EVALUATING RECLAMATION SUCCESS FOR SLOW GROWING FOREST ECOSYSTEMS[1]

by

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Abstract: Requirements for evaluating mine land reclamation success are not well developed for forest applications, particularly in the southwestern United States. Unique site features, overstory community composition and existing regulations create a situation for determining revegetation success that can be highly subjective. At the Molycorp, Inc. Questa Mine a reclamation plan has been developed around the concept of establishing a forest community similar to adjacent and predisturbance forest communities, dominated by late successional coniferous species. On undisturbed sites, commercial (timber) rotation ages of these forest types are greater than 100 years. In the case of New Mexico, the Hard Rock Mining Act regulations stipulate a 12-year post-planting period before bond release is possible. This would require evaluating performance at less than 10% of the rotation age. Further confounding the determination of revegetation success is the pre-disturbed and adjacent forest cover was composed of primarily late successional species. One method to improve late successional overstory seedling establishment is to plant early successional overstory species simultaneously. The faster growing, early successional species help mitigate deleterious site factors associated with the disturbance and hence improve late successional species establishment. The challenge in determining revegetation success becomes identifying what parameters can be used in evaluating "the performance" of this type of planting. First, reference areas are difficult to use, because in many cases, mature, late successional ecosystems surround the site. Second, reference area that are in transition from the early to later successional plant communities are entirely lacking in the area. Third, the simultaneous planting of early and late successional species will create a species composition and stand structure not normally found in nature. Finally, site indices and growth data used in traditional forest applications are not well developed for many southwestern species or for disturbed lands revegetation. Proposed solutions to the challenges are discussed.

Introduction

Designating a post-mining land use is a requirement for reclamation of lands disturbed by mining activities. Forestry as a post-mining land use has not been widely adopted in many areas for various reasons (Boyce 1999). In a review of revegetation trends, causes, and possible solutions to using forestry as a post-mining land use, Boyce (1999) identified several factors that may have deterred mines from using forestry as a post-mining land use. Two factors we find quite relevant are: 1) industry preference for revegetation options "... where the meaning (of the rules) is clear and not subject (to) uncertain interpretations by the state regulatory authority or Office of Surface Mines;" and 2) relating to internal tensions in the regulations "...the need to protect water quality and the need, or at least the desire, to encourage reforestation...it appears you can't maximize erosion control in the short run and reforestation at the same time. Ironically, forests, once established result in excellent erosion control..." (Boyce 1999).

The trade-off between long-term productivity (forest products) and stability (erosion control, water and air quality) and short-term stability (immediate erosion control, water and air quality) is challenging from an industry perspective. Many factors influence decisions dealing with this trade-off with economics and compliance being the two foremost concerns in most cases. The economics debate can be

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determined with relatively straightforward analyses. In some cases, costs will need to be estimated or research conducted to evaluate feasibility. However, compliance to state and federal laws and regulations is more problematic. In the case of many states, including New Mexico, multiple agencies, laws and regulations are involved in determining compliance. Forestry as a post-mining land use is relatively new in comparison to other post-mining land uses such as rangeland or pastureland. The impact of forestry being a relatively new designated use is that there is uncertainty and unfamiliarity with forestry as a post-mining land use and its impacts on other regulatory requirements for all parties involved.

The remaining portion of this paper will first describe the nature of New Mexico reclamation laws as they relate to revegetation and forestry as a post-mining land use. Then a case example using the Molycorp, Questa mine site as an example will be given and followed by a discussion of challenges to compliance as the laws are written. While some aspects of this discussion will be somewhat unique to this project, others will address problems associated with using novel nurse crop species and forestry as a post-mining land use.

Reclamation (Revegetation) Regulatory Framework in New Mexico

Coal reclamation regulations have been in place for more than 20 years and the New Mexico regulations reflect federal requirements. Based on that experience, the New Mexico Coal Program recently developed new standards (Mining and Minerals Division Coal Mine Reclamation Program Vegetation Standards CMRPVS; New Mexico 1999). In contrast, the New Mexico Hard Rock mining law is recent (1993) and regulations and interpretations are still developing. The New Mexico Coal Program and the Hard Rock Mining Act (HRMA; New Mexico 1994) have made a good effort in developing revegetation standards, including forestation standards, that are more objective and less subjective than previous standards. The HRMA regulations however only address new mines and new units of existing mines. The standards provide two options to measure reclamation success when forestry is the desired post-mining land use, reference areas or technical standards. The development of these types of standards will, as it has in other states, improve the objectivity in evaluating revegetation success (Buckner 1990).

The goal of the reclamation activities for existing mines as stated in the HRMA will be to:

> "...reclaim disturbed areas with the permit area to a condition that allows for the re-establishment of a self-sustaining ecosystem on the permit area following closure, appropriate for the life-zone of the surrounding area unless conflicting with the approved post-mining land use...(unless)... showing that achieving a post-mining land use or self-sustaining ecosystem is not technically or economically feasible or is environmentally unsound, the Director may waive this requirement..." (New Mexico 1994).

The only two performance criteria associated with forestry as a post-mining land use that are applicable to both the use of reference areas and approved technical standards are:

1) "the ground cover of living perennial plants shall be equal to 90 percent of the native ground cover of the reference area or the approved standard to within a 90 percent statistical confidence and shall be adequate to control erosion; and
2) tree stocking for forests shall have stocking rates of plant species equal to 90 percent of the approved reference area or other approved standard with an 80 percent statistical confidence and shall be adequate to control erosion" (New Mexico 1994).

Molycorp Mine Site Example

At the Molycorp, Inc. Questa Molybdenum Mine located in Taos County, New Mexico, the reclamation and revegetation requirements fall under the HRMA as an existing mine (New Mexico 1994). Forestry was selected as the post-mining land use in part because much of the adjacent and pre-mine vegetation types are and were mature coniferous forests. Species dominating the overstory canopy vary from Ponderosa pine (*Pinus ponderosa*) stands, to mixed conifer stands with Douglas-fir (*Pseudotsuga menziesii*), limber pine (*Pinus flexilis*) and white fir (*Abies concolor*), to spruce-fir stands with blue spruce (*Picea pungens*) and white fir. Most of these species would be classified as mid to late successional or climax species (USFS 1997).

Two types of trees are often recommended when establishing a forest on disturbed sites, crop trees and nurse trees. Crop trees, or in the case of New Mexico, commercial timber species, are the tree species from which some value, in most cases economic, will be derived from the revegetation effort. Nurse trees are trees planted to assist the establishment and growth of crop trees (Burger and Torbert 1997). Nurse trees can benefit crop trees in several ways, including enhancing soil organic matter content and nitrogen status. Nurse trees can also be used to create an environment that is more conducive for crop tree growth. For example, nurse trees may reduce soil surface temperatures and create shaded environments more favorable to seedling establishment and growth of crop trees. Nurse trees can also accelerate soil stabilization and can be used in satisfying stocking and ground cover requirements (Burger and Torbert 1997).

Desirable traits of nurse trees include rapid growth, ability to establish in full sunlight and in some cases, fix atmospheric nitrogen. Some tree species such as members of *Robinia* and *Alnus* posses all three of these traits, while others such as members of *Populus* are fast growing and have the ability to grow in full sunlight. Recent research at the Molycorp site indicates that New Mexico locust (*Robinia neomexicana*), thin leaf alder (*Alnus tenuifolia*), and narrowleaf cottonwood (*Populus angustifolia*) would all make good candidate nurse trees at this site (Harrington et al. 2000). The latter two species occur adjacent to the mine, primarily in riparian areas, and some individuals have established themselves on the overburden piles at the mine. New Mexico locust has not been found naturally in the area around the mine but does grow in similar locations elsewhere in the region. These candidate nurse trees, as well as the majority of other nurse trees, are all considered components of early successional stages and not likely to persist as major components in the final self-sustaining ecosystem that is the ultimate goal as stated in the HRMA (New Mexico 1994).

A principle component of the Molycorp revegetation plan is the simultaneous planting of nurse trees along with the final (late sere) overstory species (Harrington et al. 2000). The differential growth of the two types of overstory species (nurse and crop trees) is intended to shorten the time frame to achieve a more stable, later successional plant community. The rationale behind this approach is that the faster, shorter lived nurse crop will create an environment more conducive for the establishment of the later, longer lived commercial species, including Douglas-fir, limber pine, ponderosa pine and white fir being planted simultaneously.

Use of Reference Areas to Measure Forestation Performance

The challenge to meet regulatory requirements regarding reclamation success relates to several factors. First is the lack of suitable reference areas to use as a measure of success. The nature of the reclamation stand, including species composition, density, age distribution, etc. would be unique. In the case of the Questa reclamation program, the two native nurse crop species occur primarily in adjacent riparian areas whereas the reclamation is on upland overburden piles. The other woody species such as chokecherry (*Prunus virginiana*), various willow species (*Salix* spp.), water birch (*Betula occidentalis*), and Rocky Mountain maple (*Acer glabrum*) dominate the mid and upper canopies in these riparian forests. The species growing in the riparian areas are considered the climax species whereas these same species on the mine site are considered early successional or nurse crop species. Therefore, using the riparian areas as a reference area for the mine site reclamation does not seem to make sense or ensure that the ultimate goal of the later successional species establishment will be attained.

Conversely, areas where the crop species are regenerating naturally have overstories dominated by the crop tree species, and are considered mature, late successional ecosystems. These ecosystems are difficult to use as reference areas, in part, because the growing environment for seedlings and saplings is dramatically different from mined sites.

Use of Technical Standards to Measure Forestation Performance

A second problem is in developing technical standards for both the nurse tree species and crop tree species (Table 1). While not defined in the HRMA regulations, technical standards are likely to be based primarily on two performance criteria, survival (stocking or density) and growth. Developing performance standards for the first criterion, survival, is fairly easy. Survival or stocking levels are easily and objectively measured. Most of the standards have stopped here in terms of performance of woody plants

Table 1. Comparison of reclamation evaluation techniques.

Method of Evaluation	Description	Advantages	Disadvantages
Reference Areas	Use comparisons with designated areas	Allows comparisons of vegetation within the same year Generally accepted by regulators as appropriate technique Useful when compare vegetation in same state	In western regions, suitable reference areas are difficult to locate Generally, differences exist in stage of succession and age of woody plants Differences may also exist in composition of species
Technical Standards	Measure specific parameters such as survival and growth	Quantitative Site and species specific Generally easily measured	Site indices not developed for many western species (especially nurse crops) Use of early stages of growth and establishment for long term prediction of success Measure individual not stand

However, the development of the second standard, performance or growth, is more challenging and is probably a more critical predictor of success of the stand. Regarding crop or commercial trees in the revegetation project area, a first logical choice for a performance measure and an indirect measure of site quality, would be the use of site index curves for the species being planted. Site index is the average height of selected dominant or co-dominant trees of a given species at some index age, usually 50 or 100 years in the western U.S. Site index as it is used in forestry, estimates the capacity of a species to produce wood on a given site.

To the best of our knowledge, site index curves do not exist for the three nurse crop species being used in this project. Using the growth rates of thin leaf alder and narrow leaf cottonwood in riparian stands to predict or set goals for growth of these species on overburden piles would appear to be illogical because of the inherent differences between the two sites. An unbiased measure of the upland performance of these species would need to be developed.

Developing technical standards to evaluate the performance of crop tree species also presents challenges. Use of site index curves is hampered by the fact that at the time of bond release (e.g., year 12), the utility of these curves as indirect predictors of site performance is questionable. A measure of early performance (less than 15 years) for the species of interest would need to be developed. In order to measure and evaluate early performance, stands would need to be found that would be similar in structure, both in terms of the plant community and soil structure, to the revegetated area at the time of bond release, or at 12 years.

In summary, a key limitation to the use of site index curves for disturbed land vegetation is that the site index curves are lacking for many of the western tree species, both crop and nurse tree species. Secondly, the age at which reclamation success will be evaluated is very early in the age of the stand and problems with correlating early performance and mature stand performance exist. There are no well-developed correlations that can be used as guidelines.

A possible approach to develop useful technical standards would be to locate similarly structured stands at approximately the same age/stage of development at the time of reclamation success evaluation. As mentioned previously, this may not be feasible because of the reclamation approach of establishing nurse and crop trees simultaneously. In some cases, a stand with a species composition similar to the revegetated stand may exist although not necessarily with the exact same species composition. A more practical solution, if no such stands exist, would be to develop a sampling regime where the performance of a representative population of individuals growing in a relatively similar (soil, topography, climate, etc.) environment at a similar age as the revegetation stand would be used for comparisons. Generally, this would involve developing "juvenile site index curves" based on the early performance of the trees. This approach would need to be restricted to only those native species used in the revegetation program because of site specific constraints such as climate and soil factors. This approach could be used to develop a local or site-specific performance estimates for the given species.

Three significant challenges to this approach would be: 1) determining plant age of the sample trees; 2) the large variation in growth during the establishment phase (usually less than five years); and, 3) the information generated would be on an individual tree basis. The first two limitations would be more pronounced in the slower growing crop tree species than the faster growing nurse tree species. Measurements of diameter at breast height (DBH, 4.5 feet above the ground) for a given age are used in site index curves. This would be impractical for revegetation analysis in the western U.S. because many of the crop tree species would barely be reaching this height when reclamation success has to be evaluated for bond release. A possible alternative may involve destructive sampling of sample trees to determine tree age. Since these trees may be limited in number this approach might not be acceptable. Provided stem diameters are large enough, the age could be determined using increment core analysis at some point less than DBH, perhaps 10 cm above the ground. This approach still would not address the number of years involved in the establishment phase.

To address the number of years occupied prior to age determinations, (i.e., establishment phase duration) surveys would have to be performed on younger individuals growing in similar environments. This could be accomplished in several ways including examining terminal bud scale scars and through the use of destructive analysis.

Should height growth be the only indexed growth parameter in developing these "juvenile site index measures"? In forestry, height is used as the measure of tree performance largely in part because height growth is independent of stand density. However, height growth may not be as important to reclamationists, who might be more concerned with crown spread and canopy coverage. Unfortunately, crown spread is sensitive to stand density (competition) and may not provide a reliable measure of performance if the canopies of individual trees are overlapping. Open grown trees usually have larger crowns than trees growing in the shade. If the sample trees were all open grown, then their crown spread could possibly be used as a performance criteria. This would be the case only up to the point when the individual crowns of the revegetation plants begin to overlap. The decision to use crown spread rather than height would be based on an obligation to meet some predetermined (either through the use of a reference area or a technical standard) canopy coverage.

Recall the rationale behind using a technical standard arose due to the lack of a representative reference area existing naturally. The above mentioned procedure is based on individual tree performance and not stand performance. The question then becomes whether or not individual tree parameters (survival and growth) will predict the successful establishment of a stand. Further refinement of the tree parameters may be needed unless there is acceptance of these measures as predictors of stand success.

Self-Sustaining Ecosytem

The third challenge to using forestry as a post-mining land use is the validation of a self-sustaining ecosystem. Although undefined in the New Mexico HRMA, a general definition of a self-sustaining ecosystem is an ecosystem that is self-perpetuating. The four crop tree species proposed in this example normally do not reach sexual maturity until approximately 20 years of age, and in the case of white fir, 40 years (USFS 1974). Further complicating this is the reported gaps between good seed crops that may be as long as five years (USFS 1974) and in the case of ponderosa pine and limber pine can be as long as seven years in the project area (Harrington pers. obser.). If regeneration is used as a criterion, this could extend the validation of a self-sustaining ecosystem to at least 25 years. Clearly, shorter and objective measures of "self-sustaining" must be developed.

One possible solution would be measuring encroachment of adjacent, mature over-story species in the revegetation area. This criterion would be limited by several factors, including proximity to seed source and presence of a viable seed crop in the adjacent stands. A second approach would be to conduct broadcast seeding experiments using seed from the crop tree species. A significant limitation to this approach would be the influence of the seed handling process on *in situ* germination estimation.

Conclusions

The ultimate goal of a reclamation program in this instance is to create a self-sustaining ecosystem through a forestry post-mining land use. This translates to the establishment of crop trees at the site. However, the starting point is an artificial system using both nurse trees and crop trees simultaneously. The combination of both types of species suggests that at year 12, when bond release is first available, there may be more nurse trees that are larger and more dominant than the crop trees. The difficulty is then how the year 12 (or subsequent years) evaluation will determine that the long-term goal will be met. In other words, how can we develop a technical standard that evaluates establishment and growth and takes into account the benefits of nurse trees while allowing that the ultimate goal is crop trees.

Although progress is being made in developing meaningful post-mining land uses and reclamation standards, there are still some gaps. It appears that for many sites, development of technical standards to evaluate reclamation success will be necessary. It is also clear that these standards do not currently exist in the Southwestern U.S. There is an opportunity for forest researchers, minedland reclamation specialists, regulators and others to work towards development of technical standards that provide an objective measure of reclamation success when forestry is the post-mining land use.

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