MULGA (*ACACIA ANEURA*) DEATH ADJACENT TO HAUL ROADS IN THE NORTHERN GOLDFIELDS, WESTERN AUSTRALIA

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ABSTRACT

Increasing numbers of mulga (*Acacia aneura*) deaths have been observed adjacent to mine haul roads in the Northern Goldfields, Western Australia. Although there may be several causes of tree death, it is thought that increased soil salt levels, due to watering of the haul road with hypersaline water, and/or road shadow effect are the two most likely causes.

This study compared treated roads (watered with hypersaline water) and control roads (not watered) and the upslope and downslope sides of the roads. Tree canopy decline was significantly greater at treated road sites than control sites. The proportion of old dead trees was significantly higher at control road sites than treated road sites. The downslope side of roads (treated and control) showed a significantly higher proportion of both dead trees and recently dead trees. The downslope side of the treated road had significantly greater soil conductivity than the control road (both upslope and downslope) and the upslope side of the treated road. This suggests that runoff from watered roads causes salinity increases downslope, which in turn results in tree death.

Keywords: mulga; *Acacia aneura*; roads; salinity; road shadow; sheetflow

INTRODUCTION

The extraction and production of mineral and energy resources has occurred in Australia since European settlement. The discovery of gold and subsequent immigration led to the exploration and settlement of the remote interior (Howard 1996a). This area encompasses what is now known as the rangelands and occupies more than 75% of Australia, with 2% used for mining (Harrington *et al.* 1984; Commonwealth of Australia 2001). The majority of Australian gold mines are located in rangeland areas (Howard 1996a). Gold mining techniques have changed from alluvial and underground deposits to the large scale open-pit mining operations of today. This change in the scale of operations has seen the development of large pits, often intercepting the water table and increasing the need for disposal of mine pit water, and the construction of haul roads. These and other changes have led to an increased potential for environmental problems and an increasing need for environmental impact assessment before mining, appropriate environmental management during mining and effective rehabilitation of the land after mining (Farrell and Kratzing 1996; Howard 1996a).

Although the collective area of land disturbed by mining may be small and the life of a mine relatively short, dramatic impacts can occur to the local and surrounding environment during the operational period. This includes the exploration, mining or mineral processing phases or for the years after mining (Bell 1996; McQuade and Riley 1996). Mining impacts from infrastructure such as the pit, waste dump and tailings dam affect the major area of the mine and are usually confined to a discrete area. However, these are not the only impacts caused by mine infrastructure and others include haul roads, access roads, railways, conveyor belts, dump sites, airstrips, settlements and offices. Haul roads which link satellite pits with existing infrastructure have become popular in recent years on account of the costs associated with moving infrastructure such as crushers, mills, laboratories and offices. It has become easier and cheaper to transport ore from a satellite pit (usually between 10-50 km away) to a centrally established crushing and extraction plant. This however, has led to a substantial network of roads around mine sites often with detrimental effects on the surrounding landscape. In recent years at Placer (Granny Smith) mine site near Laverton, in Western Australia, there have been observations of increasing tree death along haul roads. Several factors have been thought to cause tree death; this paper concentrates on two of these, namely road shadow effect and salinity.

In the arid and semi-arid zones of Australia, surface or sheet-flow occurs on slopes between 0.2 and 2% rather than channelised flow (Ludwig *et al.* 1997; Wakelin-King 1999; d'Herbes *et al.* 2001). Depending on construction design, roads can impede the flow of water along the slope resulting in water starvation on the downslope side causing tree death (road shadow effect) and eventually changes in vegetation (Pringle *et al.* 1994). To date, road shadow effect has been identified across other areas of Western Australia including grazing land and road verges (Hussey and Wallace 1993). It therefore needs to be examined to see if it is a relevant problem and if improvements in road design can help to alleviate the problem. However, around the Placer (Granny Smith) mine site it has been speculated that road shadow effect is not the only cause of tree death, but that other factors or multiple factors are the cause.

Salinity is a major issue as haul roads at many mines are watered to suppress dust. Dust suppression is considered necessary for both safety and environmental reasons. Excessive dust is considered pollution and poses a health risk. Research at the Fimiston Pit, Kalgoorlie confirmed the importance of adequately watering the haul road surface to reduce dust emissions (Howard 1996b). Dust leads to a reduction in visibility for drivers on the haul road, which is a safety concern. At Placer (Granny Smith) the water used on the haul road is sourced from the Sunrise Pit and contains approximately 200,000 mg/L TDS (total dissolved solids). The use of pit water has two advantages. Firstly, it facilitates dewatering. Dewatering is the disposal of water, which accumulates in the bottom of the mine pit from groundwater interception and rainfall. Secondly, due to the scarcity of water in the arid zone, pit water is a convenient and economical source of water for use on haul roads. The salt in this water binds the soil to form a crust on the haul road, which further helps to suppress dust. The watering of haul roads is now considered normal practice in Western Australia and is a convenient way to dewater pits and suppress dust. Runoff of salty water from roads and the subsequent effects on soil need to be examined as part of this issue. It is hypothesised here that the 'Placer – Sunrise' haul road, which is watered to suppress dust and other local roads, which are not watered, will show differences.

The Mulga woodlands are one of the principal vegetation formations of the semi-arid and arid zone, (Beard 1990; Greig 1992). *Acacia aneura* (mulga) is a variable bushy shrub or small tree to 14 m tall with a number of characteristics being specific to provenance or ecotype (Randell 1992; William 2002). Mulga is widely distributed (landscape and soil types) over the arid areas of inland Australia, but is most commonly found on the lowland plains and sand plains (Greig 1992; William 2002). In terms of nutrient capture, transfer and hydrological regimes mulga plays an important role in arid landscapes (William 2002).

The tree form of mulga is such that its upward sloping branches and leaves capture up to 40% of the rain that falls on the canopy. These channel much of the intercepted water down the trunk (stemflow), increasing soil moisture close to the root zone (Harrington *et al.* 1984; Burnside *et al.* 1995; William 2002). The root systems of mulga are specially adapted to obtain water from the thin surface soil layer allowing it to exploit the moisture from even minor showers enhanced by stemflow (Greig 1992; Burnside *et al.* 1995; Wickens 1998; Brearley 2000). These extensive, radially extending root systems are likely to be of importance to this research.

METHODS

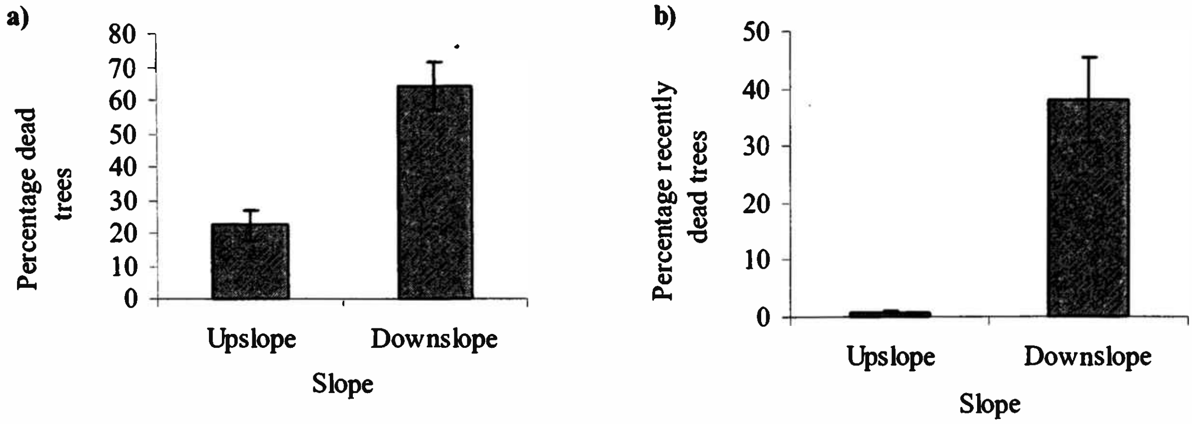
This research has been undertaken at Placer (Granny Smith) gold mine 25 km south of Laverton, Western Australia. The experimental design included a treated haul road (watered) and a control road (not watered). The treated road lies between the Granny Smith mine site and the Sunrise pit, is 30 km in length and has been watered 1-3 times daily since 1995. The control roads used were the Bindah Road and the Hacks Well Track, both of which are well-established roads, and are not watered. The presence of mulga was noted and the patterns of tree death were documented. This allowed for suitable site selection, which include mulga in both poor and good condition. Sites consisted of 2-3 adjoining quadrats. Quadrats were either 5x10m or 10x10m (with the 10 m side being parallel to the road). These adjoining quadrats also acted as a transect corresponding with distance from road edge. Altogether 20 sites were established (5 upslope and 5 downslope on the treated road and 5 upslope and 5 downslope on the control road). The treated and control roads intercepted an east-west slope of less than two degrees.

Within each quadrat, height, stem diameter and status of the mulga trees were noted. Status referred to whether the tree was dead or alive. For live trees the canopy volume, estimated as a percentage of the volume of a typical tree of full canopy, was recorded and for dead trees the 5 smallest branch/stem diameters were measured using calipers. This allowed for the dead trees to be classified as "recently dead" if the mean branch diameter was less than 1.5 mm and as "old dead" if the mean branch diameter was greater than 5 mm. The number of dead and alive trees (and per cent full canopy for live trees) was noted at two periods, once in 2000 and once in 2001, approximately a year apart. Within each quadrat, soil samples were taken with increasing soil depth (cm). Soil samples were taken from two areas within the quadrat and combined to form a bulk sample to overcome soil spatial variation within the quadrats. Soil samples were taken back to the laboratory and dried (100°C for 24 hours), sieved to 2 mm and then measured for electrical conductivity using the 1:5 ratio saturation method.

Data were analysed using two-way Analysis of Variance and *t*-tests in SPSS to examine mean differences between the variables measured and control and treated roads and the upslope and downslope sides of the roads.

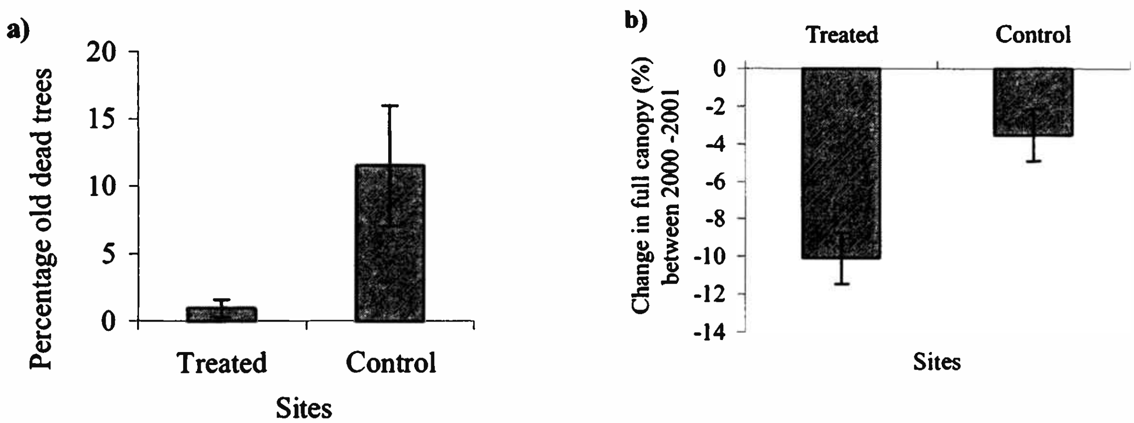
RESULTS

Two-way Analysis of Variance showed no significant interaction between treatment and position for dead trees, recently dead trees or old dead trees and therefore *t*-tests were used to analyse the data. The data for percentages dead trees, recently dead trees and old dead trees were arcsine transformed. The downslope sides of both the treated and control roads showed significantly more dead and recently dead trees than the upslope sides of the roads (Figures 1a & 1b). Of the average 65% of dead trees on the downslope side of the control and treated roads, an average 37% were recently dead. Of the remaining dead trees on the downslope sides of the roads, an average 10% were old dead trees, however this was not found to be significant.



Figures 1a & b. Mean percentage of **a)** dead (t=-4.78 p<0.001) and **b)** recently dead (t=5.5 p<0.001) trees at upslope and downslope sites on both treated and control roads.

There were significantly more old dead trees at control road sites regardless of side of the road (Figure 2a). The results of the tree canopy assessment between 2000-2001 showed that four trees died during that period (three trees from treated downslope sites and one tree from treated upslope sites). All of these trees had a canopy volume below 25% during 2000. However, although most of the trees alive during 2000 did not die, many of the trees on the treated road showed a significant decrease in canopy volume between 2000-2001 (Figure 2b).



Figures 2a & b. **a)** Mean percentage of old dead (t=2.0 p<0.001) trees; and **b)** mean change in per cent full canopy (t=3.4 p<0.01) between 2000-2001 at treated and control sites.

At 0-1 cm of soil depth there was a significantly higher electrical conductivity (EC) (μS/cm) on the downslope side of the treated road (Figure 3). The average EC on the downslope side of the treated road was 3636 μS/cm compared to the downslope side of the control road, which had an average EC of 162 μS/cm. This pattern continued with increasing soil depth, for instance at 1-3 cm soil depth the EC on the downslope side of the treated road averaged 6068 μS/cm whilst the downslope side of the control road had an average EC of 274 μS/cm. However, the upslope side of the treated road at 0-1 cm soil depth showed a much lower average EC of 526 µS/cm, but this was still higher than the upslope control sites at 0-1 cm soil depth, which averaged 149 µS/cm (Figure 3).

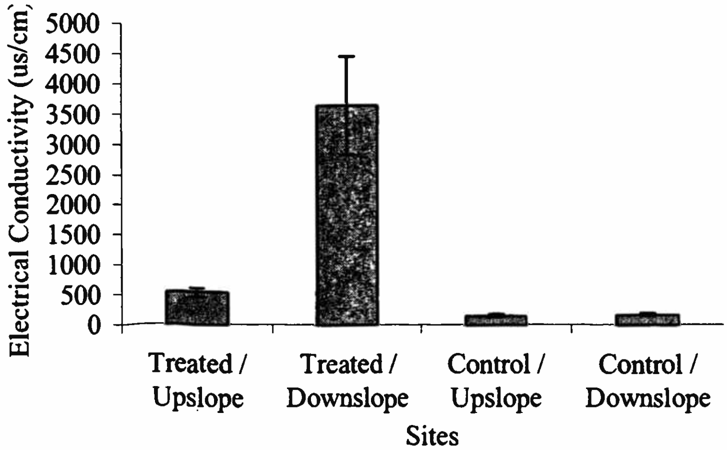


Figure 3. Electrical Conductivity (µS/cm) at 0-1 cm soil depth (interaction, F=36.1, df=3, p=<0.001).

DISCUSSION

Following visual assessments at both control and treated roads it was observed that there were substantially more dead mulga on the downslope side of the treated road than anywhere along the control road. In particular there appeared to be many recently dead trees within the first 5-10 m from the road edge beyond which mulga appeared to be alive. Another observation made along the treated road was that salt scald was often present on the soil surface amongst the road edge vegetation, particularly on the downslope side. The results presented here accord with the observations made.

A higher percentage of dead trees was found on the downslope side of both the control and treated roads. The aim was not to demonstrate that these areas had more dead mulga as this was expected from the observations, rather it was to show that within tree patches the proportion of dead mulga was similar between control and treated roads, but varied according to side of the road. This result may reflect sampling bias as sites selected on the downslope sides of the roads contained predominantly dead trees. More important was the proportion of recently dead and old dead trees at sites. Over half of the dead trees on the downslope side of both the control and treated roads were classified as recently dead. Based on observation it was expected that the downslope side of the treated road and not both the treated and control roads would show this result. The results thus far could be attributed to road construction impeding sheetflow and leading to road shadow effect (the death of trees) primarily on the downslope side of the road and that this may be occurring at both treated and control sites.

In the case of old dead trees the justification for road shadow effect being the cause is less clear. The control roads are older than the treated and this would account for the higher proportion of old dead trees found on this road if road shadow effect was the cause. However, road shadow effect is said to cause tree death downslope but the percentage of old dead trees is similar on both sides of the control road. This pattern of old dead trees may reflect other historical factors, such as differences in grazing regimes, not examined as part of this study.

Although the proportion of trees classified as recently dead was similar between treated and control roads, canopy condition declined far more on the treated road from 2000 to 2001. This is an important finding as it suggests other underlying causes of tree decline or death rather than road shadow effect because of the magnitude of the decline and because trees on either side of the road were similarly affected. A potential cause that was examined was enhanced soil salinity adjacent to the treated road. The average electrical conductivity on the downslope side of the treated road was over 20 times higher than on the downslope side of the control road. The upslope side of the treated road also displayed a higher electrical conductivity and although it was approximately 7 times lower than that on the downslope side of the treated road it was still 3.5 times higher than at the upslope control sites on average. The conclusion therefore is that salt in the water which runs off the watered road is likely to have contributed to the most recent tree declines adjacent to this road.

Soil degradation encompasses many issues including that of salinisation (Harrington *et al.* 1984; National Research Council (US) Committee on Rangeland Classification 1994). In arid climates salts tend to accumulate in soil, particularly near the soil surface, as they are not leached by regular rainfall (McBride 1994). As mentioned previously the root systems of mulga are specially adapted to obtain water from the thin surface soil layer (Greig 1992; Burnside *et al.* 1995; Wickens 1998; Brearley 2000) and consequently increased salt levels in this layer would be expected to affect water uptake.

The management options for Placer (Granny Smith) related to this research are still being considered. In an ideal world the watering of haul roads with hypersaline water should be stopped. However, considering the lack of alternative water sources this is unlikely. A reduction in the level of salts in the water may be a good starting point. However, without knowing at what salinity threshold mulga begins to decline it is difficult to set such levels. There are other dust suppression products available that can be applied to roads, although many of these need water to act as a dispersing agent. Road design is another management option and is mainly oriented to alleviating road shadow effect. Roads in northern Western Australia have in the past been designed to allow water to be redistributed by installing additional culverts and drains (Dames and Moore 1984). However, experience at Placer (Granny Smith) has shown that these do not always work. Drainage culverts on the downslope side of the treated roads at Placer (Granny Smith) were found to contain dead mulga at the end of culverts and beyond. Culverts may work by redistributing sheetflow, though when hypersaline water has been applied to the road it seems to move problems further into the landscape. Other options on haul roads may include the use of culverts with pits to contain the salt residue. However, what happens during large rainfall event in this scenario is not known. Another very important issue is that of grading and avoiding leaving salt laden spoils on the road edge.

While gold mining and ore-processing methods are essentially very similar across Australia, there exists a wide range of environmental management issues driven by the differences in climate, geology and history (Howard 1996a). It is therefore appropriate for the mining industry to be concerned with protecting the whole environment in which it works or has influence upon (Happs and Kinnear 1992), and that companies study and ameliorate adverse effects by seeking relevant management options which can also accomplish their sustainability and environmental objectives. It is unacceptable for companies to sacrifice good quality land such as that along haul roads through inadequate knowledge and management.

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