

# Forest restoration

**Tim Morald\*** and **Rachel Standish\*\*** consider the fertiliser conundrum for jarrah forest restoration after mining

**M**ining and conservation are often considered to be incompatible land uses. Yet, economically important mineral deposits often occur in areas with high biodiversity and therefore, high conservation value. The challenge then is for mining companies to maintain or enhance the conservation value of these sites, especially with regard to rehabilitation or restoration after mining.

One such example is the northern jarrah forest southeast of Perth, Western Australia. It is botanically diverse; home to almost 800 plant species and it also contains vast bauxite reserves. Alcoa of Australia commenced mining here in 1963 and currently mines and restores some 600 ha/y. Restoration is crucial because, among other considerations, the mining operations occur within Perth's drinking water catchments. The forest is also important for conservation, recreation and timber production. In fact, much of Alcoa's initial research into

rehabilitation focused on its ability to return a productive forest. More recently, its aim has been to return a self-sustaining jarrah forest ecosystem. This includes returning botanical diversity to pre- or unmined forest levels.

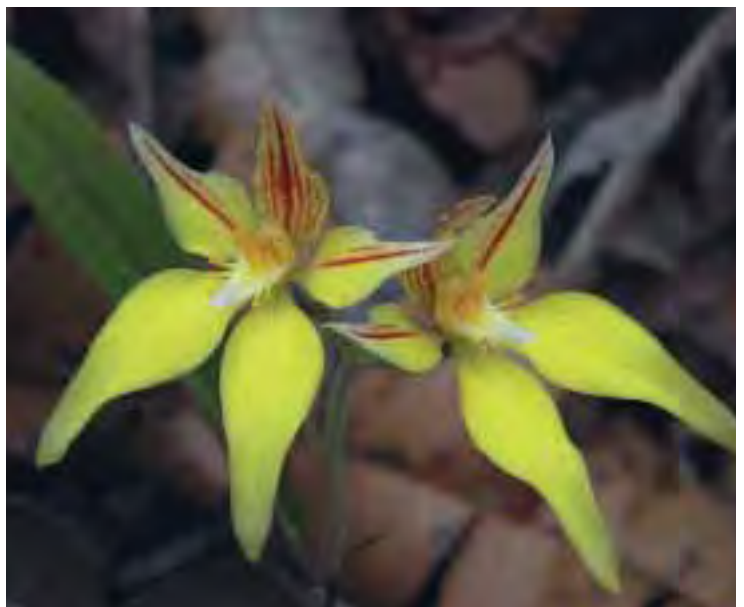
The soils in the jarrah forest are nutrient-poor, especially with regards to phosphorus. This has contributed to the high plant diversity and resulted in some interesting nutrient-acquisition strategies. These strategies include specialised root structures, such as cluster roots (particularly evident among the *Proteaceae* family). Another strategy

common in many jarrah forest plants is the formation of mycorrhizal associations with fungi - whose fine hyphae can explore and extract nutrients from a much larger area than the plants own root system could.

At progressive companies like Alcoa, the restoration is regarded as part of the mining process. The first step in this process in bauxite mining is the removal of all vegetation. The soil is then stripped in two distinct layers: the organic rich topsoil (~150 mm); followed by the overburden (~350 mm) occurring between the cap-rock and the topsoil. The bauxite layer (including the cap-rock) which averages 4.5 m depth is then mined. After completion of mining, the mine faces are battered down and the pit is landscaped to meld it with the surrounding unmined forest. The area is ripped to relieve mining related compaction. Then overburden and topsoil are returned. Final scarification is undertaken with a multiple tine and a diverse native seed mix is applied. The landscaping, soil return and seeding occur over summer when the soil is dry and fertiliser is applied by helicopter in the following spring.

So, whilst nutrients, principally phosphorus, are required to replace the nutrients lost during mining, some plant species adapted to nutrient-poor soils are sensitive to fertiliser application. Our concern was that increased fertility would reduce plant species diversity and alter species composition - in short, that we would lose biodiversity. To test this prediction we used a field experiment established by Alcoa in 1994, where high levels of phosphorus (P) had been applied at establishment.

The experiment was conducted in four restored pits, two pits at each of two Alcoa sites (Jarrahdale and Huntly). We selected treatments that had received no phosphorus



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and two or three times the current rate (40 kg P/ha). All treatments received 80 kg/ha of nitrogen and comparisons were made to surrounding unmined forest.

Fourteen years after fertiliser application we sampled the soil to see if the effects of high fertiliser application were still apparent. We sampled from the ripline furrows because this is where the nutrients, leaf litter, seeds and moisture are generally concentrated. Incredibly, phosphorus in the P fertilised plots was still five to ten times higher than in unmined forest. This is despite 14 years of vegetation growth and nutrient uptake on these sites. The

fertilised soil was also up to five times higher in nitrate concentration and was more acidic. These results could have implications for the species composition in the restored sites. Whilst good vegetation growth and litter accumulation was apparent at all restored sites, soil organic carbon pools (1.2 – 2.9%) were lower than in the unmined forest (3.4 – 5.5%).

So, have these differences in soil fertility affected the vegetation on the restored sites? To find out we monitored 80 m<sup>2</sup> of vegetation in restored treatments and compared this to 80 m<sup>2</sup> of unmined forest. We used an ordination of the vegetation data to compare species

composition. Remarkably, after only 14 years and despite all the mining related soil handling processes, restored sites with no added phosphorus were similar to the unmined forest in terms of native plant species richness, diversity and evenness. In contrast, the sites which had P fertiliser applied (at two or three times the current rate), were not similar to the unmined forest for these same measures. The species composition of restored sites was different to unmined forest. Differences in composition between Huntly and Jarrahdale (for both forest and restored sites) were apparent, but differences between restoration treatments were not apparent.

Finally, we looked at density of understorey species because this is where most of the diversity in the jarrah forest stems from. We also compared density of the *Proteaceae* family because their sensitivity to phosphorus is well documented and this family is well represented in unmined forest. Density of *Proteaceae* was greater in unmined forest than in the restored sites. In the restored sites, density of both *Proteaceae* and understorey plants decreased with application of phosphorus. In other words, phosphorus application resulted in restored sites that were less similar to unmined forest.

In conclusion, this research found that phosphorus fertiliser applied at two to three times the current application rate was still evident in the soil after 14 years. We also found that for some vegetation measures, restored sites with no added phosphorus are more like unmined forest. These findings have implications for mine restoration in other parts of the world where mining takes place in low fertility ecosystems. Further research aims to determine if botanical diversity of Alcoa's restoration can be enhanced by amending the current fertiliser application practices.

Revegetation issues and many more (from geotechnical, to social, to financial, as well as ecological) will be part of the now well established Mine Closure Conference series run jointly by the Australian Centre for Geomechanics and the Centre for Land Rehabilitation. More than 330 delegates attended the First International Seminar on Mine Closure that was held in Perth, Western Australia in 2006. Following on from successful seminars held in Chile (2007) and South Africa (2008), the ACG and CLR bring the Fourth International Conference on Mine Closure back to Perth in September 2009. Over 100 papers covering the topical geotechnical, social, financial and ecological mine closure issues will be presented over the three day event. [www.mineclosure2009.com](http://www.mineclosure2009.com) **IM**

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