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Ecological effects of repeated low-intensity fire on carbon, nitrogen and phosphorus in the soils of a mixed eucalypt foothill forest in south-eastern Australia


Research report no. 60

Victoria
The Place To Be

Effects of repeated low-intensity fire on carbon, nitrogen and phosphorus in the soils of a mixed eucalypt foothill forest in south-eastern Australia

Research Report No. 60

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Cover photographs 1. Nitrogen fixation plot, DSE/K.Tolhurst 2. Ashbed after fre, DSE/K.Tolhurst

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Foreword

The vegetation, topography and climate of south-eastern Australia combine to make the region one of the most wildfire-prone areas on Earth. Over tens of thousands of years, naturally occurring fires have been highly significant in shaping the distribution and composition of much of the region's native flora and fauna. The arrival of humans here is also considered to have had a more recent influence on these evolutionary processes. Paradoxically, it has been estimated that, in the last one hundred years, two-thirds of all human deaths related to bushfires in Australia and more than half of all significant related property losses have occurred in Victoria.

The severity of a bushfire depends on topography, weather and fuel conditions. Fuel is the only factor over which a land manager can exert some control. The strategic use of prescribed fire (under specified environmental and fire behaviour prescriptions), generally in spring or autumn, is the only practical method of reducing fuels over significant areas and has been a key component of park and forest management in Victoria since the late 1950s – early 1960s.

The threat posed by fire to life and property and the relationship between fire regimes and biodiversity are arguably the key on-going issues confronting the managers of Victoria's parks and forests.

In 1984, a multidisciplinary study was established in the Wombat State Forest, 80 km north-west of Melbourne (Victoria), to investigate the effects of repeated low-intensity prescribed burning in mixed eucalypt foothill forest. The study—the Wombat Fire Effects Study—is quantitative and statistically based and includes various aspects of fauna, flora, soils, tree growth, fuel management and fire behaviour.

On the same permanent plots, various methodologies are used to investigate the ecological impacts of fire on understorey flora, invertebrates, birds, bats, reptiles, terrestrial mammals, soil chemistry and the growth, bark thickness and defect development in trees. Local climate and weather, fuel dynamics and fire behaviour are also studied, along with their interactions. Numerous published papers and reports have been produced as a result of the work. Fire Management Research Reports comprising the current (2003) series are:

No.	Title
57.	Ecological effects of repeated low-intensity fire in a mixed eucalypt foothill forest in south-eastern Australia - Summary report (1984–1999) - Department of Sustainability and Environment
58.	Effects of repeated low-intensity fire on the understorey of a mixed eucalypt foothill forest in south-eastern Australia - K.G. Tolhurst
59.	Effects of repeated low-intensity fire on fuel dynamics in a mixed eucalypt foothill forest in south-eastern Australia - K.G. Tolhurst & N. Kelly
60.	Effects of repeated low-intensity fire on carbon, nitrogen and phosphorus in the soils of a mixed eucalypt foothill forest in south-eastern Australia - P. Hopmans
61.	Effects of repeated low-intensity fire on the invertebrates of a mixed eucalypt foothill forest in south-eastern Australia - N. Collett & F. Neumann
62.	Effects of repeated low-intensity fire on bird abundance in a mixed eucalypt foothill forest in south-eastern Australia - R. Loyn, R. Cunningham & C. Donnelly
63.	Effects of repeated low-intensity fire on terrestrial mammal populations of a mixed eucalypt foothill forest in south-eastern Australia - M. Irvin, M. Westbrooke & M. Gibson
64.	Effects of repeated low-intensity fire on insectivorous bat populations of a mixed eucalypt foothill forest in south-eastern Australia - M. Irvin, P. Prevett & M. Westbrooke

65. Effects of repeated low-intensity fire on reptile populations of a mixed eucalypt foothill forest in south-eastern Australia - M. Irvin, M. Westbrooke & M. Gibson
66. Effects of repeated low-intensity fire on tree growth and bark in a mixed eucalypt foothill forest in south-eastern Australia - K. Chatto, T. Bell & J. Kellas

The foreword to the summary report (Fire Management *Research Report* No. 57) sets out more fully the background to the research, the impact it has had on fire management in the State and the future of the program.

I would like to acknowledge the very considerable efforts of the scientists and technical officers who have contributed to this specific report and more generally to this most significant project.

Gary Morgan AFSM

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Department of Sustainability and Environment

2003

Summary

The impact of repeated prescribed fires on total carbon (C) and nitrogen (N) and extractable phosphorus (P) in soil profiles was evaluated at five Fire Effects Study Areas in the Wombat State Forest, north-west of Melbourne. Soil profile samples were collected in 1985, prior to the commencement of trial applications of prescribed low-intensity fires in spring and autumn at three-year and ten-year intervals, and again in 1998.

Comparison of initial soil properties between fire treatments across the five study areas showed close agreement, although variability was generally high, with coefficients of variation ranging between 20% and 30%. Because of the low replication within treatments, it was therefore important to examine the effects of fire on soils across the full range of study areas rather than just one or two areas.

Based on a comparison of soil profiles collected in 1998, extractable P was not affected by any of the fire regimes. Phosphorus showed a substantial decline across all treatments after 1985, including the unburnt control, which could not be attributed to the prescribed fire treatments.

In the absence of fire, total C and N in the surface soil increased by 16 g kg^{-1} and 0.47 g kg^{-1} respectively, equivalent to a change of 14% and 11% relative to their initial levels. In contrast, burning at three-year intervals caused a decline in both C and N in surface soils; estimated at 15 g kg^{-1} (13%) and 13 g kg^{-1} (12%) for C, and 0.31 g kg^{-1} (7.8%) and 0.27 g kg^{-1} (7.6%) for N in spring and autumn burning treatments respectively. At the less-frequent burning intervals (10 years nominally), changes were negligible for the spring burning treatment. However, small increases in C of 10 g kg^{-1} (9.5%) and in N of 0.28 g kg^{-1} (7.4%) were noted for autumn burning.

A slight change in the C/N ratios was observed, indicating an increase in C relative to N where there was an accumulation of organic matter, such as in the unburnt controls. In contrast, a decrease in C relative to N was observed where there was a loss in organic matter due to frequent low-intensity fires. While these changes in C/N ratios were small, it is suggested that they are indicative of subtle changes in the pools of labile C and N important to biological processes in forest soils.

Introduction

Since the devastating wildfires in 1939, prescribed fire, or fuel-reduction burning, has been used extensively for fire protection as well as silvicultural and environmental management of natural forests in Victoria. The effectiveness of this practice and the ecological impacts of prescribed fire compared with wildfires were reviewed at a symposium in 1983 (Ealy 1983). This review identified the need, in particular, for long-term ecological research to determine the environmental impacts of repeated fuel-reduction burning on eucalypt ecosystems. In the wake of the wildfires in February 1983, the Forests Commission of Victoria in 1984 initiated a multidisciplinary research program to study the ecological effects of repeated prescribed fires in mixed eucalypt foothill forest in the Wombat State Forest. Details of this program together with progress to date for each of the ecological components and implications for fire management of eucalypt forests were published in 1992 (Tolhurst et al. 1992; Tolhurst & Flinn 1992).

The impacts of fire on soils, nutrient cycling and forest hydrology were reviewed at the commencement of the program (Flinn et al. 1984) and specific studies on the effects of fire intensity on soil chemistry and nitrogen mineralisation were completed early in the program (Tolhurst & Flinn 1992). A considerably body of knowledge exists on the effects of single fires on forest soils—in general, the degree of change in soil properties is linked with fire intensity and resultant soil heating. In contrast, few studies had examined the cumulative effects of repeated prescribed fires on soils, nutrient cycling and site productivity (Adams et al. 1994; Flinn et al. 1984; Raison et al. 1993).

A long-term study on the impacts of repeated low-intensity fires on soil chemistry was undertaken at five experimental areas in the Wombat State Forest (Tolhurst & Flinn 1992). Soil profile samples were collected in 1985, prior to the commencement of three- and ten-year cycles of prescribed fires, and again in 1998. Soils of two of the experimental areas were examined in detail to determine the variability in carbon (C), nitrogen (N) and phosphorus (P) within and between treatment areas and the changes in soils in response to fire treatments (Hopmans 2000). Analysis of soils collected from the remaining three areas was completed in 2001 and results for all experimental areas are presented in this report.

Methods

The five experimental Fire Effects Study Areas (FESAs)—Blakeville, Barkstead, Burnt Bridge, Kangaroo Creek and Musk Creek—are located within the Wombat State Forest on the Great Dividing Range, Victoria. Detailed descriptions of these FESAs, including climate, physiography, vegetation and fire history are given by Tolhurst and Flinn (1992). The forest type selected for the study is dominated by Messmate Stringybark (*Eucalyptus obliqua*), Candlebark (*E. rubida*) and Narrow-leaved Peppermint (*E. radiata*). The range in height of overstorey trees in the study areas was 32 to 35 m and in total basal area from 29 to 37 m^2 ha^{-1}. It should be noted that the fire history of each FESA was quite different; the time since the last fire was 54 years at Barkstead, 50 at Blakeville, 41 at Kangaroo Ck and 32 years at Burnt Bridge, but only 11 years at Musk Ck.

Soils were sampled at the commencement of this study in 1985 and again in 1998 after cycles of fuel reduction burning in spring and autumn, as set out below. At each experimental site five adjacent forested catchment areas were assigned to the following fire treatments:

- frequent fires (approximately every three years) in spring—short-rotation spring, S3 (four fires)
- frequent fires (approximately every three years) in autumn—short-rotation autumn, A3 (three fires)
- infrequent fires (approximately every 10 years) in spring—long-rotation spring, S10 (two fires)
- infrequent fires (approximately every 10 years) in autumn—long-rotation autumn, A10 (two fires)
- fire exclusion (unburnt for more that 20 years)—long-unburnt control, C.

Autumn fires were less frequent at Burnt Bridge (A3, two fires and A10, one fire) and Musk Ck (A10, one fire) due to unfavourable weather conditions in the years when burning was scheduled.

Three circular sampling plots each of 0.1 ha within each treatment area were selected along a toposequence—viz., upper slope or ridge, mid-slope and lower slope or gully at Blakeville, Kangaroo Ck, Burnt Bridge and Musk Ck. This ensured that samples were collected across the range of soil conditions within each area. Only two sampling plots (mid-slope and gully) were selected within each treatment area at the relatively flat Barkstead FESA. Circular sampling plots were subdivided into six equal sectors and soil samples were collected from each sector at depths of 0–2 cm, 2–5 cm, 5–10 cm and 10–20 cm.

Soil samples collected in 1985 were air-dried and stored until soil analysis commenced in 1999. The post-treatment samples were collected in 1998 from the same 0.1-ha sampling plots and sectors from most of the FESAs. (Unfortunately, the original sampling plots in the unburnt and A10 treatment areas of the Burnt Bridge FESA could not be re-located with any confidence, so these plots were treated as missing values in the statistical analysis of the post-treatment data.) It should be noted that spring burning treatments were completed in 1994 while the autumn burning program was completed in 1997, only one year prior to the final collection of soil profile samples in 1998.

Samples were separated into coarse organic matter, charcoal, gravel (> 2 mm) and mineral soil (< 2 mm) fractions. The mineral soil fractions of the 1985 and 1998 sample collections were analysed for total C and N based on the Dumas combustion procedure using a LECO CN Analyser (Bremner & Mulvaney 1982; Nelson & Sommers 1982). Extractable P was determined after a 10-minute extraction with acidified ammonium fluoride at a soil-extractant ratio of 1:10 (adapted from Bray & Kurtz 1945; Stewart et al. 1990).

Soil profile samples collected from the Blakeville and Kangaroo Ck FESAs were prepared and analysed in 1999. These particular samples were analysed to determine variability within sampling plots (six samples per 0.1-ha plot) and between plots located at upper, middle and lower slope positions. This provided useful information on the initial and post-treatment variability in soil C, N and P within and between sampling plots and the changes due to repeated fires at these two study areas (Hopmans 2000). However, for the remaining three FESAs, samples collected from the 0.1-ha sampling plots were combined on an equal dry-weight basis to provide one composite sample for each depth. Analysis of variance procedures were used to evaluate the variability in soil C, N and P between FESAs and fire treatment areas, and to determine the effects of repeated prescribed fires at the four depths in the soil profiles.

Results

All samples collected from the Blakeville and Kangaroo Ck FESAs and the composite samples from the Burnt Bridge, Musk Ck and Barkstead areas were analysed for total C, N and extractable P. The Appendix tabulates the average values for each soil depth of the three plots (ridge, midslope, gully) together with standard deviations for each FESA and fire treatment. Pre-treatment data were analysed to evaluate the variability in C, N and P in soil profiles within and between FESAs. The effects of repeated prescribed fires on C, N and P in soil profiles were evaluated in 1998 as were the changes in these soil properties since treatments commenced in 1985.

Soil C, N and P prior to fire treatments

Comparison of pre-treatment C, N and P in soil profiles showed small but statistically significant differences in C and N between FESAs (Table 1). There was a strong concentration gradient with depth with levels at 5–10 cm being approximately one-third that at the soil surface (0–2 cm).

Comparison of FESAs showed that the soils at Burnt Bridge were consistently higher in C and N compared with the other areas (Table 1). Levels of extractable P in soil profiles were similar across all FESAs except for the somewhat higher levels of P in surface soils at Blakeville and Kangaroo Ck (Table 1).

Sampling plots were deliberately selected to represent soil profiles along a toposequence from ridge to gully at each of the fire treatment areas. Initial variability in soil C and N between sampling plots (ridge, mid-slope and gully) was comparatively small, indicating reasonable uniformity within the treatment areas at Blakeville, Kangaroo Ck and Barkstead in 1985 (only C is shown in Figure 1). For example, mean values for C at 2–5 cm depth at these areas were 51, 46 and 46 g $kg^{-1}$with coefficients of variation of 15, 17 and 14% respectively. In contrast, variability was higher at Burnt Bridge and Musk Ck with coefficients of variation of 25 % and 40 % for mean values of C at the same depth. This was mainly due to the greater concentration gradients between sampling plots in these areas (Figure 1). Total soil N followed the same trends as C. In contrast, variability in extractable P was generally higher, with coefficients of variation ranging between 16 % and 52% for mean values of P at 2–5 cm depth. In general, sampling plots in the gullies were higher in P throughout the soil profile at all treatment areas.

Comparison of C, N and P in soil profiles of the fire treatment areas across all FESAs showed that there was no significant difference in total C and N between treatments at the start of the study (Figure 2). For example, mean values for C at 2–5 cm depth for unburnt, S3, A3, S10 and A10 treatments were 52, 49, 49, 52 and 53 g kg^{-1} respectively, with associated coefficients of variation of 21, 33, 24, 34 and 29%.

Results for extractable P showed slightly lower levels in the areas selected for the A3 treatments compared with the unburnt, S3 and S10 treatments (Figure 2). Initial differences in P between the unburnt, S3, S10 and A10 treatments were not statistically significant.

Table 1 Average concentrations of carbon and nitrogen (g/kg) and extractable phosphorus (mg/kg) in soil profiles in 1985 prior to prescribed fire treatments at the five Fire Effects Study Areas in the Wombat State Forest

Element	Depth	Blakeville		Kangaroo Ck		Burnt Bridge		Musk Ck		Barkstead		F value*	PLSD‡
	(cm)	Mean	SE#	Mean	SE	Mean	SE	Mean	SE	Mean	SE		
C (g kg^{-1})	0–2	118	6.4	108	5.2	114	5.4	98	7.4	100	4.6	NS	-
	2–5	51	2.0	46	2.0	64	4.2	45	4.7	46	2.1	***	10
	5–10	33	1.6	28	1.5	42	2.6	31	3.2	31	2.2	***	7
	10–20	24	1.2	18	1.1	29	1.9	23	2.4	22	1.6	***	5
N (g kg^{-1})	0–2	3.9	0.20	4.1	0.18	4.4	0.24	3.3	0.25	3.5	0.22	**	0.7
	2–5	2.0	0.09	2.0	0.12	2.7	0.20	1.8	0.18	1.8	0.13	***	0.5
	5–10	1.4	0.07	1.3	0.10	1.9	0.13	1.4	0.14	1.3	0.12	**	0.4
	10–20	1.1	0.05	0.9	0.07	1.4	0.10	1.1	0.11	1.0	0.07	**	0.2
P (mg kg^{-1})	0–2	27	1.8	25	1.6	22	2.1	17	2.4	18	1.7	*	6
	2–5	12	0.9	11	0.5	11	0.7	9	1.3	9	0.5	NS	-
	5–10	8	0.7	7	0.3	7	0.6	6	0.7	6	0.6	NS	-
	10–20	5	0.5	5	0.2	5	0.5	4	0.5	4	0.4	NS	-

* Differences between means are significant at $P < 0.05$ (*), $P < 0.01$ (**), $P < 0.001$ (***) or not significant (NS).

‡ PLSD, Fisher's Protected Least Significant Difference at $P = 0.05$.

\# SE, standard error of the mean.

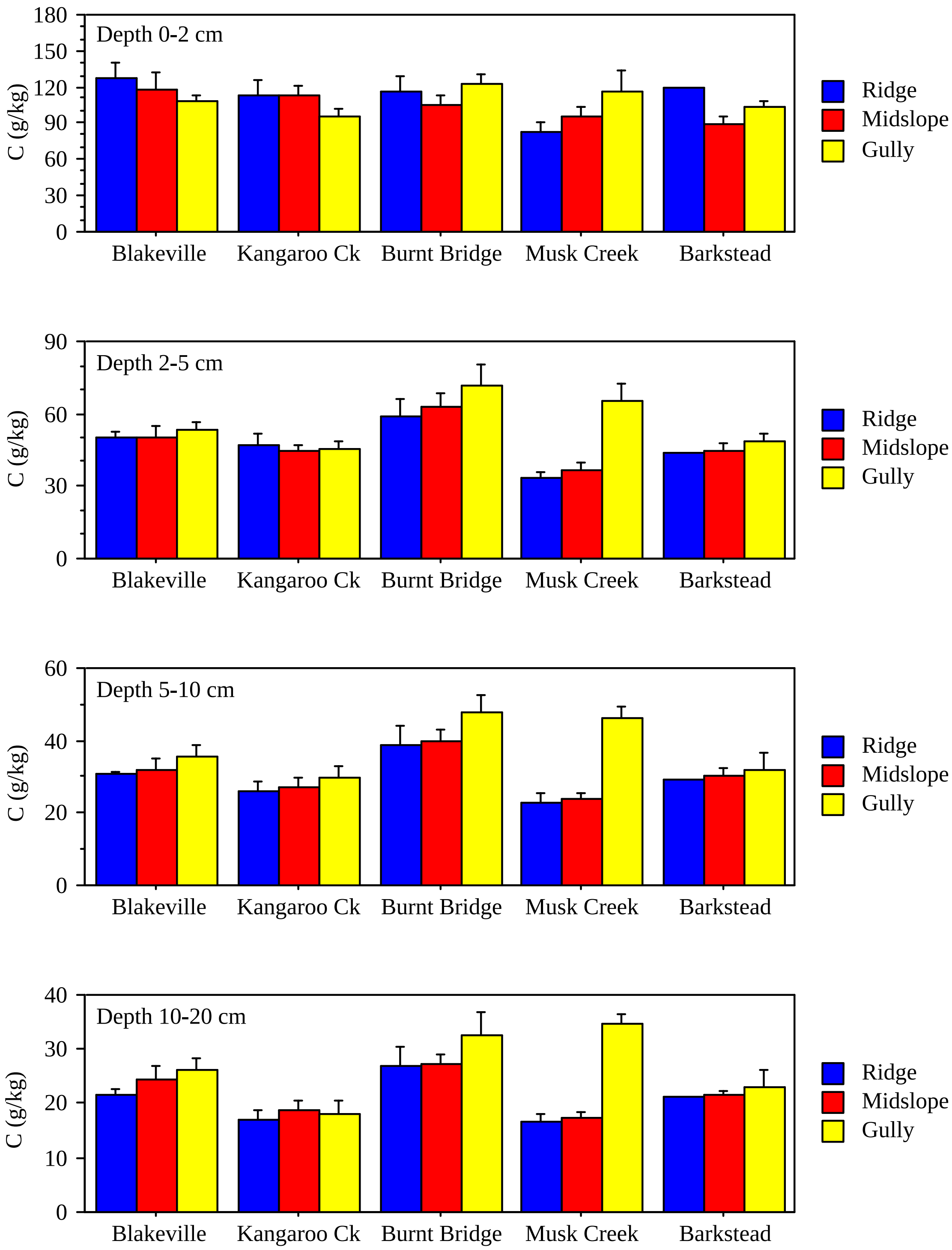


Figure 1 Total C in soil profiles of sampling plots (ridge, mid-slope and gully) at the five Fire Effects Study Areas in 1985. Bars indicate standard errors of the means.

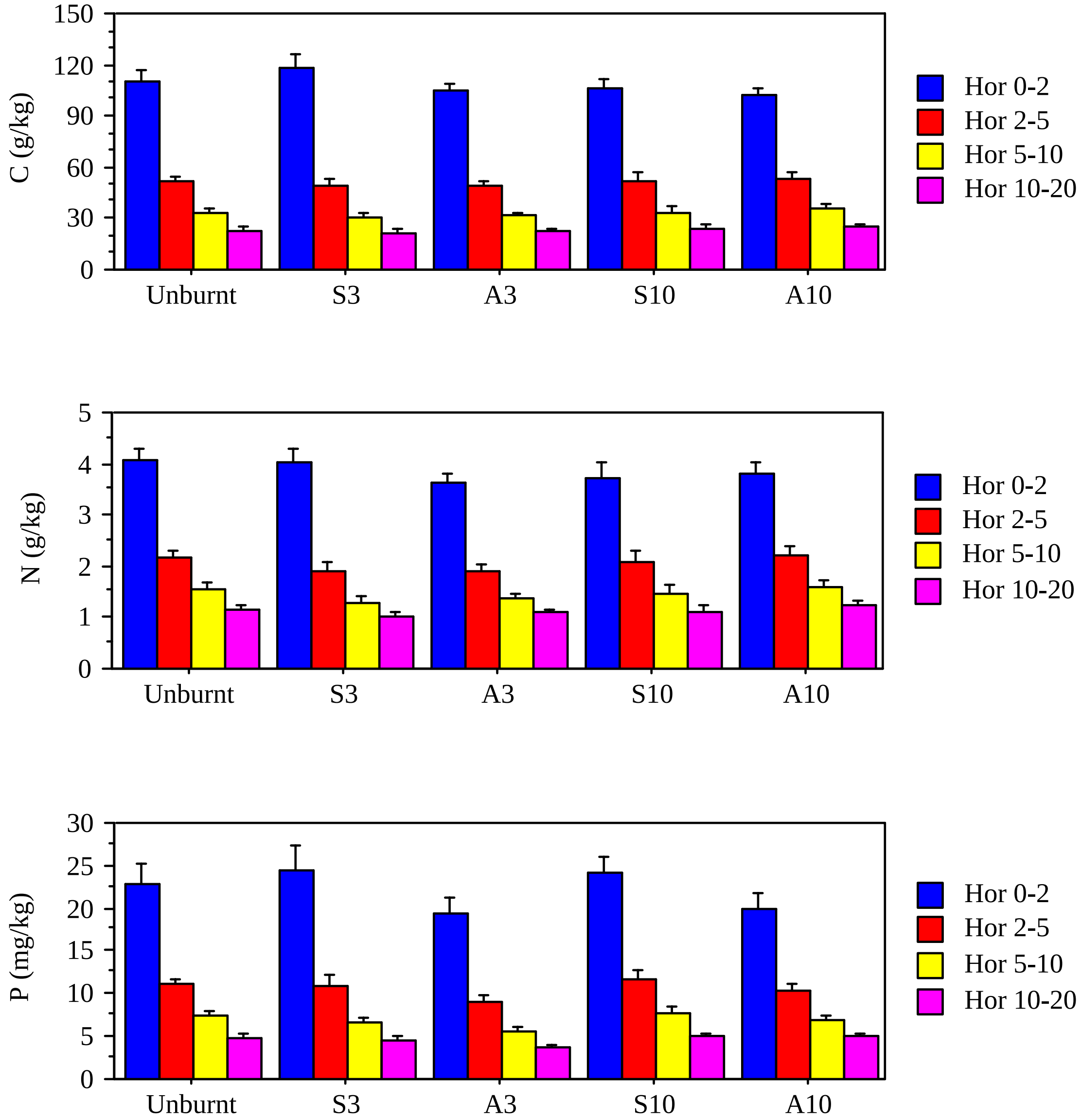


Figure 2 Total C and N and extractable P in soil profiles of the fire treatment areas at the five Fire Effects Study Areas in 1985. Bars indicate standard errors of the means.

Effects of repeated prescribed fires

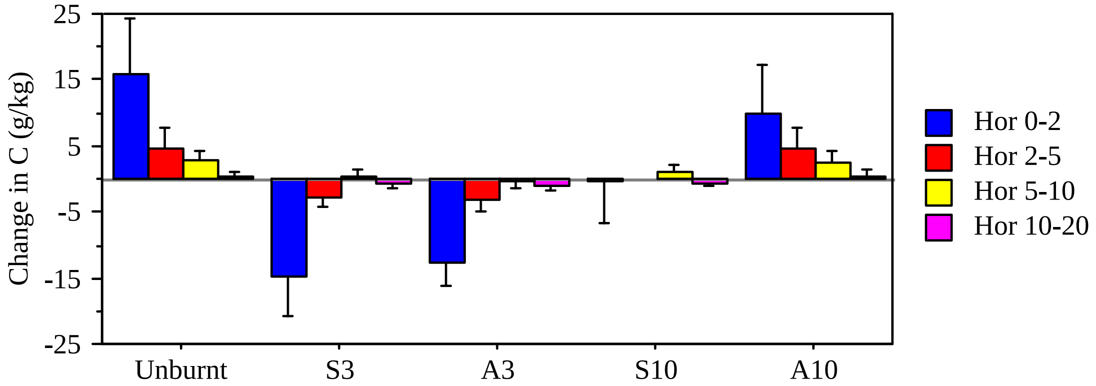
Average concentrations of total C and N and extractable P in soil profiles for the various treatments across the five FESAs are shown in Table 2. Results indicate a significant change in C and, to a lesser extent, N between fire treatments and this effect was limited to the surface soil layers (0–2 and 2–5 cm). Soil C and N below these surface layers were not affected by fire treatment.

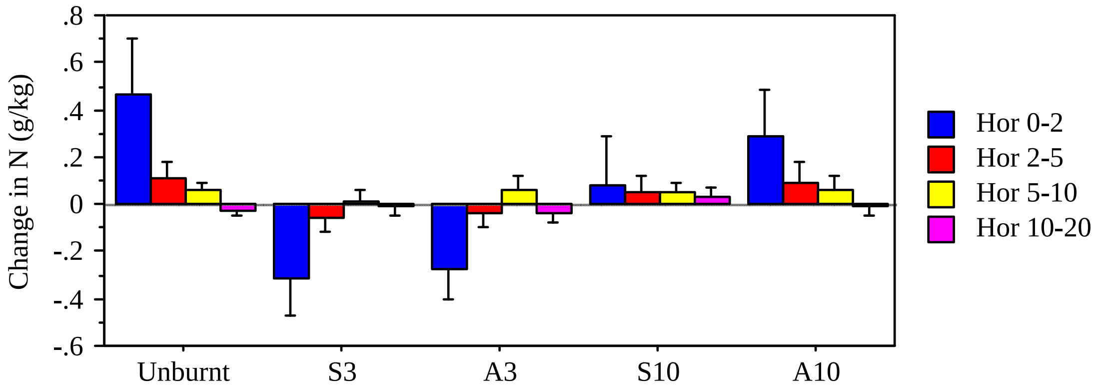
Table 2 Average concentrations of C and N (g kg^{-1}) and extractable P (mg kg^{-1}) in soil profiles in 1998 following repeated fires at 3- and 10-year cycles in spring (S3 and S10) and autumn (A3 and A10) at the five Fire Effects Study Areas in the Wombat State Forest. Standard errors of the means are shown in parenthesis.

Soil	Unburnt	S3	A3	S10	A10	F value#	PLSD‡
Carbon (g kg^{-1})							
0–2 cm	122 (7.5)	103 (8.2)	91 (5.8)	105 (6.7)	107 (7.5)	**	18
2–5 cm	52 (4.2)	46 (3.4)	44 (3.3)	52 (4.4)	50 (4.0)	*	6
5–10 cm	33 (3.3)	31 (2.4)	31 (2.8)	35 (3.3)	34 (2.7)	NS	-
10–20 cm	21 (2.3)	21 (1.8)	21 (2.0)	23 (2.4)	23 (2.0)	NS	-
Nitrogen (g kg^{-1})							
0–2 cm	4.3 (0.25)	3.7 (0.28)	3.3 (0.22)	3.8 (0.26)	3.8 (0.21)	*	0.5
2–5 cm	2.1 (0.16)	1.8 (0.14)	1.8 (0.14)	2.1 (0.19)	2.0 (0.15)	NS	-
5–10 cm	1.4 (0.13)	1.3 (0.11)	1.4 (0.12)	1.5 (0.14)	1.5 (0.11)	NS	-
10–20 cm	1.0 (0.11)	1.0 (0.08)	1.0 (0.09)	1.1 (0.10)	1.1 (0.08)	NS	-
Phosphorus (mg kg^{-1})							
0–2 cm	9.6 (0.5)	10.0 (1.1)	11.1 (1.5)	9.7 (0.7)	11.7 (1.2)	NS	-
2–5 cm	4.5 (0.3)	4.3 (0.4)	4.0 (0.3)	4.7 (0.4)	4.4 (0.4)	NS	-
5–10 cm	3.3 (0.2)	3.1 (0.3)	2.8 (0.2)	3.5 (0.3)	3.4 (0.4)	NS	-
10–20 cm	2.3 (0.1)	2.1 (0.2)	1.9 (0.1)	2.5 (0.2)	2.7 (0.3)	NS	-

Differences between means are significant at $P < 0.05$ (*), $P < 0.01$ (**), $P < 0.001$ (***), or not significant (NS).

‡ PLSD, Fisher's Protected Least Significant Difference at $P = 0.05$.





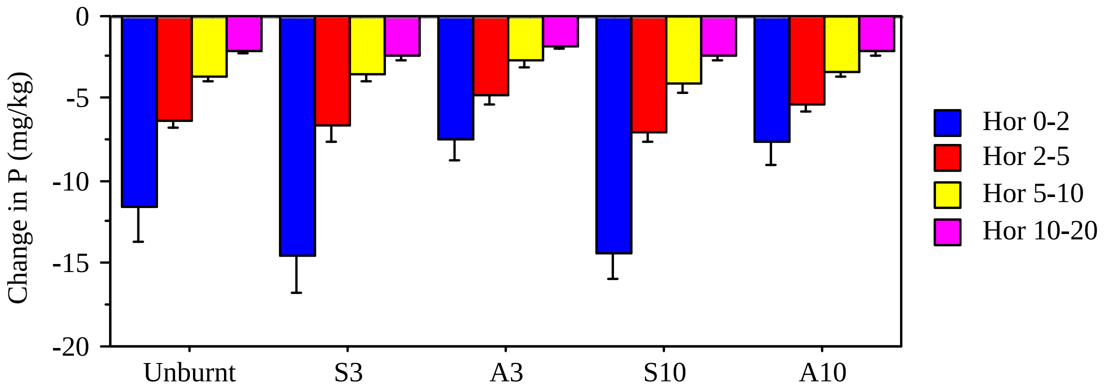


Figure 3 Changes in total C and N and extractable P in soil profiles following repeated fires at 3- and 10-year cycles in spring (S3 and S10) and autumn (A3 and A10) at the five Fire Effects Study Areas in the Wombat State Forest. Bars indicate standard errors.

Evaluation of the changes in soil profiles, since the fire treatments commenced in 1985, showed an accumulation of C and N in the surface soil layers (0–2 cm and 2–5 cm depths) of the unburnt areas (Figure 3). In contrast, a decline in C and N was observed in the areas with three-year fire cycles in spring (S3) and autumn (A3). Changes in areas with ten-year fire cycles were not significant when compared with the unburnt controls, although C and N in the surface soil layers increased in the A10 areas compared to the S3 and A3 treatments. However, no changes in soil C and N were observed for the S10 treatment. Soil C and N in the lower layers of the soil profiles followed the same trends (Figure 3) but changes were small and not statistically significant.

The general relationship between C and N in soil profiles at the commencement of the study and after the fire treatments showed little if any change with time (Figure 4). However, evaluation of the C/N ratios at each depth in 1985 and 1998 showed a slight increase in C/N—by 0.5–1.0 units—in soil profiles of unburnt and A10 treatments consistent with an accumulation of C relative to N. In contrast, decreases in C/N ratios by 0.5–1.5 units were observed in S3, A3 and S10 treatments, indicating a loss of C relative to N (Figure 4).

Levels of extractable P in the soil profiles in 1998 were not significantly different between fire treatments (Table 2). Comparison of 1985 and 1998 soil P levels showed a substantial decrease in extractable P in the soil profiles at all sites (Figure 2 and Table 2). For example, levels of P decreased by between 6 and 7 mg kg^{-1} in the 2–5 cm horizon, equivalent to a decline in available P of approximately 58% across all treatments, including the unburnt control. Further testing of the 1985 soil collection confirmed the high levels of Bray-P extractable P in the pre-treatment samples compared with those collected in 1998. The change in P in soil profiles since 1985 indicates a general decline in extractable P (Figure 3). These changes were similar for the unburnt control and spring burning at three- and ten-year cycles, but were smaller for the autumn burning treatments. Differences between autumn and spring burning were statistically significant for surface soils (0–2 cm) only.

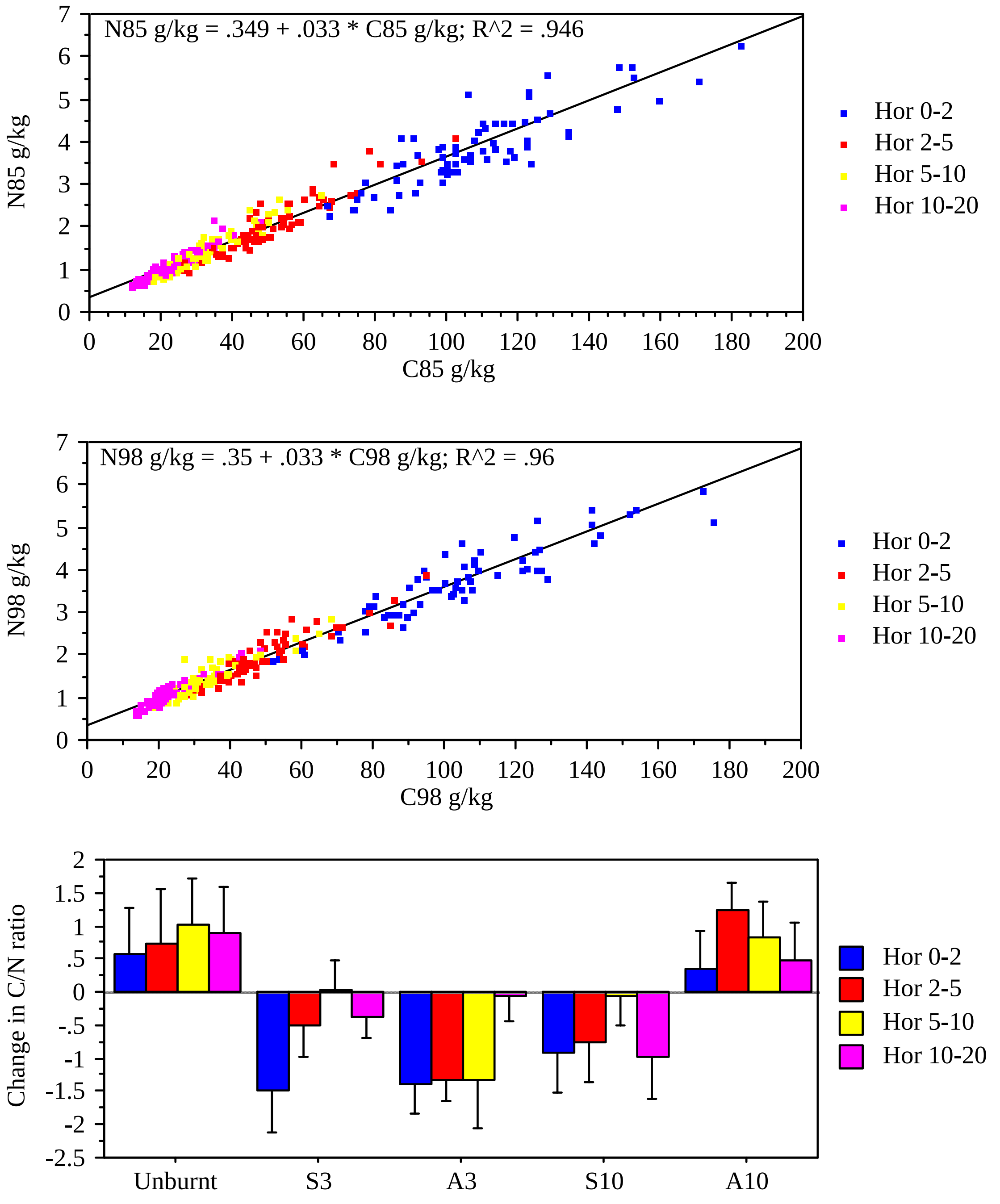


Figure 4 Relationships between C and N in soil profiles prior to treatment in 1985 and in 1998 after fires at 3- and 10-year cycles in spring (S3 and S10) and autumn (A3 and A10) and changes in C/N ratios at the five Fire Effects Study Areas in the Wombat State Forest. Bars indicate standard errors of the means.

Discussion

Comparison of the initial levels of total C and N and extractable P in soil profiles at the five FESAs showed small, but statistically significant differences between the various locations in the Wombat State Forest. Soil profiles at Blakeville, Kangaroo Ck and Barkstead FESAs were quite similar and more uniform compared with Burnt Bridge and Musk Ck. Results demonstrated the importance of taking into account the initial variation between experimental sites when evaluating changes induced by forest management practices, in this case the effects of repeated low-intensity fires.

The comparison of the initial levels of C, N and P in soil profiles between the fire treatments—that is, unburnt, S3, A3, S10 and A10—showed that the mean values across the five FESAs were generally in close agreement (Figure 2). However, variability was high, with coefficients of variation ranging between 20% and 30% for the upper layers in the soil profile. Consequently, comparatively large changes are required to test the hypothesis that repeated low-intensity fires have affected these soil properties. For example, a change in C of 18 g kg^{-1} in the surface soil (15% of unburnt control) represents a statistically significant effect at the 5% level of probability. Likewise, the least significant difference (LSD—at $P < 5\%$) for extractable P in the surface soil in 1998 was 3.2 mg kg^{-1}, or a change of 33% with respect to the unburnt control. These comparatively large LSD values are a reflection of the inherent variability between the FESAs and a consequence of the low level of replication within treatment areas (two or three replicates). With the benefit of hindsight, greater replication within treatment areas, by increasing the number of sampling plots from three to six, would have improved the sensitivity of the analysis, but this would also have almost doubled the already substantial cost of this soil study. Because of the low level of replication within treatments, it is important to evaluate the effects of fire across all five FESAs as discussed previously in the more detailed examination of the Blakeville and Kangaroo Ck areas (Hopmans 2000).

Based on a comparison of soil profiles collected in 1998, extractable P was not affected by any of the fire regimes. However, a comparatively large change in P was required to reveal a statistically significant difference between treatments. Phosphorus showed a substantial decline from the initial level across all fire treatments, including the unburnt control, because of the high initial levels of extractable P in 1985 compared with the post-treatment samples in 1998. Therefore the results are not quite as robust and a more subtle impact on extractable soil P is difficult to discern. However, it cannot be assumed that fuel-reduction burning will necessarily increase extractable P as is often the case with high-intensity regeneration or slash fires. Repeated low-intensity fires increased extractable P in the surface soils in some studies (Adams et al. 1994; McKee 1982) while other work showed little if any change in soil P (Binkley et al. 1992; Boyer & Miller 1994).

The present evaluation of the effects of repeated low-intensity fires across all FESAs showed an accumulation of C and N in the surface soil (0–2 cm) and, to a lesser extent, in the next layer (2–5 cm) of the soil profiles in the unburnt control treatments. In the absence of fire, surface soil C and N increased by 16 g kg^{-1} and 0.47 g kg^{-1} respectively, equivalent to a change of 14% and 11% relative to the initial levels of C and N. In contrast, a decline in C and N was evident in surface soils of areas with spring and autumn burning at three-year intervals. Decreases were estimated at 15 g kg^{-1} (13%) and 13 g kg^{-1} (12%) for C, and 0.31 g kg^{-1} (7.8%) and 0.27 g kg^{-1} (7.6%) for N in spring (S3) and autumn (A3) burning treatments respectively. At the less frequent burning intervals (10 years nominal), changes were negligible for the spring (S10) burning treatment. However small increases in C and N of 10 g kg^{-1} (9.5%) and 0.28 g kg^{-1} (7.4%) respectively were noted for autumn (A10) burning. It should be noted that these changes in the surface soils of the S10 and A10 treatments were not significantly different from the unburnt control.

The effects on C and N were mainly limited to the surface layer (0–2 cm) which includes a relatively large proportion of partly decomposed litter and coarse organic matter. This material is readily volatilised or combusted during low-intensity fires (e.g. 50–350 kW m^{-1}) with surface temperatures often in excess of 200 °C (Humphreys & Craig 1981; Neary et al. 1999). The impacts on C and N in the surface soil dependt on a rather complex range of conditions, including fuel characteristics (load, size, spatial distribution, moisture content, etc.), weather conditions (temperature, wind, humidity, etc), fire behaviour (intensity, duration, rate of spread, etc.) and soil conditions (moisture content, bulk density, heat capacity and conductance, etc.). Therefore the effects of a single prescribed fire on soil C and N can be expected to vary considerably between events depending on conditions at the time of the fire (Humphreys & Craig 1981; Neary et al. 1999; Raison et al. 1993). In an attempt to address this inherent variability associated with single fire events, fuel characteristics and fire behaviour, the present study examined the longer-term effects of repeated fires at the five FESAs in the Wombat State Forest.

Results showed a general decline in surface soil C and N associated with low-intensity fires at three-year intervals. However, there was significant variation between sites; for example, the changes in C and N were negligible at Blakeville where fires were mostly classed as ‘cool’ burns (Tolhurst[1], pers. comm. 2002). In contrast, significant changes in C and N where observed at Kangaroo Ck where fires were generally more intense, often resulting in significant crown scorch. It is suggested that the results of the present study of soil C and N need to be examined in the context of the observed differences in fire behaviour between the FESAs. This would provide a better understanding of the relationship between fire conditions and their effect on soil C and N. Furthermore, this could also be developed into an important ‘tool’ for the management of prescribed fires and as an indicator of the sustainable management of native forests.

The changes in soil C and N due to repeated fires were comparatively small but statistically significant and limited to the surface soil. This is consistent with the small changes in C and N due to repeated fuel reduction burning reported from similar studies (e.g. Boyer & Miller 1994; McKee 1982; Raison et al. 1993). The present study also showed a slight change in the C/N ratios, indicating an increase in C relative to N where there was an accumulation of organic matter (unburnt control) and a decrease in C relative to N where there was a loss in organic matter due to frequent low-intensity fires. While these changes in C/N ratios were small, they are indicative of subtle changes in the pools of labile C and N. For example, the studies reported by Raison et al. (1993) measured various ‘available’ forms of N and showed significant reductions in N mineralisation due to repeated fires, indicating important changes in microbial activity of soil in sub-alpine Snow Gum forest. Likewise, repeated low-intensity fires decreased, not only total C and N, but also mineralisable N and phosphatase activity in the surface soil of heathland at Wilsons Promontory in Victoria (Adams et al. 1994). These studies showed that even comparatively small changes in total C and N pools in surface soils are often associated with significant changes in the biological processes and availability of labile forms of C and N at the litter–soil interface.

The present study of the long-term effects of low-intensity fires in the Wombat State Forest examined the impacts on the total pools of C and N, and continuation of the program to get a better understanding of the soil processes affected by low-intensity fires should be given serious consideration.

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Appendix

Carbon, nitrogen and extractable phosphorus in soil profiles prior to treatment in 1985 and in 1998 after prescribed fires in spring and autumn at three- and ten-year intervals

Key to the columns in the following table:

Soil C85 and C98 indicate carbon in 1985 and 1998 respectively; similarly for nitrogen (N85, N98) and phosphorus (P85, P98)
Measurements for C and N are in grams/kilogram; for P in milligrams/kilogram

FESA Fire Effects Study Area

Depth (cm) depth (in centimetres) to the sampled soil horizons

Treatment burning treatments:
S3, S10 = spring burning at three-year and 10-year intervals respectively
A3, A10 = autumn burning at three-year and 10-year intervals respectively

Mean average values of C, N and P (ridge, mid-slope and gully) for each soil depth

Std Dev. Standard deviation

Soil	FESA	Depth (cm)	Treatment	Mean	Std. Dev.
C85 g/kg	Blakeville	Hor 0–2	Unburnt	129	27
C85 g/kg	Blakeville	Hor 0–2	S3	139	36
C85 g/kg	Blakeville	Hor 0–2	A3	119	16
C85 g/kg	Blakeville	Hor 0–2	S10	95	10
C85 g/kg	Blakeville	Hor 0–2	A10	109	12
C85 g/kg	Blakeville	Hor 2–5	Unburnt	52	2
C85 g/kg	Blakeville	Hor 2–5	S3	56	11
C85 g/kg	Blakeville	Hor 2–5	A3	52	4
C85 g/kg	Blakeville	Hor 2–5	S10	50	14
C85 g/kg	Blakeville	Hor 2–5	A10	46	3
C85 g/kg	Blakeville	Hor 5–10	Unburnt	31	2
C85 g/kg	Blakeville	Hor 5–10	S3	36	8
C85 g/kg	Blakeville	Hor 5–10	A3	32	2
C85 g/kg	Blakeville	Hor 5–10	S10	35	12
C85 g/kg	Blakeville	Hor 5–10	A10	30	1
C85 g/kg	Blakeville	Hor 10–20	Unburnt	22	2
C85 g/kg	Blakeville	Hor 10–20	S3	26	7
C85 g/kg	Blakeville	Hor 10–20	A3	23	2
C85 g/kg	Blakeville	Hor 10–20	S10	26	8

Soil	FESA	Depth (cm)	Treatment	Mean	Std. Dev.
C85 g/kg	Blakeville	Hor 10–20	A10	24	1
C85 g/kg	Kangaroo Ck	Hor 0–2	Unburnt	106	15
C85 g/kg	Kangaroo Ck	Hor 0–2	S3	123	14
C85 g/kg	Kangaroo Ck	Hor 0–2	A3	105	23
C85 g/kg	Kangaroo Ck	Hor 0–2	S10	112	32
C85 g/kg	Kangaroo Ck	Hor 0–2	A10	91	7
C85 g/kg	Kangaroo Ck	Hor 2–5	Unburnt	45	5
C85 g/kg	Kangaroo Ck	Hor 2–5	S3	44	2
C85 g/kg	Kangaroo Ck	Hor 2–5	A3	46	10
C85 g/kg	Kangaroo Ck	Hor 2–5	S10	44	16
C85 g/kg	Kangaroo Ck	Hor 2–5	A10	49	4
C85 g/kg	Kangaroo Ck	Hor 5–10	Unburnt	26	5
C85 g/kg	Kangaroo Ck	Hor 5–10	S3	24	2
C85 g/kg	Kangaroo Ck	Hor 5–10	A3	31	9
C85 g/kg	Kangaroo Ck	Hor 5–10	S10	25	8
C85 g/kg	Kangaroo Ck	Hor 5–10	A10	31	1
C85 g/kg	Kangaroo Ck	Hor 10–20	Unburnt	18	5
C85 g/kg	Kangaroo Ck	Hor 10–20	S3	15	3
C85 g/kg	Kangaroo Ck	Hor 10–20	A3	21	6
C85 g/kg	Kangaroo Ck	Hor 10–20	S10	17	6
C85 g/kg	Kangaroo Ck	Hor 10–20	A10	19	2
C85 g/kg	Burnt Bridge	Hor 0–2	Unburnt	125	24
C85 g/kg	Burnt Bridge	Hor 0–2	S3	102	21
C85 g/kg	Burnt Bridge	Hor 0–2	A3	112	3
C85 g/kg	Burnt Bridge	Hor 0–2	S10	112	38
C85 g/kg	Burnt Bridge	Hor 0–2	A10	122	8
C85 g/kg	Burnt Bridge	Hor 2–5	Unburnt	70	3
C85 g/kg	Burnt Bridge	Hor 2–5	S3	49	6
C85 g/kg	Burnt Bridge	Hor 2–5	A3	58	5
C85 g/kg	Burnt Bridge	Hor 2–5	S10	67	32
C85 g/kg	Burnt Bridge	Hor 2–5	A10	78	3
C85 g/kg	Burnt Bridge	Hor 5–10	Unburnt	47	3
C85 g/kg	Burnt Bridge	Hor 5–10	S3	34	2
C85 g/kg	Burnt Bridge	Hor 5–10	A3	36	3
C85 g/kg	Burnt Bridge	Hor 5–10	S10	43	20
C85 g/kg	Burnt Bridge	Hor 5–10	A10	51	3
C85 g/kg	Burnt Bridge	Hor 10–20	Unburnt	30	2
C85 g/kg	Burnt Bridge	Hor 10–20	S3	24	3

Soil	FESA	Depth (cm)	Treatment	Mean	Std. Dev.
C85 g/kg	Burnt Bridge	Hor 10–20	A3	26	1
C85 g/kg	Burnt Bridge	Hor 10–20	S10	31	15
C85 g/kg	Burnt Bridge	Hor 10–20	A10	34	3
C85 g/kg	Musk Creek	Hor 0–2	Unburnt	97	5
C85 g/kg	Musk Creek	Hor 0–2	S3	113	61
C85 g/kg	Musk Creek	Hor 0–2	A3	83	21
C85 g/kg	Musk Creek	Hor 0–2	S10	104	19
C85 g/kg	Musk Creek	Hor 0–2	A10	93	21
C85 g/kg	Musk Creek	Hor 2–5	Unburnt	46	13
C85 g/kg	Musk Creek	Hor 2–5	S3	50	37
C85 g/kg	Musk Creek	Hor 2–5	A3	39	22
C85 g/kg	Musk Creek	Hor 2–5	S10	45	7
C85 g/kg	Musk Creek	Hor 2–5	A10	44	13
C85 g/kg	Musk Creek	Hor 5–10	Unburnt	34	14
C85 g/kg	Musk Creek	Hor 5–10	S3	31	21
C85 g/kg	Musk Creek	Hor 5–10	A3	28	16
C85 g/kg	Musk Creek	Hor 5–10	S10	28	9
C85 g/kg	Musk Creek	Hor 5–10	A10	33	7
C85 g/kg	Musk Creek	Hor 10–20	Unburnt	25	11
C85 g/kg	Musk Creek	Hor 10–20	S3	23	14
C85 g/kg	Musk Creek	Hor 10–20	A3	21	11
C85 g/kg	Musk Creek	Hor 10–20	S10	21	7
C85 g/kg	Musk Creek	Hor 10–20	A10	23	8
C85 g/kg	Barkstead	Hor 0–2	Unburnt	88	20
C85 g/kg	Barkstead	Hor 0–2	S3	109	14
C85 g/kg	Barkstead	Hor 0–2	A3	103	4
C85 g/kg	Barkstead	Hor 0–2	S10	104	26
C85 g/kg	Barkstead	Hor 0–2	A10	95	4
C85 g/kg	Barkstead	Hor 2–5	Unburnt	44	0
C85 g/kg	Barkstead	Hor 2–5	S3	43	0
C85 g/kg	Barkstead	Hor 2–5	A3	46	1
C85 g/kg	Barkstead	Hor 2–5	S10	56	8
C85 g/kg	Barkstead	Hor 2–5	A10	42	7
C85 g/kg	Barkstead	Hor 5–10	Unburnt	28	6
C85 g/kg	Barkstead	Hor 5–10	S3	26	5
C85 g/kg	Barkstead	Hor 5–10	A3	30	2
C85 g/kg	Barkstead	Hor 5–10	S10	39	9
C85 g/kg	Barkstead	Hor 5–10	A10	32	10

Soil	FESA	Depth (cm)	Treatment	Mean	Std. Dev.
C85 g/kg	Barkstead	Hor 10–20	Unburnt	19	4
C85 g/kg	Barkstead	Hor 10–20	S3	19	4
C85 g/kg	Barkstead	Hor 10–20	A3	23	2
C85 g/kg	Barkstead	Hor 10–20	S10	26	7
C85 g/kg	Barkstead	Hor 10–20	A10	25	7
C98 g/kg	Blakeville	Hor 0–2	Unburnt	110	11
C98 g/kg	Blakeville	Hor 0–2	S3	113	11
C98 g/kg	Blakeville	Hor 0–2	A3	97	16
C98 g/kg	Blakeville	Hor 0–2	S10	100	11
C98 g/kg	Blakeville	Hor 0–2	A10	95	6
C98 g/kg	Blakeville	Hor 2–5	Unburnt	48	5
C98 g/kg	Blakeville	Hor 2–5	S3	50	10
C98 g/kg	Blakeville	Hor 2–5	A3	43	1
C98 g/kg	Blakeville	Hor 2–5	S10	49	11
C98 g/kg	Blakeville	Hor 2–5	A10	45	8
C98 g/kg	Blakeville	Hor 5–10	Unburnt	32	4
C98 g/kg	Blakeville	Hor 5–10	S3	35	10
C98 g/kg	Blakeville	Hor 5–10	A3	31	2
C98 g/kg	Blakeville	Hor 5–10	S10	35	11
C98 g/kg	Blakeville	Hor 5–10	A10	32	6
C98 g/kg	Blakeville	Hor 10–20	Unburnt	21	3
C98 g/kg	Blakeville	Hor 10–20	S3	23	7
C98 g/kg	Blakeville	Hor 10–20	A3	22	1
C98 g/kg	Blakeville	Hor 10–20	S10	22	6
C98 g/kg	Blakeville	Hor 10–20	A10	22	5
C98 g/kg	Kangaroo Ck	Hor 0–2	Unburnt	147	24
C98 g/kg	Kangaroo Ck	Hor 0–2	S3	125	27
C98 g/kg	Kangaroo Ck	Hor 0–2	A3	87	15
C98 g/kg	Kangaroo Ck	Hor 0–2	S10	117	22
C98 g/kg	Kangaroo Ck	Hor 0–2	A10	103	7
C98 g/kg	Kangaroo Ck	Hor 2–5	Unburnt	55	12
C98 g/kg	Kangaroo Ck	Hor 2–5	S3	45	9
C98 g/kg	Kangaroo Ck	Hor 2–5	A3	41	8
C98 g/kg	Kangaroo Ck	Hor 2–5	S10	48	14
C98 g/kg	Kangaroo Ck	Hor 2–5	A10	49	7
C98 g/kg	Kangaroo Ck	Hor 5–10	Unburnt	27	5
C98 g/kg	Kangaroo Ck	Hor 5–10	S3	26	5

Soil	FESA	Depth (cm)	Treatment	Mean	Std. Dev.
C98 g/kg	Kangaroo Ck	Hor 5–10	A3	28	7
C98 g/kg	Kangaroo Ck	Hor 5–10	S10	29	10
C98 g/kg	Kangaroo Ck	Hor 5–10	A10	31	3
C98 g/kg	Kangaroo Ck	Hor 10–20	Unburnt	18	4
C98 g/kg	Kangaroo Ck	Hor 10–20	S3	16	3
C98 g/kg	Kangaroo Ck	Hor 10–20	A3	19	4
C98 g/kg	Kangaroo Ck	Hor 10–20	S10	17	5
C98 g/kg	Kangaroo Ck	Hor 10–20	A10	19	2
C98 g/kg	Burnt Bridge	Hor 0–2	Unburnt	.	.
C98 g/kg	Burnt Bridge	Hor 0–2	S3	93	23
C98 g/kg	Burnt Bridge	Hor 0–2	A3	118	13
C98 g/kg	Burnt Bridge	Hor 0–2	S10	136	12
C98 g/kg	Burnt Bridge	Hor 0–2	A10	.	.
C98 g/kg	Burnt Bridge	Hor 2–5	Unburnt	.	.
C98 g/kg	Burnt Bridge	Hor 2–5	S3	46	8
C98 g/kg	Burnt Bridge	Hor 2–5	A3	58	4
C98 g/kg	Burnt Bridge	Hor 2–5	S10	73	20
C98 g/kg	Burnt Bridge	Hor 2–5	A10	.	.
C98 g/kg	Burnt Bridge	Hor 5–10	Unburnt	.	.
C98 g/kg	Burnt Bridge	Hor 5–10	S3	34	6
C98 g/kg	Burnt Bridge	Hor 5–10	A3	36	1
C98 g/kg	Burnt Bridge	Hor 5–10	S10	47	19
C98 g/kg	Burnt Bridge	Hor 5–10	A10	.	.
C98 g/kg	Burnt Bridge	Hor 10–20	Unburnt	.	.
C98 g/kg	Burnt Bridge	Hor 10–20	S3	23	3
C98 g/kg	Burnt Bridge	Hor 10–20	A3	24	1
C98 g/kg	Burnt Bridge	Hor 10–20	S10	31	16
C98 g/kg	Burnt Bridge	Hor 10–20	A10	.	.
C98 g/kg	Musk Creek	Hor 0–2	Unburnt	132	8
C98 g/kg	Musk Creek	Hor 0–2	S3	89	57
C98 g/kg	Musk Creek	Hor 0–2	A3	79	31
C98 g/kg	Musk Creek	Hor 0–2	S10	78	16
C98 g/kg	Musk Creek	Hor 0–2	A10	134	37
C98 g/kg	Musk Creek	Hor 2–5	Unburnt	60	23
C98 g/kg	Musk Creek	Hor 2–5	S3	47	28
C98 g/kg	Musk Creek	Hor 2–5	A3	42	23
C98 g/kg	Musk Creek	Hor 2–5	S10	41	10
C98 g/kg	Musk Creek	Hor 2–5	A10	61	21

Soil	FESA	Depth (cm)	Treatment	Mean	Std. Dev.
C98 g/kg	Musk Creek	Hor 5–10	Unburnt	43	19
C98 g/kg	Musk Creek	Hor 5–10	S3	29	16
C98 g/kg	Musk Creek	Hor 5–10	A3	33	22
C98 g/kg	Musk Creek	Hor 5–10	S10	29	10
C98 g/kg	Musk Creek	Hor 5–10	A10	39	17
C98 g/kg	Musk Creek	Hor 10–20	Unburnt	28	13
C98 g/kg	Musk Creek	Hor 10–20	S3	21	13
C98 g/kg	Musk Creek	Hor 10–20	A3	23	17
C98 g/kg	Musk Creek	Hor 10–20	S10	22	7
C98 g/kg	Musk Creek	Hor 10–20	A10	26	10
C98 g/kg	Barkstead	Hor 0–2	Unburnt	89	1
C98 g/kg	Barkstead	Hor 0–2	S3	93	15
C98 g/kg	Barkstead	Hor 0–2	A3	81	4
C98 g/kg	Barkstead	Hor 0–2	S10	90	14
C98 g/kg	Barkstead	Hor 0–2	A10	90	4
C98 g/kg	Barkstead	Hor 2–5	Unburnt	40	5
C98 g/kg	Barkstead	Hor 2–5	S3	40	5
C98 g/kg	Barkstead	Hor 2–5	A3	38	2
C98 g/kg	Barkstead	Hor 2–5	S10	48	7
C98 g/kg	Barkstead	Hor 2–5	A10	45	12
C98 g/kg	Barkstead	Hor 5–10	Unburnt	28	0
C98 g/kg	Barkstead	Hor 5–10	S3	28	3
C98 g/kg	Barkstead	Hor 5–10	A3	27	0
C98 g/kg	Barkstead	Hor 5–10	S10	34	5
C98 g/kg	Barkstead	Hor 5–10	A10	35	7
C98 g/kg	Barkstead	Hor 10–20	Unburnt	19	1
C98 g/kg	Barkstead	Hor 10–20	S3	20	2
C98 g/kg	Barkstead	Hor 10–20	A3	19	2
C98 g/kg	Barkstead	Hor 10–20	S10	25	2
C98 g/kg	Barkstead	Hor 10–20	A10	26	9
N85 g/kg	Blakeville	Hor 0–2	Unburnt	4.3	0.70
N85 g/kg	Blakeville	Hor 0–2	S3	4.6	0.91
N85 g/kg	Blakeville	Hor 0–2	A3	3.9	0.50
N85 g/kg	Blakeville	Hor 0–2	S10	3.2	0.73
N85 g/kg	Blakeville	Hor 0–2	A10	3.6	0.29
N85 g/kg	Blakeville	Hor 2–5	Unburnt	2.1	0.12
N85 g/kg	Blakeville	Hor 2–5	S3	2.1	0.41

Soil	FESA	Depth (cm)	Treatment	Mean	Std. Dev.
N85 g/kg	Blakeville	Hor 2–5	A3	1.9	0.14
N85 g/kg	Blakeville	Hor 2–5	S10	1.9	0.71
N85 g/kg	Blakeville	Hor 2–5	A10	1.7	0.04
N85 g/kg	Blakeville	Hor 5–10	Unburnt	1.4	0.17
N85 g/kg	Blakeville	Hor 5–10	S3	1.5	0.27
N85 g/kg	Blakeville	Hor 5–10	A3	1.2	0.18
N85 g/kg	Blakeville	Hor 5–10	S10	1.5	0.56
N85 g/kg	Blakeville	Hor 5–10	A10	1.2	0.01
N85 g/kg	Blakeville	Hor 10–20	Unburnt	1.1	0.13
N85 g/kg	Blakeville	Hor 10–20	S3	1.2	0.23
N85 g/kg	Blakeville	Hor 10–20	A3	1.1	0.15
N85 g/kg	Blakeville	Hor 10–20	S10	1.2	0.34
N85 g/kg	Blakeville	Hor 10–20	A10	1.0	0.05
N85 g/kg	Kangaroo Ck	Hor 0–2	Unburnt	4.0	0.45
N85 g/kg	Kangaroo Ck	Hor 0–2	S3	4.3	0.34
N85 g/kg	Kangaroo Ck	Hor 0–2	A3	3.9	0.98
N85 g/kg	Kangaroo Ck	Hor 0–2	S10	4.2	1.32
N85 g/kg	Kangaroo Ck	Hor 0–2	A10	3.8	0.31
N85 g/kg	Kangaroo Ck	Hor 2–5	Unburnt	2.0	0.45
N85 g/kg	Kangaroo Ck	Hor 2–5	S3	1.7	0.22
N85 g/kg	Kangaroo Ck	Hor 2–5	A3	2.0	0.58
N85 g/kg	Kangaroo Ck	Hor 2–5	S10	2.0	0.81
N85 g/kg	Kangaroo Ck	Hor 2–5	A10	2.3	0.21
N85 g/kg	Kangaroo Ck	Hor 5–10	Unburnt	1.2	0.39
N85 g/kg	Kangaroo Ck	Hor 5–10	S3	1.0	0.18
N85 g/kg	Kangaroo Ck	Hor 5–10	A3	1.4	0.52
N85 g/kg	Kangaroo Ck	Hor 5–10	S10	1.2	0.44
N85 g/kg	Kangaroo Ck	Hor 5–10	A10	1.6	0.20
N85 g/kg	Kangaroo Ck	Hor 10–20	Unburnt	0.9	0.26
N85 g/kg	Kangaroo Ck	Hor 10–20	S3	0.7	0.19
N85 g/kg	Kangaroo Ck	Hor 10–20	A3	1.1	0.37
N85 g/kg	Kangaroo Ck	Hor 10–20	S10	0.9	0.35
N85 g/kg	Kangaroo Ck	Hor 10–20	A10	1.1	0.05
N85 g/kg	Burnt Bridge	Hor 0–2	Unburnt	5.0	0.56
N85 g/kg	Burnt Bridge	Hor 0–2	S3	3.8	0.69
N85 g/kg	Burnt Bridge	Hor 0–2	A3	4.0	0.20
N85 g/kg	Burnt Bridge	Hor 0–2	S10	4.1	1.58
N85 g/kg	Burnt Bridge	Hor 0–2	A10	5.0	0.58

Soil	FESA	Depth (cm)	Treatment	Mean	Std. Dev.
N85 g/kg	Burnt Bridge	Hor 2–5	Unburnt	2.9	0.47
N85 g/kg	Burnt Bridge	Hor 2–5	S3	2.1	0.43
N85 g/kg	Burnt Bridge	Hor 2–5	A3	2.3	0.33
N85 g/kg	Burnt Bridge	Hor 2–5	S10	2.6	1.29
N85 g/kg	Burnt Bridge	Hor 2–5	A10	3.4	0.53
N85 g/kg	Burnt Bridge	Hor 5–10	Unburnt	2.2	0.23
N85 g/kg	Burnt Bridge	Hor 5–10	S3	1.5	0.25
N85 g/kg	Burnt Bridge	Hor 5–10	A3	1.7	0.14
N85 g/kg	Burnt Bridge	Hor 5–10	S10	1.8	0.85
N85 g/kg	Burnt Bridge	Hor 5–10	A10	2.3	0.43
N85 g/kg	Burnt Bridge	Hor 10–20	Unburnt	1.5	0.03
N85 g/kg	Burnt Bridge	Hor 10–20	S3	1.2	0.12
N85 g/kg	Burnt Bridge	Hor 10–20	A3	1.2	0.16
N85 g/kg	Burnt Bridge	Hor 10–20	S10	1.4	0.66
N85 g/kg	Burnt Bridge	Hor 10–20	A10	1.7	0.46
N85 g/kg	Musk Creek	Hor 0–2	Unburnt	3.5	0.25
N85 g/kg	Musk Creek	Hor 0–2	S3	3.9	2.10
N85 g/kg	Musk Creek	Hor 0–2	A3	2.8	0.80
N85 g/kg	Musk Creek	Hor 0–2	S10	3.2	0.38
N85 g/kg	Musk Creek	Hor 0–2	A10	3.0	0.46
N85 g/kg	Musk Creek	Hor 2–5	Unburnt	1.9	0.69
N85 g/kg	Musk Creek	Hor 2–5	S3	2.0	1.37
N85 g/kg	Musk Creek	Hor 2–5	A3	1.5	0.88
N85 g/kg	Musk Creek	Hor 2–5	S10	1.7	0.30
N85 g/kg	Musk Creek	Hor 2–5	A10	1.7	0.33
N85 g/kg	Musk Creek	Hor 5–10	Unburnt	1.6	0.66
N85 g/kg	Musk Creek	Hor 5–10	S3	1.4	0.91
N85 g/kg	Musk Creek	Hor 5–10	A3	1.2	0.75
N85 g/kg	Musk Creek	Hor 5–10	S10	1.2	0.33
N85 g/kg	Musk Creek	Hor 5–10	A10	1.5	0.21
N85 g/kg	Musk Creek	Hor 10–20	Unburnt	1.3	0.57
N85 g/kg	Musk Creek	Hor 10–20	S3	1.1	0.63
N85 g/kg	Musk Creek	Hor 10–20	A3	1.0	0.46
N85 g/kg	Musk Creek	Hor 10–20	S10	1.0	0.24
N85 g/kg	Musk Creek	Hor 10–20	A10	1.2	0.32
N85 g/kg	Barkstead	Hor 0–2	Unburnt	3.1	0.92
N85 g/kg	Barkstead	Hor 0–2	S3	3.4	0.43
N85 g/kg	Barkstead	Hor 0–2	A3	3.5	0.17

Soil	FESA	Depth (cm)	Treatment	Mean	Std. Dev.
N85 g/kg	Barkstead	Hor 0–2	S10	4.1	1.41
N85 g/kg	Barkstead	Hor 0–2	A10	3.4	0.56
N85 g/kg	Barkstead	Hor 2–5	Unburnt	1.7	0.17
N85 g/kg	Barkstead	Hor 2–5	S3	1.6	0.04
N85 g/kg	Barkstead	Hor 2–5	A3	1.7	0.01
N85 g/kg	Barkstead	Hor 2–5	S10	2.3	0.74
N85 g/kg	Barkstead	Hor 2–5	A10	1.7	0.49
N85 g/kg	Barkstead	Hor 5–10	Unburnt	1.3	0.02
N85 g/kg	Barkstead	Hor 5–10	S3	1.0	0.19
N85 g/kg	Barkstead	Hor 5–10	A3	1.3	0.06
N85 g/kg	Barkstead	Hor 5–10	S10	1.8	0.58
N85 g/kg	Barkstead	Hor 5–10	A10	1.4	0.57
N85 g/kg	Barkstead	Hor 10–20	Unburnt	0.9	0.01
N85 g/kg	Barkstead	Hor 10–20	S3	0.8	0.16
N85 g/kg	Barkstead	Hor 10–20	A3	1.1	0.03
N85 g/kg	Barkstead	Hor 10–20	S10	1.2	0.38
N85 g/kg	Barkstead	Hor 10–20	A10	1.2	0.33
N98 g/kg	Blakeville	Hor 0–2	Unburnt	3.9	0.37
N98 g/kg	Blakeville	Hor 0–2	S3	4.0	0.38
N98 g/kg	Blakeville	Hor 0–2	A3	3.2	0.57
N98 g/kg	Blakeville	Hor 0–2	S10	3.6	0.89
N98 g/kg	Blakeville	Hor 0–2	A10	3.2	0.21
N98 g/kg	Blakeville	Hor 2–5	Unburnt	2.0	0.29
N98 g/kg	Blakeville	Hor 2–5	S3	2.0	0.41
N98 g/kg	Blakeville	Hor 2–5	A3	1.7	0.12
N98 g/kg	Blakeville	Hor 2–5	S10	1.9	0.63
N98 g/kg	Blakeville	Hor 2–5	A10	1.7	0.34
N98 g/kg	Blakeville	Hor 5–10	Unburnt	1.4	0.17
N98 g/kg	Blakeville	Hor 5–10	S3	1.5	0.41
N98 g/kg	Blakeville	Hor 5–10	A3	1.3	0.15
N98 g/kg	Blakeville	Hor 5–10	S10	1.4	0.50
N98 g/kg	Blakeville	Hor 5–10	A10	1.3	0.28
N98 g/kg	Blakeville	Hor 10–20	Unburnt	1.0	0.11
N98 g/kg	Blakeville	Hor 10–20	S3	1.2	0.31
N98 g/kg	Blakeville	Hor 10–20	A3	1.0	0.12
N98 g/kg	Blakeville	Hor 10–20	S10	1.1	0.25
N98 g/kg	Blakeville	Hor 10–20	A10	1.0	0.24

Soil	FESA	Depth (cm)	Treatment	Mean	Std. Dev.
N98 g/kg	Kangaroo Ck	Hor 0–2	Unburnt	5.2	0.62
N98 g/kg	Kangaroo Ck	Hor 0–2	S3	4.3	0.93
N98 g/kg	Kangaroo Ck	Hor 0–2	A3	3.4	0.73
N98 g/kg	Kangaroo Ck	Hor 0–2	S10	4.4	0.94
N98 g/kg	Kangaroo Ck	Hor 0–2	A10	4.2	0.41
N98 g/kg	Kangaroo Ck	Hor 2–5	Unburnt	2.3	0.44
N98 g/kg	Kangaroo Ck	Hor 2–5	S3	1.7	0.49
N98 g/kg	Kangaroo Ck	Hor 2–5	A3	1.8	0.51
N98 g/kg	Kangaroo Ck	Hor 2–5	S10	2.1	0.64
N98 g/kg	Kangaroo Ck	Hor 2–5	A10	2.3	0.55
N98 g/kg	Kangaroo Ck	Hor 5–10	Unburnt	1.2	0.42
N98 g/kg	Kangaroo Ck	Hor 5–10	S3	1.1	0.32
N98 g/kg	Kangaroo Ck	Hor 5–10	A3	1.3	0.44
N98 g/kg	Kangaroo Ck	Hor 5–10	S10	1.4	0.44
N98 g/kg	Kangaroo Ck	Hor 5–10	A10	1.5	0.36
N98 g/kg	Kangaroo Ck	Hor 10–20	Unburnt	0.9	0.33
N98 g/kg	Kangaroo Ck	Hor 10–20	S3	0.8	0.20
N98 g/kg	Kangaroo Ck	Hor 10–20	A3	1.0	0.29
N98 g/kg	Kangaroo Ck	Hor 10–20	S10	1.0	0.22
N98 g/kg	Kangaroo Ck	Hor 10–20	A10	1.1	0.15
N98 g/kg	Burnt Bridge	Hor 0–2	Unburnt	.	.
N98 g/kg	Burnt Bridge	Hor 0–2	S3	3.7	0.96
N98 g/kg	Burnt Bridge	Hor 0–2	A3	4.4	0.18
N98 g/kg	Burnt Bridge	Hor 0–2	S10	4.6	0.34
N98 g/kg	Burnt Bridge	Hor 0–2	A10	.	.
N98 g/kg	Burnt Bridge	Hor 2–5	Unburnt	.	.
N98 g/kg	Burnt Bridge	Hor 2–5	S3	2.1	0.38
N98 g/kg	Burnt Bridge	Hor 2–5	A3	2.3	0.08
N98 g/kg	Burnt Bridge	Hor 2–5	S10	2.9	0.92
N98 g/kg	Burnt Bridge	Hor 2–5	A10	.	.
N98 g/kg	Burnt Bridge	Hor 5–10	Unburnt	.	.
N98 g/kg	Burnt Bridge	Hor 5–10	S3	1.5	0.25
N98 g/kg	Burnt Bridge	Hor 5–10	A3	1.5	0.01
N98 g/kg	Burnt Bridge	Hor 5–10	S10	1.9	0.81
N98 g/kg	Burnt Bridge	Hor 5–10	A10	.	.
N98 g/kg	Burnt Bridge	Hor 10–20	Unburnt	.	.
N98 g/kg	Burnt Bridge	Hor 10–20	S3	1.1	0.15
N98 g/kg	Burnt Bridge	Hor 10–20	A3	1.1	0.06

Soil	FESA	Depth (cm)	Treatment	Mean	Std. Dev.
N98 g/kg	Burnt Bridge	Hor 10–20	S10	1.4	0.63
N98 g/kg	Burnt Bridge	Hor 10–20	A10	.	.
N98 g/kg	Musk Creek	Hor 0–2	Unburnt	4.3	0.69
N98 g/kg	Musk Creek	Hor 0–2	S3	3.1	1.99
N98 g/kg	Musk Creek	Hor 0–2	A3	2.7	1.02
N98 g/kg	Musk Creek	Hor 0–2	S10	2.6	0.53
N98 g/kg	Musk Creek	Hor 0–2	A10	4.1	0.93
N98 g/kg	Musk Creek	Hor 2–5	Unburnt	2.2	0.96
N98 g/kg	Musk Creek	Hor 2–5	S3	1.8	1.06
N98 g/kg	Musk Creek	Hor 2–5	A3	1.6	0.91
N98 g/kg	Musk Creek	Hor 2–5	S10	1.6	0.32
N98 g/kg	Musk Creek	Hor 2–5	A10	2.1	0.55
N98 g/kg	Musk Creek	Hor 5–10	Unburnt	1.7	0.75
N98 g/kg	Musk Creek	Hor 5–10	S3	1.2	0.66
N98 g/kg	Musk Creek	Hor 5–10	A3	1.4	0.89
N98 g/kg	Musk Creek	Hor 5–10	S10	1.2	0.36
N98 g/kg	Musk Creek	Hor 5–10	A10	1.6	0.48
N98 g/kg	Musk Creek	Hor 10–20	Unburnt	1.3	0.67
N98 g/kg	Musk Creek	Hor 10–20	S3	1.0	0.53
N98 g/kg	Musk Creek	Hor 10–20	A3	1.1	0.76
N98 g/kg	Musk Creek	Hor 10–20	S10	1.0	0.29
N98 g/kg	Musk Creek	Hor 10–20	A10	1.2	0.33
N98 g/kg	Barkstead	Hor 0–2	Unburnt	3.4	0.30
N98 g/kg	Barkstead	Hor 0–2	S3	3.3	0.59
N98 g/kg	Barkstead	Hor 0–2	A3	3.1	0.15
N98 g/kg	Barkstead	Hor 0–2	S10	3.9	0.69
N98 g/kg	Barkstead	Hor 0–2	A10	3.4	0.58
N98 g/kg	Barkstead	Hor 2–5	Unburnt	1.7	0.18
N98 g/kg	Barkstead	Hor 2–5	S3	1.6	0.15
N98 g/kg	Barkstead	Hor 2–5	A3	1.6	0.27
N98 g/kg	Barkstead	Hor 2–5	S10	2.2	0.45
N98 g/kg	Barkstead	Hor 2–5	A10	1.7	0.68
N98 g/kg	Barkstead	Hor 5–10	Unburnt	1.3	0.17
N98 g/kg	Barkstead	Hor 5–10	S3	1.1	0.11
N98 g/kg	Barkstead	Hor 5–10	A3	1.6	0.45
N98 g/kg	Barkstead	Hor 5–10	S10	1.6	0.35
N98 g/kg	Barkstead	Hor 5–10	A10	1.5	0.67
N98 g/kg	Barkstead	Hor 10–20	Unburnt	0.9	0.04

Soil	FESA	Depth (cm)	Treatment	Mean	Std. Dev.
N98 g/kg	Barkstead	Hor 10–20	S3	1.0	0.18
N98 g/kg	Barkstead	Hor 10–20	A3	0.9	0.04
N98 g/kg	Barkstead	Hor 10–20	S10	1.4	0.04
N98 g/kg	Barkstead	Hor 10–20	A10	1.2	0.54
P85 mg/kg	Blakeville	Hor 0–2	Unburnt	28.9	7.2
P85 mg/kg	Blakeville	Hor 0–2	S3	27.4	5.1
P85 mg/kg	Blakeville	Hor 0–2	A3	23.1	7.2
P85 mg/kg	Blakeville	Hor 0–2	S10	29.5	11.5
P85 mg/kg	Blakeville	Hor 0–2	A10	26.8	5.1
P85 mg/kg	Blakeville	Hor 2–5	Unburnt	12.5	0.6
P85 mg/kg	Blakeville	Hor 2–5	S3	10.9	0.8
P85 mg/kg	Blakeville	Hor 2–5	A3	10.3	2.2
P85 mg/kg	Blakeville	Hor 2–5	S10	15.4	7.0
P85 mg/kg	Blakeville	Hor 2–5	A10	10.9	1.7
P85 mg/kg	Blakeville	Hor 5–10	Unburnt	8.6	0.8
P85 mg/kg	Blakeville	Hor 5–10	S3	7.4	0.6
P85 mg/kg	Blakeville	Hor 5–10	A3	5.5	1.6
P85 mg/kg	Blakeville	Hor 5–10	S10	11.2	5.2
P85 mg/kg	Blakeville	Hor 5–10	A10	7.2	0.8
P85 mg/kg	Blakeville	Hor 10–20	Unburnt	5.6	0.7
P85 mg/kg	Blakeville	Hor 10–20	S3	5.1	0.6
P85 mg/kg	Blakeville	Hor 10–20	A3	3.0	1.2
P85 mg/kg	Blakeville	Hor 10–20	S10	7.2	2.6
P85 mg/kg	Blakeville	Hor 10–20	A10	5.5	0.4
P85 mg/kg	Kangaroo Ck	Hor 0–2	Unburnt	24.7	2.3
P85 mg/kg	Kangaroo Ck	Hor 0–2	S3	33.7	4.5
P85 mg/kg	Kangaroo Ck	Hor 0–2	A3	21.6	4.5
P85 mg/kg	Kangaroo Ck	Hor 0–2	S10	26.1	2.8
P85 mg/kg	Kangaroo Ck	Hor 0–2	A10	18.1	3.7
P85 mg/kg	Kangaroo Ck	Hor 2–5	Unburnt	11.9	0.6
P85 mg/kg	Kangaroo Ck	Hor 2–5	S3	11.3	1.6
P85 mg/kg	Kangaroo Ck	Hor 2–5	A3	9.4	1.6
P85 mg/kg	Kangaroo Ck	Hor 2–5	S10	10.4	1.0
P85 mg/kg	Kangaroo Ck	Hor 2–5	A10	11.0	3.0
P85 mg/kg	Kangaroo Ck	Hor 5–10	Unburnt	6.8	0.5
P85 mg/kg	Kangaroo Ck	Hor 5–10	S3	6.8	1.3
P85 mg/kg	Kangaroo Ck	Hor 5–10	A3	6.1	0.9

Soil	FESA	Depth (cm)	Treatment	Mean	Std. Dev.
P85 mg/kg	Kangaroo Ck	Hor 5–10	S10	6.5	0.9
P85 mg/kg	Kangaroo Ck	Hor 5–10	A10	7.4	2.3
P85 mg/kg	Kangaroo Ck	Hor 10–20	Unburnt	4.4	0.6
P85 mg/kg	Kangaroo Ck	Hor 10–20	S3	4.4	0.8
P85 mg/kg	Kangaroo Ck	Hor 10–20	A3	4.3	0.6
P85 mg/kg	Kangaroo Ck	Hor 10–20	S10	4.5	0.8
P85 mg/kg	Kangaroo Ck	Hor 10–20	A10	5.3	1.5
P85 mg/kg	Burnt Bridge	Hor 0–2	Unburnt	28.3	13.7
P85 mg/kg	Burnt Bridge	Hor 0–2	S3	18.3	8.1
P85 mg/kg	Burnt Bridge	Hor 0–2	A3	21.4	6.4
P85 mg/kg	Burnt Bridge	Hor 0–2	S10	21.6	7.8
P85 mg/kg	Burnt Bridge	Hor 0–2	A10	22.5	6.8
P85 mg/kg	Burnt Bridge	Hor 2–5	Unburnt	12.4	2.6
P85 mg/kg	Burnt Bridge	Hor 2–5	S3	9.5	3.4
P85 mg/kg	Burnt Bridge	Hor 2–5	A3	11.1	1.7
P85 mg/kg	Burnt Bridge	Hor 2–5	S10	10.6	2.9
P85 mg/kg	Burnt Bridge	Hor 2–5	A10	12.6	3.0
P85 mg/kg	Burnt Bridge	Hor 5–10	Unburnt	9.1	3.5
P85 mg/kg	Burnt Bridge	Hor 5–10	S3	5.6	1.4
P85 mg/kg	Burnt Bridge	Hor 5–10	A3	6.4	0.2
P85 mg/kg	Burnt Bridge	Hor 5–10	S10	6.2	1.8
P85 mg/kg	Burnt Bridge	Hor 5–10	A10	7.8	2.5
P85 mg/kg	Burnt Bridge	Hor 10–20	Unburnt	6.1	3.0
P85 mg/kg	Burnt Bridge	Hor 10–20	S3	3.7	1.1
P85 mg/kg	Burnt Bridge	Hor 10–20	A3	4.1	1.0
P85 mg/kg	Burnt Bridge	Hor 10–20	S10	4.2	1.2
P85 mg/kg	Burnt Bridge	Hor 10–20	A10	5.3	2.5
P85 mg/kg	Musk Creek	Hor 0–2	Unburnt	14.7	0.2
P85 mg/kg	Musk Creek	Hor 0–2	S3	25.1	18.8
P85 mg/kg	Musk Creek	Hor 0–2	A3	10.4	1.0
P85 mg/kg	Musk Creek	Hor 0–2	S10	18.7	6.6
P85 mg/kg	Musk Creek	Hor 0–2	A10	16.6	5.5
P85 mg/kg	Musk Creek	Hor 2–5	Unburnt	9.2	2.0
P85 mg/kg	Musk Creek	Hor 2–5	S3	12.9	10.1
P85 mg/kg	Musk Creek	Hor 2–5	A3	5.1	1.8
P85 mg/kg	Musk Creek	Hor 2–5	S10	11.3	0.6
P85 mg/kg	Musk Creek	Hor 2–5	A10	8.8	2.0
P85 mg/kg	Musk Creek	Hor 5–10	Unburnt	5.9	1.8

Soil	FESA	Depth (cm)	Treatment	Mean	Std. Dev.
P85 mg/kg	Musk Creek	Hor 5–10	S3	7.5	5.3
P85 mg/kg	Musk Creek	Hor 5–10	A3	3.4	1.3
P85 mg/kg	Musk Creek	Hor 5–10	S10	6.2	1.0
P85 mg/kg	Musk Creek	Hor 5–10	A10	5.8	0.7
P85 mg/kg	Musk Creek	Hor 10–20	Unburnt	3.9	1.3
P85 mg/kg	Musk Creek	Hor 10–20	S3	5.8	3.5
P85 mg/kg	Musk Creek	Hor 10–20	A3	2.8	0.7
P85 mg/kg	Musk Creek	Hor 10–20	S10	3.9	0.5
P85 mg/kg	Musk Creek	Hor 10–20	A10	3.9	0.8
P85 mg/kg	Barkstead	Hor 0–2	Unburnt	14.4	0.8
P85 mg/kg	Barkstead	Hor 0–2	S3	14.5	0.1
P85 mg/kg	Barkstead	Hor 0–2	A3	20.3	7.9
P85 mg/kg	Barkstead	Hor 0–2	S10	24.5	3.7
P85 mg/kg	Barkstead	Hor 0–2	A10	14.2	0.0
P85 mg/kg	Barkstead	Hor 2–5	Unburnt	8.8	1.6
P85 mg/kg	Barkstead	Hor 2–5	S3	9.7	1.0
P85 mg/kg	Barkstead	Hor 2–5	A3	9.9	1.7
P85 mg/kg	Barkstead	Hor 2–5	S10	10.8	0.3
P85 mg/kg	Barkstead	Hor 2–5	A10	7.5	2.5
P85 mg/kg	Barkstead	Hor 5–10	Unburnt	6.4	0.6
P85 mg/kg	Barkstead	Hor 5–10	S3	4.7	0.8
P85 mg/kg	Barkstead	Hor 5–10	A3	7.1	0.8
P85 mg/kg	Barkstead	Hor 5–10	S10	8.2	2.1
P85 mg/kg	Barkstead	Hor 5–10	A10	6.3	4.0
P85 mg/kg	Barkstead	Hor 10–20	Unburnt	3.3	0.5
P85 mg/kg	Barkstead	Hor 10–20	S3	3.4	0.1
P85 mg/kg	Barkstead	Hor 10–20	A3	4.9	0.6
P85 mg/kg	Barkstead	Hor 10–20	S10	4.6	1.2
P85 mg/kg	Barkstead	Hor 10–20	A10	4.6	3.0
P98 mg/kg	Blakeville	Hor 0–2	Unburnt	9.1	1.1
P98 mg/kg	Blakeville	Hor 0–2	S3	9.4	1.9
P98 mg/kg	Blakeville	Hor 0–2	A3	15.1	7.8
P98 mg/kg	Blakeville	Hor 0–2	S10	12.7	3.6
P98 mg/kg	Blakeville	Hor 0–2	A10	14.5	0.7
P98 mg/kg	Blakeville	Hor 2–5	Unburnt	4.9	0.5
P98 mg/kg	Blakeville	Hor 2–5	S3	4.3	0.6
P98 mg/kg	Blakeville	Hor 2–5	A3	4.5	1.7
P98 mg/kg	Blakeville	Hor 2–5	S10	6.2	2.1

Soil	FESA	Depth (cm)	Treatment	Mean	Std. Dev.
P98 mg/kg	Blakeville	Hor 2–5	A10	5.7	1.8
P98 mg/kg	Blakeville	Hor 5–10	Unburnt	3.8	0.2
P98 mg/kg	Blakeville	Hor 5–10	S3	3.2	0.3
P98 mg/kg	Blakeville	Hor 5–10	A3	3.1	0.7
P98 mg/kg	Blakeville	Hor 5–10	S10	4.8	1.6
P98 mg/kg	Blakeville	Hor 5–10	A10	4.4	1.7
P98 mg/kg	Blakeville	Hor 10–20	Unburnt	2.7	0.1
P98 mg/kg	Blakeville	Hor 10–20	S3	2.4	0.1
P98 mg/kg	Blakeville	Hor 10–20	A3	2.2	0.4
P98 mg/kg	Blakeville	Hor 10–20	S10	3.5	1.0
P98 mg/kg	Blakeville	Hor 10–20	A10	3.6	1.5
P98 mg/kg	Kangaroo Ck	Hor 0–2	Unburnt	11.5	0.4
P98 mg/kg	Kangaroo Ck	Hor 0–2	S3	15.3	5.7
P98 mg/kg	Kangaroo Ck	Hor 0–2	A3	15.0	2.4
P98 mg/kg	Kangaroo Ck	Hor 0–2	S10	11.1	1.4
P98 mg/kg	Kangaroo Ck	Hor 0–2	A10	14.4	5.7
P98 mg/kg	Kangaroo Ck	Hor 2–5	Unburnt	5.0	1.2
P98 mg/kg	Kangaroo Ck	Hor 2–5	S3	5.3	1.0
P98 mg/kg	Kangaroo Ck	Hor 2–5	A3	4.7	0.7
P98 mg/kg	Kangaroo Ck	Hor 2–5	S10	4.5	0.5
P98 mg/kg	Kangaroo Ck	Hor 2–5	A10	4.6	1.1
P98 mg/kg	Kangaroo Ck	Hor 5–10	Unburnt	3.1	0.2
P98 mg/kg	Kangaroo Ck	Hor 5–10	S3	3.5	1.2
P98 mg/kg	Kangaroo Ck	Hor 5–10	A3	2.9	0.3
P98 mg/kg	Kangaroo Ck	Hor 5–10	S10	3.5	0.5
P98 mg/kg	Kangaroo Ck	Hor 5–10	A10	3.3	0.6
P98 mg/kg	Kangaroo Ck	Hor 10–20	Unburnt	2.3	0.2
P98 mg/kg	Kangaroo Ck	Hor 10–20	S3	2.2	0.4
P98 mg/kg	Kangaroo Ck	Hor 10–20	A3	2.2	0.2
P98 mg/kg	Kangaroo Ck	Hor 10–20	S10	2.4	0.2
P98 mg/kg	Kangaroo Ck	Hor 10–20	A10	2.6	0.7
P98 mg/kg	Burnt Bridge	Hor 0–2	Unburnt	.	.
P98 mg/kg	Burnt Bridge	Hor 0–2	S3	7.4	1.3
P98 mg/kg	Burnt Bridge	Hor 0–2	A3	11.5	2.8
P98 mg/kg	Burnt Bridge	Hor 0–2	S10	9.3	1.5
P98 mg/kg	Burnt Bridge	Hor 0–2	A10	.	.
P98 mg/kg	Burnt Bridge	Hor 2–5	Unburnt	.	.
P98 mg/kg	Burnt Bridge	Hor 2–5	S3	3.5	1.6

Soil	FESA	Depth (cm)	Treatment	Mean	Std. Dev.
P98 mg/kg	Burnt Bridge	Hor 2–5	A3	4.2	0.0
P98 mg/kg	Burnt Bridge	Hor 2–5	S10	4.7	1.5
P98 mg/kg	Burnt Bridge	Hor 2–5	A10	.	.
P98 mg/kg	Burnt Bridge	Hor 5–10	Unburnt	.	.
P98 mg/kg	Burnt Bridge	Hor 5–10	S3	2.6	0.9
P98 mg/kg	Burnt Bridge	Hor 5–10	A3	2.6	0.2
P98 mg/kg	Burnt Bridge	Hor 5–10	S10	2.9	1.1
P98 mg/kg	Burnt Bridge	Hor 5–10	A10	.	.
P98 mg/kg	Burnt Bridge	Hor 10–20	Unburnt	.	.
P98 mg/kg	Burnt Bridge	Hor 10–20	S3	1.9	0.7
P98 mg/kg	Burnt Bridge	Hor 10–20	A3	1.6	0.1
P98 mg/kg	Burnt Bridge	Hor 10–20	S10	1.9	0.7
P98 mg/kg	Burnt Bridge	Hor 10–20	A10	.	.
P98 mg/kg	Musk Creek	Hor 0–2	Unburnt	9.3	1.3
P98 mg/kg	Musk Creek	Hor 0–2	S3	9.3	2.8
P98 mg/kg	Musk Creek	Hor 0–2	A3	5.3	0.9
P98 mg/kg	Musk Creek	Hor 0–2	S10	7.6	0.4
P98 mg/kg	Musk Creek	Hor 0–2	A10	8.2	1.0
P98 mg/kg	Musk Creek	Hor 2–5	Unburnt	4.1	1.2
P98 mg/kg	Musk Creek	Hor 2–5	S3	4.8	2.1
P98 mg/kg	Musk Creek	Hor 2–5	A3	2.7	0.3
P98 mg/kg	Musk Creek	Hor 2–5	S10	4.1	0.3
P98 mg/kg	Musk Creek	Hor 2–5	A10	3.6	1.1
P98 mg/kg	Musk Creek	Hor 5–10	Unburnt	3.0	0.7
P98 mg/kg	Musk Creek	Hor 5–10	S3	3.3	1.6
P98 mg/kg	Musk Creek	Hor 5–10	A3	2.3	1.0
P98 mg/kg	Musk Creek	Hor 5–10	S10	3.0	0.4
P98 mg/kg	Musk Creek	Hor 5–10	A10	2.5	0.6
P98 mg/kg	Musk Creek	Hor 10–20	Unburnt	2.0	0.7
P98 mg/kg	Musk Creek	Hor 10–20	S3	2.5	1.2
P98 mg/kg	Musk Creek	Hor 10–20	A3	1.4	0.4
P98 mg/kg	Musk Creek	Hor 10–20	S10	2.1	0.3
P98 mg/kg	Musk Creek	Hor 10–20	A10	1.9	0.5
P98 mg/kg	Barkstead	Hor 0–2	Unburnt	8.1	1.2
P98 mg/kg	Barkstead	Hor 0–2	S3	7.8	0.7
P98 mg/kg	Barkstead	Hor 0–2	A3	7.7	2.1
P98 mg/kg	Barkstead	Hor 0–2	S10	6.9	1.2
P98 mg/kg	Barkstead	Hor 0–2	A10	8.8	1.4

Soil	FESA	Depth (cm)	Treatment	Mean	Std. Dev.
P98 mg/kg	Barkstead	Hor 2–5	Unburnt	3.6	0.1
P98 mg/kg	Barkstead	Hor 2–5	S3	3.5	0.4
P98 mg/kg	Barkstead	Hor 2–5	A3	3.9	0.9
P98 mg/kg	Barkstead	Hor 2–5	S10	4.1	0.2
P98 mg/kg	Barkstead	Hor 2–5	A10	3.6	1.4
P98 mg/kg	Barkstead	Hor 5–10	Unburnt	3.6	0.3
P98 mg/kg	Barkstead	Hor 5–10	S3	2.5	0.6
P98 mg/kg	Barkstead	Hor 5–10	A3	3.2	0.1
P98 mg/kg	Barkstead	Hor 5–10	S10	3.1	0.2
P98 mg/kg	Barkstead	Hor 5–10	A10	3.2	1.6
P98 mg/kg	Barkstead	Hor 10–20	Unburnt	2.5	0.1
P98 mg/kg	Barkstead	Hor 10–20	S3	1.6	0.0
P98 mg/kg	Barkstead	Hor 10–20	A3	1.9	0.3
P98 mg/kg	Barkstead	Hor 10–20	S10	2.5	0.7
P98 mg/kg	Barkstead	Hor 10–20	A10	2.4	1.5