# Sustainable Farming through Improved Understanding of Soil Quality

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**Aim**

To understand how agricultural and mining practices alter soil quality through collaboration with local farmers, in order to enable land management practices to progress towards more sustainable systems.

**Background**

With a growing global population, food demands are increasing worldwide and it is therefore required that there is increased and ongoing agricultural production (Lemenih et al., 2005). Soil is a fundamental resource for agricultural production; however, management practices of this industry have the potential to have adverse effects on the quality and health of the soil (Lemenih et al., 2005). The extraction of mineral resources is an obtrusive process, where the overlying vegetation is cleared and topsoil is removed. Rehabilitation is required to return the area to its natural state. For soil to be productive and stable the physical, chemical and biological properties must be robust (Department of Environment and Primary Industries, 2006).

Assessing soil quality through investigation of the chemical and biological properties is an approach widely used across Western Australia. These properties are assessed as they react effectively to soil disturbance. Assessment of these properties can also indicate how capable a soil is of recovery from these disturbances. Fundamental knowledge of how soils biological and chemical properties have been altered through land management practices will enable steps towards possible improvements in practices to retain optimum microbial functioning.

The overall objective of this study was to determine if and how agricultural and mining land management practices have altered soil quality in the grain belt of Western Australia, focusing specifically in the Liebe Group area. This was done by comparing soil chemical and biological properties between anthropogenically altered land (through agriculture or post-mining rehabilitation) with adjacent remnant vegetation. The study was based on the hypothesis that soil microbial indicators will differ as a consequence of agricultural production and rehabilitation following mining operations. Specifically, it was hypothesised that soil microbial biomass would be greater in remnant areas compared to altered areas, whereas $CO_2$ emissions (microbial respiration) would be lower. Understanding changes in soil chemical and biological properties can assist in the continuing development of sustainable farming practices and best practice rehabilitation strategies.

**Methodology**

Soil samples were taken from five study sites that had a paired altered and a remnant bush land area (Figure 1). Sites 1 to 4 were paired agricultural and remnant bush sites. Land holders provided information of previous management of the sampled areas. Site 1 had gypsum applied in 1994 and lime in 2006. Cropping rotation for the past 5 years was pasture, wheat, wheat, pasture and wheat in 2013, 2012, 2011, 2010 and 2009 respectively. Site 2 had no gypsum applied, but lime was applied in 1999. It has been most recently been cropped with wheat in 2013, which followed on from pasture, pasture, wheat and pasture in 2012, 2011, 2010, and 2009 respectively. Site 3 cropping history was lupins, barley, wheat, wheat and lupins in 2013, 2012, 2011, 2010 and 2009, respectively and lime was applied in 2009. Site 4 had no gypsum applied, but lime was applied in 2010. The site was most recently cropped with canola in 2013 and previously in wheat, lupins and wheat in 2012, 2011 and 2010 respectively.

Site 5 was a paired rehabilitation and remnant bush site within the Mount Gibson mine site. The Mount Gibson mine site, of Extension Hill Limited, has been in operation since 2011. The study site was subject to the removal of 26,429$m^3$ of gravel and subsequently rehabilitated. Rehabilitation occurred in 2011 and included reshaping and ripping of the land, and the respreading of topsoil. There was no application of fertiliser to the rehabilitated site.

Study sites were visually assessed before soil sampling for suitable pairing of the bush land and altered land. This involved assessing if there were differences in landscape (e.g. presence of rocky outcrops), colour of soil, and slope between paired sites. All sites selected passed this preliminary assessment.

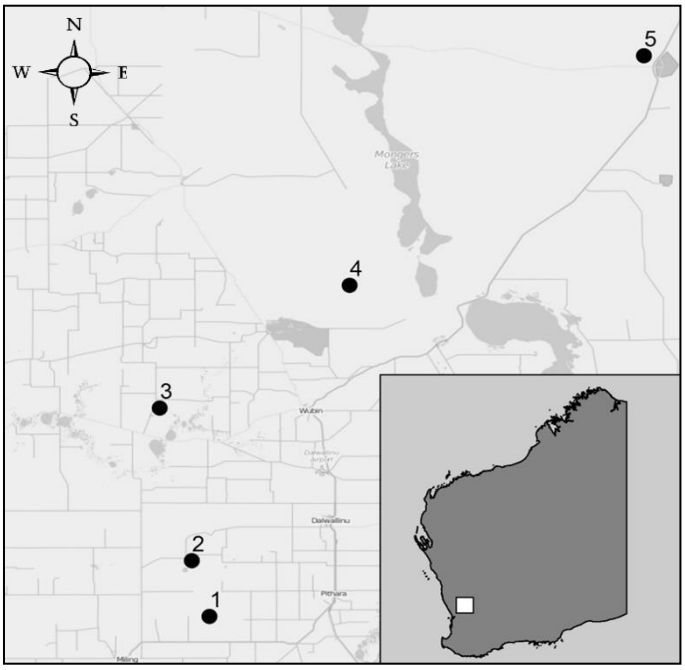


**Figure 1:** Map displaying sites where soil samples were collected within the Liebe focus area.

Soil cores were taken from the depths of 0–10cm, 10–20cm, and 20–30cm at every site and were transferred to the University of Western Australia for further analysis. Standard methods were used to assess soil texture (by particle size analysis), soil pH ($CaCl_2$) and soil salinity (EC). Total carbon (C) and nitrogen (N) were analysed by dry combustion (Elementar CHN analyser). Inorganic N ($NO_3^-$ and $NH_4^+$) was analysed spectrophotometrically on soil extracts using an auto analyser.

Soil microbial biomass carbon was measured by the fumigation-extraction technique using the $k_{EC}$ correction factor of 0.45. This provides a measure of the mass of living microorganisms (mostly bacteria and fungi) within the soil. Soil microbial respiration, a measure of the heterotrophic activity of the living microorganisms, was analysed by incubation of soil in sealed glass jars with measurement of the headspace $CO_2$-C concentration using an infrared gas analyser three times with three day intervals.

**Results**

*Soil Texture*

Particle size analysis in the laboratory determined that soil texture at sites 2, 3, 4 and 5 did not vary between the altered agricultural/rehabilitated areas and remnant bushland areas (Table 1). However, soil textures at site 1 were different between the altered and remnant areas indicating that this site was not well paired. Therefore, comparisons based on site 1 were not included when drawing overall conclusions drawn from this study.

**Table 1:** Texture of each site at the depths of 0-10, 10-20, and 20-30cm.

| Depth (cm) | Site 1 | | Site 2 | | Site 3 | | Site 4 | | Site 5 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Altered** | **Bush** | **Altered** | **Bush** | **Altered** | **Bush** | **Altered** | **Bush** | **Altered** | **Bush** |
| **0-10** | Sandy loam | Loamy sand | Sand | Sand | Sand | Sand | Sand | Sand | Loamy sand | Loamy sand |
| **10-20** | Sandy loam | Loamy sand | Sand | Sand | Sand | Sand | Loamy sand | Loamy sand | Loamy sand | Loamy sand |
| **20-30** | Sandy loam | Loamy sand | Sand | Sand | Sand | Sand | Loamy sand | Loamy sand | Loamy sand | Loamy sand |

*Biological properties*

Overall microbial biomass carbon did not change in response to disturbances from agriculture or rehabilitation with no significant differences between altered samples and remnant bushland samples. Microbial biomass carbon from the surface soil (0-10cm; 355 mg/kg) of site 1 bushland was 3 times greater than the average value for the remaining sites (127 mg/kg) (Figure 2). Sites 2, 3, 4 and 5 had no significant change between study areas (Figure 2). There is clear stratification between depths with significantly increased microbial biomass carbon at shallow depths (0-10cm, 10-20cm) at sites 1, 2, 3 and 4 ($P \leq 0.05$, Figure 2). Microbial biomass carbon in the subsoil (20-30cm) did not exceed 100 mg/kg$^{-1}$, with most sites (site 2, 3 and 4) having between 0-27 mg/kg$^{-1}$ microbial biomass carbon (Figure 2).

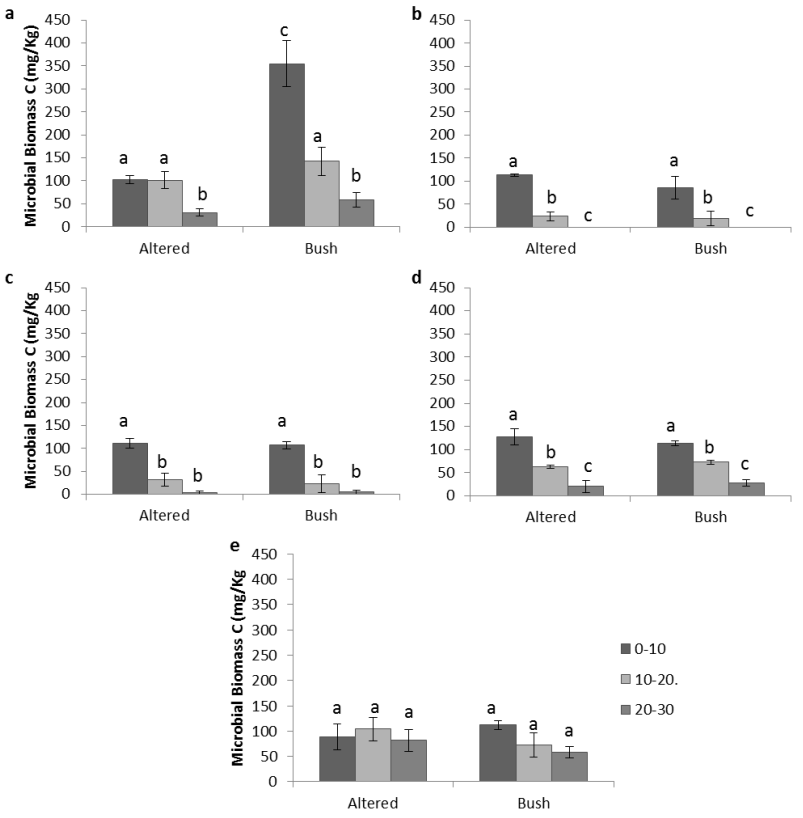


**Figure 2:** Average microbial biomass C with standard error bars, at each depth, 0-10cm, 10-20cm and 20-30cm, at each site: (a) site 1, (b) site 2, (c) site 3, (d) site 4 and (e) site 5, in anthropogenically altered areas and remnant bushland areas. Different letters above bars indicated significance at $P \leq 0.05$.

Microbial respiration was greater in the altered samples at sites 2 and 4 than in the remnant bushland samples, reaching averages of 100 and 84 mg/kg dry soil/day ($P \leq 0.05$ Figure 3). The highest microbial respiration (activity) was found at site 1 in the remnant bushland samples, with an average of 112.26 mg/kg dry soil/day, respiration in the altered samples averaged 62.4 mg/kg dry soil/day (Figure 3). No significant difference in respiration was found at site 3 and 5 between the altered and remnant bushland samples.

Metabolic quotients (a ratio of the respiration rate per unit of microbial biomass) revealed significantly higher activity per unit biomass at sites 1, 4 and 5 from the altered samples ($P \leq 0.05$ Table 2). Sites 2 and 3 did not have significantly different metabolic quotients between the altered and bushland samples (Table 2).

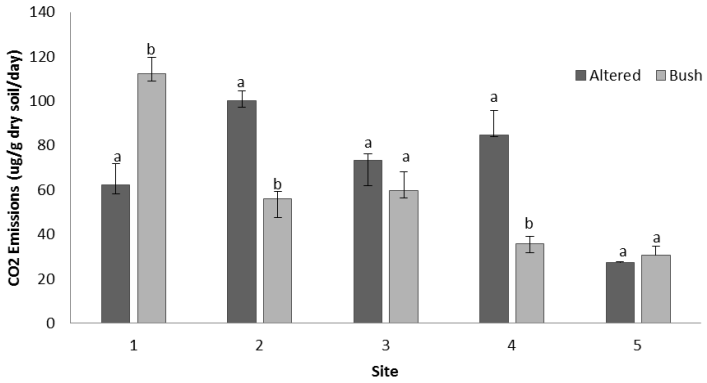


**Figure 3:** Average microbial respiration, as $CO_2$ emissions, with standard error bars, in the top 10cm of the soil profile at each site for altered and remnant bushland samples. Different letters above bars indicate significance at P≤ 0.05.

**Table 2:** Metabolic quotients (rate of respiration per unit biomass) of altered and remnant bushland samples from the top 10cm samples at each site with standard error.

| | **Site 1** | | **Site 2** | | **Site 3** | | **Site 4** | | **Site 5** | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Altered** | **Bush** | **Altered** | **Bush** | **Altered** | **Bush** | **Altered** | **Bush** | **Altered** | **Bush** |
| **Metabolic Quotient** | 0.64 | 0.33 | 0.88 | 0.84 | 0.69 | 0.55 | 0.66 | 0.31 | 0.40 | 0.25 |
| **Standard Error** | (0.13) | (0.41) | (0.03) | (0.22) | (0.09) | (0.04) | (0.00) | (0.01) | (0.06) | (0.02) |

All sites within the study were found to be nitrate ($NO_3^-$) dominant with $NO_3^-$ ranging between 41 mg/kg$^{-1}$ and 8 mg/kg$^{-1}$ (Figure 4). Inorganic N present as ammonium ($NH_4^+$) ranges between averages of 2.4 mg/kg$^{-1}$ and 0 mg/kg$^{-1}$ of dry soil (Figure 4). There was no difference between the amount of inorganic N as $NO_3$ altered and remnant bushland areas for sites 1, 3, 4, and 5 (Figure 4). There was increased $NO_3$ in the altered samples at site 2 with a mean of 29.17 mg/kg$^{-1}$ compared to 9.85 mg/kg$^{-1}$ within the remnant bushland samples after 23 days of incubation (P≤0.05, Figure 4). Low $NH_4^+$ concentrations were measured throughout the incubation of soils from all sites.

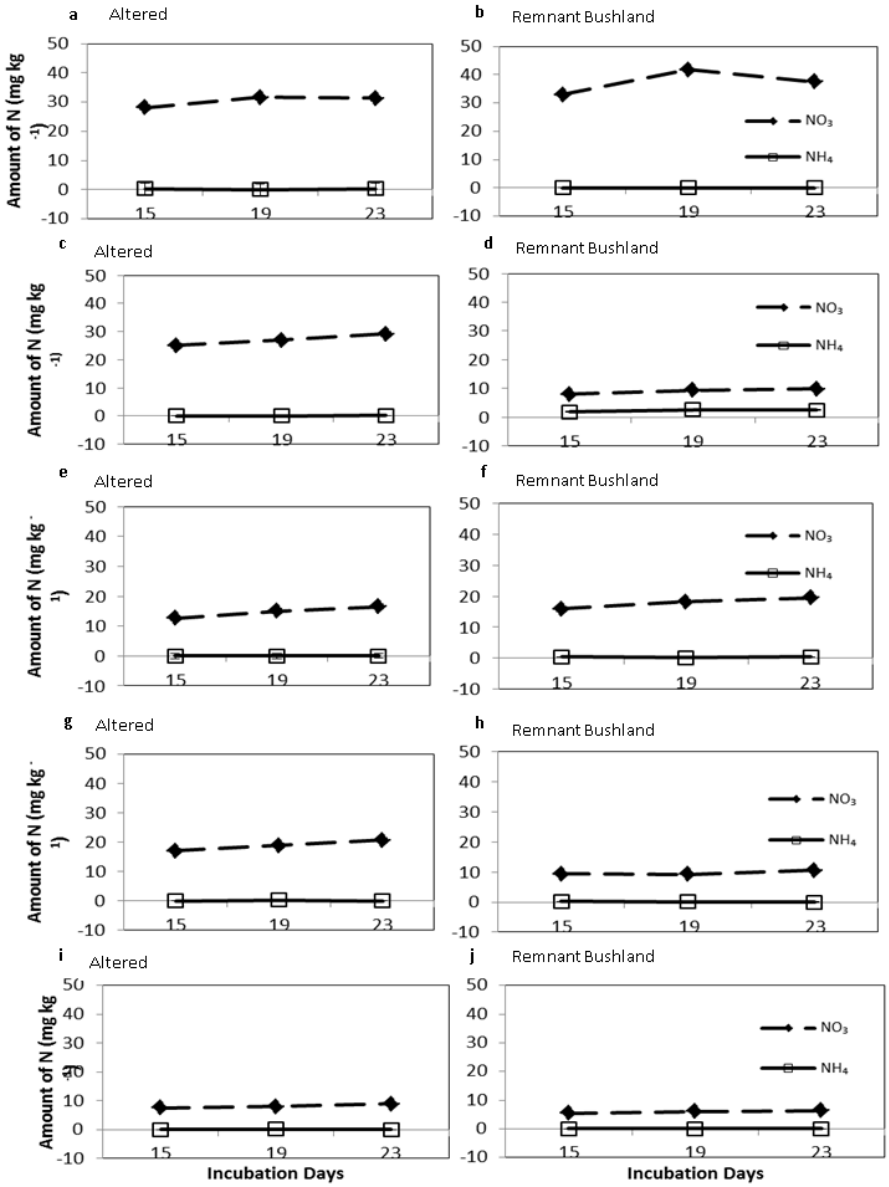


**Figure 4:** Average $NO_3^-$ and $NH_4^+$ with standard error bars, at each depth, 0-10cm, 10-20cm and 20-30cm, at each site: (a) site 1, (b) site 2, (c) site 3, (d) site 4 and (e) site 5, in anthropogenically altered areas and remnant bushland areas.

*Chemical properties*

Total C and N were greatest in the remnant bush land samples from site 1 with 1.98% and 0.125% respectively at 0-10cm (Figure 5). All other sites had total C ranging between 0.2 – 0.8% and total N between 0.01 – 0.06% (Figure 5). Percentage of total C and N behave in the same pattern as each other at all sites (Figure 5). No difference was found between altered samples and bush land samples at Sites 4 and 5 of total C and N. Site 1 only had significantly increased total C in altered samples compared to bush land samples at 20-30cm ($P \leq 0.05$, Figure 5). Sites 2 and 3 have significantly higher total C and N in altered samples compared to bush land samples in the top 20cm ($P \leq 0.05$, Figure 5). Total C and N decreased with depth at sites 1, 2 and 3 in both altered and remnant bush land samples ($P \leq 0.05$, Figure 5).

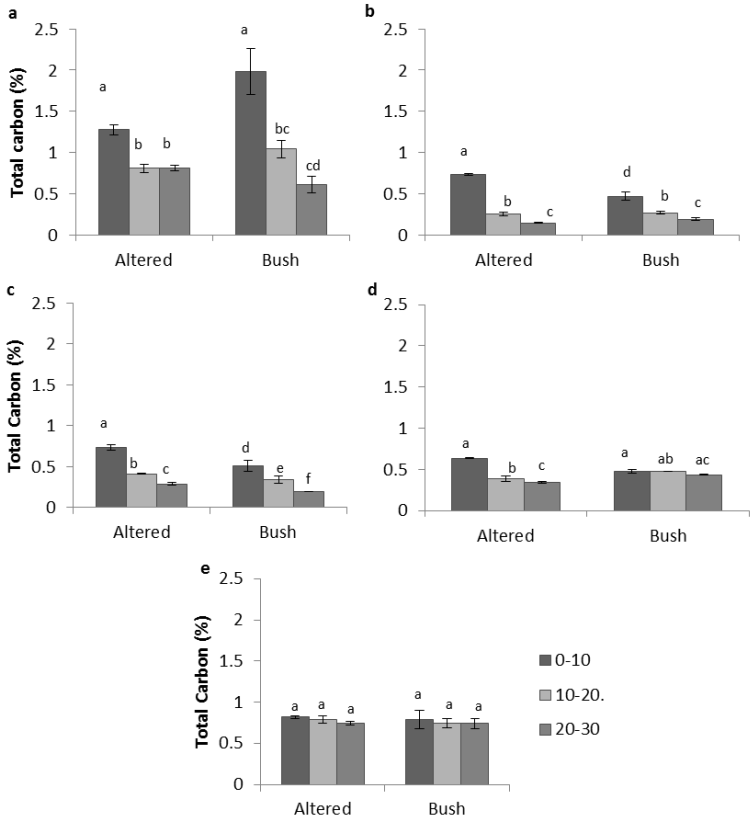


**Figure 5:** Mean total carbon as a percentage, with standard error bars, at each depth, 0-10cm, 10-20cm and 20-30cm, at each site: (a) site 1, (b) site 2, (c) site 3, (d) site 4 and (e) site 5, in anthropogenically altered areas and remnant bushland areas. Different letters above bars indicate significance at P≤ 0.05.

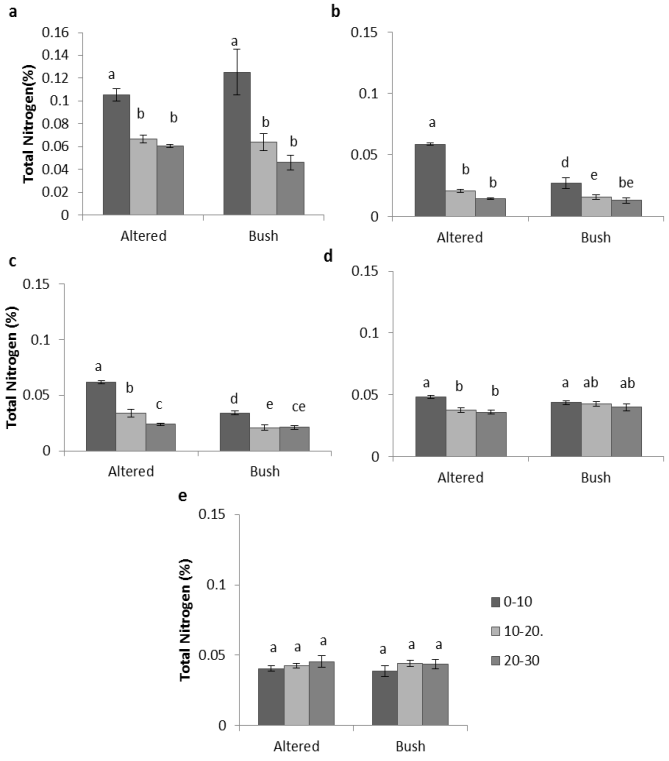


**Figure 6:** Mean total nitrogen (N) as a percentage, with standard error bars, at each depth, 0-10cm, 10-20cm and 20-30cm, at each site: (a) site 1, (b) site 2, (c) site 3, (d) site 4 and (e) site 5, in anthropogenically altered areas and remnant bushland areas. Different letters above bars indicate significance at P≤ 0.05.

Soil pH varied between 3.97 – 5.76 at most sites, however, site 1 had higher pH, reaching 8.17 (Table 3). Anthropogenically altered areas at sites 3 and 4 had greater pH in the top 10cm compared to remnant bushland areas (P≤ 0.05, Table 3). There was no difference between soil pH in the altered area and remnant bushland area at site 5 (Table 3). Site 1 increases in pH between depths in altered samples, however, not in the remnant bushland samples (P≤ 0.05, Table 3). Altered samples had a decrease in pH with depth at site 2, whereas there was no change with depth in bushland samples.

**Table 3:** Average pH ($CaCl_2$) with standard error, of each depth (0-10cm, 10-20cm and 20-30cm depth), in anthropogenically altered areas and remnant bushland areas at each site.

| Depth | Site 1 | | Site 2 | | Site 3 | | Site 4 | | Site 5 | |
|---|---|---|---|---|---|---|---|---|---|---|
| (cm) | Altered | Bush | Altered | Bush | Altered | Bush | Altered | Bush | Altered | Bush |
| **0-10** | 5.42 (0.12) | 5.76 (0.06) | 5.72 (0.23) | 4.82 (0.16) | 5.92 (0.16) | 4.95 (0.06) | 5.56 (0.11) | 3.97 (0.02) | 4.20 (0.04) | 4.29 (0.06) |
| **10-20** | 7.52 (0.40) | 6.37 (0.17) | 4.76 (0.36) | 4.97 (0.14) | 5.13 (0.13) | 4.98 (0.08) | 4.35 (0.35) | 3.99 (0.02) | 4.16 (0.06) | 4.05 (0.11) |
| **20-30** | 8.17 (0.59) | 6.89 (0.17) | 4.29 (0.43) | 4.81 (0.06) | 5.13 (0.19) | 5.03 (0.28) | 4.35 (0.28 | 4.09 (0.00) | 4.16 (0.06) | 3.65 (0.11) |

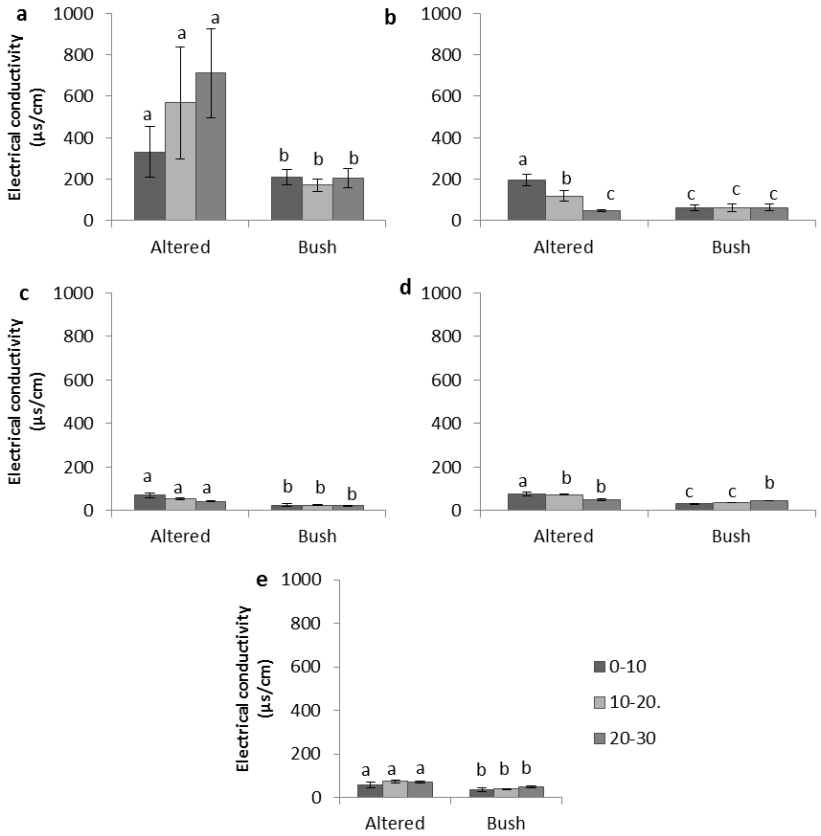


**Figure 7:** Electrical conductivity of anthropogenically altered areas and remnant bushland areas samples at 3 depths: 0-10cm, 10-20cm and 20-30cm, at each site: (a) site 1, (b) site 2, (c) site 3, (d) site 4 and (e) site 5, in. These are mean across each site with standard error. Different letters above bars indicate significance at P≤ 0.05.

Electrical conductivity ranged from 30-200 µs/cm in most sites; however, at site 1 it was as high as 701 µs/cm at a depth of 20-30cm (Figure 7). Anthropogenically altered areas had a greater EC than remnant bushland at all sites (P≤ 0.05, Figure 7). The observed increase occurred at all depths at sites 1, 3 and 5 whereas this only occurred in the surface 20cm at site 2 and 4 (P≤ 0.05, Figure 7b and 7d). Soil EC did not consistently vary with depth across all sites (Figure 7). For example, sites 1, 3 and 5 did not change with depth in either altered or bushland samples (Figure 7a, 7c, 7e). By contrast EC decreases with depth at site 2 (altered area only), and increased with depth at site 4 (bush area only), (Figure 7b and 7d).

**Discussion and conclusion**

This study demonstrated that soil under agricultural land-use and post-mining rehabilitation at the selected sites did not differ in key chemical and biological properties in comparison with adjacent remnant bush land. Land management practices such as no till farming, 'precision' fertiliser application and liming may have been important factors contributing to the lack of major differences between the remnant bush land soils and the altered soils. No till farming can allow greater organic matter build-up near the surface and reduce the incorporation of this organic matter into the subsoil (Feng et al., 2003). Liming has the ability to counteract increased acidity, in the already naturally acidic soils, caused by the application of fertiliser and precision management techniques can reduce the excess application of N fertilisers (Chen et al., 2009).

In conclusion, this study indicated that land management practices within the agricultural industry in the studied region, have resulted in little to no detrimental effects in the microbial properties of the soil. Rehabilitation processes undergone at the Extension Hill mine of Mt Gibson Iron Limited have returned the studied site to near remnant bushland state in regards to soil chemical and biological properties. This research has been critical in understanding how these land uses have affected the soil as an ecosystem. Analysis of a wider range of study sites would help to gain a greater understanding of anthropogenic impacts on soil on a regional scale.

**Acknowledgements**

This research was conducted as part of a Bachelor of Science Honours degree at the University of Western Australia. The author acknowledges the assistance of supervisors Dr Natasha Banning and Assoc/Prof Louise Barton. The assistance of the environmental officers at Extension Hill mine site of Mount Gibson Iron Limited, Jessica Sackmann and Michelle Holland, Clare Johnston and Sarah Tholstrup of the Liebe Group and Yoshi Sawada and Xiaodi Li of the UWA Soil Biology and Molecular Ecology Group is gratefully acknowledged. This research was predominantly funded through the Gunduwa Regional Conservation Association.

**Paper reviewed by:** Natasha Banning and Louise Barton, UWA

**References**

CHEN, W., BELL, R. W., BRENNAN, R. F., BOWDEN, J. W., DOBERMANN, A., RENGEL, Z. & PORTER, W. 2009. Key crop nutrient management issues in the Western Australia grains industry: a review. *Soil Research,* 47**,** 1-18.

DEPARTMENT OF ENVIRONMENT AND PRIMARY INDUSTRIES. 2006. *What is a Healthy Soil* [Online]. State Government of Victoria. Available: http://www.depi.vic.gov.au/agriculture-and-food/farm-management/soil-and-water/soils/what-is-a-healthy-soil March 2014].

FENG, Y., MOTTA, A. C., REEVES, D. W., BURMESTER, C. H., VAN SANTEN, E. & OSBORNE, J. A. 2003. Soil microbial communities under conventional-till and no-till continuous cotton systems. *Soil Biology and Biochemistry,* 35**,** 1693-1703.

LEMENIH, M., KARLTUN, E. & OLSSON, M. 2005. Assessing soil chemical and physical property responses to deforestation and subsequent cultivation in smallholders farming system in Ethiopia. *Agriculture, ecosystems & environment,* 105**,** 373-386.

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