Communities in Landscapes project
Benchmark Study of Innovators

Gulgong, Central West Catchment NSW

By Peter Ampt & Sarah Doornbos

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Report completed Dec 2010

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Working together to integrate conservation and production across Box-Gum Woodlands

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A multi-partner collaboration including Landcare NSW Inc, Conservation Management Network, Department of Environment Climate Change and Water, Industry & Investment NSW, CSIRO, University of Sydney, STIPA Native Grasses Association Inc, Greening Australia's Florabank and Birds Australia.

Disclaimer

Acknowledgments

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1 Introduction

The Communities in Landscapes project aims to improve management of the Box Gum grassy woodlands and derived grasslands through the provision of targeted and relevant information to land managers across the range. A key aspect of the project is to identify management strategies that effectively integrate production and conservation and to analyse the environmental, social and economic impacts of these practices.

The Benchmark Study of Innovators aims to involve landholders across a wide range of grazing management regimes and evaluate the present and potential impact of their management practices. To be able to make meaningful comparisons between sites under different management we have identified ten paired sites on neighbouring properties that are similar in most aspects other than grazing management and have been under the current management regime for a minimum of five years. Innovative grazing management practices were characterized as those that aim to integrate production and conservation by increasing the component of native perennial grasses in the pasture through different forms of strategic grazing, and were compared to more conventional set stocking or continuous grazing strategies. Interviews were conducted with participating landholders to collect information about the history, nature and apparent impact of their grazing management. In addition, a detailed on-site environmental investigation was carried out to measure the impact of grazing management on the physical environment in terms of landscape function and vegetation diversity and density. Invertebrate surveys will be carried out at a later date and reported on separately. On a subset of sites, soil chemical properties and microbial activity and diversity were also measured.

This report was produced as part of the Communities in Landscapes project and provides the results of Landscape Function Analysis, a vegetation survey, and soil chemical and microbial testing carried out in May 2010 on a paired site near Gulgong NSW.

2 Management

Table 1 summarises the different management regimes on each site on the property as a whole as well as for the benchmark paddock in particular. There are some key differences in management between the two sites. Grazing management on the innovator site is characterised by short-duration high-intensity grazing followed by long periods of rest, whereas on the comparison site grazing periods are longer and rest periods shorter. Stocking rates are higher on the innovator site. On the innovator site crops are sown directly into pasture without the use of herbicides and with fertilizer inputs much reduced in the past 10 years. The comparison site is cropped in a more conventional way with higher inputs and introduced pasture species.

Table 1. Summary of property type and management on both sites

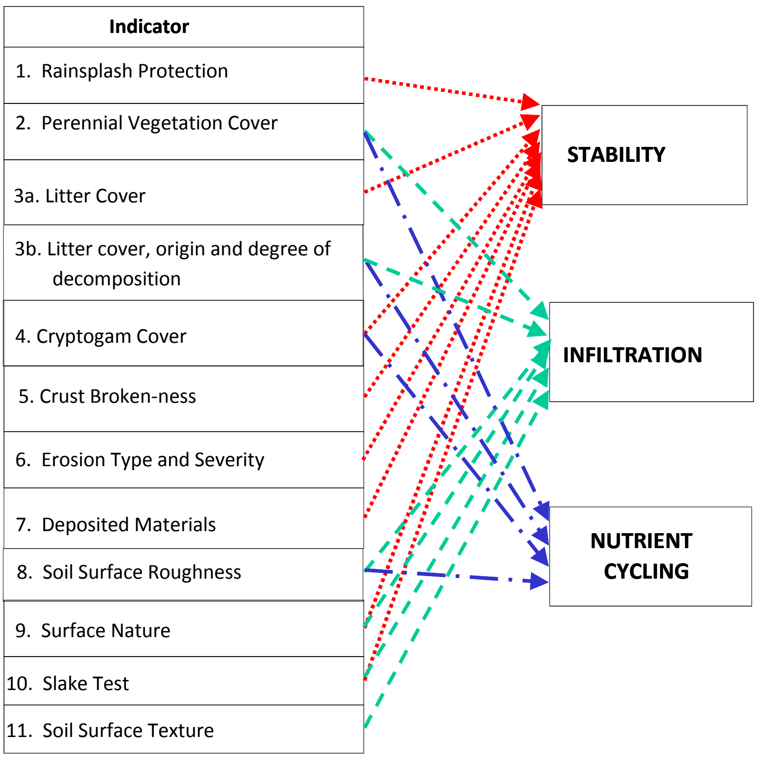
	Innovator	**Comparison**
Property size (ha)	809	384
No of paddocks	75	8
Av. paddock size (ha)	12	14-25
Enterprise	Merino stud	Merino wethers
Years of current management regime	10 years (began to change 30 years ago)	50
Practice	Rotational grazing and pasture cropping	Set stocked grazing and conventional cropping
Cropping cycle	One crop every 4 years, sown into native perennial pasture. Wheat 2000, oats 2004, cereal rye 2009	One crop every 3-4 years, followed by introduced pasture phase
Fertilizer (kg/ha)	**1945-1978:** 125 kg/ha superphosphate per year **1979 – 1990s:** 100 kg DAP/ha under crop only **Current:** 30 kg DAP/ha under crop only, moving towards organic fertilizer	**1945-1978:** 125 kg/ha superphosphate per year **1980s – 2010:** 60 kg/ha phosphate-based fertilizer under crop only
Herbicide (kg/ha)	None	Occasionally Roundup before cropping
Pasture type	Native - no pasture sown since 1979	Sown to sub-clover and/or rye grass under crop
Grazing period per cycle (days)	2-5	30
Rest period per cycle (days)	80-120	30-60
Average dse/ha/year	6.2	3.7
Landholder objectives	Regenerate grassland through pasture cropping and grazing management while generating income from wool, sale of stud animals, cropping and harvest of native grass seed.	Generate income from wool production.
Specifics of CiL Benchmark paddock – where different from entire property		
Use of the paddock	Part of grazing rotation and pasture crop paddock	Grazing and cropping paddock
Years of current management regime	10 – first pasture crop sown in 2000	50
Paddock size (ha)	12.1	14
Last crop	2009 – cereal rye	2007 - oats
Average dse/ha/year	8	3.7
Landholder comments	This paddock is improving from a low initial base. Aiming for further succession to more palatable and productive native grasses.	Useful paddock for cropping and grazing – other land elsewhere used for finishing lambs.

3 Landscape Function Analysis

Landscape Function Analysis (LFA) is a procedure for the objective assessment of 'soil health' and reflects the capacity of the soil to act as a habitat for plants. LFA is easy to learn and needs only simple field equipment, yet is based on careful scientific research. It was developed over 30 years by David Tongway and other CSIRO scientists. It is being widely used around the world and we believe it has great potential for use by landholders. LFA involves assessing the soil surface for 11 indicators of soil health (Fig 1) and, using a specially designed computer program, assesses how well each site is functioning in terms of:

- stability (is the surface eroding or at risk of erosion? Is material being lost or likely to be lost?)
- water infiltration (what is the likelihood that water that falls will soak in or run off? Will the flow of water be slowed down?) and
- nutrient cycling (is there evidence that the water and nutrients are being used and cycled by plants?).

Fig 1. Contribution of soil surface indicators to the three indices of Stability, Infiltration and Nutrient Cycling



Stability, Infiltration and Nutrient Cycling are expressed as numbers in a scale from 0 to 100, with higher values indicating better function. By comparing these values to reference sites, you can work out how well a site is functioning. If you do LFA regularly, you can collect evidence for how your landscape is changing over time.

A landscape with high functionality has a high retention of vital resources such as water, topsoil and organic matter. Dense patches of perennial grasses cause overland water flow to slow down, increasing water infiltration and "sieving out" topsoil, litter and seeds. Dense perennial grasslands therefore have high landscape function.

By contrast, landscapes with a low functional status tend to lose or leak existing material resources, fail to capture sufficient incident rainfall and are unable to capture new replacement materials. A reduction in the size, number, spacing or effectiveness of perennial grass patches may be an indication of degradation. Degraded grasslands with few perennial grass patches are unable to retain resources flowing across the landscape and therefore have low functionality.

The LFA indicator values do not absolutely indicate the functional state of a site. Rather, it is a tool to monitor change over time, or to compare the functionality between sites in a particular landscape. For this study, initial benchmark data was collected to facilitate potential long-term monitoring.

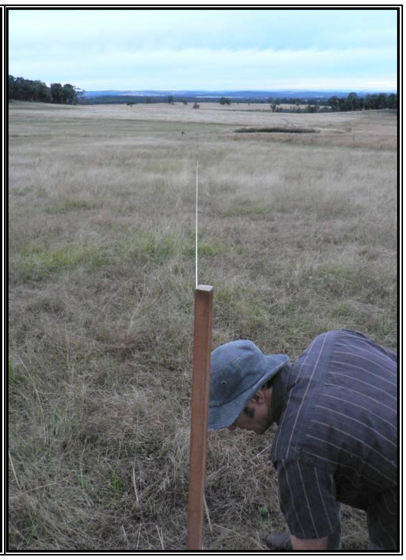
The following sections show the functional zones we found on the sites, the values the LFA process gave them and whether the differences in functionality between sites were significant or not.

3.1 Landscape organisation

Table 2 outlines the position in the landscape of the 50 metre monitoring transects on each site that were used to conduct Landscape Function Analysis. The position of the transects in the landscape and their slope was very similar on both sites. Their direction and aspect differed slightly due to variable local topography but this is unlikely to have an impact on the data.

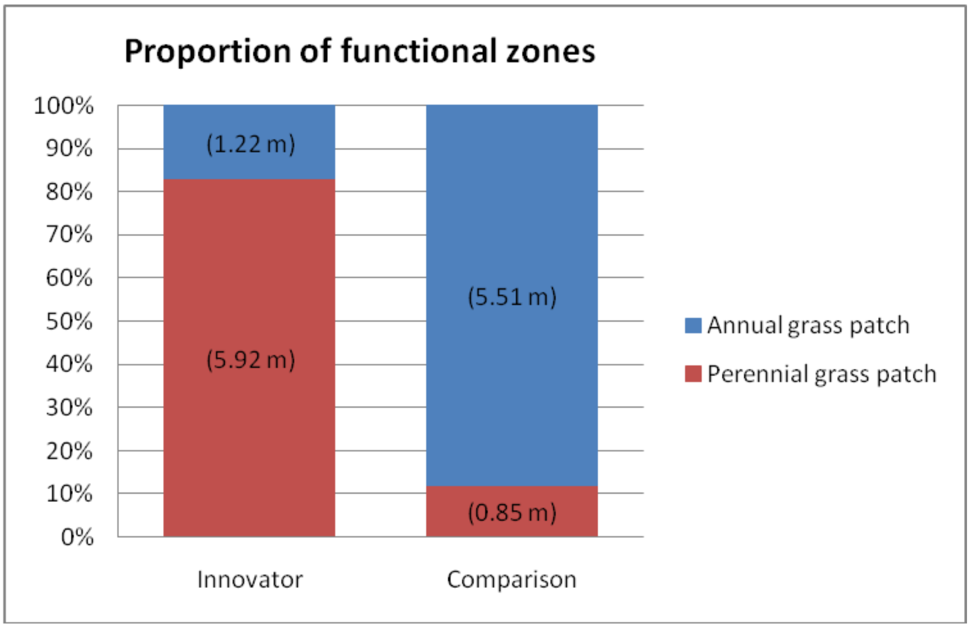
Table 2. Geographic setting of the monitoring transects

	Innovator	**Comparison**
Transect compass bearing	48°	23°
Position in landscape	Mid-slope	Mid-slope
Soil	Light granite	Light granite
Slope	4°	4°
Aspect	NE	N
Vegetation type	Native perennial pasture dominated by *Bothriochloa macra*	Mixed pasture dominated by annual grasses
Land use	Rotational grazing and pasture cropping	Set stocking and conventional cropping
State of soil surface	Close to 100% ground cover, spongy and friable soil	Some bare ground

LFA transect overview		

There were no signs of resource loss along either of the LFA transects, so no inter-patches were identified. Two patch types were identified on both sites, one dominated by annual grasses (“Annual grass patch”) and one dominated by perennial grasses (“Perennial grass patch”). Figure 2 shows the proportion of these two patch types, or functional zones, on the transect with the mean length of each patch type in brackets. On the innovator site 82.9% consisted of “Perennial grass patch”, whereas on the comparison site “Annual grass patch” was the dominant functional zone (88.1%).

Fig 2. Proportion of functional zones on each site and average patch/interpatch length (m)



3.2 Soil Surface Assessment of functional zones

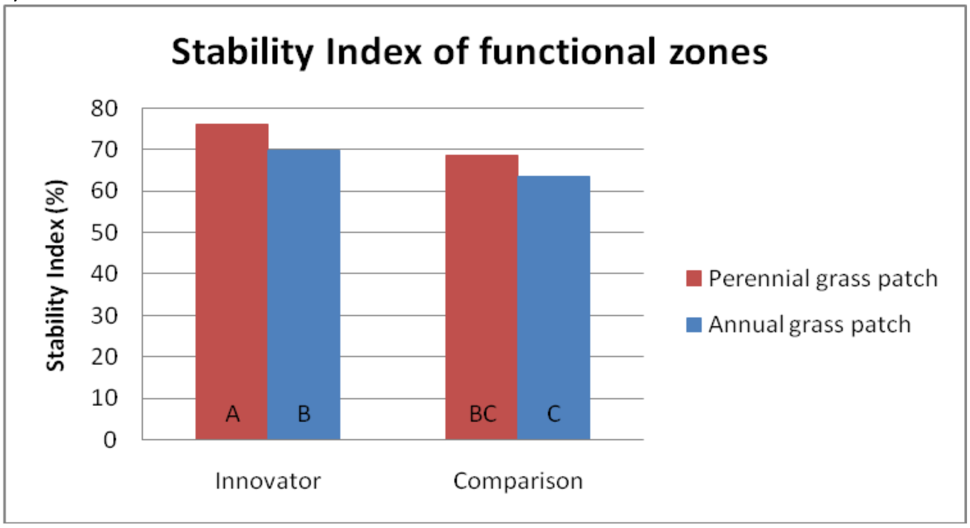
For each of the functional zones the soil surface was assessed to enable the generation of indices of stability, infiltration and nutrient cycling. Figures 3a-c show the values for each of the three indices for the different functional zones identified. For each LFA index the results for the different functional zones were compared within as well as between sites to test for significant differences in functionality.

On the innovator site, the Stability Index is significantly higher for “Perennial grass patch” compared to “Annual grass patch” on the same site. There is no significant difference between functional zones on the innovator site in Infiltration and Nutrient Cycling Indices. On the comparison site, the only index that shows a significant difference between functional zones is Nutrient Cycling. In other words, there isn’t a great functional difference between patch types within sites. However, it should be noted that the comparison transect appears to be meta-stable, supported by seasonal conditions (high recent rainfall) and data could be quite different in a drier time.

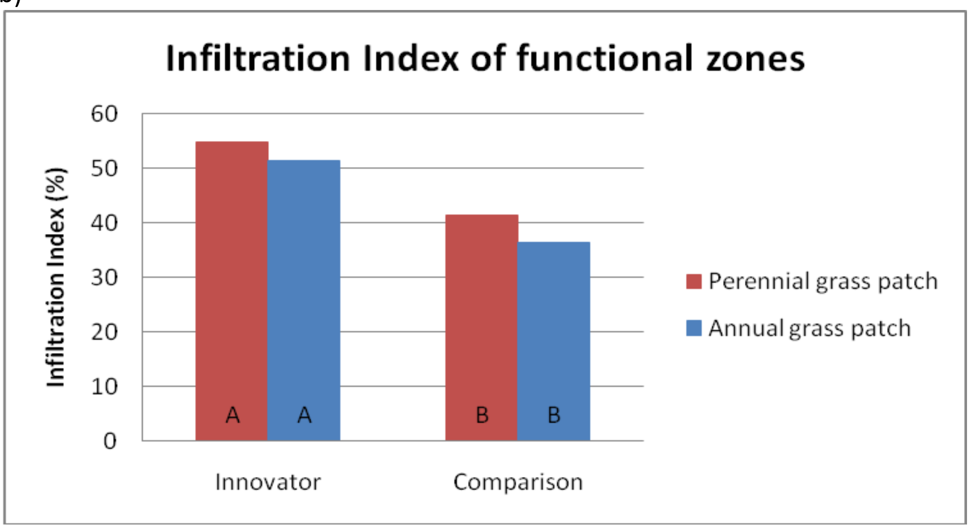
If we compare the indices for each zone between sites, the difference in functionality is much starker. “Perennial grass patch” has a significantly higher Stability (Fig 3a) and Infiltration (Fig 3b) Index on the innovator site than on the comparison site. “Annual grass patch” has significantly higher values for all three Landscape Function Indices on the innovator site than on the comparison site (Fig 3a-c). In terms of Stability and Nutrient Cycling, “Annual grass patch” on the innovator site and “Perennial grass patch” on the comparison site are comparable.

Fig 3. Landscape Function Indices of Functional Zones on Innovator and Comparison sites
(a) Stability Index of functional zones, (b) Infiltration Index of functional zones and (c) Nutrient Cycling Index of functional zones. Bars that do not share a letter are significantly different (P<0.05).

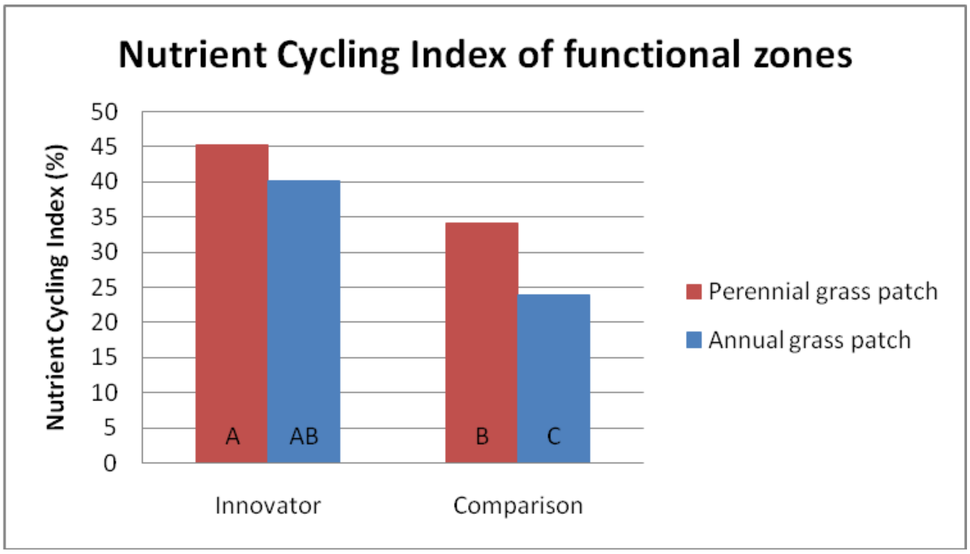
a)



b)



c)



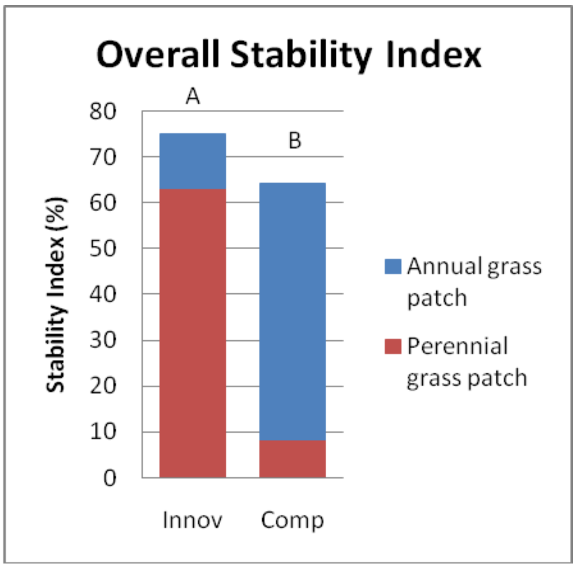
3.3 Contribution of functional zones to the whole site

The proportion of each functional zone (Fig. 2) and the LFA indices for each individual zone (Fig. 3a-c) can be combined to calculate the relative contribution to the whole site of each functional zone and the overall LFA indices for the whole site (Fig 4a-c).

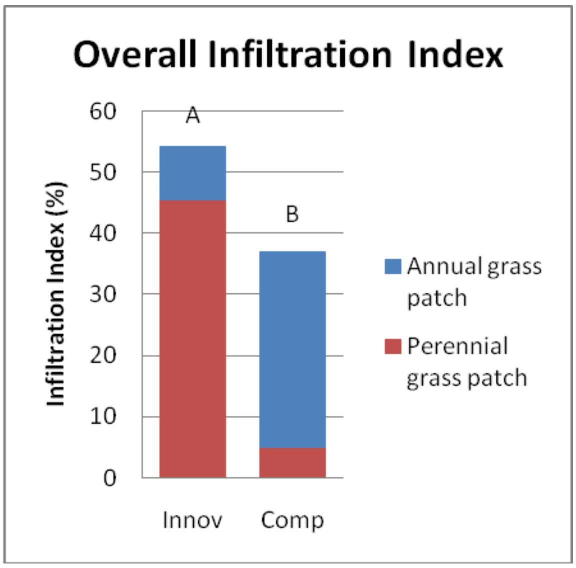
Figures 4a – c show that the innovator site has significantly higher values than the comparison site for all three overall Landscape Function Indices. This is primarily a result of both sites having one highly dominant patch type ("Perennial grass patch" and "Annual grass patch" on innovator and comparison sites respectively) (Fig 2), and the dominant patch type on the innovator site having significantly higher functionality for all three Landscape Function Indices than the dominant patch type on the comparison site (Fig 3a-c).

Fig 4. Contribution of functional zones to the whole site
(a) Overall Stability Index, (b) Overall Infiltration Index and (c) Overall Nutrient Cycling Index, on innovator (innov) and comparison (comp) sites. In each figure, different letters between bars denote a statistically significant difference ($P<0.05$).

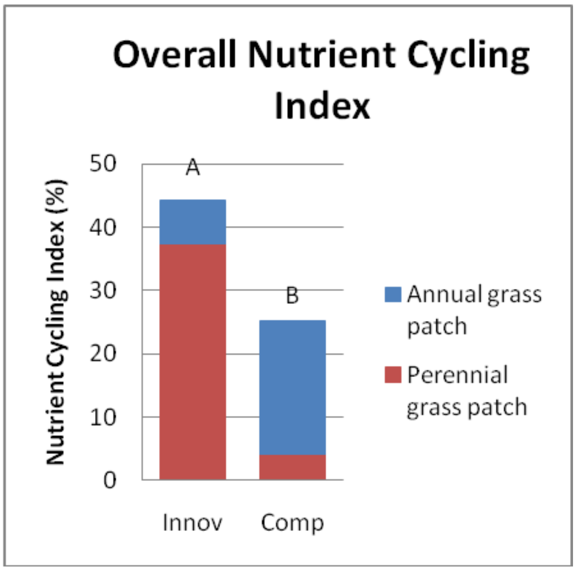
(a)



(b)



(c)



LFA summary: The difference between the sites is largely due to the dominant patch type (perennial grass patch) covering most of the transect on the innovator site and functioning better than all other zones. The dominant patch type on the comparison site (annual grass patch) covers most of the site and functions lower than the lowest functioning zone on the innovator site. As a result the innovator site is more stable, more capable of retaining water and more able to cycle nutrients. This is mostly due to higher perennial grass and litter cover.

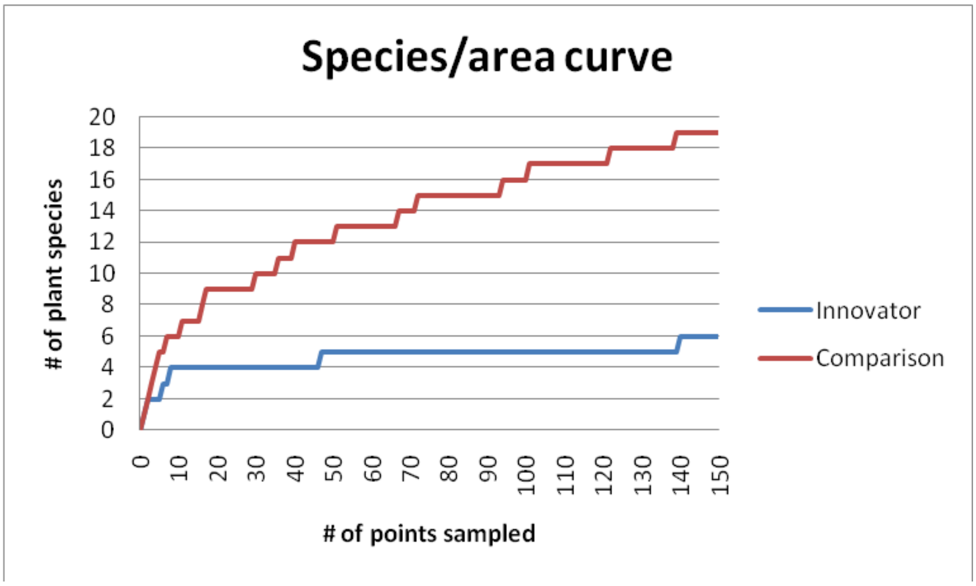
4 Vegetation

4.1 Plant species diversity and abundance

On each site plant species diversity (number of different plant species) and plant basal cover were assessed along the LFA transect and two more 50m parallel transects spaced 10m apart. At every one metre interval along the three transects the plant species intersecting the metre point across its basal parts was recorded. This resulted in a maximum of 150 plant records per site, with data points recorded as litter or bare soil if no basal hits were made. Plants were identified according to the list of species and genera in Table 3 and amalgamated into species groups.

Species diversity was very low on the innovator site with a total of 6 species identified compared to 19 on the comparison site (Fig 5). On both sites the species/area curve did not level off after 150 sampling points indicating that actual diversity was likely to have been higher than recorded.

Fig 5. Species/area curve



Species composition and species group abundance differed greatly between sites (Table 3 and Fig 6). Native perennial grasses were the dominant species group on the innovator site (87.6%) and annual grasses on the comparison site (41.5%). On the innovator site, the native perennial grass *Bothriochloa macra* (Red grass) was very dominant (73.3%), while on the comparison site the introduced annual grass *Eragrostis cilianensis* (Stink grass) had the highest basal cover (19.3%). Native forbs were not recorded on either of the sites. Total basal cover was higher on the innovator site than the comparison site.

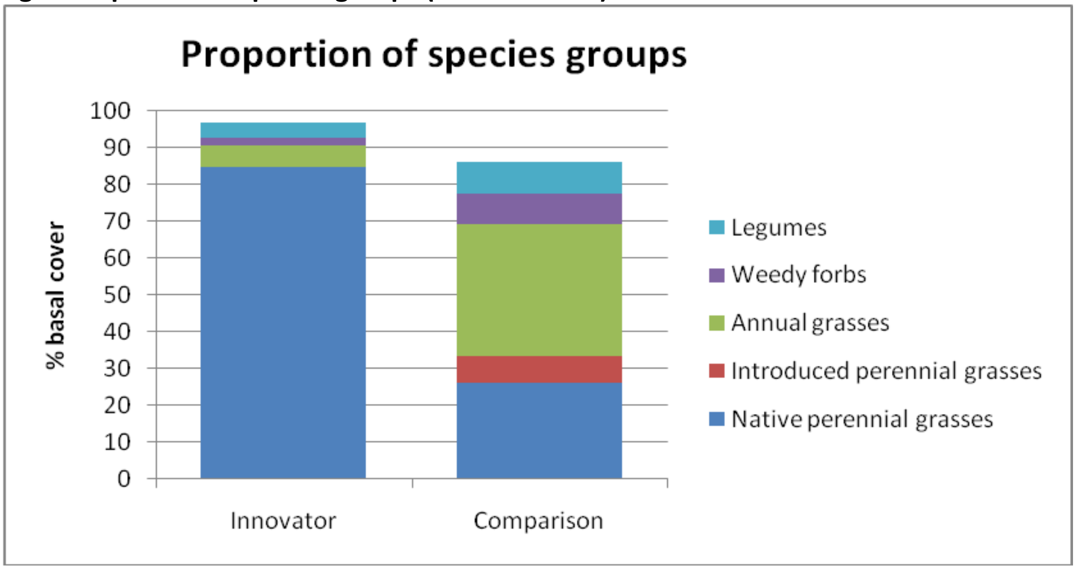
Table 3. Proportion of species/species groups in % basal cover (n=150 points)

Scientific name	Common name	Innovator	Comparison
Native perennial grasses			
Bothriochloa macra	Red grass	73.3	4.0
Austrodanthonia spp.	Wallaby grass	1.3	1.3
Paspalidium distans	Spreading panic grass	10.0	
Panicum effusum	Hairy panic		4.0
Digitaria brownii	Cotton panic		5.3
Cynodon dactylon	Couch grass		0.7
Sporobolus spp.	Rat-tail grass		7.3
Chloris truncata	Windmill grass		0.7
Eriochloa spp.	Cup grass, Spring grass		2.7
Introduced perennial grasses			
Paspalum spp.	Paspalum		1.3
Setaria parviflora	Pigeon grass		6.0
Annual grasses			
Eragrostis cilianensis	Stink grass	6.0	19.3
Urochloa piligera	Hairy armgrass		13.3
Eragrostis parviflora	Weeping lovegrass		3.3
Weedy forbs			
Hypochaeris radicata	Flatweed, Catsear		0.7
*Malva spp.**	Mallow		2.7
Thistle	Thistle	2.0	
Arctotheca calendula	Capeweed		0.7
Alternanthera pungens	Khaki weed		3.3
Salvia spp.	Sage		0.7
Legumes			
Trifolium subterraneum	Sub clover	4.0	8.7
TOTAL		**96.7**	**86.0**

* Tentative identification

Note: % basal cover does not add to 100% due to bare soil or litter in between plants

Fig 6. Proportion of species groups (% basal cover)



Note: % basal cover does not add to 100% due to bare soil or litter in between plants

4.2 Mature perennial grass basal cover

To assess the density of mature perennial grass plants that have established a long-term perennial presence and are providing landscape function by capturing vital resources, we used the Wandering Quarter (WQ) or the Point Centered Quarter (PCQ) technique, depending on the density of mature perennial grass plants (both native and introduced) with a minimum butt size of 4 cm^2 on each site. Both techniques rely on measuring the distance between target plants either while walking along in the direction of the transect (WQ) or at every 2.5 m point along the transect in the four quadrants around each sample point (PCQ). For each target plant we also measured the breadth and width of the grass butt close to the soil surface.

On the innovator site, mature perennial grass plants were spaced closer together and had a larger butt size than on the comparison site (Table 4). As a result, basal cover of mature perennial grass plants was 18 times higher on the innovator site than on the comparison site.

Table 4. Basal cover of perennial grass plants with a minimum butt size of 4 cm^2

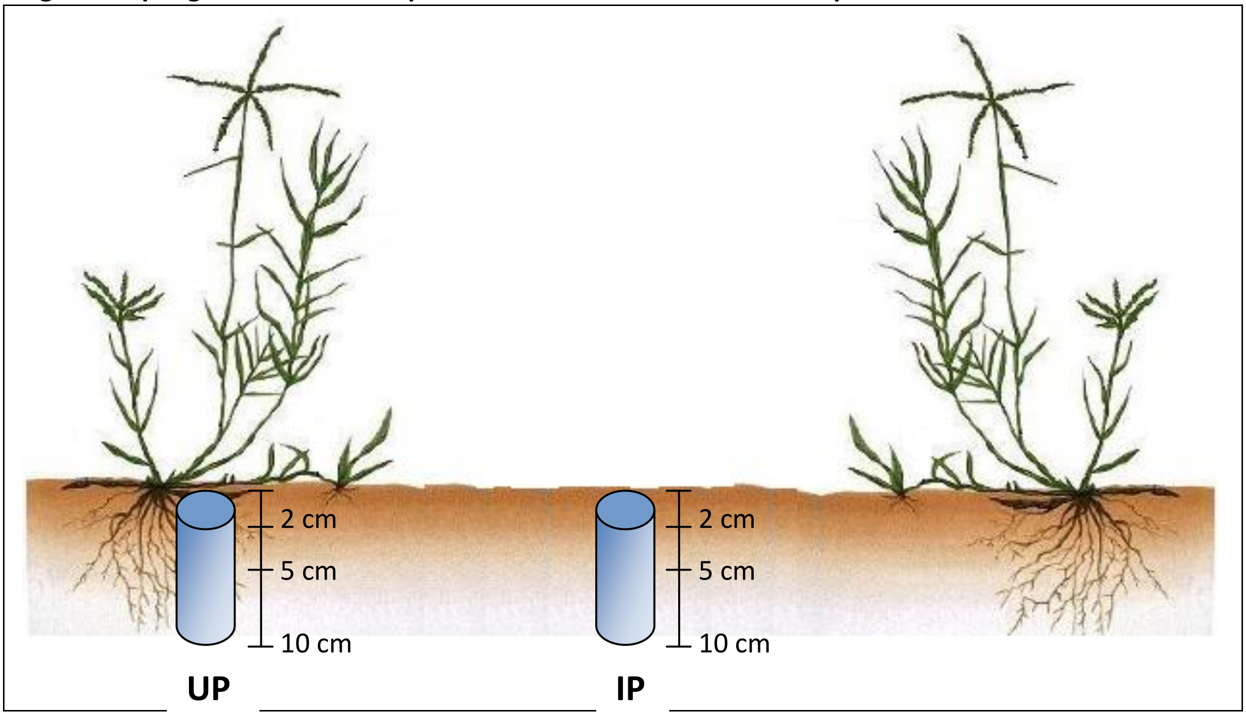
	Innovator	**Comparison**
Mean distance b/w plants (m)	0.20	0.74
No. of plants/ha	260308.2	18143.6
Mean basal area (cm^2)	15.9	12.3
Basal cover (m^2/ha)	414.2	22.4

5 Soil chemical and physical properties

Soil samples were collected along the LFA transect at the dominant perennial grass species and from in between perennial grass plants. The dominant perennial grass plant was determined based on basal area and abundance.

On each site, 15 target plants of the dominant perennial grass species with a minimum butt size of 4 cm^2, were marked and soil samples taken from right underneath the plant (UP) at three depth intervals; 0-2cm, 2-5cm and 5-10cm (Fig 7). Another 15 samples at the same depth intervals were collected at inter-plant locations (IP), in between sampled grass plants and the next perennial grass plant with at least 10cm to the next perennial plant on either side (Fig 7).

Fig 7. Sampling locations and depth intervals for UP and IP soil samples



On both sites UP samples were collected at *Bothriochloa macra* (Red grass) plants and IP sample locations were mostly litter covered. The samples were analysed for pH, soil conductivity, available phosphorus, total carbon, total nitrogen and bulk density.

Table 5 shows the results of the soil chemical and bulk density analyses and whether differences between sites were statistically significant.

5.1 What does this mean?

Soil pH - The soil on the innovator site was strongly acidic (pH_w 5.4 – 5.7) and very strongly acidic on the comparison site (pH_w<5.3). At pH_w levels below 5.3 toxic aluminium or manganese becomes more available, limiting plant growth. Soil pH levels of around 6.5 are considered ideal for soil chemical reactions to occur without causing toxicity problems.

Salinity - Both sites had a low soil salinity rating based on their soil texture and conductivity.

Phosphorus - Soil available phosphorus levels (extractable Bray 1) were low on both sites consistent with the relative lack of fertilizer inputs on both sites for the past decades. Research indicates that diverse perennial native pastures only persist when the available soil phosphorous is below approximately 20mg/kg, which was the case on both sites.

Carbon - Measured total carbon levels were the same as organic carbon levels due to the low pH on both sites. Total carbon was higher on the innovator site for all three depth increments with the difference decreasing with increasing depth.

Nitrogen - Total nitrogen levels usually correlate broadly with organic carbon levels, which was the case on both sites, with higher levels of total N across the top 10 cm of the soil on the innovator site.

Carbon/nitrogen ratio - The ratio of carbon to nitrogen was similar on both sites and close to the optimum C:N ratio of 10 – 12 for organic matter decomposer organisms. A C:N ratio greater than 30 is believed to result in a loss of nitrogen as microbial cells draw any available nitrogen to make use of the available carbon in the proper proportion.

Bulk density - Bulk density of a soil reflects aspects of soil structure and provides a good indication of the suitability for root growth and permeability. Bulk density values were significantly lower on the innovator site than on the comparison site across all three depth increments. On both sites bulk density levels were at the lower end of the normal range (1.1 – 1.8 g/cm^3), indicating the soils on both sites have good permeability and provide suitable conditions for root growth and microbial activity. Soils with a bulk density greater than 1.5-1.6 g/cm^3 tend to restrict root growth.

Under plant and between plant differences

Results were also compared within sites between the two different sample locations; underneath dominant perennial grass plants (UP) and in inter-plant spaces between dominant perennial grass plants (IP). This analysis showed that on the innovator site there were no significant differences between sample locations for any of the soil variables, but on the comparison site the top layer of the soil had higher levels of carbon (0-2 cm) and nitrogen (2-5 cm) on the UP locations than on the IP locations.

This result is consistent with the results from the Landscape Function Analysis showing that on the comparison site individual perennial plants function as islands of fertility separated by annual dominated soil while on the innovator site perennial grass plants and the litter between them function similarly and act as a continuous sward.

Table 5. Soil chemical properties and bulk density in the 0 – 10 cm depth range of the soil.

** P<0.01; * P<0.05; n.s., not significant at P=0.05

	Innovator	Comparison	significance
Soil pH (1:5 water) (0-10 cm)	**5.70**	**5.21**	**
Soil Conductivity (1:5 water µS/m) (0-10 cm)	**0.14**	**0.16**	**n.s.**
Extractable Bray I Phosphorus (mg/kg P) (0-10 cm) #	**5.55**	**5.00**	
0-2cm	10.00	10.46	n.s.
2-5cm	5.90	4.83	n.s.
5-10cm	3.55	2.92	n.s.
Total Carbon (% C) (0-10 cm) #	**2.20**	**1.30**	
0-2cm	4.47	2.03	**
2-5cm	2.23	1.39	**
5-10cm	1.28	0.96	**
Total Nitrogen (%N) (0-10 cm) #	**0.19**	**0.11**	
0-2cm	0.38	0.17	**
2-5cm	0.20	0.12	*
5-10cm	0.10	0.08	**
Carbon/Nitrogen ratio (C:N) (0-10 cm)	**11.98**	**11.98**	**n.s.**
Bulk Density (g/cm^3) (0-10 cm) #	**1.25**	**1.38**	
0-2cm	0.89	1.04	*
2-5cm	1.22	1.38	**
5-10cm	1.41	1.52	*

0-10cm figures calculated by weighting the 0-2,2-5 and 5-10cm data by 0.2, 0.3 and 0.5

6 Soil micro-organisms

Soil micro-organisms regulate a majority of ecosystem processes in soil that are essential for plant growth, soil health and sustained productivity. Microbial organisms in the soil play an important role in facilitating nutrient uptake by plants, improving soil quality through build-up of higher soil organic matter, reducing disease incidence in plants and reducing environmental degradation through soil erosion and nutrient losses. To do this soil microbes require carbon and nutrient sources for their growth, organic matter and suitable soil physical and chemical conditions to support their activity. In Australian pasture systems, factors that are known to limit microbial activity are soil compaction, lack of carbon and available nutrients, chemical inputs and unsuitable moisture conditions.

Soil micro-organisms are extremely abundant (up to 10 billion per gram of soil), diverse (many millions of different species of bacteria and fungi exist in soils) and poorly understood by science. Microbiological research is currently being revolutionized with the use of gene technologies. There is no single test or technique that is widely accepted as the best way to 'measure' them or to assess their impact in different locations or under different management regimes. We wanted to assess, if possible, the broad types of organisms present, how abundant they were, and whether there were any measurable differences in the way the mix of organisms present functioned in the soil. For this project we used the services of a consultant qualified and experienced in soil microbiological techniques which he uses in the reclamation of mine sites.

Soil samples for microbial analysis were collected at the same locations as for soil chemical properties to 10 cm deep. Samples were analysed for soil moisture content, microbial numbers and community functionality. Standardized sample treatments and isolation media were utilized to distinguish the numbers - as colony forming units (CFU) - of different populations of non-filamentous bacteria, actinomycetes (bacteria that produce filaments) and fungi.

The functional properties of the bacterial and fungal communities were determined using BIOLOG microtitre plates that measure the activity of microorganisms through their utilization of 95 different carbon sources. This shows whether different communities can use similar of different carbon sources. If they are different then we can conclude that the colonies are different from each other which means that the conditions under which that colony was growing in the field are different.

Results were compared between sites (innovator and comparison) as well as between sample locations within sites (under plant (UP) or in between plants (IP)) to test for significant differences in microbial numbers and functionality.

6.1 Microbial numbers

Actinomycetes and fungi are the microbial groups that are most important in litter decomposition and are also most sensitive to disturbance. A low ratio of actinomycetes to non-filamentous bacteria is an indicator of disturbance with the ratio in soils from undisturbed native grasslands usually being ≥0.2. Copiotrophic bacteria are fast growing bacteria usually associated with abundant nutrient conditions in soils. A higher proportion of copiotrophic bacteria as a fraction of total bacterial numbers is an indicator of a nutrient rich soil.

Both soils had adequate water activity for microbial growth at the time of sampling. Numbers of non-filamentous bacteria were similar on both sites, but numbers of both actinomycetes and fungi were significantly higher on the innovator site than on the comparison site (Table 6). As a result the ratio of actinomycetes to non-filamentous bacteria was also significantly higher on the innovator site.

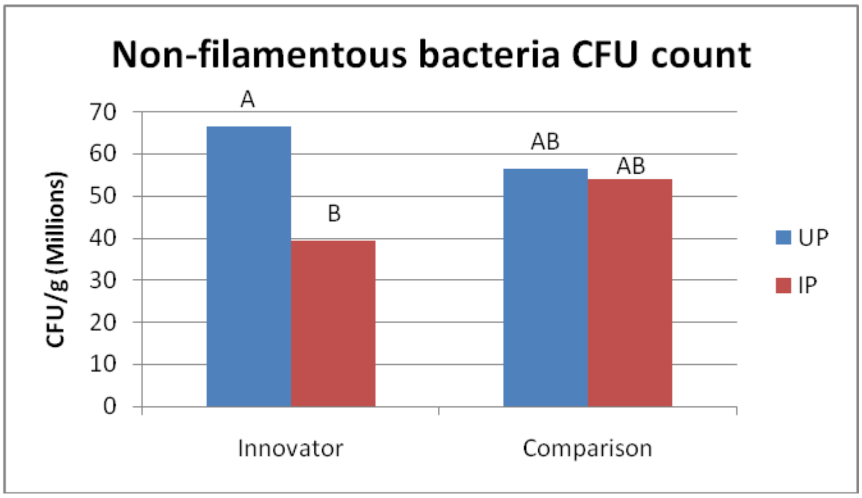
Table 6. Mean CFU counts for non-filamentous bacteria, actinomycetes and fungi; ratio of actinomycetes/non-filamentous bacteria; and proportion of copiotrophic bacteria as a fraction of total bacterial numbers.

	Innovator	Comparison	Significance
Non-filamentous bacteria CFU count	53,055,556	55,277,778	n.s.
Actinomycetes CFU count	5,666,667	2,666,667	*
Fungi CFU count	497,222	340,556	**
Ratio Actinomycetes/Non-filamentous bacteria	0.14	0.06	*
Proportion of copiotrophic bacteria	0.30	0.26	n.s.

Statistical significance of differences between sites: ** P<0.01; * P<0.05; n.s., not significant at P=0.05

Within sites the only statistically significant difference was between under plant (UP) and inter-plant (IP) sampling locations for numbers of non-filamentous bacteria on the innovator site, with higher numbers on UP than on IP locations (Fig 8).

Fig 8. Mean numbers of colony forming units (CFU) of non-filamentous bacteria per gram dry weight of soil. Different letters between bars denote a statistically significant difference (P<0.05).

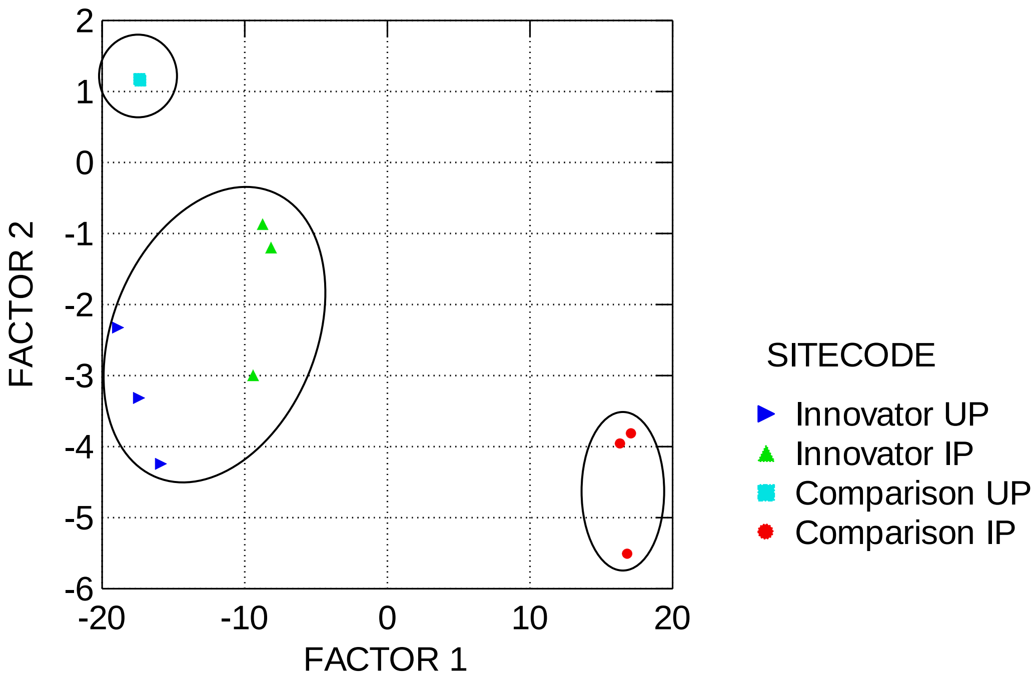


6.2 Microbial community functionality

6.2.1 Bacteria

Analysis of the bacterial community C-source richness (number and types of C-sources utilized) and C-source activity (amounts of different C-source types utilized) showed no significant difference between the innovator and comparison site or between UP and IP sampling locations within sites. Figure 9 shows the functional diversity of the bacterial communities on both sites. The bacterial communities from the UP and IP locations were functionally similar on the innovator site (closely grouped) whereas the bacterial communities from the UP and IP locations on the comparison site were functionally distinct (Fig 9).

Fig 9. Functional diversity of bacterial communities on innovator and comparison sites from UP and IP sample locations.

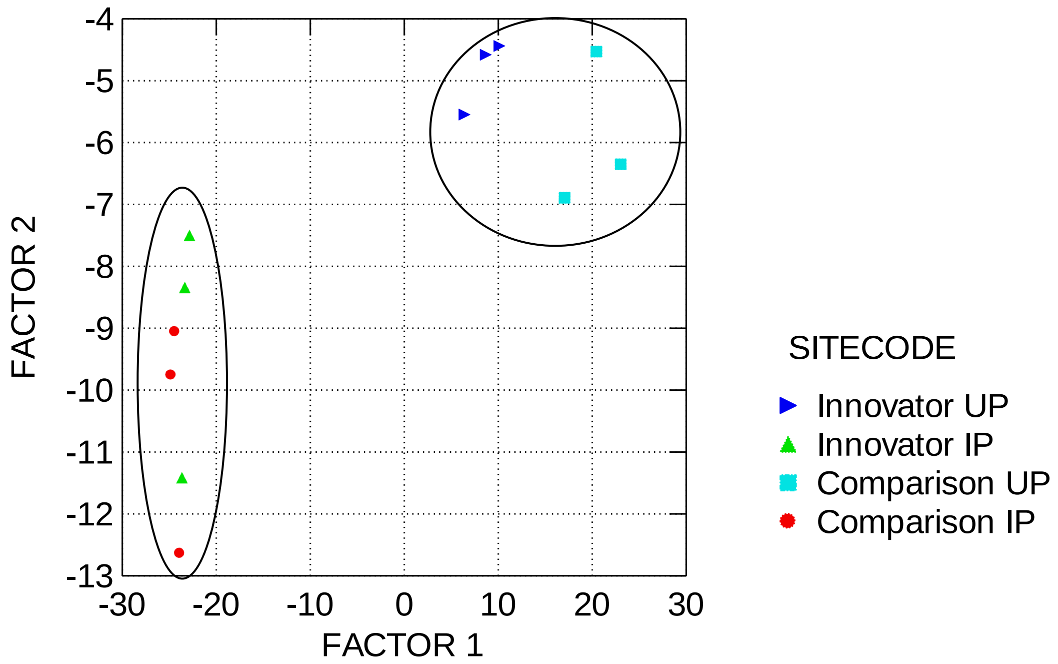


This result indicates that on the innovator site similar types of bacteria inhabit the soil around perennial grass plants and in between plants. On the comparison site, the types of bacteria inhabiting the soil around perennial grass plants are different from the types of bacteria living in the soil in between plants.

6.2.2 Fungi

Analysis of the fungal community C-source richness (number and types of C-sources utilized) and C-source activity (amounts of different C-source types utilized) showed significantly higher fungal activity on the innovator than the comparison site. Figure 10 shows that fungal communities from the UP sample locations were functionally similar on both sites (closely grouped) and fungal communities on the IP locations were also functionally similar to each other on both sites.

Fig 10. Functional diversity of fungal communities on innovator and comparison sites from UP and IP sample locations.



This result indicates that on both sites similar types of fungi live in the soil surrounding perennial grass plants, which on both sites are different from the types of bacteria that live in the soil in between plants.

7 Conclusion

For this study we compared the effects on the biophysical environment of two different grazing and cropping strategies. The two sites on neighbouring properties are similar in most aspects other than grazing and cropping management and have been under the current management regime for a sufficiently long period (10 and 50 years respectively) for any observed differences to be attributed to different management.

On the research paddock on the innovator site a cereal crop is sown directly into the native pasture every four years with limited fertilizer inputs. In the past a herbicide was used to suppress pasture growth early in the crop establishment stage, but more recently herbicide use has been stopped. The pasture-crop phase is followed by a three-year grazing phase with high intensity short duration grazing of native pasture by merino sheep followed by long rest periods. On the comparison site a crop is also sown every 3-4 years, but the pasture is sprayed out before cropping, fertilizer inputs are higher and the crop is sown conventionally. The paddock is sown to sub-clover and/or rye grass and grazed with merino wethers for longer periods followed by shorter rest than on the innovator site. Average stocking rates on the innovator site are higher than on the comparison site.

Soil structural and physical conditions, vegetation and biological activity under crop-pasture rotations all link together and play an important role in ecosystem functions both within the pasture and in the wider landscape. Grazing and cropping management influence these conditions directly through their impact on vegetative ground cover and diversity, litter inputs, root extent and soil compaction. These in turn influence soil chemical composition, soil stability, nutrient cycling, water infiltration and microbial activity.

Management on the innovator site has resulted in a pasture that at the time of sampling had low plant species diversity but was highly dominated by native perennial grasses as a species group. Plant species diversity on the comparison site was higher, but the site was dominated by annual grasses and had a higher level of weedy forbs than the innovator site. The perennial grass patches on the innovator site had high basal cover of mature, deep-rooted perennial grasses and litter, providing better landscape function than the annual grass patches on the comparison site. This difference in perennial vegetative ground cover and litter has resulted in the innovator site being more stable, more capable of retaining water and more able to cycle nutrients than the comparison site.

The plant species diversity is likely to change significantly throughout any given year and depend heavily on seasonal conditions. However the landscape function and basal area data are less dependent on time of year and seasonal conditions but will respond over longer time scales to the interaction of management and climate. Native pastures exist in different states related to species composition and disturbance history, particularly fertilizer inputs and grazing pressure. It takes time to transition from one state to another and regeneration and biodiversity enhancement start with restoring landscape function.

The structural differences in vegetation and ground cover are also reflected in the differences in soil chemical and physical properties and microbial activity between the sites. On the innovator site, a higher density of deep rooted perennials and higher inputs of organic material in the form of litter have led to higher levels of soil organic carbon and nitrogen in the top 10 cm of the soil than on the comparison site. Microbial organisms are dependent on these carbon and nutrient sources for their growth and in turn assist with nutrient access and improve soil structure for adequate air and water supply to plants. Soil conditions on the innovator site are more favourable to soil microbes which is reflected in a significantly greater abundance of actinomycetes and greater abundance and activity of fungi on the innovator than on the comparison site. These soil micro-organisms play an important role in the decomposition of litter and improve soil structure by forming aggregates of soil particles and creating space between aggregates for air and drainage of excess water. This has led to better soil structure which is reflected in lower bulk density in the top 10 cm of the soil on the innovator site than on the comparison site.

Within sites the effects of perennial vegetation and litter cover on soil chemical properties and the microbial community were also apparent. On the innovator site there was no significant difference in soil chemical composition between samples collected from underneath perennial grass plants (UP) and at inter-plant locations (IP). On the comparison site the top layer of the soil had higher levels of carbon (0-2 cm) and nitrogen (2-5 cm) on the UP locations than on the IP locations. This same difference between sampling locations was reflected in the functional diversity of the bacterial communities with the bacterial community being functionally similar for UP and IP samples on the innovator site and functionally distinct on UP and IP samples on the comparison site. These results indicate that in terms of functionality the grazing management on the innovator site has produced a fairly homogenous system with perennial grass plants and the litter between them acting as a continuous sward. Management on the comparison site has resulted in a much patchier system with individual perennial grass plants functioning as “islands of fertility” separated by annual dominated soil with poor functionality.

These results illustrate that the rotational grazing and pasture cropping practiced on the innovator site can increase perennial vegetative ground cover and litter inputs, compared to the continuous grazing system and conventional cropping practiced on the comparison site. Increased perenniality and ground cover lead to improved landscape function in the pasture through increased stability, water infiltration and nutrient cycling which in turn can lead to improved soil physical and chemical properties, more growth of plants and micro-organisms and an ultimately more sustainable landscape. It also shows that rotational grazing and pasture cropping can improve landscape function while sustaining higher stocking rates over the year compared to the conventional system.