Kanmantoo Mine

LFA Monitoring – Autumn 2012

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Prepared by EBS Ecology for Hillgrove Resources

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Front cover photo: Typical *Eucalyptus odorata* (Peppermint Box) Woodland in good condition.

GLOSSARY AND ABBREVIATION OF TERMS

EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
LFA	Landscape Function Analysis
MARP	Mining and Rehabilitation Program
SSA	Soil Surface Assessment
TPC	Threshold of Potential Concern

EXECUTIVE SUMMARY

A Landscape Function Analysis (LFA) monitoring program has been implemented into the ongoing environmental management, restoration and SEB offset program components of the Kanmantoo Mine.

2012 is the second year of monitoring the three vegetation communities, which include two nationally threatened ecological communities listed as critically endangered under the *Environment Protection and Biodiversity Conservation Act 1999* (the EPBC Act); *Eucalyptus odorata* (Peppermint Box) Open Woodland and *Lomandra effusa* (Scented Mat-rush) +/- *Lomandra multiflora* subsp. *dura* (Stiff Mat-rush) Open Tussock Grassland. The third vegetation association is *Austrostipa scabra* (Spear grass) Tussock Grassland.

Analysis of the data has demonstrated that the analogue sites are in very good condition and are consistent with the previous year's datasets. They are still yielding the higher end of the target values, due to exceptional seasonal condition over the past three years and it will be important to monitor the analogue sites annually for several more years to capture the lower end of a 'target range' of values.

The rehabilitation sites established in *Eucalyptus odorata* (Peppermint Box) Open Woodland areas are generally in poor condition, however there are small variations in the data which indicate that the removal of grazing and the favourable seasonal conditions are benefiting the vegetation community. It is anticipated that the LFA indices values will begin to improve further, once active restoration of the sites is commence.

Rehabilitation sites for the other two vegetation types will need to be established as soon as they are identified and restorative activities have been initiated.

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1 INTRODUCTION

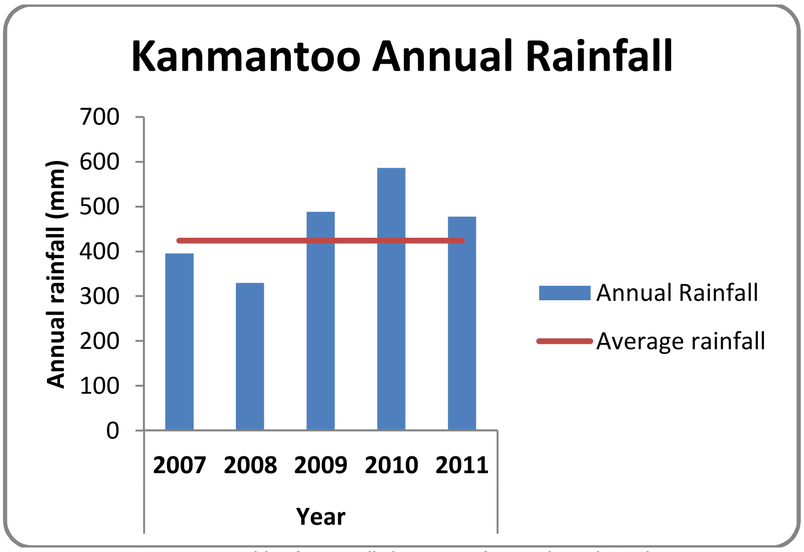
For Hillgrove Resources to meet its objectives and obligations under the MARP, the nominated offset areas will require annual monitoring to determine the overall success of the ongoing restoration programs. EBS Ecology has been commissioned by Hillgrove Resources to undertake a Landscape Function Analysis (LFA) (Tongway and Hindley, 2005) land condition monitoring program across the Kanmantoo Copper Mine project site. Details of the monitoring program and associated methodologies are detailed in *Kanmantoo Mine Vegetation Monitoring – Landscape Function Analysis. (*EBS Ecology, 2011). It is the intent that data collection be repeated over time to achieve a time series trajectory for the different land types across the mine site, enabling critical indicators to be identified, their values analysed and used to adapt future management activities if required.

This primary aims of this report are to:

- provide the second year of LFA monitoring data for the existing sites across the Kanmantoo Mine site
- provide discussion and analysis of data for relevant critical indicators
- provide recommendations for future LFA monitoring.

1.1 Seasonal conditions

The long-term average annual rainfall for the district is 424 mm. 2011 was another above average rainfall season contributing to the 'pulse' event (Figure 1). It is important to note that a natural decline may be experienced in the data index values following this period of above average precipitation. It is necessary that during and after this period, to collect a series of 'target values' for the analogue sites which will become the 'target range' the rehabilitation sites are aiming for.



Data source: Commonwealth of Australia/Bureau of Metrology (2012)

Figure 1. Kanmantoo annual rainfall 2007-2011.

2 RESULTS

Data was collected at the analogue sites for a second year during May 2012 and will be used in association with one or two additional datasets to determine what the 'target range' of values are for each vegetation association.

Vegetation communities have responded well to above average seasonal conditions over the past few years, with good cover of native perennial and annual species. Some juvenile grass and other native herb recruitment is evident mainly throughout *Eucalyptus odorata* Open Woodland and *Lomandra effusa* / *Lomandra multiflora* spp. *dura* Grassland associations. Mosses and lichens have also responded well and appear to be much more prevalent than in 2011. Local disturbance to the soil surface brought about by high mouse numbers in 2011, appear to have declined significantly and the subsequent damage is recovering.

Site photos for 2012 are displayed in Figures 2 – 5.

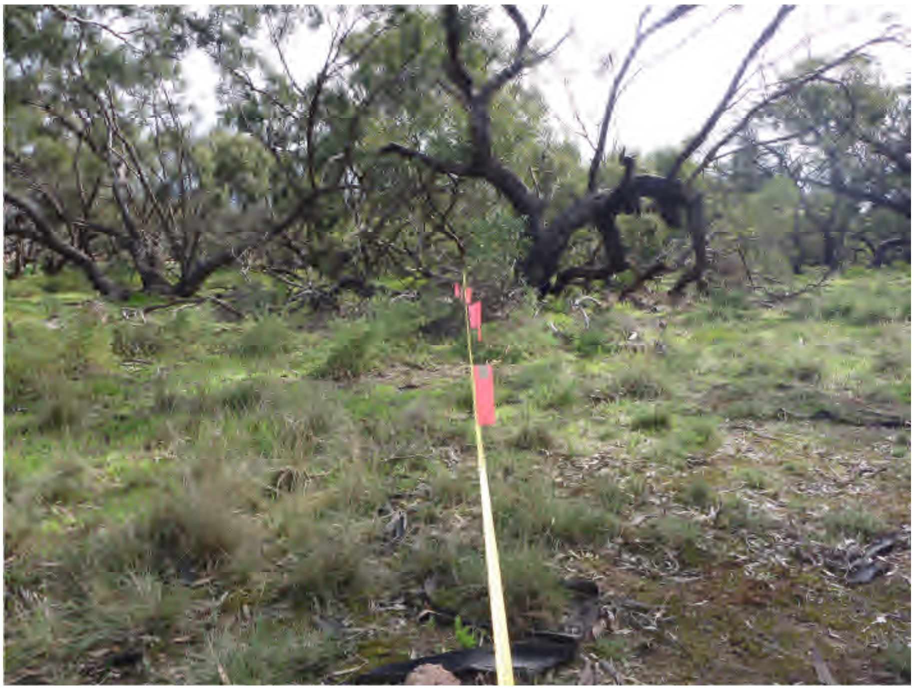


Figure 2. Analogue site - *Eucalyptus odorata* (Peppermint Box) Open Woodland 2012.

Figure 3. Analogue site - *Lomandra effusa* (Scented Scented Mat-rush) +/- *Lomandra multiflora* ssp. dura (Hard Mat-rush) Grassland, 2012.

Figure 4. Analogue site - *Austrostipa* spp. (Spear Grass) Grassland, 2012.

Figure 5. Rehabilitation site - *Eucalyptus odorata* (Peppermint Box) Open Woodland 2012.

2.1 LFA

Results for Soil Surface Assessments for individual zones and contribution to whole of site values are provided in Table 1. Data from each of the three replicate sites within the same vegetation associations have been combined to obtain average values. For example KANODO 1, 2 and 3 have a single set of values for each indices.

Year 2 results (2012) have been added to the table, with subsequent years also to be included following each monitoring event. As new rehabilitation sites are established, more datasets will be included within the annual reports.

Table 1. SSA results.

			Stability (%)		Infiltration (%)		Nutrients (%)	
Site name	Zones		2011 (baseline)	2012 (Year 2)	2011 (baseline)	2012 (Year 2)	2011 (baseline)	2012 (Year 2)
KANODO Analogue site (8:1)	**Whole of landscape**		**61.26**	**60.56**	**37.4**	**44.3**	**26.6**	**31.76**
	Individual zones	Bare Ground	60.2	57.7	28.36	30.3	20.8	19.36
		Grass Sward	64.6	62	34.46	39.4	27.7	26.9
		Tree Patch	61.2	62.46	45.8	57.96	31.46	44.4
		Shrub Patch	62.45	62.5	36.7	49.53	24.5	35.26
KANODO Rehabilitation site (4:1)	**Whole of landscape**		**69.66**	**61.3**	**54.4**	**54.8**	**47.3**	**40.9**
	Individual zones	Bare Ground	-	61.3	-	51.6	-	34.05
		Exotic Grass Sward	70.1	62.3	48.26	53.9	41.36	38.1
		Tree Patch	69.6	60.4	59.93	56.1	52.7	44.16
KANLOM Analogue site (8:1)	**Whole of landscape**		**62.5**	**61.5**	**27.1**	**30.03**	**21.6**	**21.9**
	Individual zones	Grass Sward	64.1	63.4	29.2	32.5	23.6	25.2
		Bare Stony Ground	56.3	58.6	20.1	25.6	14.8	15.9
		Shrub Patch	69.4	68.1	31.1	51.5	27.7	50
KANSTI Analogue site (8:1)	**Whole of landscape**		**64.9**	**60.6**	**36**	**39.3**	**29.5**	**25.2**
	Individual zones	Grass Sward	66.4	63	37.43	42.3	30.9	27.8
		Bare Ground	55.1	56.36	20.5	34.26	14.9	20.6

A number of graphs display data for each of the vegetation associations. Data has only been compared between *Eucalyptus odorata* analogue and rehabilitation sites where sites were both assessed (see Figures 6 - 10). *Lomandra* and *Austrostipa* Grassland sites have data displayed only for analogue sites as the rehabilitation sites are yet to be established. Site comparison will become possible for these associations as further sites are selected for restoration.

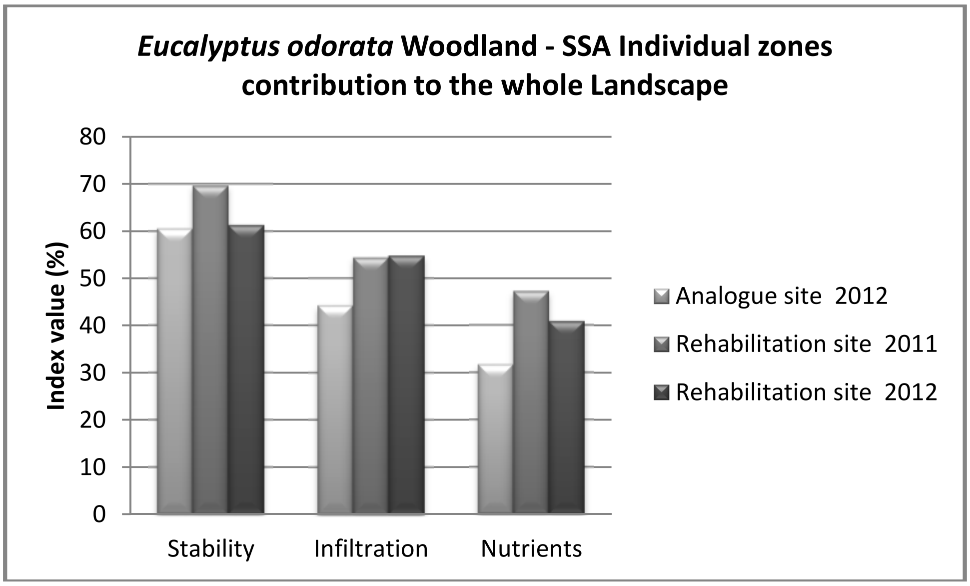


Figure 6. ***Eucalyptus odorata*** **Woodland SSA individual zones contribution to the whole of the landscape site comparison**

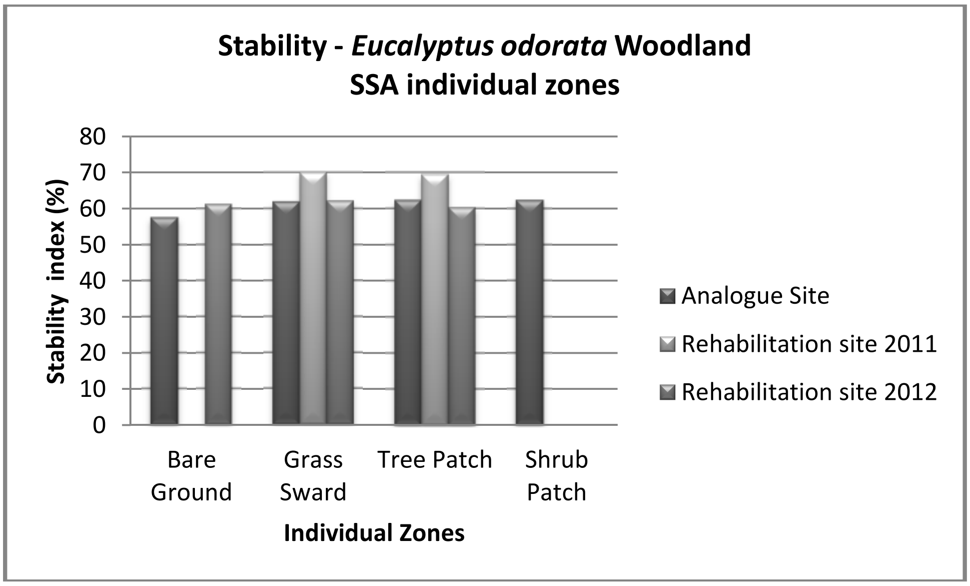


Figure 7. ***Eucalyptus odorata*** **Woodland SSA individual zones contribution to Stability**

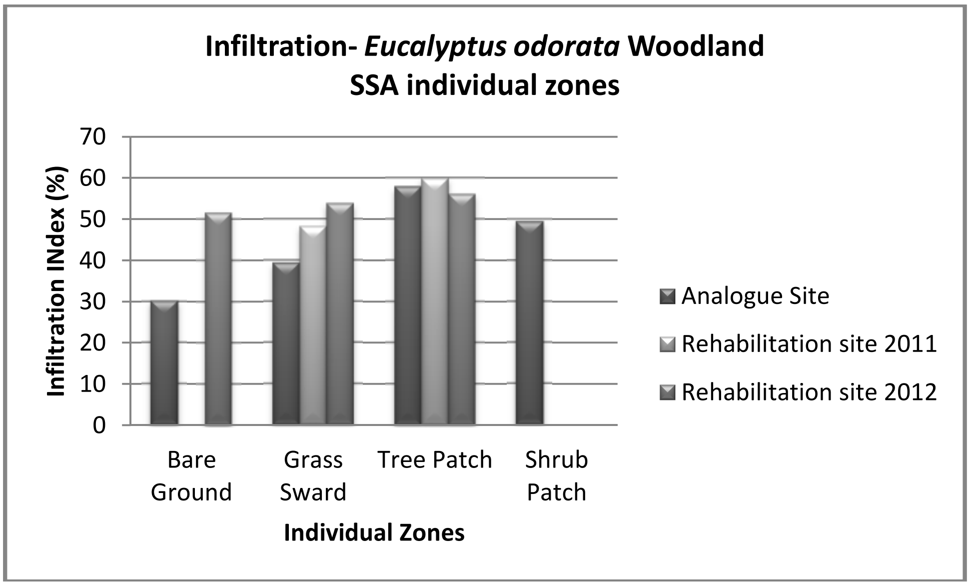


Figure 8. ***Eucalyptus odorata*** **Woodland SSA individual zones contribution to Infiltration.**

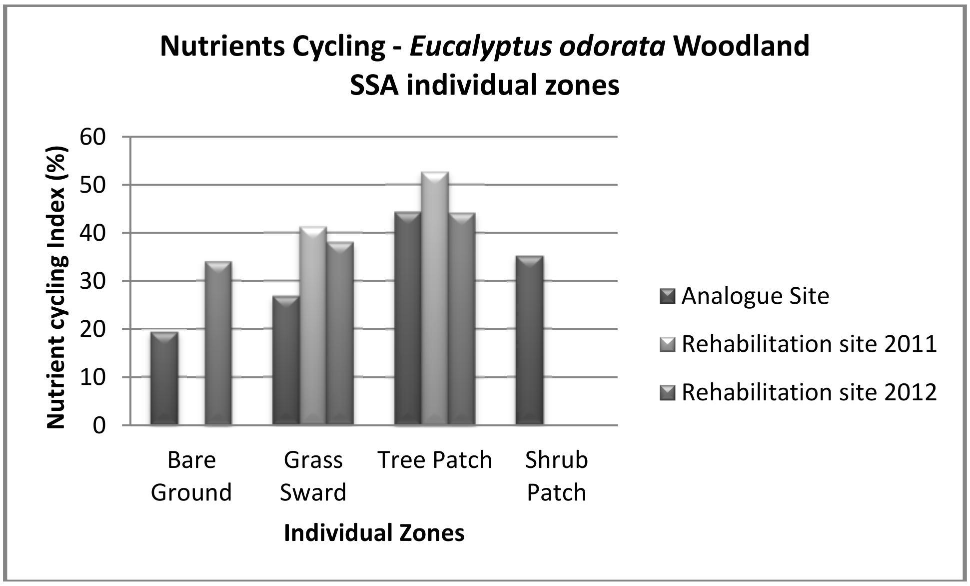


Figure 9. ***Eucalyptus odorata*** **Woodland SSA individual zones contribution to Nutrient Cycling.**

A summary of the landscape organization data is provided in Table 5. This includes the averaged values between the three replicate sites for number of landscape patches per 10 m, Total patch area (m^2), average inter-patch length and Landscape Organisational Index. The landscape organization index is the proportion of the length of patch to the total length of the transect i.e. a totally bare transect would have an index of zero or if it was all patch (e.g. a sward) the index would be 1. These values can be compared from year to year to measure changes in the landscape. For example, patch sizes and/or number of patches are increasing and by extension, inter-patch lengths are decreasing.

Table 2. Summary of the landscape organisation data for KANODO analogue and rehabilitation sites.

Site Type	No. of patch zones per 10m	Total patch area (m²)	Average inter-patch length (m)	Landscape Organisational Index*
Analogue 2011	2.6	242.4	1.94	0.59
Analogue 2012	2.9	327.5	1.6	0.75
Rehabilitation 2011	0.96	520.46	0	1
Rehabilitation 2012	1.16	476.2	1.2	0.97

*length of patches/length of transect

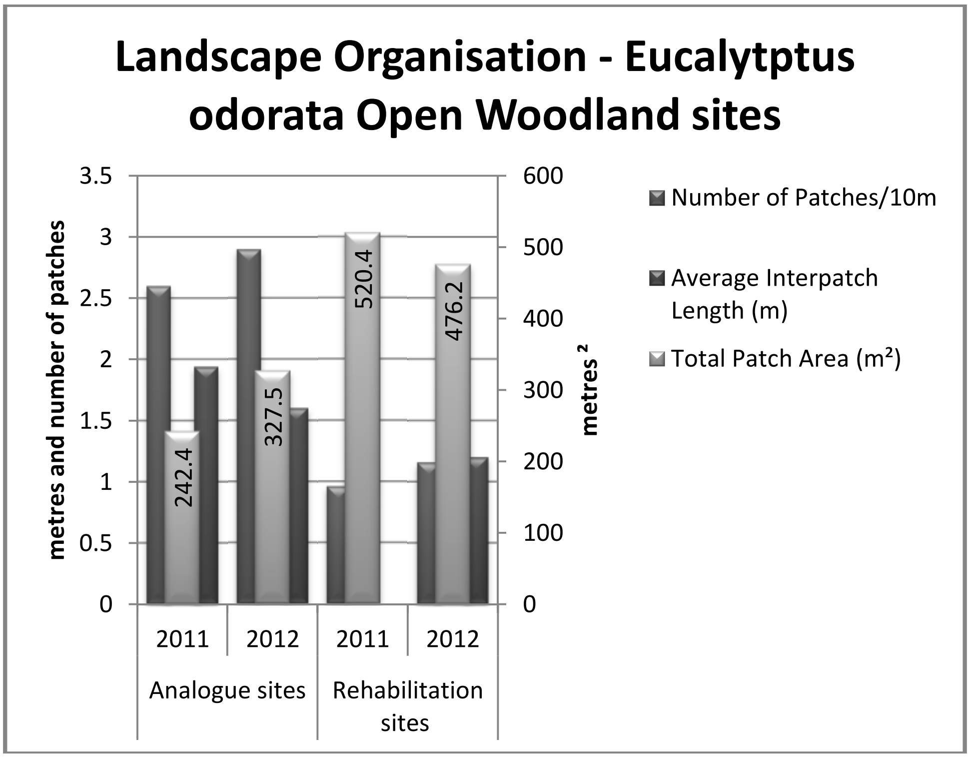


Figure 101. ***Eucalyptus odorata*** **Woodland Landscape organisation data**

Collated data for Lomandra ssp. Grassland sites is presented in Figures 11 and 12. Note that only two replicates of the shrub patch type were recorded when five are required for statistical reliability. This may increase over time if shrub cover increases within the transect monitoring zones. The existing data is probably not overly robust with only two replicates.

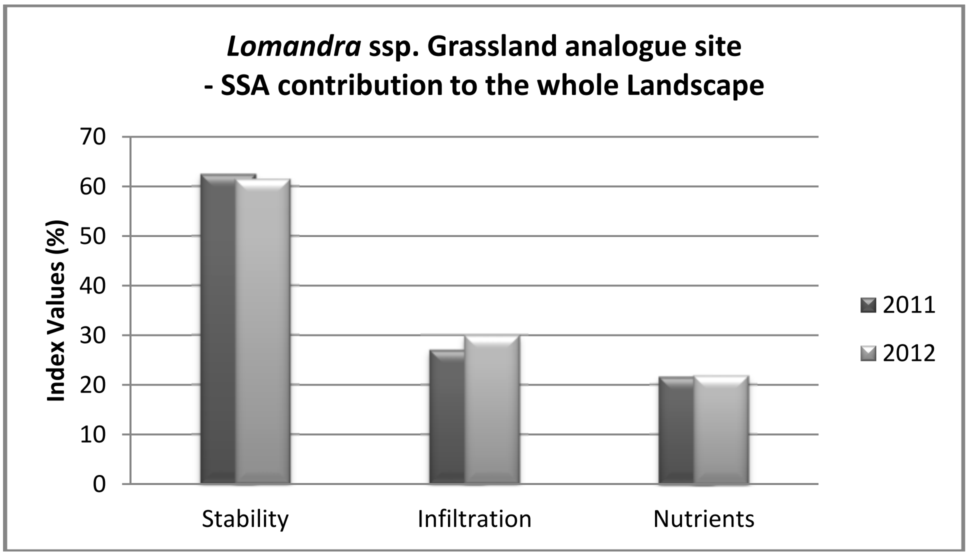


Figure11. Lomandra ssp. Grassland analogue site - SSA contribution to the whole of the landscape.

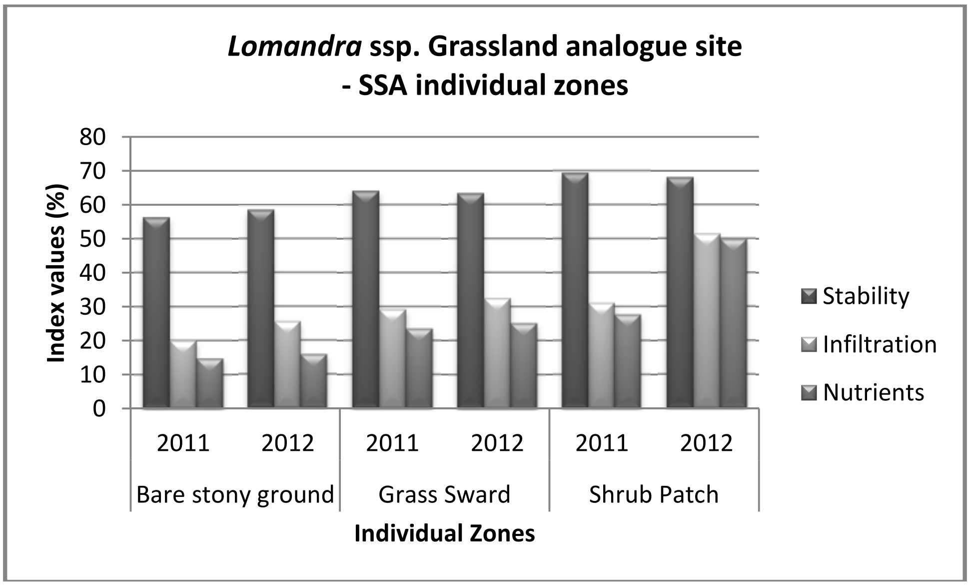


Figure 12. Lomandra ssp. Grassland SSA individual zones.

A summary of the landscape organization data is provided in Table 6.

Table 3. Summary of the landscape organisation data for KANLOM analogue sites.

Site type	No. of patch zones per 10m	Total patch area (m²)	Average inter-patch length (m)	Landscape Organisational Index*
Analogue 2011	4.4	92.9	0.76	0.64
Analogue 2012	5.4	95.1	0.71	0.56

*length of patches/length of transect

Collated data for *Austrostipa* ssp. Grassland sites is presented in Figures 13 and 14.

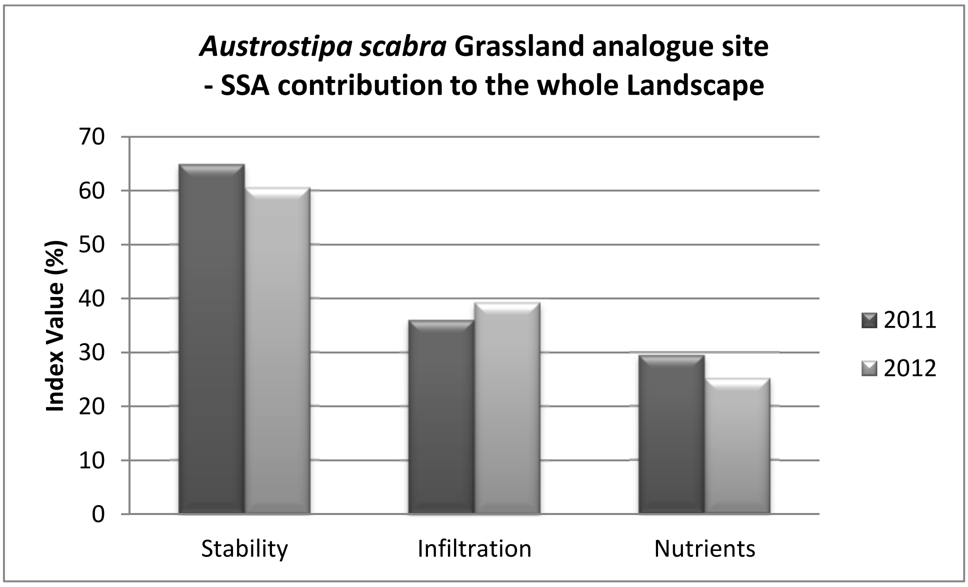


Figure 13. *Austrostipa* spp. (Spear Grass) Grassland analogue site - SSA contribution to the whole of the landscape.

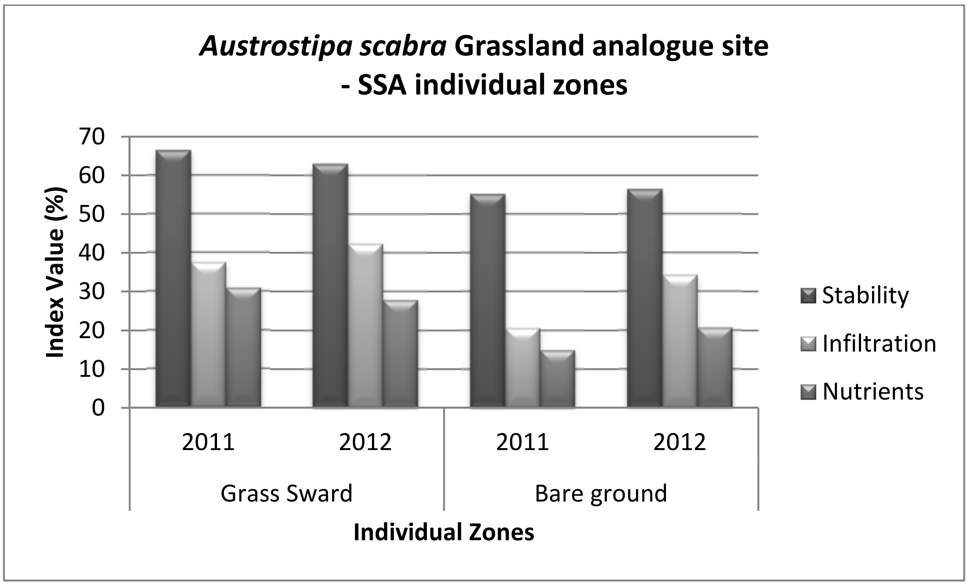


Figure 14. *Austrostipa* spp. (Spear Grass) Grassland analogue site SSA individual zones.

A summary of the landscape organization data is provided in Table 4.

Table 4. Summary of the landscape organisation data for KANSTI analogue sites.

Site Type	No. of patch zones per 10 m	Total patch area (m²)	Average inter-patch length (m)	Landscape Organisational Index*
Analogue 2011	2.5	215.5	20.18	0.85
Analogue 2012	6.9	122	0.58	0.61

*length of patches/length of transect

3 DISCUSSION

Eucalyptus odorata (Peppermint Box) Open Woodland

As expected the indices values obtained from the analogue sites are consistent with those collected in 2011, indicating that the community is in a highly functional and stable state. Another year of above average rainfall has again inflated the values somewhat and it will be important in the following few years to collect annual data from the analogue sites to obtain more realistic values and the development of a 'target range' of values in which the rehabilitation sites can aspire to.

The whole of landscape values obtained from the rehabilitation sites are higher than the analogue sites for infiltration and nutrient cycling, primarily due to the exceptional season and the continuous dense cover of annual grasses. This has led to the retention of soil moisture, enhanced infiltration due to high volumes of below-ground biomass, and nutrients in the soil from the breakdown of the annual biomass in the previous two years. Stability has stabilised and in 2012 is more in line with the analogue sites (Figure 6) and is probably also due to the high cover of grasses and exotic herbs. The values of the individual zones show that there is significant variation in the indices between analogue and rehabilitation sites within the bare ground and areas dominated by grass, whereas the tree patches yield very similar values for stability, infiltration and nutrient levels. The influence of the trees appears to have a consistent effect upon the soil function. An important feature of the woodland landscapes are that they tend to be more resilient to degradation through weed invasion because the trees groves are scarcely impacted and continue to cycle nutrients in spite of bare patches between the tree groves (in summer months), which tend to be prey to wind and water erosion when their surfaces are disturbed. Future analysis aimed at detecting genuine degradation of a site, will need to focus on the data between tree patches in the inter-patch areas, and use any of the bare soil inter-patch values as indicators of soil degradation, augmented by the inter-patch length, rather than the whole of site indices, which will always be buffered by good tree patch values. These may not be available until the continuous annual grass cover has died off.

Some of the general observations made during the 2012 monitoring survey included a higher incidence of mosses and cryptograms, higher levels of litter and softer ground due to the exceptional high rainfall in May. Infiltration rates in particular appear to have been influenced by these factors and exhibit elevated levels, particularly within the analogue sites. Increases in moss cover appear to be influencing native grass recruitment within the *Eucalyptus odorata* (Peppermint Box) Open Woodland rehabilitation sites. Despite only occurring in small localised areas, it is suggesting the early stages of recovery following the removal of grazing and favourable seasonal conditions.

Once future targeted management activities are initiated (outlined in *Kanmantoo Mine Vegetation Monitoring – Landscape Function Analysis* (EBS Ecology, 2011)), it is anticipated that the LFA indices values will gradually begin to improve, that is, infiltration and nutrient cycling levels will begin reducing and stability remaining consistent with the Analogue site value..

The landscape organisational data shows that the rehabilitation sites are behaving very differently in terms of patch/interpatch variation. Much of the community is dominated by grassy exotics forming a ‘continuous’ homogenous patch in the understorey. Some small areas of bare ground were evident during the 2012 survey, as well as small areas dominated by the moss / native grass combination. This may be the emergence of a more heterogeneous landscape structure now that the primary degrading factor has been removed (grazing), coupled with good seasonal conditions. The proposed management activities (understorey restoration) will aim to accelerate this process by mimicking landscape patch arrangement observed in the analogue sites.

Lomandra effusa (Scented Scented Mat-rush) +/- Lomandra multiflora ssp. dura (Hard Mat-rush) Grassland

The overall condition of the analogue sites from a biodiversity perspective is excellent. There are very few weeds, a high cover of native vegetation and high species diversity for the vegetation community. The LFA values obtained from the indices demonstrate that the sites are highly functional and in a stable state, however they are likely to be higher than normal for the same reason that the woodland sites have inflated values. Very little has changed overall since 2011. Some small increases in infiltration and nutrient cycling were noted within the patch and interpatch zones, and may be attributed to the increase in cryptograms, particularly within the interpatch zones. The soils were also relatively moist given the above average rainfall in the months of March and May 2012. It is recommended that additional datasets are collected in the next few years to obtain more realistic target values.

Austrostipa spp. (Spear Grass) Grassland

The overall condition of the *Austrostipa* spp. analogue sites is very good and LFA values have remained fairly consistent with 2011. There are few weeds and a high cover of native grasses, however many of the plants are old and some senescing, with elevated levels of surface litter, mainly made up of native grass thatch. The LFA values obtained from the sites demonstrate that the sites are highly functional and in a stable state.

Landscape organisational data has yielded significant variation from 2011 data, where the patchiness has increased due to an overall decrease in surface litter. The litter appeared in 2011 to be creating ‘land bridges’ between the tussocks and led to larger areas being measured as grass swards. The decrease in dry grass litter levels may be a result of the widespread disturbance to soil surface due to mouse activity throughout 2011, subsequently breaking up the thick thatch layer.

For the same reasons as the other land types, the SSA values obtained are likely to be higher than would normally be expected due to exceptional seasonal conditions. It is therefore recommended that additional datasets are collected in the next few years to obtain more realistic target values.

4 REFERENCES

EBS Ecology (2011) *Kanmantoo Mine Vegetation Monitoring – Landscape Function Analysis.* Report to Hillgrove Resources. EBS Ecology, Adelaide.

Commonwealth of Australia (2012) *Bureau of Meteorology – Climate data, Kanmantoo*.

Tongway, D.J., and Hindley, N.L. (2005) *Landscape Function Analysis: Procedures for monitoring and assessing landscapes. With special reference to Minesites and Rangelands.* CSIRO Sustainable Ecosystems, Canberra.

Tongway, D.J (2005) *Landscape Function Analysis: Field Procedures* CSIRO Sustainable Ecosystems, Canberra.

5 APPENDICES

Appendix 1. Potential question for repeat visits

Landscape Organisation

- Is Landscape Organisation due to biological or physical/engineering features? If a mixture of biological and physical, what is the balance between them?
- Has physical patchiness declined since the last monitoring period? If so, is there cause for concern? Specify threatening processes (e.g. sedimentation, rill or gully initiation).
- Is biological patchiness increasing; is the rate significant?
- Has patch width increased or decreased since the previous monitoring? If decreasing, can the cause be identified (e.g. banks cut by rills, vegetation patches no longer linked by "litter bridges"). If increasing, what is the cause? (e.g. plant litter build-up between adjacent grass plants?)
- Are patches increasing or decreasing in length (ie. up and down slope)?
- Is the patch area increasing or decreasing?
- Has biological patch quality compensated for loss of physical patchiness, or not? Note that 'whole transect' LFA indices (bottom line in last table on Summary page) are comprised of both 'quality' and 'proportion' values. Comment should be made on the make-up of the final number.
- Does patchiness change with season? E.g. massive annual plant growth that 'hays off" in the non-growing season?
- Is a stony surface a significant inter-patch type? Is the stone embedded or resting on the surface?
- Is stone cover of such significance that a soil crust has not formed between stones?
- If patches are due to applied mulch, is the density and spacing of mulch having an effect on runoff and erosion/sedimentation processes? Can check rill density to confirm. Look also for sediment trapped in upslope edges of mulch. Comment on whether too much or too little mulch appears to have been used, giving reasons.
- What are the major differences between the analogue site and the rehabilitation sites? (E.g. patch type and size).
- Are any of the assessed sites approaching the Landscape Organisation of the analogue sites?
- Is a rill assessment necessary? If so, observe the nature of the rill floor and note if it is rock or is unstable (loose alluvium, slaking soil)
- Are rills increasing or decreasing in number or cross-section; are live plant or litter obstructions becoming established?
- Is sediment noticeably being captured in developing patches? If so, watch these areas in future for plant germination. If no sediment is being trapped, consider an intervention to supply more

resource flow "obstructions"

- Are patch/inter-patch types changing in character; are new names necessary? The need to do so should be explained, as both beneficial and detrimental changes can occur: explain in terms of resource regulation (patches may now be more complex: grass-shrub clumps forming? shrubs colonising? troughs growing plants? troughs becoming flats? Banks becoming slopes?)

Soil Surface Assessment

- Is rainsplash protection due to physical or biological factors? Is the protection threatened by disturbance? If so, specify and discuss. Is rainsplash protection likely to increase over time (vegetation growth) or remain the same (rock)
- Is litter accumulating noticeably? Is decomposition becoming a more conspicuous process? What is the balance between litter derived from perennial vs. annual plants?
- Is annual litter robust enough to be considered perennial (e.g. from biennial plants)? Is litter decomposition being reflected in soil darkening (look at the boundary between the litter and the mineral soil colour)?
- Is the surface crust becoming more or less pronounced? Is the sub-crust soil coherent (hard or weakly aggregated or single-grain) Are there any bio-aggregates (e.g. worm pellets, termite carton) present?
- Is all the litter accumulated subject to consumption by fire? (some landscapes have highly discontinuous litter beds, reducing the potential for complete loss in fire; grasslands are likely to lose all litter in a fire)
- Is plant litter (or applied mulch) sufficiently dense as to effectively filter out all particulate matter during overland flow? Look for deposited materials (physical or biological) near the upslope edge of the litter or mulch patch.
- Does the architecture of plant foliage tend to trap or accumulate resources at ground level, or is there a "gap" between the soil surface and the plant canopy? Can this be used to infer litter accumulation potential? Consider deploying the full vegetation function procedure in EFA.
- Are there some indicators that do not alter across the function/dysfunction continuum? (e.g. soil texture, surface roughness) If so, comment on this and concentrate on the more informative dynamic indicators.
- What are the threatening processes for the patch types assessed? (e.g. trampling, weeds, vehicular traffic, erosion, burial under sediment, fire)
- Do the indicators of cryptogam cover, surface condition and slake test "match" each other, or can a mis-match be interpreted in functional terms?
- If evidence of current erosion is rarely observed, is this because potentially available material is held in a "safe" location in the landscape, or because there is no erodible material present, or remaining?

- Is alluvium frequently or infrequently encountered? If infrequent, is this due to its rapid outflow from the landscape, or is little soil available for transport: look for clues off the line transect for guidance. Look for alluvial fans at the foot of the slope to confirm.
- How strongly differentiated are the index values for patches and inter-patches? If differences are small, discuss the significance. If marked, discuss whether patches are vulnerable to disturbance or robust. Good discrimination implies that the L/O task has been done well.
- Are any indicators reaching their maximum score? If so, identify and comment on as having reached a significant 'milestone' in rehabilitation.

Interpretational Framework

- This step involves examining both the whole-of-site LFA values and the respective patch inter patch LFA values so as to effectively summarize the findings of successive monitoring episodes, looking for trend over time. A sigmoidal or 'S' shaped curve with time should be expected.
- Are LFA indices increasing, implying that rehabilitation is progressing satisfactorily?
- Is there a particular factor which is restraining improved function? Is additional management intervention necessary? What recommendations for action can be specified from the data? Is the increase expressed at the whole site level or just within a single patch type? Discuss.
- Has there been a significant increase in LFA values from the initial value?
- Can a critical threshold be discerned in the index values (ie. LFA values about midway between initial and reference site values)? Discuss in terms of consequences for management actions (no problem; monitor at infrequent intervals; potential problem close to critical threshold, monitor more frequently; current problem, design intervention actions based on LFA indices. Devise target values and rehabilitation success and failure criteria for future monitoring.
- Expect the stability index to reach its plateau value before the infiltration index does. The nutrient cycling index will be the slowest as, for its plateau value, a mature vegetation stand, providing substantial litter fall and decomposition is necessary. A site may be concluded to be self-sustaining well before this however, if the stability and infiltration indices have progressed well and the nutrient cycling index is on an upward plane.

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