Confidence in Monitoring Rehabilitation Outcomes

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Introduction

The mining industry have supported many research programs that have presented an array of valuable techniques for assessing the sustainability, dynamics and functioning of vegetation and ecosystem processes on rehabilitated lands. There is a range of new and innovative techniques that have recently been demonstrated as useful in the context of ecosystem assessment and mine revegetation by a number of groups. Minesite rehabilitation assessment ranges from using broad-scale ecological indicators at a landscape scale to determining species population and physiological responses. A combination of indicators represents the most promising approach as ecosystem parameters are most effectively probed at different scales.

At the present time, minesite environmental personnel face a myriad of assessment tools and techniques. They need to determine how data from these different techniques can be integrated, whether gaps exist in assessment of rehabilitation functioning, and which may be the most appropriate technique for the problem at hand. New techniques also need to be integrated with existing long-term data collected across the many mine sites, and measurements at the plant level need to be integrated with measurements at the community and landscape level.

Mining companies undertake rehabilitation of disturbed ground to comply with state environmental regulations, and conduct monitoring of established areas to assess performance. The aim is to demonstrate the presence of a stable non-polluting landform, thereby facilitating relinquishment of the lease and release of the company from ongoing liability. Government regulators, however, are reluctant to provide sign-off and take on the risk of future liabilities. There are two areas of uncertainty creating this risk. The first is that the rehabilitation produced will fail some time after mine closure (ie it is non-sustainable). The second area, and one that has received far less attention, is that the quality of rehabilitation can be spatially highly variable, due to the heterogeneity of growth media resulting from the mining and/or mineral processing operations. Rehabilitation meeting or exceeding the set criteria in one location may well fail a short distance away. Given that rehabilitation monitoring or sampling is usually undertaken on a point basis, there remains uncertainty in the modelling of data. Thus, beyond addressing the issues relating to monitoring techniques for improving data collection and validity *per se*, this paper introduces a process that seeks to manage the uncertainty in the data generated, and the risk it generates for rehabilitation, by using spatial stochastic modelling. The paper presents an introduction to the potential of this approach so that the industry can utilise modelling results to assess overall quality of rehabilitation and reduce the occurrence of areas that require costly remedial attention. Of parallel benefit from this approach, the regulators will have a clearer resolution of the risks associated with any particular decision, thereby assisting the sign-off process for all parties.

Other papers at this workshop have very competently addressed and reviewed various approaches to monitoring rehabilitation and identifying success criteria. Thus, this presentation will concentrate on outlining two issues that are fairly topical and, in recent times, have occupied a reasonable amount of our research effort in this field. Both have ‘confidence in outcomes’ as a central theme. The first looks at our current understanding about the confidence we can place in Landscape Function Analysis (LFA) as a means of ascertaining successful rehabilitation, and the second introduces the approach whereby we can quantify the uncertainties (and locations and probabilities of possible risk) associated with a rehabilitated landscape, and thus develop a mechanism that can lead to achieving confidence and ultimate acceptance of the outcomes.

LFA - its “validation” and its appropriateness

One of the current “trend” areas relating to monitoring rehabilitated sites after mining, with which many are now familiar, involves the use of LFA and the assigning of values to up to 11 parameters as part of a Soil Surface Condition (SSC) assessment. Various indices are then generated and compared with an unmined analogue, from which an assumption about the relative functioning of the rehabilitated site is made. Apart from the recognised difficulties with the selection of an appropriate analogue, testing the “validity” of the indices themselves has been the subject of a recently completed industry-funded ACMER project conducted by CSIRO in association with the University of Queensland (UQ) and the University of Western Australia. The draft report from CSIRO is now with the sponsors, but some of the information generated from the sites that UQ participated in will be outlined during the presentation. The presentation highlights some of the pros and cons of the technique and where it did (or did not) appear to correlate well with the more traditional quantitative measurements. While it was evident that the technique was not able to provide absolute confidence about its value as a generic monitoring tool across the range of rehabilitation media against which it was challenged, there were clearly circumstances where its value was proven. As an example, the three indices (Stability, Infiltration and Nutrient Cycling) appeared to be successfully verified at the bauxite mining operations at Nhulunbuy in the Northern Territory, and it is likely that the level of topsoil management may be a large contributing factor to this success (Seaborn, 2003). The nature of the mining process at this location means that there is direct return of topsoil, minimal mixing of the soil profile and a resulting majority of re-spread topsoil with similar physical, chemical and biological attributes to those of the native sites, right from the outset. At other sites, the method appeared to have some difficulty coping with variability in substrate materials. For example, at the rehabilitated sites at Gregory coal mine which have their origins as dragline spoil piles that are re-shaped and typically topsoiled prior to seeding, the surface substrates were extremely variable in their physical properties at least, and as such created greater difficulties in achieving a uniform correlation with the SSC assessments and the resulting indices (Seaborn, 2003). Future work will need to look at possibilities for fine-tuning the methodology to cater for the differences in substrates between sites. The indices also appeared to have some difficulty 'estimating' stability, infiltration and nutrient cycling on younger rehabilitated sites, where nutrient pools are poorly developed and the contribution of vegetation to soil stability and infiltration is not yet fully expressed. Assessment of soil surface features for the calculation of indices may be more meaningful once biophysical processes are better developed (Seaborn, 2003).

In summary, it is evident that the LFA approach has its value as one of a number of tools that can be used for monitoring rehabilitation success, not perhaps in so far as using an index value that equates to one generated from an 'analogue' site to delineate 'success', but moreso from the value it provides over time by the ability to demonstrate that the surface conditions, which can then be related to key functional processes, are improving over time. As more information and data become available from progressive monitoring, the stronger will become the case for linking the indices to landscape function.

Quantifying uncertainty to manage and reduce risk in rehabilitation

In collaboration with the geostatistical/mining modellers at UQ, the CMLR has been exploring an area which shows promise in delivering a robust technology to quantify the likelihood of success, or the 'risk' of failure, of a discrete area of rehabilitation. In essence, the technology provides predictions of key environmental attributes across areas of rehabilitation, based on limited information, and presents the *probability* of occurrence for each of those attributes. Linked with 'threshold' information defining whether vegetation (pasture-based or native species) will respond satisfactorily or not, a quantification of the probability of revegetation success can thus be made.

To date, a pilot study has been undertaken to quantify the likelihood of a successful revegetation outcome:

1. By applying geological modelling tools to the rehabilitation context to better define spatial variation in key properties; and
2. By linking that variation to varying degrees of plant performance.

The approach uses a computationally efficient stochastic (Gaussian) simulation method based on minimum/maximum autocorrelation factors (MAF) (eg Desbarats and Dimitrakopoulos, 2000). The approach takes advantage of the fact that attributes are rarely independent of each other, and that spatial patterning will impart different weightings to data points around the point being estimated, to improve overall predictive power. Multiple simulations are run to produce a distribution of possible values for every point being modelled. This distribution forms the basis for determining probabilities for one or more attributes and therefore revegetation success.

Analysis of data from monitoring sites upon which draft completion criteria for pasture-based rehabilitation were developed (ACARP Project C8038; Grigg et al., 2001) indicated a strong influence of average salinity (EC) on pasture performance, as judged by the amount of total dry matter produced (Grigg et al.,2001). An exponential increase in dry matter production occurred with decreasing salinity levels, and since the amount of dry matter was also related to groundcover, an increase in groundcover likewise occurred. From past erosion research studies, 70% groundcover has been considered a level necessary to maintain surface stability in these pasture-based systems (Grigg et al., 2001). From the above relationships that have been reported, an EC of 0.6 dS/m would permit development of sufficient dry matter to achieve such a groundcover of 70%.

Using a dataset of 96 points from a spoil dump at an open-cut coal mine in central Queensland, Dimitrakopoulos and Mackie (2003) have shown that it is possible to simulate spoil parameters across the dumps and that these simulations enable us to quantify the variability of certain parameters. These simulations can thus be used to assess the probability, or risk, that EC will exceed 0.6 dS/m, the cut off value as discussed above to ensure 70% vegetation cover. This is determined from the number of simulations in which the generated value for a given location is above the cut off value. While in this example it was determined that a cover of 70% was required for successful rehabilitation, other goals may be tested by assessing different cut off levels. For ECs of 0.8 and 1.0 dS/m, the simulations by Dimitrakopoulos and Mackie (2003) show that the level of groundcover will be reduced to approximately 60% and 50%, respectively.

Using a threshold value (or several, depending on the accepted level of risk), in conjunction with the simulated probability maps, we are able to map areas of ‘success’ or potential ‘failure’. Thus, the significance of probability maps is their ability to display the risk associated with the rehabilitation goal, and enable decision makers to choose a level of risk that is appropriate and identify areas that may require special attention, as well as in some cases identify areas that will not require any remediation.

The key advantage of this approach is the potential for regulators to better understand the risks associated with decisions regarding sign-off, facilitating the relinquishment process. Industry can also benefit by using the approach as an internal continuous improvement mechanism. For example, depth of replaced topsoil could be strategically varied to address variations in spoil quality that are known in advance to potentially impact on revegetation outcomes. Greater consistency in the quality of rehabilitation outcomes can be achieved, and costly remedial work minimised.

Beyond these immediate benefits, the framework offers huge potential in ‘capturing’ and applying the body of rehabilitation knowledge acquired through company-sponsored and ACARP-funded rehabilitation research, in a manner akin to decision-support tools developed for land-use managers in different sectors. Such a framework would facilitate the identification of gaps in the current knowledge base to effectively target future research effort, and act as a mechanism to store knowledge and overcome problems associated with turnover of industry personnel and regulators alike.

Future research with this approach will need to concentrate on two inter-related areas. The first needs to focus on the enhancement and improved application in the rehabilitation context of suitable geostatistical modelling and simulation approaches, particularly with regard to their up-scaling to large areas of rehabilitation. This work will determine the success of modelling combinations of key soil and spoil attributes, site factors and other ‘soft’ data that are considered to significantly affect revegetation success. The second area relates to the determination of these key attributes, and associated values that may define important ‘thresholds’ of success. This work would examine the integration of existing information, and would include that emanating from current research that is defining factors affecting the productivity of pasture-based rehabilitation (ACARP C9038), exploration of the inclusion of native species communities in the approach, and the establishment of field trial areas as test sites and for model validation.

In summary, the technique offers a way of generating confidence in rehabilitation outcomes through the development of a decision-support methodology for assessing rehabilitation success, and furthermore will provide a framework for integrating, and more effectively applying, existing and future knowledge of rehabilitation, both pasture-based and native species dominated.

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References

Desbarats, A.J. and Dimitrakopoulos, R. (2000). Geostatistical simulation of regionalised pore-size distributions using min/max autocorrelation factors. Mathematical Geology, 32, 919-942.

Dimitrakopoulos, R. and Mackie, S. (2003). Stochastic simulation for the quantification of mine spoil variability and rehabilitation decision-making. ModSim 2003, Townsville, July 2003 (in press).

Grigg, A.H., Emmerton, B.R. and McCallum, N.J. (2001). The development of draft completion criteria for ungrazed rehabilitation pastures after open-cut coal mining in central Queensland. Final report ACARP Project C8038. Centre for Mined Land Rehabilitation, The University of Queensland.

Seaborn, V (2003). An assessment of the indices of Landscape Function Analysis on rehabilitated mine sites. MPhil Thesis, The University of Queensland (in preparation)