is not possible, topsoil could be stored in wider, flatter stockpiles with a cover crop to reduce weed invasion and fix nitrogen.

The subsoil (soil below 30 to 60 or 90 cm depending on unfavourable substrate[4] conditions) is also beneficial and should be used beneath the topsoil on timber production areas, or could be amended to create an artificial topsoil for use on other areas. Organic amendments could include chipped and composted slash from initial mine clearing, or cover crops that are annually tilled into wide, flat storage piles.

Forestry As An End Use

Normal forestry operations are based on management plans that schedule harvesting through the working forest in a series of passes, often about 20 years apart. Each pass removes only a portion of the available timber in an area, so that impacts on other resource values are reduced. Based on the "rotation age" for the stands being managed in an area, a four pass system may take anywhere from 80 to 110 years for a full rotation (higher at high elevation). Depending on the lifespan of the mine, and opportunities for early reclamation, a range of stand ages may be created during reclamation. If a range of ages can not be created, this can affect other harvest scheduling, or local hydrology, discussed below.

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[4] Unfavourable substrates have been defined for forestry and include sandy materials with sand or loamy sand textures, fragmentai soil (over 70 percent coarse fragments > 2 mm in diameter), dense clayey soils and dense subsoils that are very difficult to dig with a shovel, permanent water tables, bedrock, and calcareous soils that fizz with 10 percent HCl acid. "Soil degradation hazard rating keys for soil compaction, displacement, and erosion are found in the *Forest Practices Code of British Columbia, Hazard Assessment Keys for Evaluating Site Sensitivity to Soil Degrading Processes Guidebook.* Forest floor displacement hazard and the mass wasting hazard are described in Forest Practices Branch field guide SIL411, and all hazard keys and data required for them appear on the BCMOF field forms FS39.[4]

The clearing created by a mine increases the equivalent clear-cut area for a watershed, and depending on the amount of harvesting elsewhere in the watershed, this can effect the hydrology and cause delay in other harvesting to ensure a maximum level of equivalent clear-cut area is not exceeded. Early reclamation can help prevent these problems in sensitive watersheds (the Interior Watershed Assessment Procedure can be helpful and is required in forest planning in sensitive areas).

It is desirable to have the rehabilitated areas reforested with local native species and in landscape patterns similar to the undisturbed areas. Seed collection and transfer guidelines are contained in the Seed and Vegetative Material Guidebook (Ministry of Forests). In addition, Ministry seed orchards and the tree improvement program have helped to select more productive seed for reforestation. At the minimum, mines should follow the collection and seed transfer guidelines; preferably, they should be using more hardy and productive seed that is available either commercially or from the Ministry. Species selection guidelines are contained in regional Establishment to Free Growing Guidebooks (Ministry of Forests).

Understanding the local growth limiting factors is important in species selection. Certain forms of site preparation can create disturbance types that ameliorate growth limiting factors such as cold soil (e.g., mounding). Common growth limiting factors are often described in regional ecology guides and also in the model SYTEPREP, based on classifying the biogeoclimatic site series (ecosystem; Braumandl and Curran, 1992; Curran and Johnston, 1992). Many mine sites that we have visited often have soil moisture, soil temperature, and air temperature (frost) as common growth limiting factors.

What Constitutes Adequate Productivity?

In a Silviculture Prescription, a forest Licensee makes a legal commitment to regenerate a site to an acceptable species. Fulfilling this obligation requires that the new forest meets defined conditions (e.g., stocking levels, growth rate, freedom from competition, and absence of disease). The conditions are set out in the Establishment to Free Growing guidebooks for each forest region. The time frame required to meet these obligations ranges from less than ten to as high as twenty years, depending on the site and soil conditions.

Estimates of forest site productivity are also needed for determining the effectiveness of reclamation, and for evaluating the contributions of reclaimed lands towards timber supply (e.g., Chief Forester, 1996).

These evaluations would likely involve the determination of site index based on tree height and age for reclaimed areas. Site index is a measure of site productivity for a target species, expressed in terms of height at age 50.

Although the mining community has had a long and intensive research program investigating forest productivity, information from research trials needs to be compared to local benchmarks of productivity for forests on undisturbed sites. Such expectations may be contained in regional research publications or through contact with regional silviculture research staff, or inventory staff responsible for Permanent Sample Plots (e.g., Thompson 1995, Thompson 1996, Pollack et al. 1985). Information could also be obtained directly through sampling programs, Ministry staff are available to provide advice on such programs. Research and operational trials associated with mine reclamation represent a good example of adaptive management at work. Some statistical methods for adaptive management are discussed in Sit and Taylor (1998). Some discussion is also provided below.

Because of die long time between establishment and harvest for forest sites, reclamation success is difficult to evaluate using short-term results. According to Morris and Miller (1994), acceptable evidence for long-term changes in site productivity must meet three conditions:

1. growth differences must be attributable to differences in site conditions, rather than to differences in resource allocation among target and non-target species or to differences in plant potential,

2. growth results must be available for a sufficient period of time so that the influence of ephemeral conditions is diminished, and the capacity of the site to support trees is stressed, and

3. adequate experimental control must exist.

Morris and Miller (1994) consider measures of site index based on 10 (fast-growing stands) or 20+ (slow-growing stands) years of data to be reasonable criteria for meeting the first two conditions. For experimental control, they cited requirements presented in Mead et al. (1991), including:

=> at least four replications in randomized or randomized complete block designs,

=> suitable pre-treatment site and crop information for individual experimental plots,

=> measurement plots of at least 400 m^2,

=> at least 12 trees left at the end of the experiment, and

=> buffer areas at least 10m wide surrounding each measurement plot

Although much work has been done, based on these criteria, more information is clearly needed to verify effects of mine reclamation on forest productivity. Establishment of long-term experimental sites where forest productivity is assessed for rehabilitated areas is therefore a priority.

Two methods of determining site index are commonly used for young stands (BC Ministry of Forests, 1995). The biogeoclimatic method predicts site index based on the subzone and site series, and is suitable for trees with less than three years growth above breast height. The biogeoclimatic method is based on investigations into the use of site factors for predicting site index (e.g., Wang et al., 1994).

The growth intercept method predicts site index from height and age measurements taken on selected sample trees. Growth intercept tables are available for a number of coastal and interior species, and the method is suitable for trees that have at least three years of growth after achieving breast height (1.3 m).

Most reclaimed sites in BC have trees that are too young to be suitable for site index estimation using the growth intercept method. Therefore, reliable estimates of site index for these stands are still several years in the future. Evaluation of the relative success of rehabilitation treatments has to be based on the survival and early growth of trees on rehabilitated sites, and the soil conditions in comparison to nearby undisturbed sites.

CONCLUSION

In summary, we feel that, with adequate topsoil handling, we can restore soil (forest) productivity on smaller disturbances such as skid (exploration) roads, haul roads and log landings. However, we are continuing our monitoring to ensure long-term success. Even on small, linear disturbances such as skid trails, adequate management of topsoil is key. Restoration of full productivity on larger areas has not been proven, but is highly desirable.

Evaluation of forest productivity based on short-term information is difficult, so plans need to accommodate a high level of uncertainty about the success of reclamation programs aimed at restoring forests. Continued monitoring of tree growth is needed to evaluate reclamation success over the long time frames that characterize forest production. Even if mine reclamation can restore 60 to 80 percent of the productivity, this could have significant positive benefit in terms of allowable annual cut and other resource values. Mine reclamation will continue to benefit from on-going adaptive management.

There are a number of other resource values that must be considered in forest plans - reclaimed mines can help provide for some types of habitat. In some cases, this might relieve some pressures from the naturally productive forest land surrounding a mine.

Acknowledgements

We appreciate review comments from Oliver Thomae, Operations Manager, Cranbrook Forest District; Steve Byford, Small Business Officer, Cranbrook Forest District; and Paul Gevatkoff, Operations Manager, Dawson Creek Forest District. We also appreciate the patience and encouragement of Rieva Rosentreter, Reclamation Inspector, Mines Branch, Cranbrook.

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