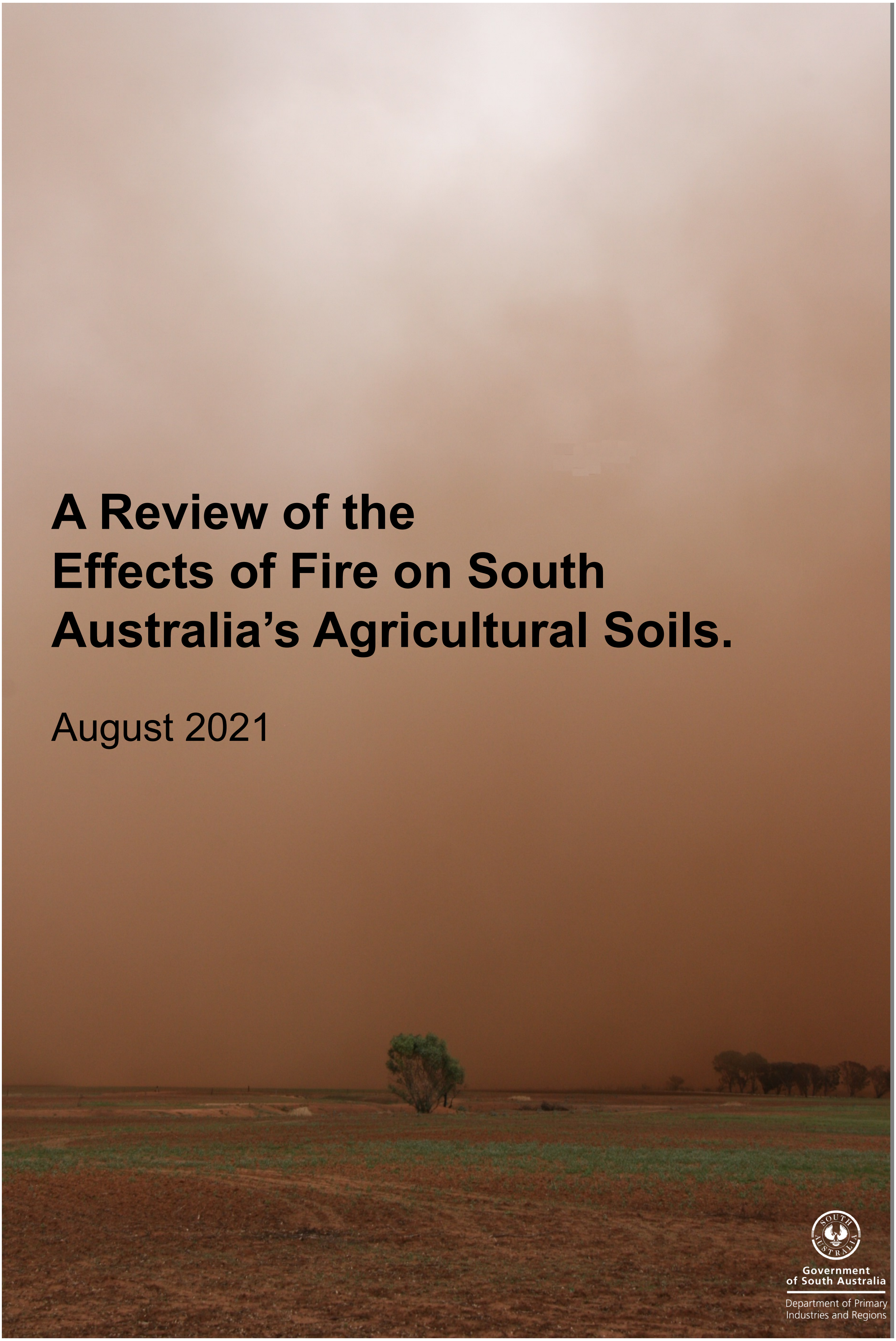

A Review of the Effects of Fire on South Australia's Agricultural Soils.

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Government of South Australia
Department of Primary Industries and Regions

A Review of the Effects of Fire on South Australia's Agricultural Soils.

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Introduction

South Australia has experienced numerous bushfires[1] on agricultural land in recent decades. These fires have occurred during an era of significant improvement in soil condition on land used for primary production. Retention and maintenance of crop and pasture residues to provide surface cover, reduced tillage to minimise soil disturbance, and use of grazing practices that stimulate plant growth and maintain surface cover, have all contributed to improving the productivity, profitability and resilience of soil.

Farmers who have invested such effort in their soils are therefore very concerned about the soil's condition after a fire. They are extremely conscious of the significant erosion that can occur as a result of loss of surface cover. There is concern also about soil health – the effect of the fire and resultant soil temperatures on mineral, organic and structural properties of the soil.

There can be extreme anxiety in the aftermath of a fire about the damage it has caused, particularly after a very large, intense and traumatic event. People affected by such an event seek simple, clear, consistent and appropriate messages to address their concerns on a range of matters. They do not have time or energy to absorb information from a range of sources.

A story-hungry media often publishes or broadcasts stories using information taken out of context and sensationalised to attract readers or viewers. For example: "Fire ruined soil's health" [2] relates to the Sampson Flat fire and states that "Organic matter in thousands of hectares of soil has been destroyed". In other situations, agencies and organisations have made claims to attract investment, e.g. ""The bushfires severely damaged millions of hectares of land, not just above ground but the soil beneath us. This has clear implications for soil fertility, Australia's agricultural productivity and the recovery of native vegetation" said Professor McBratney.[3] Media articles such as these do not help assuage anxiety.

Most of the literature regarding soil properties and the effect of heat from fires on them in Australia refers to studies in bushland, areas of native vegetation or forests. The profiles of these soils can be significantly different to those under agricultural land use. For example, a weed-free, mature cereal crop would have very little organic material at the soil surface – at the most, this would be residues from preceding crops and pastures. In contrast, areas of bushland would have a wide range of plant species producing stems, leaves, roots and a depth of organic material at the soil surface.

This review of 11 fires in South Australia contains observations, data and experience related to soil properties on agricultural land.

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[1] The term "bushfire" is used as a broad term to cover wild, non-prescribed and not deliberate fire.
[2] The Advertiser, 26/08/2015 pp 23
[3] "More work crucial to help our soil recover from bushfires" Australian Academy of Science Media Release 22/07/2020

Effects of fire on soil properties

Heat produced from bushfires can result in changes to the biological, chemical and physical properties of a soil. The extent of such changes is dependent on a myriad of factors which are often interconnected, often resulting in highly variable impacts between sites (even row to row). Such factors include; temperature, severity, residence, seasonality and frequency of fires, climate, topography, fuel, fuel loads and soil properties (Pereira et al 2019).

There is sometimes confusion about the terms used when discussing bushfire heat, temperatures and their effect on soils. The primary factors that affect soil condition during a fire are peak fire intensity and duration of heat transfer (residence time). Fire intensity is the rate at which fire produces thermal energy. Fast-moving fires on grass can produce high energy release per unit area but do not transfer the same amount of heat to the soil as slow-moving fires in moderate to heavy fuels (Rollins et al, 1993). Fire severity or burn severity refers to the loss or decomposition of organic matter above and below ground.

Maximum soil temperatures in forest fires are typically in the range of 200-300^{0}C; under heavy fuel loads soil surface temperatures can reach 500-700^{0}C. Grassland fires with fuel loads of less than 1 t/ha usually generate soil surface temperatures of less than 25^{0}C. Fires in grassland rarely exceed 100^{o}C at the soil surface and 50^{o}C at 50 mm depth (Knicker, 2007).

In the context of bushfires on agricultural land, fires can be approximately categorised by soil surface temperatures as follows:

- Cool (<100°C): unburnt surface vegetation remains with surface seeds present. Perennials and subterranean-seeded annuals will emerge soon after the fire.
- Moderate (100-150°C): most vegetation will be burnt, with some trees and crowns remaining. Most surface seed will be destroyed, with perennials and subterranean-seeded annuals returning.
- Hot to very hot (>150°C): topsoil will be bare and charred, particularly under trees, haystacks and dense, long grass. Surface seed is destroyed, and there is low emergence of perennials and subterranean-seeded annuals Soil will often be rendered infertile. Long-term effects are observed.

Bushfires commonly occur throughout the summer months when the fuel load is high, and the fuel is dry. In South Australia, topsoils are often quite dry in the summer and early autumn. This often results in a fast-moving fire with a short residence time and moderate surface burn temperatures (100-150°C) (Egan n.d.). As a result, the effects on soil properties are often superficial, with minimal disturbance at depths greater than a few cm deep (Table 1).

Most fires on agricultural land are within the cool to moderate range, but on rare occasions, surface fire temperatures can exceed 400°C. Such temperatures are only observed when fuel loads are concentrated, such as under hay bales or trees. In these areas, considerable effects on various soil properties can occur.

In bushfires over pastures, soil temperatures rarely increase by more than 10°C at depths greater than 15 mm (Egan n.d.). Although some surface soil organic matter will be degraded and the death of some microorganisms may occur in this layer, there will likely be no wholesale changes to soil properties that could potentially affect agricultural productivity.

Table 1 Temperature thresholds of various soil properties at which damage or destruction occurs.

Soil Property	**Classification**	***Soil Temperature Threshold (°C)***
Plant roots	*Sensitive*	*48-54*
Fungi		*60-80*
Seed mortality		*70-90*
Bacteria		*80-120*
Organic matter	*Moderately Sensitive*	*100-220*
Nitrogen		*200*
Soil hydrophobicity (water repellence)		*250*
Soil structure		*300*
Sulfur		*375*
Clay alteration	*Relatively Insensitive*	*460-980*
P & K		*774*
Crystal structures lost (forming new mineral phases)		*950-1100*
Mg		*1107*
Ca		*1484*
Mn		*1962*

Soil heating

Fire temperature does not always determine the degree to which the soil heats up (Stoof et al 2013). Soil heating, and the depths to which it extends, is a dynamic process. It depends on fire intensity and duration of heat transfer, heat conductivity of the mineral component, soil porosity and soil moisture:

- ***Fuel load****:* the greater the fuel load, the greater the intensity of the fire, the longer the residence time, therefore, the greater potential for soil heating. Soils under heavy fuel loads, such as fallen trees, can experience considerable soil heating at greater depths and for extended periods of time.
- ***Fuel size****:* fine fuel includes dead grass, twigs and leaf litter, <6 mm in size. Coarse fuels consist of fallen limbs and trees. Fine fuels dry quickly, and combust easier with a very short residence time, often resulting in minimal soil surface heating. Coarse fuels, while generally combusting slowly, will often burn longer and will heat the soil to a greater extent and to greater depths.
- ***Soil moisture***: heat transfer down the soil profile increases with decreasing soil moisture.

- ***Soil texture:*** coarser soils heat up quicker than finer textured soils (Abu-Hamdeh 2003). This is closely related to the water holding capacity of the soil.
- ***Organic matter content**:* organic matter content, particularly when moist, can provide a barrier between the soil and fire surface, reducing potential soil heating.
- ***Bulk density***: heat is more readily transferred through soils of lighter bulk densities so sandy soils will heat more readily than clays. Most South Australian soils have subsoil or substrate materials of higher bulk densities than their topsoils.

Mineralogy

The extent to which changes in soil mineralogy occur depends on the type and amount of fuel, which governs the fire temperature and soil temperature. Major changes to mineralogy are only experienced during severe fires when soil temperatures >400ºC (Pereira et al 2019). Clay particles suffer structural defects and particle destruction at 400ºC and 700ºC respectively but damage to silt and sand particles occur at higher soil temperatures. (>1200ºC) (Pereira et al 2019). When these temperatures are reached, decreases in soil porosity, alterations to pore distribution and an increase in bulk density can occur.

Decomposition of carbonates occurs at soil temperatures of >600ºC. At these temperatures, calcium and magnesium can be observed in greater concentrations in the soil surface post-fire (see *pH*).

pH

An increase in topsoil pH commonly occurs under all fire conditions but this change in pH is often only temporary. The release of soluble cations (Ca, Mg, K) from organic materials and minerals, the denaturation of organic acids and the neutralising effect of ash, contribute to this change (Pereira et al 2019). Fuel type, fire temperature, and concentrations of organic acids and organic matter before the fire influence the concentration of cations released into the soil, and thus the potential pH increase post-fire.

An increase in pH will generally favour the recolonisation of soil bacteria over fungi and an increase in plant-available nutrients may also be observed.

Water repellence

Organic material, when burnt, can form hydrophobic compounds which coat soil particles, creating a water repellent layer in the soil profile, parallel to the mineral surface (Knicker 2007). Sandy soils, particularly siliceous sands, are the most susceptible as their low particle surface area:volume ratio enables a smaller amount of hydrophobic compounds to effectively cover a greater proportion of the particle surface area than in a fine-textured soil (Roper et al 2015). Water repellence tends to increase as fire temperature increases, with soil type and vegetation contributing factors.

In cool to moderate fires, little to no changes to water repellence occur, and only persist for short periods of time (weeks to months) (Knicker 2007). Water repellence increases incrementally as soil temperatures reach above 150ºC and can be destroyed between 300-400ºC (Pereira et al 2019, Stavi 2019).

Soil structure and texture

Both organic matter and soil microorganisms contribute to soil aggregation so any loss of these can affect soil structure. However, as organic matter is not destroyed until soil temperatures reach >500ºC, soil structure is generally not affected by most fires (Tulau & McInnes-Clarke 2015).

Dehydration of clay minerals, and transformation of iron and aluminium oxides into cementing agents occurs as soil temperatures reach about 400ºC. This causes more aggregation of smaller particles into larger ones and thus different texture classifications. Similarly, at temperatures less than 300°C, heat-induced cracks in sand particles can reduce sizes of particles to a finer texture class (Pereira et al 2019).

Changes in clay mineralogy and organic matter content of the soil, the formation of cementing agents and particle aggregation, result in changes to soil bulk density.

Nutrient availability

Factors influencing nutrient availability are extensive and often interconnected, resulting in extremely variable impacts. During a bushfire, nutrients with low soil temperature thresholds (≥100ºC), such as carbon, nitrogen and sulfur, are readily volatilised (Pereira et al 2019).

In cool to moderate fires, no substantial losses of soil organic carbon generally occur and can even increase post-fire as a result of inputs from burnt organic material (Pereira et al 2019). Losses will generally increase with fire temperature.

Half of the soil nitrogen is volatilised at temperatures >500ºC. While nitrogen is transformed when heated, the burning of vegetation can also stimulate nitrifiers in the soil. This can increase the transformation of ammonium to nitrate (Knicker 2007). This nitrate, however, will be lost if plants cannot utilise it.

Phosphorous is transformed into insoluble orthophosphate by volatilisation at soil temperatures >700ºC (Tulau & McInnes-Clarke 2015). As phosphorus does not move through soil as easily as other nutrients, it is found in higher concentrations in the ash or near the soil surface (Pereira et al 2019).

Nutrients and organic matter can be translocated down the soil profile, increasing nutrient concentrations at greater depths (Pereira et al 2019). Nutrient availability might decrease in the topsoil but this loss of nutrients will generally not constrain agricultural production (Egan n.d.). Much more significant are losses of nutrients and organic matter that can occur in wind and water erosion after a fire.

The loss of soil microorganism activity will affect nutrient availability within the soil. See *Soil microorganisms*.

Organic materials

The effect of fire on organic materials is strongly dependent on fire temperature, vegetation type, soil texture and fuel load (Knicker 2007). Organic material is often degraded during a bushfire, but temperatures >500°C are required before complete combustion occurs (Tulau & McInnes-Clarke 2015). As soil temperatures rarely, if ever, reach this temperature, only the organic matter on the soil surface is affected.

Soil organic materials play an important role in biochemical transformations within the soil profile. Providing a high buffering capacity to environmental (e.g. temperature) and chemical (e.g. pH) changes, organic matter also has a high cation exchange capacity (CEC). Consequently, loss of organic material can result in decreased nutrient concentrations, buffering capacity and various structural defects.

The loss of organic material can result from disaggregation of surface soil particles, affecting the soil's structure (and therefore its capacity to cycle nutrients, store carbon, take in water and air), and increasing soil erodibility. The loss of aboveground vegetation exacerbates the erosion risk, increasing losses of soil, organic material and nutrients in the soil surface.

Soil erosion after fire on agricultural land usually causes far greater damage and losses than those from increased soil temperatures during the fire.

Cation Exchange Capacity (CEC)

Both organic matter and clay contribute to the CEC of a soil, therefore, any loss to either of these components will result in a reduction in CEC. As these components have different temperature thresholds, generally only minor reductions will be observed up until soil temperature reaches 400°C, when deformation of clay structures occur.

Soil microorganisms

The effects on soil microorganism communities are highly variable and generally only occur in the top few centimetres of soil. Most metabolically active microorganisms will be affected at temperatures ≥50°C, however, if microorganisms are inactive, these populations will generally not be affected (Knicker 2007). To emphasise this variability, one study demonstrated no change to the microbial population after 3 minutes of heating soil at 450°C (Knicker 2007).

Given that burn patterns and fire temperature are generally not uniform, recolonisation of microorganisms and regeneration and establishment of plants in cooler burn areas will often occur post-fire. Additionally, depending on the numbers and types of microorganisms present in the soil pre-fire, these effects will vary from site to site.

When soil microorganisms are affected by a fire, reductions in biomass, activity and diversity of microorganisms occur. As a result, nutrient cycling, decomposition, and N-fixation rates can decline. Furthermore, the loss of organisms from the soil can disaggregate soil particles, changing soil structure.

Figure 1: Crop growth on soil underneath haystack and adjacent crop land burnt during Pinery fire. Source: Woodard and Hughes 2018

Observations, data and experience from South Australian fires

After a number of fires on agricultural land in South Australia, various data, information, reports and observations have been collected, undertaken and made. Table 2 summarises findings from these.

Table 2 Summary of observed effects of major fires on soils of agricultural land in South Australia 2005 – 2021.

Wangary	January 2005 78,000 ha
Land Use	Cereal, pulse, oilseed cropping Livestock grazing – annual pastures; perennial pastures Conservation, recreation, grazing- remnant native vegetation
Fuel load (type and amount) at soil surface	Crop and annual pasture residues – moderate Perennial pasture – high Remnant native vegetation – high
Effects of fire on soil properties	Soils in burnt areas assessed for particular nutrients and organic carbon contents; no effects detected.
Effects of fire on land	Wind and water erosion due to loss of surface cover and late break in following season.
Eden Valley	January 2014 25,000 ha
Land Use	livestock grazing – mix of perennial and annual species (native grasses, introduced grasses, herbs and shrubs, broadleaf weeds, legumes, thread iris)
Fuel load (type and amount) at soil surface	Annual species dominant – low to moderate Perennial species dominant - moderate
Effects of fire on soil properties	Soil tests undertaken after the fire for establishment of pasture regeneration demonstrations and trials. No effects of fire on soil properties detected.
Effects of fire on land	No erosion observed.
Sampson Flat	January 2015 12,600 ha
Land Use	Livestock grazing – perennial and annual pastures Viticulture Forestry Horticulture Conservation, recreation, grazing – remnant native vegetation
Fuel load (type and amount) at soil surface	Forests, areas of remnant vegetation – high Some perennial grasses eg Phalaris – high Other grazing areas - moderate
Effects of fire on soil properties	Soils under livestock grazing and with very high fuel load (regarded as hot burn areas) compared to areas of cooler burns. Lower OC and nitrate N concentrations detected in hot burn areas that were small proportion of total pasture area.
Effects of fire on land	Wind erosion immediately from areas subjected to hot burns that lost surface cover, followed by water erosion where pastures failed to regenerate soon after fire.

Pinery	November 2015	82,500 ha
Land Use	Intensive cropping – cereals, pulses, oilseed, hay Livestock grazing in cropping system – annual pastures Livestock grazing unarable land – perennial pastures, remnant native vegetation	
Fuel load (type and amount) at soil surface	Standing (unreaped) crop – low Crop residues, annual pastures – low to moderate Perennial pastures, grazed areas of remnant vegetation - moderate	
Effects of fire on soil properties	Very hot burns in spots e.g. under haystacks, changes in pH, EC, P, Cl, S, CEC and ESP detected. Anecdotal observation that some soil particles became lighter – more readily dislodged and entrained by wind – suggesting loss of any coherence.	
Effects of fire on land	Major wind and some water erosion due to loss of surface cover.	
Sherwood	January 2018	12,000 ha
Land Use	Cropping – cereals, pulses, oilseeds Livestock grazing – annual and perennial pastures	
Fuel load (type and amount) at soil surface	Crop residues, annual pastures – moderate Perennial pastures – moderate	
Effects of fire on soil properties	None apparent. Anecdotal evidence that soil temperatures did not significantly rise is that poly watering pipe buried beneath the soil surface was not affected.	
Effects of fire on land	Loss of surface cover significantly increased risk of wind erosion on sandy soils but risk mitigated by extensive clay spreading.	
Yorketown	November 2019	6,700 ha
Land Use	cropping – cereals, pulses livestock grazing – annual pastures	
Fuel load (type and amount) at soil surface	Standing (unreaped) crop – low Crop residues and annual pastures - moderate	
Effects of fire on soil properties	Analysis of range of nutrients and OC contents undertaken on soils from burnt and unburnt areas. No effects of fire detected.	
Effects of fire on land	Wind erosion due to loss of surface cover.	
Keilira	December 2019	37,000 ha
Land Use	Livestock grazing – annual and perennial pastures Hay production Conservation, recreation, livestock grazing – remnant native vegetation	
Fuel load (type and amount) at soil surface	Annual pastures and areas cut for hay – low Mix of annual and perennial pasture species – high Remnant native vegetation – high	
Effects of fire on soil properties	None observed.	
Effects of fire on land	Risk of wind erosion on sandy soils increased due to loss of surface cover.	

Kangaroo Island	December 2019 – January 2020 211,500 ha
Land Use	Livestock grazing – perennial pastures (e.g. kikuyu), annual pastures and mixed annual and perennial. Cropping – cereals, pulses, oilseeds Conservation, recreation, grazing – remnant native vegetation Forestry Viticulture
Fuel load (type and amount) at soil surface	Annual pastures – moderate Perennial pastures – low Crop residues – moderate Vineyards (managed swards) – low Forestry – high Remnant native vegetation - high
Effects of fire on soil properties	Analyses of soils from burnt areas indicated no change in soil pH, OC, P, N.
Effects of fire on land	Wind and water erosion risk increased due to loss of surface cover.
Cudlee Creek	**December 2019 23,300 ha**
Land Use	Hay production – annual pastures Livestock grazing – perennial pastures and annual pastures Pome fruit Viticulture Forestry Conservation, recreation, livestock grazing – remnant native vegetation
Fuel load (type and amount) at soil surface	Annual pastures, hay cuts – low Perennial pastures – moderate Forests, horticulture, viticulture with managed swards – low to medium Remnant native vegetation and forests with unmanaged swards - high
Effects of fire on soil properties	Soil tests undertaken in cool to mild burn, moderate and hot to very hot burn areas. Under hot to very hot burn area (high fuel load at ground surface), decline in OC and nitrate N contents.
Effects of fire on land	Risk of wind and water erosion due to loss of surface cover.
Yumali	**November 2020 5,000 ha**
Land Use	Cropping – cereals, pulses Livestock grazing – annual pastures
Fuel load (type and amount) at soil surface	Annual pastures – low Standing (unreaped) crop – low Crop residues - moderate
Effects of fire on soil properties	Soil tests undertaken for range of nutrients and OC suggested no difference between burnt and unburnt land.
Effects of fire on land	Wind erosion particularly on cropped sandy loam soil types; less severe on deeper sands where veldt grass regerminated after fire.

Blackford	January 2021 14,100 ha
Land Use	Livestock grazing – perennial pastures Hay production – cereals, lucerne Cropping - cereals
Fuel load (type and amount) at soil surface	Bales of hay in paddock – high Perennial pastures e.g. Phalaris – moderate to high Crop residues - moderate
Effects of fire on soil properties	None apparent. Dung beetle numbers before and after fire were unchanged.
Effects of fire on land	Increased risk of wind erosion on sandy soils due to loss of surface cover.

Some of the data and information available in relation to these reports is presented in Appendix 1.

Figure 2: Root growth evident in sub-surface soil after Pinery fire.

Discussion

On agricultural soils, it appears that soil properties are not changed by cool to moderate burns but are affected by very hot burns of deep, dense organic material – litter, hay bales, perennial plant species with dense structures and wood piles. It is the heat and duration of the burn at the ground surface, not necessarily the heat or speed of the fire, that influences soil properties. A summary of observations that can be made to estimate the heat of the burn and therefore possible effects on soil properties is given in Table 3.

Table 3 Assessment of heat of burn at soil surface from site observations.

Heat of burn at soil surface	Visual observations after fire	Type of material on ground surface before fire
Cool to warm	• roots intact in soil • root crowns / butts evident at soil surface • some stems, leaves, grain intact, unburnt or charred	• Unreaped, weed-free crop • heavily grazed pastures • grazed annual pastures • bare swards between rows of trees and vines
Moderate	• roots intact in soil • crowns evident at soil surface • all above ground material burnt to ash	• Crop residues • Lightly grazed annual pastures • Moderately grazed mixed perennial and annual pastures • Mown or grazed swards in vineyards or orchards
Hot to very hot	• no evidence of roots in top 50 mm of soil • all above ground material burnt to ash • soil possibly different in colour, texture, physical structure • soils rich in organic matter e.g. peats possibly still smouldering underground	• Dense, perennial plants • Deep, thick litter of leaves, stems, branches, compost heaps • Hay bales • Timber piles, windrows of woody materials, “bonfires”

Figure 3: Stems of cereal straw intact at soil surface after fire.

Guidelines for determining the effects of fires on agricultural soils and appropriate treatments.

Visual observation of a burnt area and consideration of the soil type, type and amount of material burnt above ground, can provide a guide to the likely effect of a fire on soil properties.

1. Identify soil types, type and amount of vegetation present on burnt area before fire.

2. Assess the presence or absence of plant roots, root crowns, and above ground plant material.

3. On areas that appear to have experienced a hot to very hot burn, collect soil samples for analysis of pH, nutrients, organic carbon and cation exchange capacity (and if possible, biological activity) to identify deficiencies, toxicities or constraints that will require treatment to re-establish plant growth.

4. Assess erosion risk and consider practices that will mitigate risk of wind and water erosion (refer to Appendix 2).

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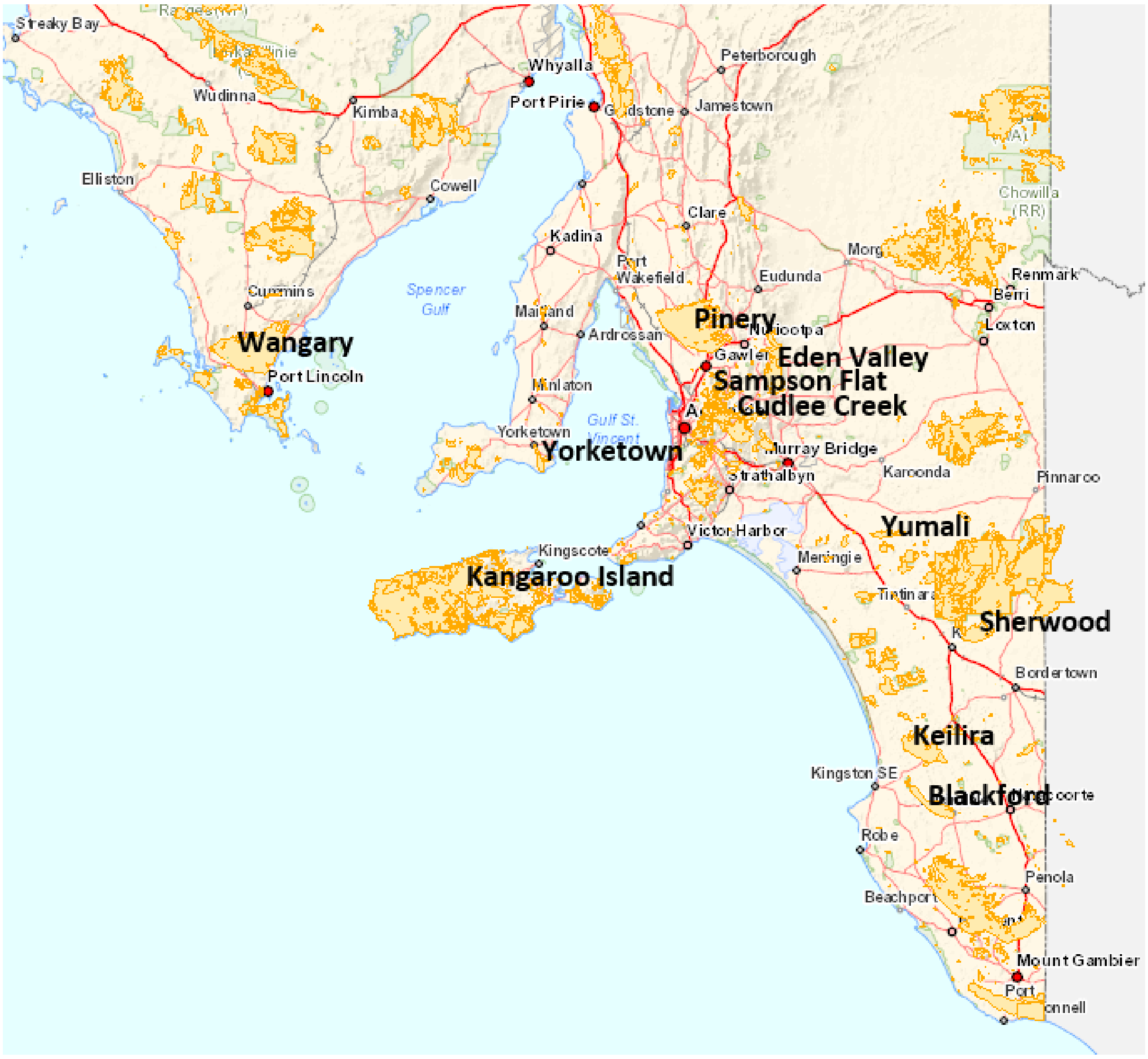
Appendix 1

Selected data and information from fire events.



Wangary

Wangary	January 2005 78,000 ha
Land Use	Cereal, pulse, oilseed cropping Livestock grazing – annual pastures; perennial pastures Conservation, recreation, grazing- remnant native vegetation
Fuel load (type and amount) at soil surface	Crop and annual pasture residues – moderate Perennial pasture – high Remnant native vegetation – high
Effects of fire on soil properties	Soils in burnt areas assessed for particular nutrients and organic carbon contents; no effects detected.
Effects of fire on land	Wind erosion particularly on cropped sandy loam soil types; less severe on deeper sands where veldt grass regerminated after fire.

A program was established in the days following the Wangary fire, to gather data from soils across the fire-affected area in response to primary producers' questions regarding the effects of fire on their land. Major conclusions were:

- **The effects of the burn on pasture regeneration and composition were only minimal.** Effects were variable, with higher plant numbers after burning at some sites, while reduced on others. But overall, no mass destruction of soil seed reserves was evident.
- **Effects on weed populations were also variable – no clearly defined changes or trends.**
- **Soil physical and chemical characteristics were largely unchanged due to the burn itself**, but subsequent erosion has removed some topsoil and nutrients with it.
- **Root pathogen populations at tested sites were low, with no evidence of a change on burnt ground.** Visual root inspection on wheat plants also showed no evidence of root diseases present.
- **Some diseases were still very prevalent after the fire (e.g. blackleg in canola and brown leaf spot in lupins),** indicating high survival of inoculum sources through the fire.
- **Late winter/ spring dry matter levels in regenerating pasture and crop appeared to be lower on burnt ground**, tied in with some observations of slower growth and possible N deficiency symptoms.
- **Grain yield and quality on burnt ground were as good as, if not better than on unburnt or pre-fire.** Our sole comparison of wheat grown on adjoining burnt and unburnt ground showed an 8% higher yield off the burnt, and higher grain protein levels, although soil type variations between the two areas may well explain this difference.

(Egan n.d.)

Table 2. Full chemical analysis of initial soil samples (0-10 cm) from unburnt and burnt areas at monitoring sites.

Soil chemical measure	Site 1 Sampled 18/2/2005		Site 2 Sampled 18/2/2005		Site 3 Sampled 18/2/2005		Site 4 18/2/2005	Site 6 Sampled 1/9/2005	
	Unburnt	Burnt	Unburnt	Burnt	Unburnt	Burnt	Burnt	Unburnt	Burnt
pH (water)	6.6	6.1	5.6	5.8	5.4	5.4	6.5	5.5	5.4
pH (calcium chloride)	6.1	5.1	4.7	4.9	4.5	4.5	6.1	4.5	4.5
Ext. P: mg/kg	37	56	29	20	40	26	24	38	31
Ext. K: mg/kg	812	320	107	136	270	151	179	91	81
Ext. S: mg/kg	5.6	6.1	4.4	4.3	8.7	8.3	18.6		
Organic Carbon: %	2.06	2.1	1.11	1.26	1.97	2.15	0.99	1.4	1.8
EC(1:5): dS/m	0.19	0.19	0.10	0.12	0.13	0.09	0.14		
ECe(est.): dS/m	1.8	1.2	1.4	1.6	1.2	0.8	1.4	0.69	0.80
Nitrate N: mg/kg	24	17	13	13	19	8	10		
Exch. Ca: mequiv/100g	11.5 (63%)	4.6 (50%)	1.8 (57%)	2.4 (63%)	2.9 (62%)	2.6 (68%)	4.5 (81%)	1.7 (71%)	1.6 (70%)
Exch. Mg: mequiv/100g	4.4 (24%)	2.7 (29%)	0.6 (19%)	0.8 (22%)	0.6 (13%)	0.6 (15%)	0.5 (9%)	0.3 (11%)	0.3 (13%)
Exch. Na: mequiv/100g	0.5 (3%)	1.1 (12%)	0.4 (13%)	0.2 (5%)	0.4 (9%)	0.2 (5%)	0.1 (2%)	0.2 (7%)	0.1 (6%)
Exch. K: mequiv/100g	2.0 (11%)	0.8 (9%)	0.3 (9%)	0.4 (9%)	0.7 (14%)	0.4 (9%)	0.4 (8%)	0.2 (8%)	0.2 (8%)
Exch. Al: mequiv/100g	0	0.05 (0.5%)	0.1 (2%)	0.05 (1%)	0.1 (2%)	0.1 (3%)	0	-	-
CEC: mequiv/100g	18.4	9.1	3.2	3.9	4.6	3.8	5.5	2.4	2.3
Exch. Ca: mg/kg	2300	981	360	488	572	5716	890	348	330
Exch. Mg: mg/kg	534	232	73	102	74	71	61	33	36
Exch. Na: mg/kg	124	242	97	46	92	44	30	36	30
Exch. K: mg/kg	766	305	106	145	254	137	172	79	71
Exch. Al: mg/kg	0	5	6	5	10	9	0		
Ext. Cu: mg/kg	1.8	1.3	0.8	0.8	1.8	1.1	0.7	1.0	0.4
Ext. Zn: mg/kg	0.8	0.5	0.3	0.4	1.8	2	2.6	1.6	2.6
Ext. Mn: mg/kg	29.4	10.9	5.2	8.3	6.4	4.7	8.7	4.1	2.7
Ext. Fe: mg/kg	95	236	147	64	166	178	68	88	55
Ext. Al: mg/kg		0.5	1.2	0.7	2.6	2			
Ext. B: mg/kg	1.5	1.0	0.4	0.5	0.8	0.6	0.7	1.4	1.1
Ext. Chloride: mg/kg	9.5	117	41	53	57	41	60		

(Egan 2006)

Sampson Flat

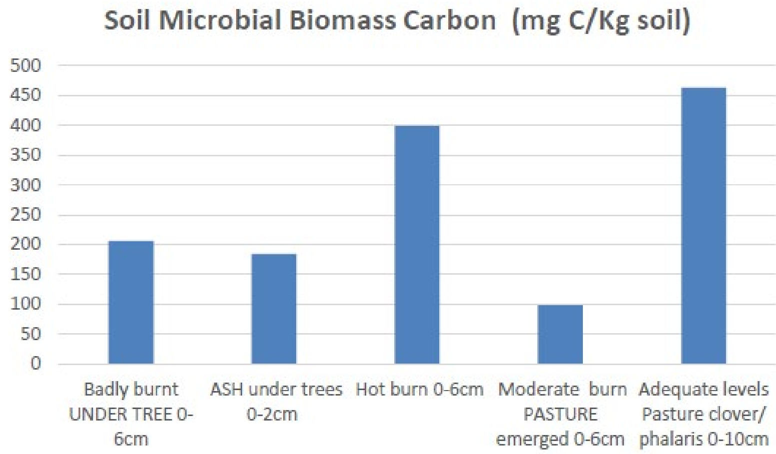
Sampson Flat	January 2015 12,600 ha
Land Use	Livestock grazing – perennial and annual pastures Viticulture Forestry Horticulture Conservation, recreation, grazing – remnant native vegetation
Fuel load (type and amount) at soil surface	Forests, areas of remnant vegetation – high Some perennial grasses eg Phalaris – high Other grazing areas – moderate
Effects of fire on soil properties	Soils under livestock grazing and with very high fuel load (regarded as hot burn areas) compared to areas of cooler burns. Lower OC and nitrate N concentrations detected in hot burn areas that were small proportion of total pasture area.
Effects of fire on land	Wind erosion immediately from areas subjected to hot burns that lost surface cover, followed by water erosion where pastures failed to regenerate soon after fire.

After the Sampson Flat fire, it was evident that the fire had different effects on soils at different sites. Investigation of these sites indicated that the fire at the ground surface was much hotter because of the type and density of the plant growth on it. Soil analyses, including tests to measure biological activity, were undertaken on sites that had experienced moderate and hot burns.

Moderate burn

Hot to very hot burn

Impact on soil biology of burn classes
Sampson Flat, Gumeracha 2015
Test used is a potential biological activity test- fire had no impact?



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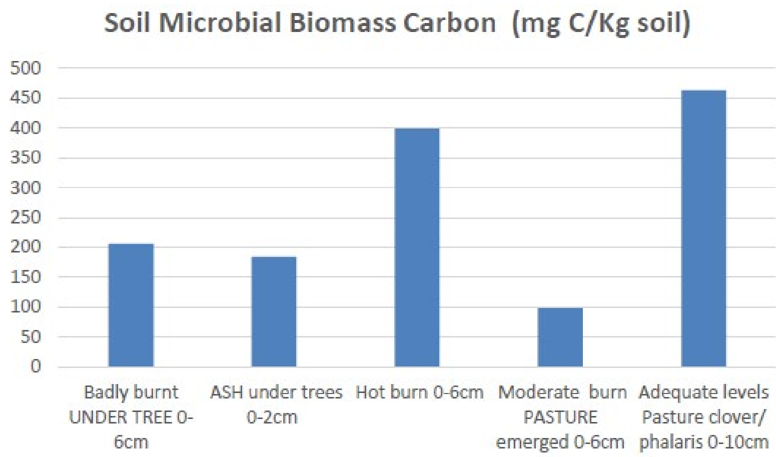


(Brian Hughes (pers.comm))

Pinery

Pinery	November 2015 82,500 ha
Land Use	Intensive cropping – cereals, pulses, oilseed, hay Livestock grazing in cropping system – annual pastures Livestock grazing unarable land – perennial pastures, remnant native vegetation
Fuel load (type and amount) at soil surface	Standing (unreaped) crop – low Crop residues, annual pastures – low to moderate Perennial pastures, grazed areas of remnant vegetation - moderate
Effects of fire on soil properties	Very hot burns in spots eg under haystacks, changes in pH, EC, P, Cl, S, CEC and ESP detected. Anecdotal observation that some soil particles became lighter – more readily dislodged and entrained by wind – suggesting loss of any coherence.
Effects of fire on land	Major wind and some water erosion due to loss of surface cover.

Monitoring of soil properties and characteristics were undertaken after the Pinery fire, to determine if there were any changes as a result of the fire. At Kapunda, soils under burnt haystacks showed significant differences in properties to adjacent soils under crop, demonstrating the difference between a “hot burn” compared to a “moderate burn”.

No discernible differences in the number of soil microorganisms in burnt and unburnt sites were detected. Soils of the fire area were generally regarded as being in good soil health before and after the fire.


Pinery fire area near Hamley Bridge December 2015 (left) and September 2016 (right).

Site location	Landform	Burn status	Treatment	Sample depth	Texture	Carbonate	pH	EC	PBI	Org C	NO_3 N	Avail P	Cl	Avail K	Boron	SO_4 - S
						%	$CaCl_2$	EC_e 1:5 dS/m		%	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Mallala	Flat	Burnt	stubble	0-10	Loam	14.9	7.6	0.106	154	1.67	23	54	7.6	742	2.2	7.8
		Unburnt	stubble	0-10	Loam	14.4	7.6	0.117	143	1.99	30	43	5.9	961	2.2	5.7
Long Plains	Sandhill	Burnt		0-10	Sand	0.3	6.8	0.128	17	1.01	29	59	10.4	367	0.8	11.7
		Unburnt		0-10	Sand	0.3	7.2	0.103	15	0.58	27	34	4.1	184	0.4	8.2
	Flat	Burnt		0-10	Clay loam	17.6	7.7	0.153	125	1.75	37	45	9.0	640	2.9	11.5
		Unburnt		0-10	Clay loam	8.5	7.7	0.128	98	1.72	25	27	8.4	558	2.4	9.8
Pinery	Flat	Burnt	Tyne seeder	0-10	Loam	17.5	7.9	0.092	156	1.65	13	52	8.5	521	3.1	5.7
		Burnt	Tyne seeder	0-10	Loam	13.6	7.9	0.105	128	1.63	24	59	7.2	699	2.8	6.9
		Burnt	Disc seeder	0-10	Loam	11.4	7.8	0.100	125	1.60	22	62	7.4	570	2.7	5.6
		Unburnt	Disc seeder	0-10	Loam	10.6	7.8	0.109	116	1.58	6	50	8.2	528	2.4	5.7
Kapunda	Lower slope	Burnt	Haystack	0-10	Clay loam		8.5	0.571	479	1.12	15	682	266.0	3177	1.1	31.8
	Lower slope	Burnt	Crop	0-10	Clay loam		5.6	0.065	53	1.36	21	103	22.0	771	0.8	7.5
	Crest	Burnt	Haystack	0-10	Clay loam		8.3	0.900	539	1.41	10	1003	356.0	3895	1.1	50.6
	Crest	Burnt	Crop	0-10	Clay loam		6.1	0.078	51	1.85	24	65	17.5	426	0.9	10.5

Site location	Landform	Burn status	Treatment	Sample depth	Texture	Trace elements (DTPA) mg/kg				CEC	Exchangeable cations meq/100g				
						Cu	Zn	Fe	Mn	meq/100 g	Ca	Mg	Na	K	ESP
Mallala	Flat	Burnt	stubble	0-10	Loam	2.13	3.15	6.90	5.38	23.97	19.94	1.90	0.19	1.90	0.79
		Unburnt	stubble	0-10	Loam	1.89	3.64	6.87	6.07	27.69	22.90	2.15	0.17	2.50	0.61
Long Plains	Sandhill	Burnt		0-10	Sand	0.83	3.08	13.10	2.47	6.05	4.23	0.88	0.05	0.90	0.83
		Unburnt		0-10	Sand	0.38	1.85	8.38	1.90	4.49	3.56	0.48	0.02	0.40	0.44
	Flat	Burnt		0-10	Clay loam	0.50	1.92	5.56	5.65	21.27	17.40	1.99	0.11	1.70	0.52
		Unburnt		0-10	Clay loam	0.53	1.71	6.34	5.63	16.68	13.60	1.50	0.11	1.40	0.66
Pinery	Flat	Burnt	Tyne seeder	0-10	Loam	0.69	2.49	6.02	5.07	23.35	19.62	2.14	0.15	1.40	0.64
		Burnt	Tyne seeder	0-10	Loam	0.66	3.12	5.99	5.93	23.93	19.60	2.24	0.10	2.00	0.42
		Burnt	Disc seeder	0-10	Loam	0.67	3.63	6.33	5.13	19.60	16.30	1.74	0.08	1.50	0.41
		Unburnt	Disc seeder	0-10	Loam	0.74	2.53	6.60	5.48	21.47	17.90	2.06	0.09	1.40	0.42
Kapunda	Lower slope	Burnt	Haystack	0-10	Clay loam	1.12	3.06	35.80	45.60	16.64	3.14	1.69	3.10	8.70	18.6
	Lower slope	Burnt	Crop	0-10	Clay loam	1.24	2.22	108.00	25.70	7.20	4.14	0.83	0.33	1.90	4.6
	Crest	Burnt	Haystack	0-10	Clay loam	1.36	2.98	40.90	25.50	20.21	3.90	2.64	4.10	9.60	20.2
	Crest	Burnt	Crop	0-10	Clay loam	1.14	1.75	57.50	9.69	8.53	6.52	0.72	0.16	1.10	1.9

(Woodard and Hughes, 2018)

Sherwood

Sherwood	January 2018 12,000 ha
Land Use	Cropping – cereals, pulses, oilseeds Livestock grazing – annual and perennial pastures
Fuel load (type and amount) at soil surface	Crop residues, annual pastures – moderate Perennial pastures – moderate
Effects of fire on soil properties	None apparent. Anecdotal evidence that soil temperatures did not significantly rise is that poly watering pipe buried beneath the soil surface was not affected.
Effects of fire on land	Loss of surface cover significantly increased risk of wind erosion on sandy soils but risk mitigated by extensive clay spreading.

Jeanneau et al (2019) studied the differences in patterns of sediment transport between burnt and unburnt crop stubble sites.

A B S T R A C T

Fires can considerably increase wind erosion risk in dryland agricultural regions. While wind erosion post-fire has been extensively studied in rangeland and grazing landscapes, limited work has considered post-fire erosion on annual plant communities and annual crops. Here we evaluated the relative spatial differences in patterns of sediment transport between burnt and unburnt crop stubble sites. Following a severe wildfire, we studied the spatio-temporal pattern of aeolian sediment transport with an array of Modified Wilson and Cooke (MWAC) dust samplers on adjacent burnt and unburnt wheat stubble. Sediment collection was conducted during nine weeks over an area of 3 ha. Collection rates were converted to horizontal sediment flux to derive spatial distribution maps and perform statistical analysis. Compared to the unburnt plot, we observed that sediment transport was up to 1000 times higher within the burnt area. This could lead to damages to emerging annual crops sown after the fire if no management strategy was applied. There was only negligible sediment flux in areas with shallow and low-density stubble, which gradually increased with distance from the unburnt area. These results suggest that strips of remaining unburnt stubble could provide a potential benefit to adjacent burnt or bare plots. Patterns of sediment transport were consistent in all sampling periods and were observed at a spatial scale undetectable in wind tunnel studies, indicating that field observations could complement fine-scale experimental studies to assess environmental processes in real-life conditions.

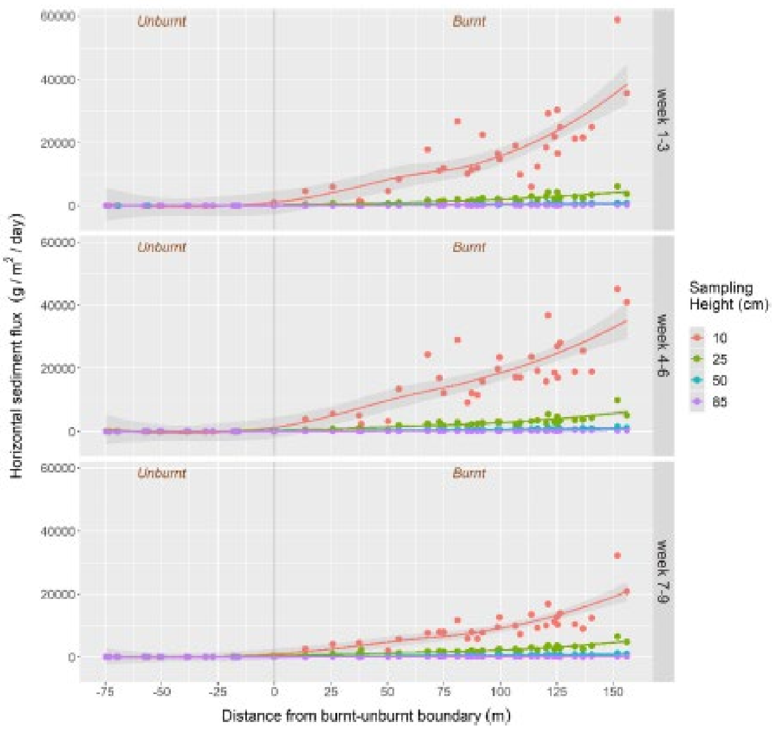


Fig. 7. Observed horizontal sediment flux distribution with sampling distance from the burnt-unburnt boundary. 95% confidence interval of the LOESS regressions are shown as shaded grey bands.

Yorketown

Yorketown	November 2019 6,700 ha
Land Use	cropping – cereals, pulses livestock grazing – annual pastures
Fuel load (type and amount) at soil surface	Standing (unreaped) crop – low Crop residues and annual pastures - moderate
Effects of fire on soil properties	Analysis of range of nutrients and OC contents undertaken on soils from burnt and unburnt areas. No effects of fire detected.
Effects of fire on land	Wind erosion due to loss of surface cover.

Soil tests were undertaken on burnt and unburnt farming land to allay concerns that the fire had damaged the soil. Soil analyses confirmed that the fire had not adversely affected soil properties.

Remote sensing images showing the Yorketown fire scar taken 16.12.2019 and 27.08.2020, showed how growth was well established over the fire area 9 months after the fire. The burnt area cannot be distinguished from the surrounding country.

Yorketown (Y) and Maitland (M) Fire areas soil test results - burnt and unburnt land

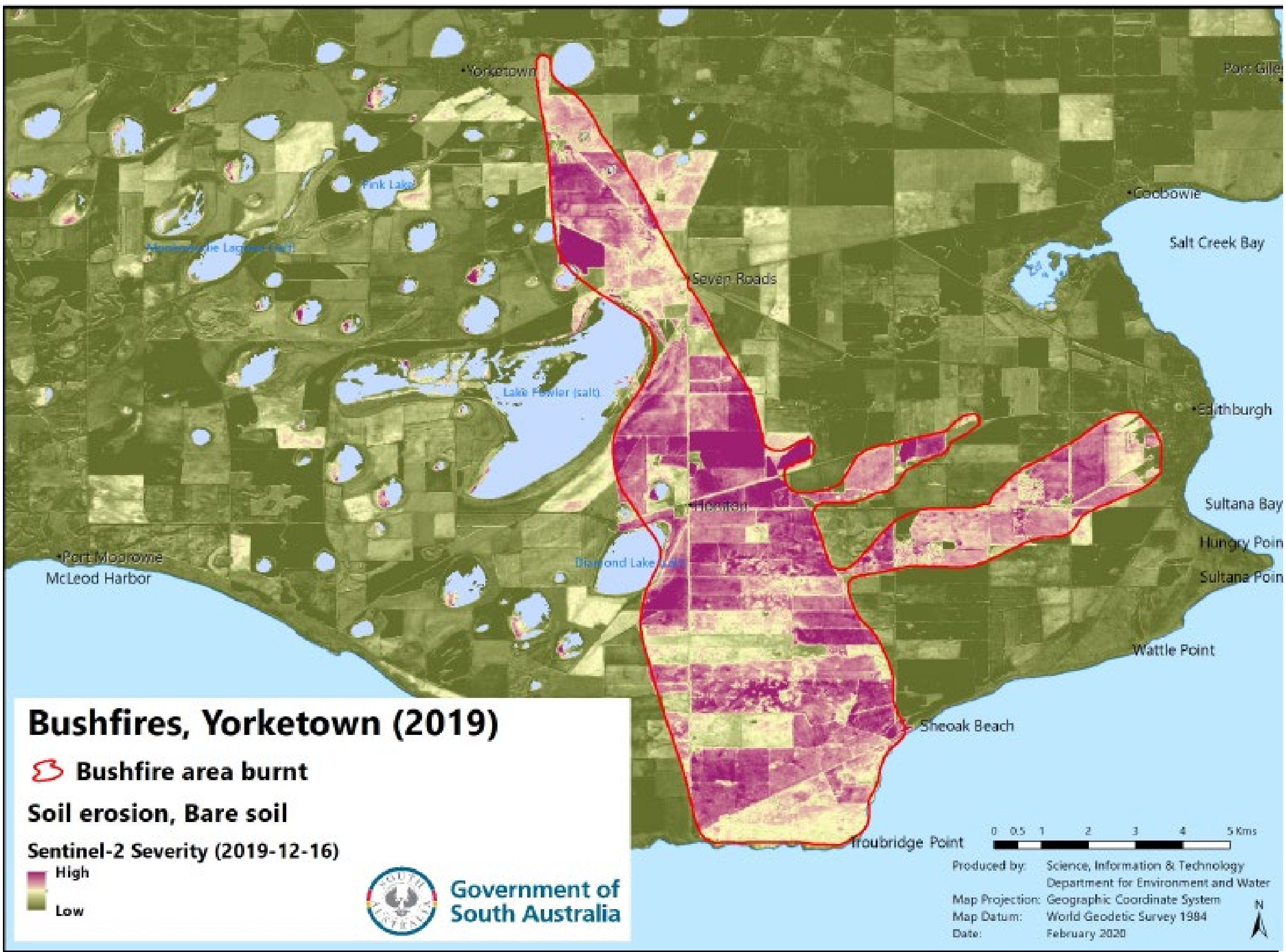
Landholder Code	Paddock	Crop type	Burnt / Unburnt	Depth cm	Texture	Total Carbon %	pH $CaCl_2$	EC esECe 1:5 dS/m	PBI	Org.C %	NO_3 N mg/kg	Avail. P mg/kg	Cl mg/kg	Avail. K mg/kg	Boron mg/kg	SO_4-S mg/kg
Y01	A	Lentils	Burnt	0-10	Clay Loam	5.73	7.5	0.291	140	2.99	54	54	103.3	890	2.47	11.6
Y01	B	Lentils	Burnt	0-10	Clay Loam	4.51	7.4	0.338	131.1	2.83	98	51	79.6	926	2.42	14.8
Y01	C	Wheat	Burnt	0-10	Clay Loam	5.99	7.6	0.341	116.5	2.92	82	63	111.1	935	2.89	18.8
Y02	D	Lentils	Burnt	0-10	Loam	3.49	7.3	0.259	117.8	2.87	69	102	37	922	2.32	30.3
Y02	D	Lentils	Unburnt	0-10	Clay Loam	3.85	7.4	0.239	129.3	3.02	29	85	42.9	878	2.05	46.5
Y02	E		Burnt	0-10	Clay Loam	3.75	6.8	0.166	110.7	3.04	27	64	44	1080	2.25	9.9
Y02	E		Unburnt	0-10	Clay Loam	3.48	7.2	0.319	113.5	2.75	13	29	232	1102	2.07	6
Y03	F	Wheat	Burnt	0-10	Clay Loam	6.23	7.5	0.47	168.4	3.02	139	91	217.5	937	3.73	25
Y03	F	Wheat	Unburnt	0-10	Clay Loam	5.56	7.4	0.559	140	3.64	154	60	287.6	964	3.32	20
Y03	G	Barley	Burnt	0-10	Clay Loam	4.98	7.4	0.378	185.7	3.41	77	85	151	1093	2.26	22
Y03	G	Barley	Unburnt	0-10	Clay Loam	4.87	7.4	0.311	191.6	3.39	26	46	163.4	1150	2.93	12.2
Y04	H	Barley	Burnt	0-10	Clay Loam	4.09	7.2	0.247	126.2	3	53	56	64.7	916	2.18	9.5
Y04	H	Barley	Burnt	0-10	Clay Loam	3.53	7.2	0.282	101.5	2.9	68	45	115.3	914	1.78	22.2
Y04	H	Barley	Unburnt	0-10	Clay Loam	4.01	7.5	0.308	101.9	3.15	26	19	200.2	1004	2.26	6.4
Y05	I	Barley	Burnt	0-10	Clay Loam	5.36	7.1	0.414	176.1	2.74	73	77	231.9	1280	3.28	18.6
Y05	I	Barley	Unburnt	0-10	Clay Loam	5.45	7.4	0.265	156.5	3.41	18	37	133.2	1444	3.07	8.3
Y05	J	Wheat	Burnt	0-10	Clay Loam	5.86	7.5	0.261	146.2	2.75	45	33	67.8	962	2.56	13.9
Y05	J	Wheat	Unburnt	0-10	Clay Loam	6.01	7.5	0.244	138.9	2.71	51	34	36.8	854	2.86	9.9
Y06	K	Wheat	Burnt	0-10	Clay Loam	4.00	7.2	0.316	149.5	3.2	73	59	40.9	1155	3.05	23.5
Y06	L	Barley	Burnt	0-10	Clay Loam	5.72	7.5	0.371	146.3	3.4	107	56	157.2	1023	2.69	39.3
Y07	M	Pasture	Burnt	0-10	Clay Loam	5.17	7	0.426	137.3	4.19	157	94	135.5	1601	3.36	25.6
Y07	M	Pasture	Unburnt	0-10	Clay Loam	6.07	7.4	0.36	175.8	3.77	118	42	61.7	1637	3.46	12.5

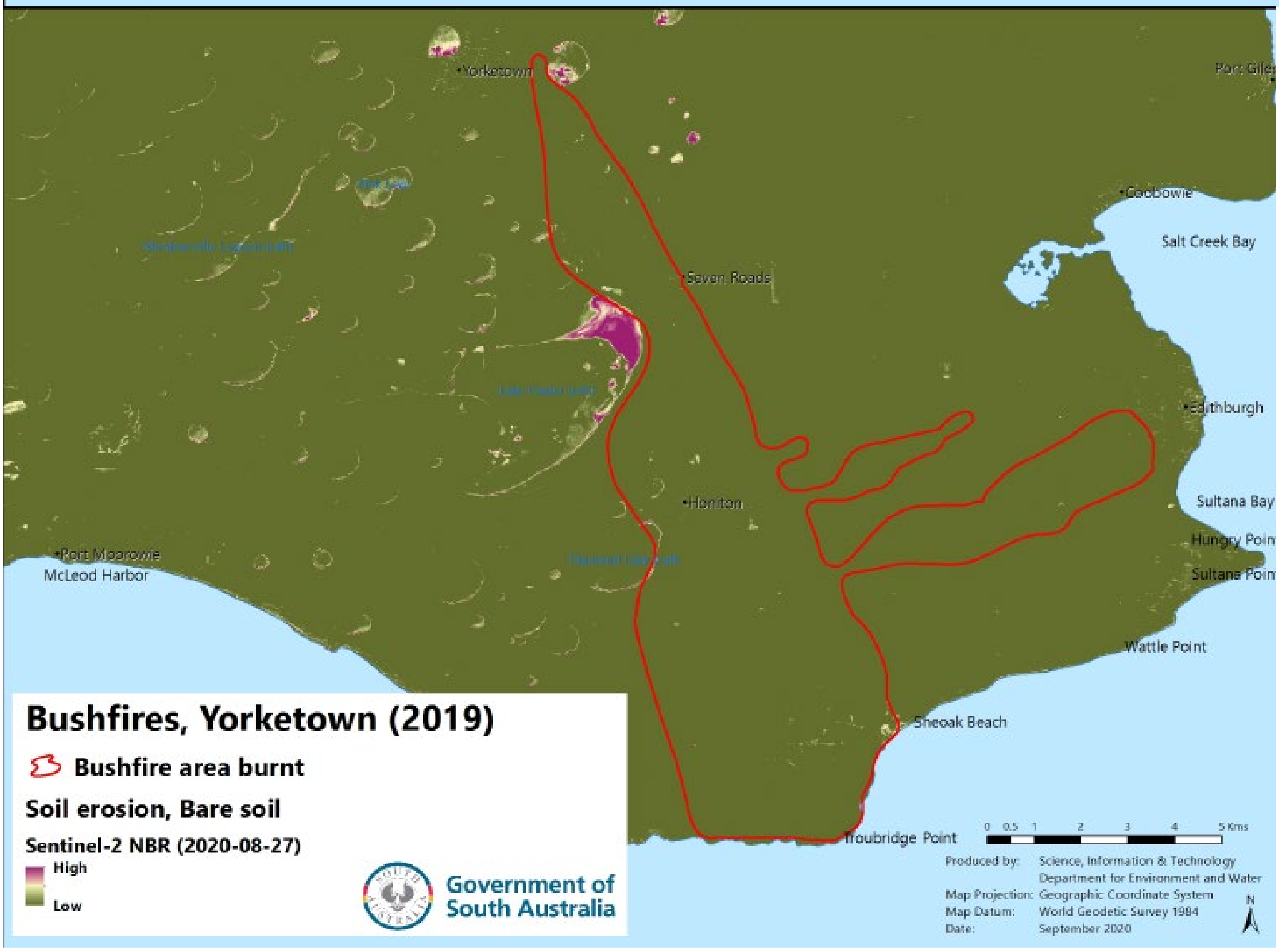
Landholder Code	Paddock	Crop type	Burnt / Unburnt	Depth cm	Texture	Trace Elements (DTPA) mg/kg				CEC meq/100gm	Exchangeable cations meq/100gm				
						Cu	Zn	Fe	Mn		Ca	Mg	Na	K	ESP
Y01	A	Lentils	Burnt	0-10	Clay Loam	0.7	2.89	16	7.89	30.23	24.56	2.64	0.41	2.6	1.36
Y01	B	Lentils	Burnt	0-10	Clay Loam	0.61	3.73	18.4	8.64	32.71	27.5	2.13	0.39	2.7	1.19
Y01	C	Wheat	Burnt	0-10	Clay Loam	0.6	2.00	16.4	9.3	32.13	25.8	3.19	0.39	2.7	1.21
Y02	D	Lentils	Burnt	0-10	Loam	0.53	0.62	15.2	7.86	31.66	26.18	2.34	0.38	2.8	1.2
Y02	D	Lentils	Unburnt	0-10	Clay Loam	0.53	0.81	18.3	8.11	31.78	26.2	2.37	0.37	2.8	1.2
Y02	E		Burnt	0-10	Clay Loam	0.71	0.58	26.2	10.5	31.91	25.2	2.81	0.42	3.5	1.3
Y02	E		Unburnt	0-10	Clay Loam	0.53	0.58	18.6	7.31	32.18	25.9	2.56	0.43	3.3	1.3
Y03	F	Wheat	Burnt	0-10	Clay Loam	0.7	7.23	20.8	10.4	34.47	27.47	3.16	1	2.8	2.9
Y03	F	Wheat	Unburnt	0-10	Clay Loam	0.61	5.01	20.1	11.7	35.98	29.1	2.94	0.87	3.1	2.42
Y03	G	Barley	Burnt	0-10	Clay Loam	0.56	8.38	20.6	8.53	40.33	33.4	2.76	0.54	3.6	1.34
Y03	G	Barley	Unburnt	0-10	Clay Loam	0.54	3.37	18.5	7.22	39.29	31.8	3.14	0.59	3.7	1.5
Y04	H	Barley	Burnt	0-10	Clay Loam	0.75	2.56	16.3	7.23	30.74	25.42	2.07	0.3	2.9	0.98
Y04	H	Barley	Burnt	0-10	Clay Loam	0.5	2.75	16.6	10.5	27.57	22.7	1.92	0.33	2.6	1.2
Y04	H	Barley	Unburnt	0-10	Clay Loam	0.58	2.75	16.7	8.32	32.2	26.5	2.25	0.46	3	1.43
Y05	I	Barley	Burnt	0-10	Clay Loam	0.91	7.91	14.6	13.1	41.56	33.38	3.45	0.67	4	1.6
Y05	I	Barley	Unburnt	0-10	Clay Loam	0.95	6.35	16.2	10.1	41.49	33	3.45	0.59	4.5	1.4
Y05	J	Wheat	Burnt	0-10	Clay Loam	0.52	2.25	16.3	7.47	28.04	22.2	2.48	0.44	2.9	1.57
Y05	J	Wheat	Unburnt	0-10	Clay Loam	0.54	2.30	14.5	6.25	27.95	22.1	2.58	0.38	2.8	1.36
Y06	K	Wheat	Burnt	0-10	Clay Loam	0.73	2.63	18.6	8.08	38.01	30.29	3.36	0.41	3.9	1.07
Y06	L	Barley	Burnt	0-10	Clay Loam	0.58	2.89	17.7	7.29	34.06	27.6	2.6	0.59	3.3	1.73
Y07	M	Pasture	Burnt	0-10	Clay Loam	0.73	2.79	20.9	11.8	39.07	29.84	3.51	0.79	4.9	2.02
Y07	M	Pasture	Unburnt	0-10	Clay Loam	0.74	3.41	16.1	8.12	43.51	34.5	3.45	0.56	5	1.28

Landholder Code	Paddock	Crop type	Burnt / Unburnt	Depth cm	Texture	Total Carbon %	pH H_2O	pH $CaCl_2$	EC esECe 1:5 dS/m	PBI	Org.C %	NO_3 N mg/kg	Avail. P mg/kg	Cl mg/kg	Avail. K mg/kg	Boron mg/kg	SO_4-S mg/kg
Y08	N		Burnt	0-10	Clay Loam	3.99	8.2	7.4	0.264	168.5	2.94	89	40	24.7	1060	2.63	15.9
Y08	N		Unburnt	0-10	Clay Loam	4.87	8.1	7.4	0.438	159.2	3.78	156	50	125.4	1793	3.07	18.4
Y08	O	Lentils	Burnt	0-10	Clay Loam	2.46	6.7	5.8	0.198	109.1	1.85	54	42	42.7	1094	1.68	26
Y08	O	Lentils	Unburnt	0-10	Clay Loam	3.24	7.3	6.6	0.315	111.7	2.52	71	100	76.3	1117	1.71	30.2
Y08	P		Burnt	0-10	Clay Loam	3.92	7.9	7.1	0.266	150.1	3.28	55	66	73.5	1009	2.53	39.8
Y08	P		Unburnt	0-10	Clay Loam	4.75	8.1	7.4	0.49	179.1	3.2	70	44	179.3	1104	2.49	143.5
Y09	Q		Burnt	0-10	Clay Loam	4.01	7.9	7.1	0.232	123	3.42	32	81	88.8	1065	1.82	8.9
Y09	Q		Unburnt	0-10	Clay Loam	3.55	7.4	6.6	0.178	118.1	3.11	16	99	99.1	1000	2.12	6.5
Y10	R	Barley	Burnt	0-10	Clay Loam	3.94	7.8	7.2	0.427	126.5	3.34	103	81	86.8	1221	2.1	89.2
Y10	R	Barley	Unburnt	0-10	Clay Loam	4.4	7.8	7.3	0.429	131.9	3.67	68	90	133.5	1305	2.24	91.6
Y10	S	Lentils	Burnt	0-10	Clay Loam	4.69	7.9	7.3	0.422	144.5	3.66	148	78	137.3	1204	2.71	9.7
Y10	S	Lentils	Unburnt	0-10	Clay Loam	4.59	8.1	7.4	0.315	128.9	3.33	75	53	107.7	1037	2.17	9.4
M01	T		Burnt	0-10	Clay loam	1.92	7	6.2	0.221	40.6	1.58	50	56	57.1	350	0.88	41.1
M01	T		Unburnt	0-10	Clay loam	2.48	6.5	6	0.302	47.4	1.91	61	64	140.9	377	1.14	34.5
M02	U		Burnt	0-10	Loamy sand	1.04	8.1	7.4	0.118	16.2	0.86	25	27	14.8	255	0.53	5.2
M02	V		Burnt	0-10	Loamy	1.33	8.3	7.5	0.183	27.7	1.05	30	30	63.4	218	1.02	5.7
M02	W		Unburnt	0-10	Loamy sand	1.78	8.2	7.4	0.18	34.4	1.13	23	23	61.2	411	0.91	4.9
M02	X			0-10	Clay	1.49	8.3	7.6	0.319	125.3	0.53	47	5	125.4	483	2.32	9
M02	Y		Unburnt	0-10	Loamy sand	1.43	8.1	7.4	0.166	41.3	1.06	23	49	30.8	327	1.01	4.9
M03	Z		Burnt	0-10	Clay loam	3.06	8.3	7.5	0.221	73.3	2.22	59	79	5.7	581	2.74	9.7
M03	Z		Unburnt	0-10	Clay loam	3.47	8.2	7.5	0.238	97.5	2.12	59	85	3.1	664	2.65	9.4

Landholder Code	Paddock	Crop type	Burnt / Unburnt	Depth cm	Texture	Trace Elements (DTPA) mg/kg				CEC meq/100gm	Exchangeable cations meq/100gm				
Y08	N		Burnt	0-10	Clay Loam	0.57	1.66	17.7	4.71	36.85	30.23	2.5	0.54	3.6	1.47
Y08	N		Unburnt	0-10	Clay Loam	0.62	3.09	16.7	7.31	42.28	33	3.1	0.69	5.5	1.6
Y08	O	Lentils	Burnt	0-10	Clay Loam	0.99	0.73	48.5	17.9	23.61	16.82	3.22	0.38	3.2	1.6
Y08	O	Lentils	Unburnt	0-10	Clay Loam	0.87	2.06	43.4	14.7	28.94	22	3.2	0.44	3.3	1.5
Y08	P		Burnt	0-10	Clay Loam	0.53	2.88	24.6	5.91	34.78	29	2.33	0.53	2.9	1.5
Y08	P		Unburnt	0-10	Clay Loam	0.56	2.26	18.5	5.5	41.14	33.8	3.02	0.68	3.7	1.65
Y09	Q		Burnt	0-10	Clay Loam	0.59	3.26	26	13.4	31.96	25.50	2.56	0.53	3.4	1.66
Y09	Q		Unburnt	0-10	Clay Loam	0.59	2.86	38.5	10.9	29.77	23.6	2.77	0.54	2.9	1.81
Y10	R	Barley	Burnt	0-10	Clay Loam	0.49	2.42	19.9	7.11	35.04	28.57	2.25	0.46	3.8	1.3
Y10	R	Barley	Unburnt	0-10	Clay Loam	0.51	2.77	20.8	8.43	36.63	29.7	2.66	0.42	3.9	1.1
Y10	S	Lentils	Burnt	0-10	Clay Loam	0.52	2.20	20.7	11.7	38.09	31.1	2.58	0.59	3.8	1.5
Y10	S	Lentils	Unburnt	0-10	Clay Loam	0.72	2.13	19.7	9.54	34.59	28.4	2.3	0.44	3.5	1.27
M01	T		Burnt	0-10	Clay loam	0.96	2.84	68.9	1.84	10.84	8.48	1.19	0.3	0.9	2.8
M01	T		Unburnt	0-10	Clay loam	1.06	2.54	92.9	2.13	9.65	7.21	1.36	0.27	0.8	2.8
M02	U		Burnt	0-10	Loamy sand	0.32	1.07	19.3	0.97	7.74	6.28	0.75	0.1	0.6	1.3
M02	V		Burnt	0-10	Loamy	0.36	0.8	46.3	0.92	9.94	8.1	0.98	0.35	0.4	3.5
M02	W		Unburnt	0-10	Loamy sand	0.35	1.41	17.5	1.64	11.46	9.32	0.86	0.2	1	1.7
M02	X			0-10	Clay	0.33	0.24	35.9	0.72	22.45	18.2	2.51	0.44	1.2	2
M02	Y		Unburnt	0-10	Loamy sand	0.4	1.5	30.6	0.94	11.82	10	0.91	0.13	0.7	1.1
M03	Z		Burnt	0-10	Clay loam	0.55	2.96	19	3.15	23.9	20.23	1.87	0.29	1.5	1.2
M03	Z		Unburnt	0-10	Clay loam	0.75	2.78	22.9	3.12	26.82	22.4	2.43	0.28	1.7	1

(David Woodard (pers. comm))



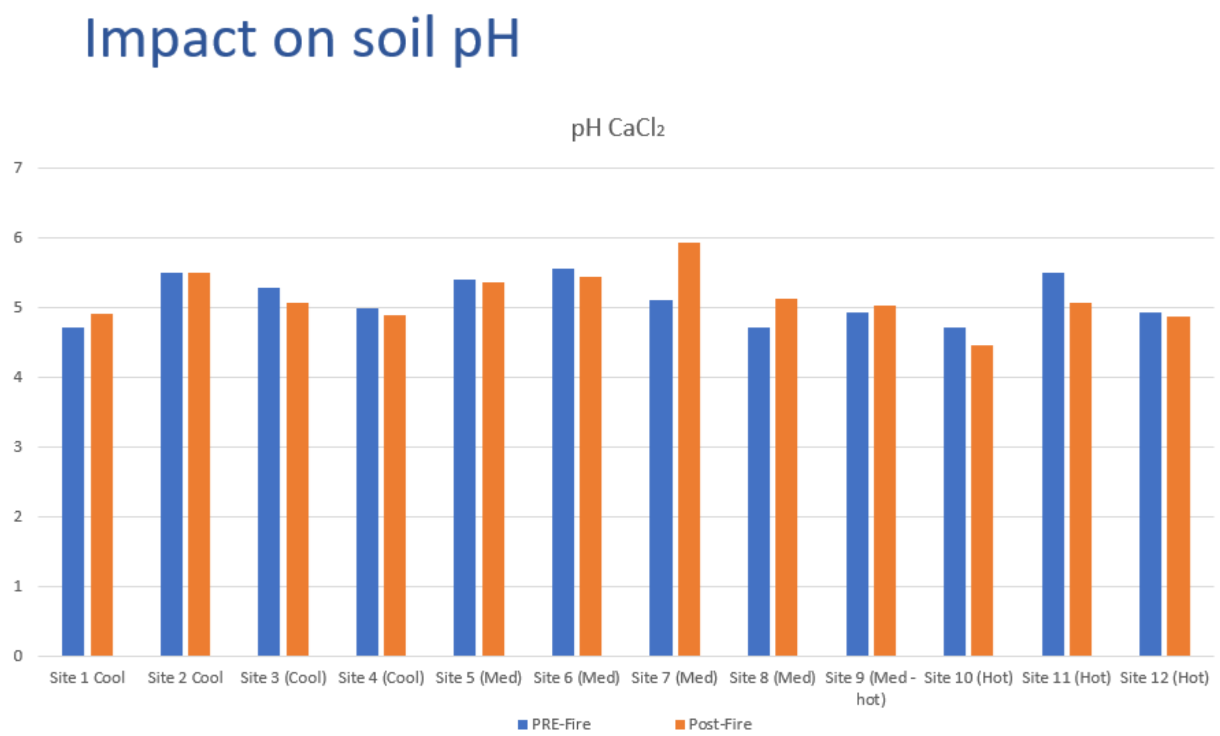


Yorketown fire area soil erosion and bare soil 16/12/2019 and 27/08/2020

Kangaroo Island

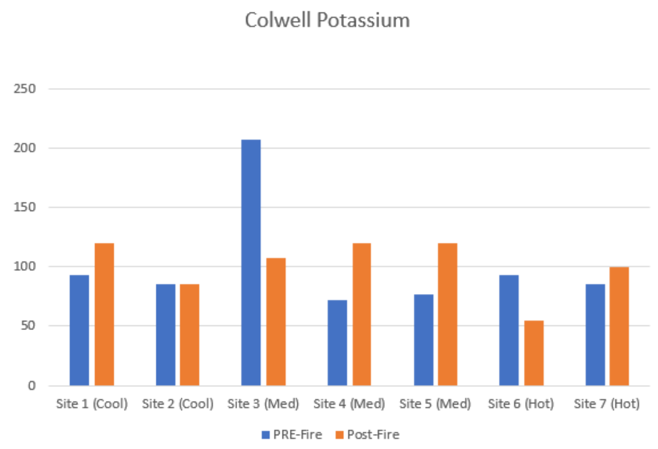
Kangaroo Island	December 2019 – January 2020 211,500 ha
Land Use	Livestock grazing – perennial pastures (e.g. kikuyu), annual pastures and mixed annual and perennial. Cropping – cereals, pulses, oilseeds Conservation, recreation, grazing – remnant native vegetation Forestry Viticulture
Fuel load (type and amount) at soil surface	Annual pastures – moderate Perennial pastures – low Crop residues – moderate Vineyards (managed swards) – low Forestry – high Remnant native vegetation - high
Effects of fire on soil properties	Analyses of soils from burnt areas indicated no change in soil pH, OC, P, N.
Effects of fire on land	Wind and water erosion risk increased due to loss of surface cover.

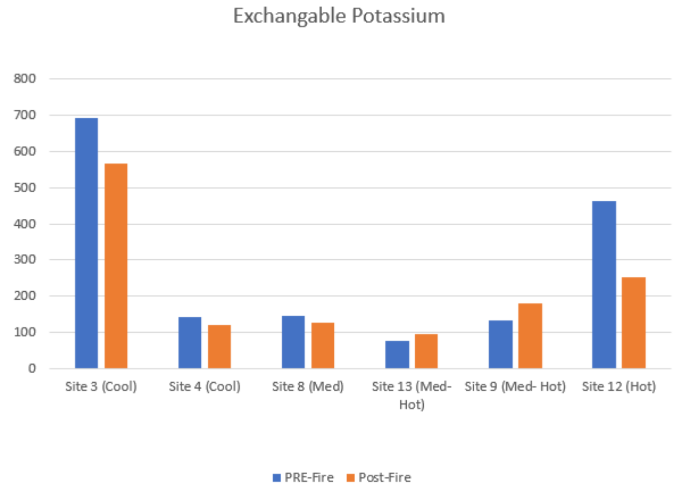
Soil tests on burnt land compared soil test results from before the fire with results after the fire. The results were sorted into cool, medium (moderate), medium to hot and hot.



Site 7 was limed between the pre and post fire sampling

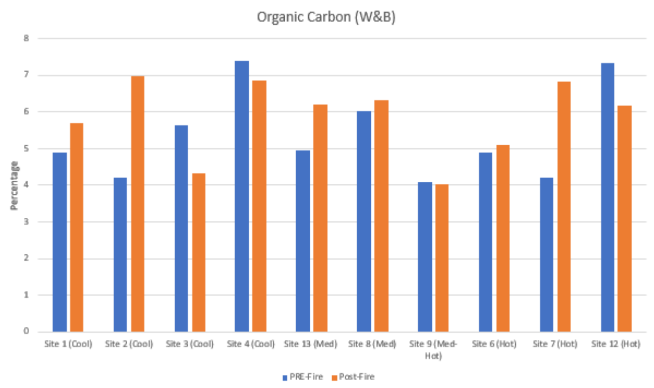
Impact on soil fertility - potassium



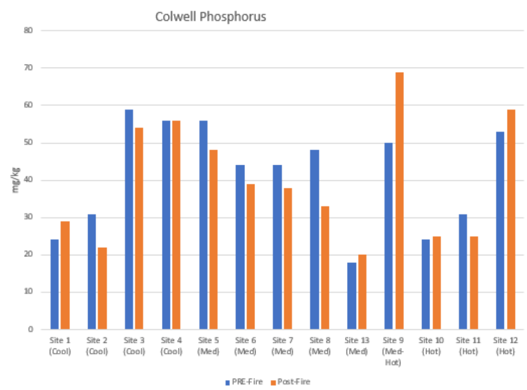


All sites (except site 3) had potassium applied between pre and post fire soil tests

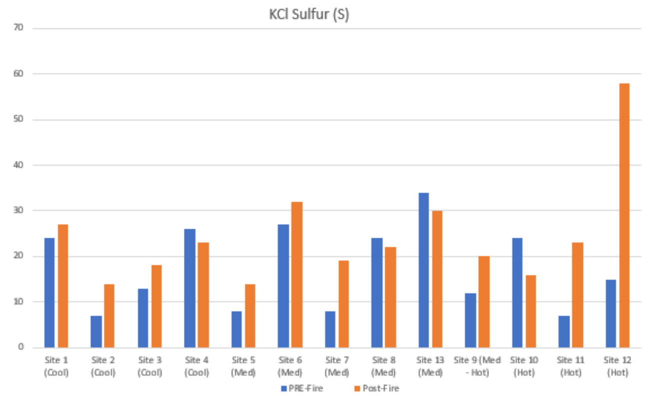
Impact on soil fertility - organic matter



Impact on soil fertility - phosphorus



Impact on soil fertility - sulphur



(Lyn Dohle (pers. comm))

Cudlee Creek

Cudlee Creek	December 2019 23,300 ha
Land Use	Hay production – annual pastures Livestock grazing – perennial pastures and annual pastures Pome fruit Viticulture Forestry Conservation, recreation, livestock grazing – remnant native vegetation
Fuel load (type and amount) at soil surface	Annual pastures, hay cuts – low Perennial pastures – moderate Forests, horticulture, viticulture with managed swards – low to medium Remnant native vegetation and forests with unmanaged swards - high
Effects of fire on soil properties	Soil tests undertaken in cool to mild burn, moderate and hot to very hot burn areas. Under hot to very hot burn area (high fuel load at ground surface), decline in OC and nitrate N contents.
Effects of fire on land	Risk of wind and water erosion due to loss of surface cover.

Investigation of the fire areas estimated the heat of the burn based on surface cover remaining and appearance of the soil surface.
Analyses of soil carbon from sites at Birdwood, Kenton Valley and Charleston were sampled in February 2020 and April 2021 and documented.

Cool / mild burn

Moderate burn

Hot to very hot burn

Birdwood – Soil Carbon Results 2021

Following the Cudlee Creek bushfire, several sites were sampled in February 2020 and April 2021 to assess and compare soil carbon concentration (OC) post-fire.

Sampling method

Several samples were collected in 2020 from various burn classes: very hot, hot, moderate, cool and unburnt. Sites that were able to be located were re-sampled on 14th April 2021. Area 1 included hot, moderate, and unburnt (b) and Area 2 cool burn (see *Image 1*). Additional unburnt sites in Area 1 (a) and 2 were included to assess soil C variability (unburnt a and b) and for future comparison.

Image 1: Site map of 2021 sampling sites. Birdwood, SA.

For each site, 10 soil samples were collected within a five-metre radius around a central point from depths 0-5 cm and 5-10 cm. Soil samples were analysed for Organic Carbon using the Walkley-Black method (OCwb), Total Carbon (TC) measured by a LECO analyser and pH in calcium chloride (pH_{CaCl2}).

Results

2021

There was high variability in OC percentages between all sites, with no clear trend *(Table 1)*. Sites Unburnt a and Unburnt b (located 5 metres apart), observed a difference of 1.04% at 0-5 cm, highlighting this variability. The lowest OC value was recorded at Unburnt a (3.74%), and the highest at Moderate burn (5.3%). The Moderate burn site also observed the greatest decrease in OC from 0-5 to 5-10 cm, 3.18%.

Total carbon (TC) results were similar for organic carbon. A conversion factor of 1.07 can be used to convert OCwb to TC results (recovery rate of 88%).

Site Unburnt b observed the highest pH (5.97), and the Mod burn, the lowest (5.58).

As the 2021 samples were not collected from the same sampling locations as 2020, there is inherent variability in the results. The 'very hot burn' site was not sampled in 2021.

Image 2: sample sites under various burn categories, 12-months post-fire.

Table 1: *2021 results for soil organic carbon (OC), total carbon (TC), and pH.*

		Area 1				Area 2	
	Depth (cm)	Hot burn	Mod burn	Unburnt a	Unburnt b	Cool burn	Unburnt
OC (%)	0-5	4.76	5.30	3.74	4.70	3.92	5.05
	5-10	2.67	2.12	2.13	1.64	1.64	1.87
	Avg. 0-10	3.72	3.71	2.94	3.17	2.78	3.46
TC (%)	0-5	5.86	6.09	4.42	5.31	5.10	5.60
	5-10	3.84	2.52	2.04	2.86	2.11	2.27
	Avg. 0-10	4.85	4.31	3.23	4.09	3.61	3.94
pH ($CaCl_2$)	0-5	5.85	5.58	5.91	5.97	5.84	5.66
	5-10	4.27	4.95	5.72	5.53	5.48	5.41
	Avg. 0-10	5.06	5.27	5.82	5.75	5.66	5.54

Comparison 2021 to 2020

Soil OC and TC results show little variability between years for hot and moderate burn categories (*Table 2*.) The larger variation in cool and unburnt may be due to inaccurate location. In 2020, there was a decrease in OC as burn intensity increased. In 2021, this trend was reversed, with higher OC in the higher burn classes, and considerably lower OC and TC at the Cool burn and Unburnt b sites. A lower soil pH in the hot burn in 2020 increased in 2021 to be similar to other sites.

Table 2: *soil OC and TC percentages, at 0-5 cm depth, recorded under various burn conditions. Comparison between 2020 and 2021.*

		Hot burn	Mod burn	Cool burn	Unburnt b
OC (%)	2020	4.51	5.10	5.44	5.66
	2021	4.76	5.30	3.92	4.70
TC (%)	2020	5.84	6.09	6.11	6.01
	2021	5.86	6.04	5.10	5.31
pH ($CaCl_2$)	2020	5.17	5.71	6.02	5.87
	2021	5.85	5.58	5.84	5.97

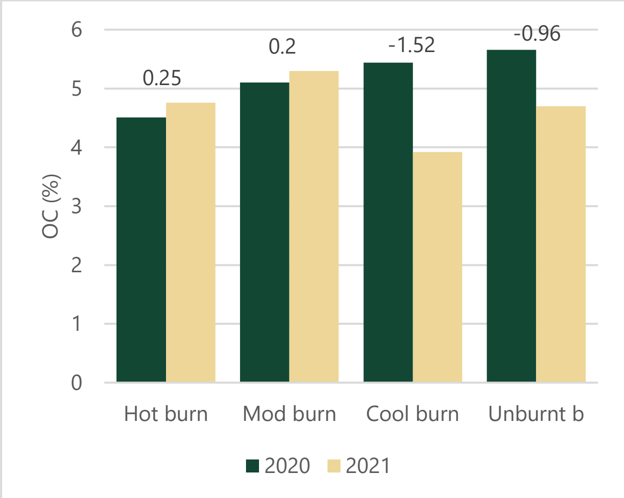


Figure 1: comparison of soil OC percentage at 0-5 cm depth across different burn categories over a 12-month period. Difference in soil OC percentages are shown above each burn category. E.g. there was a 0.25% increase in OC over the 12-month period at the Hot burn site.

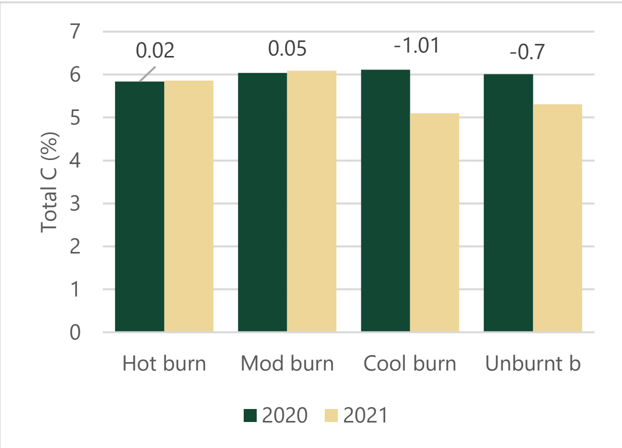


Figure 2: comparison of TC percentage at 0-5 cm depth across different burn categories, over a 12-month period. Difference in TC percentages are shown above each burn category. E.g. there was a 1.01% decrease in TC over the 12-month period at the Cool burn site.

Charleston – Soil Carbon Results 2021

Following the Cudlee Creek bushfire, several sites were sampled in February 2020 to assess soil carbon stocks. These sites were resampled in 2021 to record and compare soil carbon post-fire.

Sampling method

In line with the 2020 sampling method, a total of 20 soil samples were taken by hand. These samples were collected within a five-metre radius of a GPS centre point at 0-5 cm, 5-10 cm and 10-20 cm depths. Sampling was conducted on 14th April 2021.

The sampling depths differed to 2020, where only 0-10 cm and 10-20 cm were sampled and analysed.

Soil samples were analysed for Organic Carbon using the Walkley-Black method (OCwb), and Total Carbon measured by a LECO analyser.

Results

Soil organic carbon and total carbon have remained within levels of natural variability *(Table 1)*. *Figures 1* & *2* show a comparison of soil carbon percentages by year, at 0-10 cm and 10-20 cm depths.

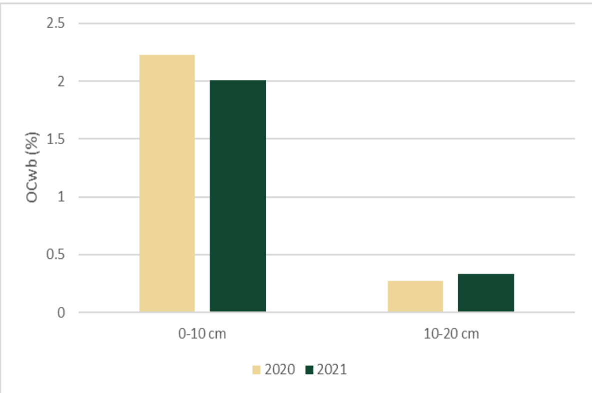


Figure 1: comparison of soil organic carbon percentage at 0-10 cm and 10-20 cm, over a 12-month period.

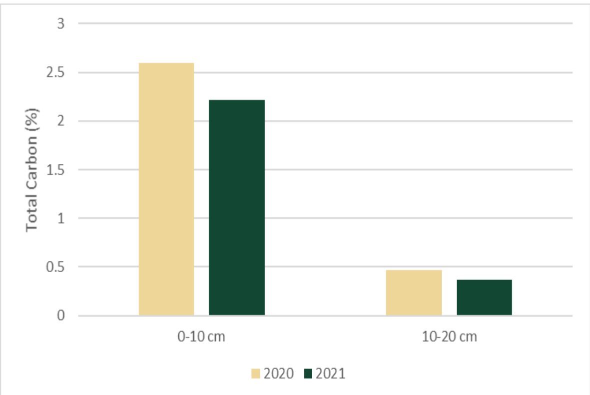


Figure 2: comparison of soil total carbon percentage at 0-10 cm and 10-20 cm, over a 12-month period.

Table 1: soil organic carbon and total carbon percentages at various depths, for years 2020 and 2021.

	Depth (cm)	2020	2021
Organic Carbon (%)	0-5	-	2.94
	5-10	-	1.08
	0-10	2.23	2.01
	10-20	0.27	0.33
Total Carbon (%)	0-5	-	3.23
	5-10	-	1.20
	0-10	2.60	2.22
	10-20	0.47	0.37

Kenton Valley – Soil Carbon Results 2021

Following the Cudlee Creek bushfire in February 2020, several sites were sampled to assess soil carbon stocks. These sites were resampled in 2021 to record and compare soil carbon post-fire.

Sampling method

In line with the 2020 sampling method, a total of 20 soil samples were taken by hand. These samples were collected within a five-metre radius of a GPS centre point at 0-5 cm, 5-10 cm and 10-20 cm depths. Sampling was conducted on 14th April 2021.

The sampling depths differed to 2020, where only 0-10 cm and 10-20 cm were sampled and analysed.

Soil samples were analysed for Organic Carbon using the Walkley-Black method (OCwb), and Total Carbon measured by a LECO analyser.

Results

Soil organic carbon and total carbon show an increasing trend in the 10-20 cm depth and within the range of inherent variability for 0-10 cm *(Table 1)*. *Figures 1* & *2* show a comparison of soil carbon percentages by year, at 0-10 cm and 10-20 cm depths.

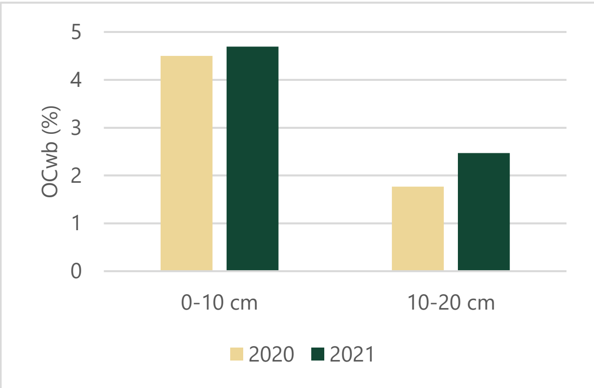


Figure 1: comparison of soil organic carbon percentage at 0-10 cm and 10-20 cm, over a 12-month period.

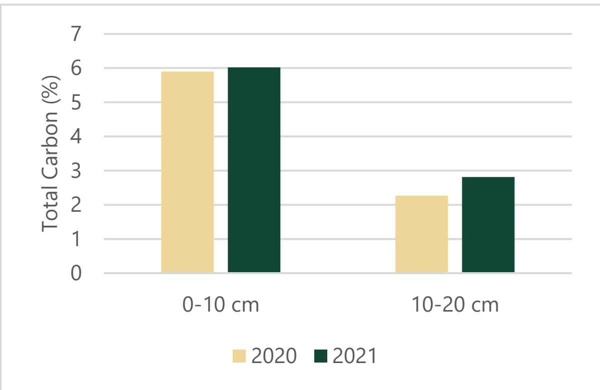


Figure 2: comparison of soil total carbon percentage at 0-10 cm and 10-20 cm, over a 12-month period.

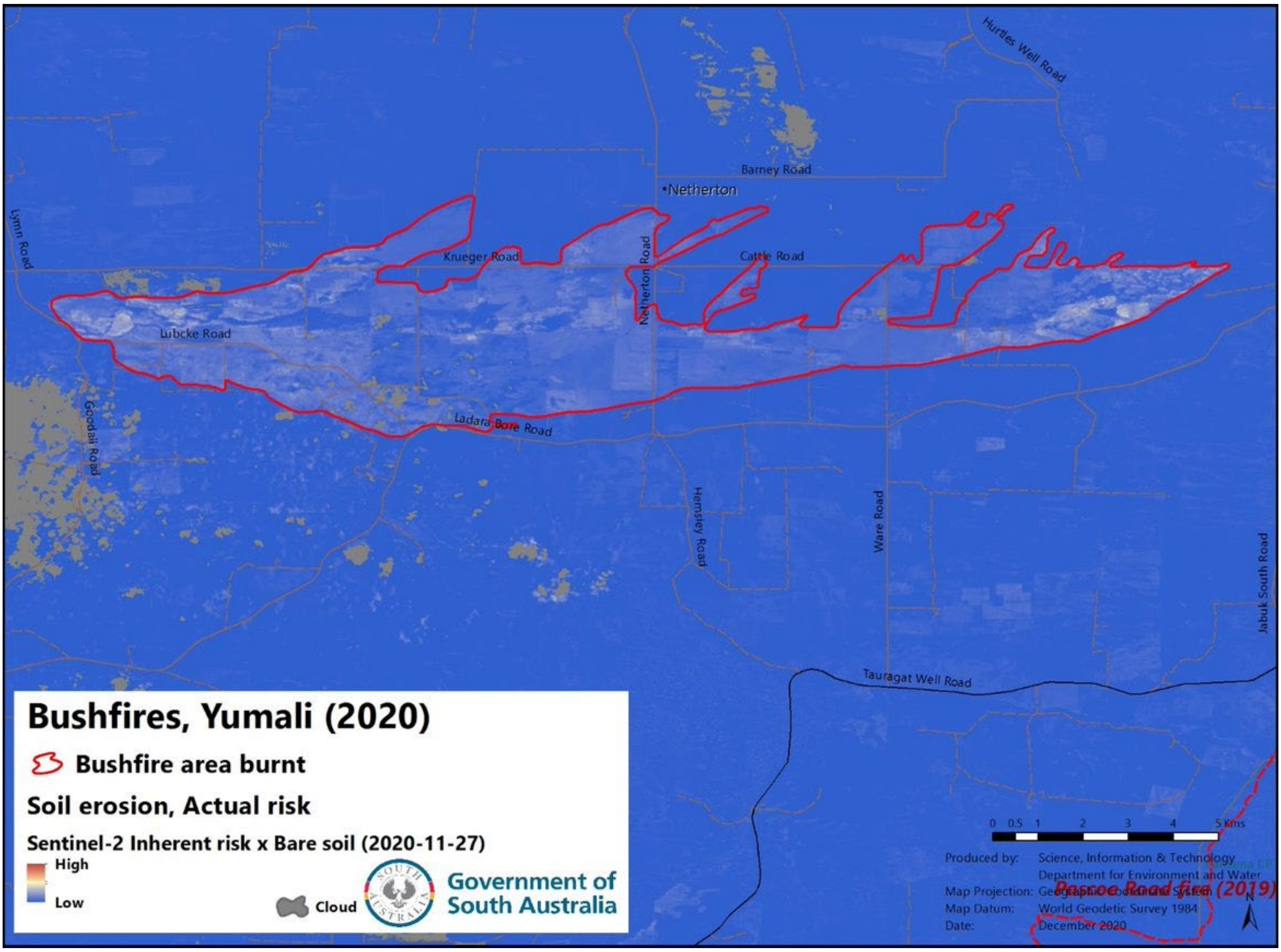
Table 1: soil organic carbon and total carbon percentages at various depths, for years 2020 and 2021.

	Depth (cm)	2020	2021
Organic Carbon (%)	0-5	-	4.44
	5-10	-	4.95
	0-10	4.50	4.70
	10-20	1.77	2.47
Total Carbon (%)	0-5	-	6.44
	5-10	-	5.59
	0-10	5.90	6.02
	10-20	2.27	2.81

Yumali

Yumali	November 2020 5,000 ha
Land Use	Cropping – cereals, pulses Livestock grazing – annual pastures
Fuel load (type and amount) at soil surface	Annual pastures – low Standing (unreaped) crop – low Crop residues - moderate
Effects of fire on soil properties	Soil tests undertaken for range of nutrients and OC suggested no difference between burnt and unburnt land.
Effects of fire on land	Wind erosion particularly on cropped sandy loam soil types; less severe on deeper sands where veldt grass regerminated after fire.

Soil erosion after the Yumali fire raised significant concern for affected land holders but an assessment of the soil types in the burnt area indicated that relatively small areas were at high risk of erosion.
A fact sheet identifying the soil types and their properties was produced so that land managers could make appropriate treatment decisions based on soil types.



Fact sheet

Yumali Bushfire Recovery

Soil Erosion Management Control Options

The Yumali fire affected land over a range of soil types. The dominant land system affected is described as the Sherlock Land System (DEW Envirodata) and is characterised by flats, with low sandy and stony rises. The main soils are predominantly grey and red sandy loams over calcrete with some shallow soils on stony areas and deeper sands and sand over clays on sandy rises. Some heavier and deeper soils are present in lower flats. The Sherlock Land System changes on the western, eastern and southern areas affected by the fire and in all cases become more sandier with a greater incidence of deep sand and sand over clay.

This document presents the key soil types and the options which may be available to reduce wind erosion within the Yumali fire scar.

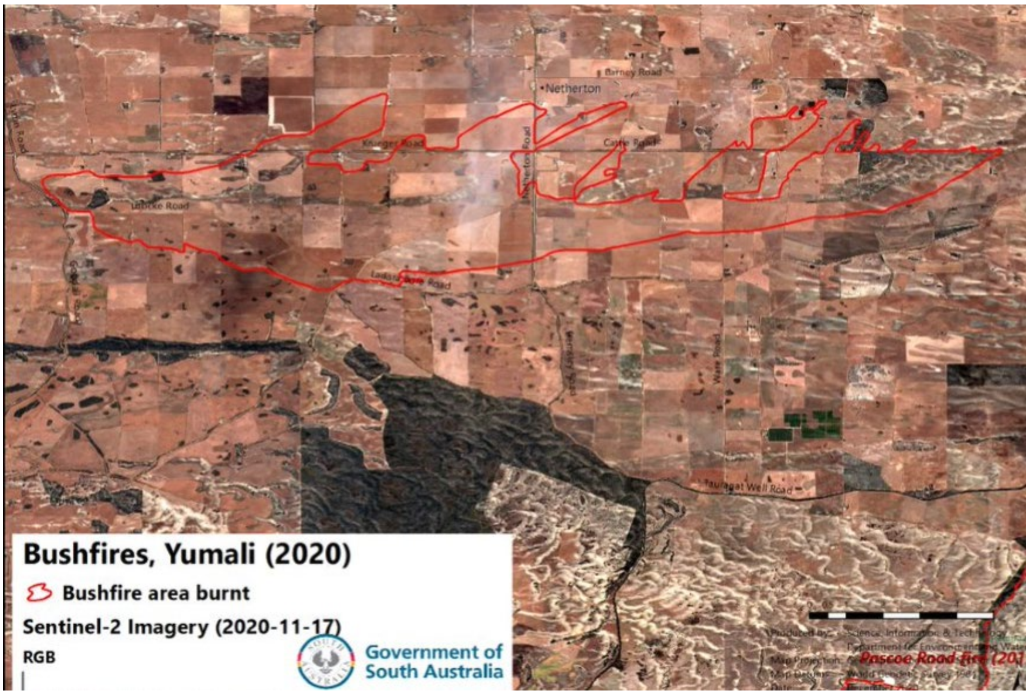


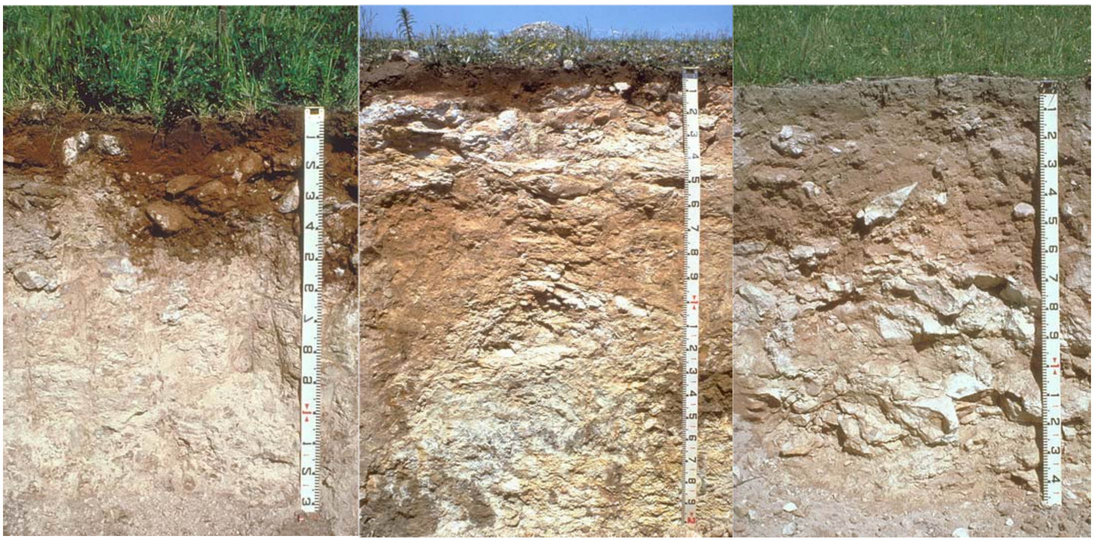
Image 1: Yumali bushfire scar

Contact Brian Hughes Email: brian.hughes@sa.gov.au
Phone: 0429691468
pir.sa.gov.au

Key Soil Types and Options for Erosion Control

Sandy Loam Over Calcrete

Image 2: Soil characteristics of a Sandy Loam Over Calcrete – the soil above the calcrete varies in depth, texture and colour.



Red Sandy Loam over Calcrete

Brown Sandy Loam over Calcrete

Grey Sandy Loam over Calcrete

Management control options for Sandy Loam over Calcrete soils include:-

1. Do nothing – where some cover or crowns of plants persist may be best to leave- avoid grazing or vehicle movement. Sometimes sandy loams will develop an armour or crust with loose material above it that prevents further soil damage- see photo below

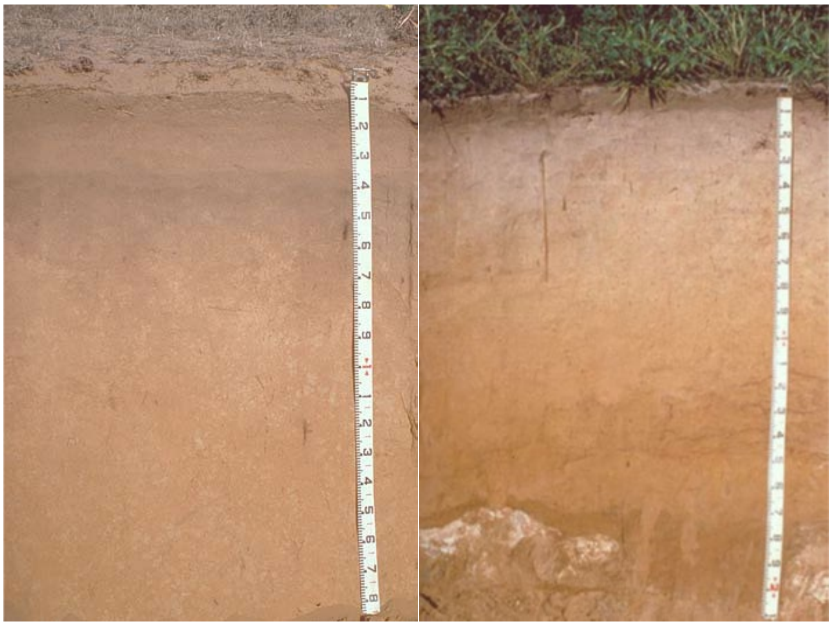
2. Patches where sweeping wind erosion is occurring: consider the use of emergency tillage This will only work on areas with suitable soil depth and soil strength and may require patching deeper areas out. Suggest trying a few runs first with a cultivator with half the tynes removed and see if you can bring up clods and avoid bringing up calcrete which will create issues later. Clods need to be around fist sized; avoid any sandier areas as clods will not persist.

3. Topdressing with pig + manure can provide cover on bad areas provided manure is lumpy and not too much straw which may blow away. Rates of around 5t/ha have been used.

4. Summer emergency cropping maybe possible if a significant rain event happens on bad areas. (>50 mm, sow immediately leaving ridged surface)

Deep Sand

Image 3: Soil characteristics of a Deep Sand profile.



Deep Sand (buried top soil) | Deep Sand over clay and calcrete

Management control options for Deep Sand soils include:-

Options include

1. Do nothing – where significant perennial grasses persist (e.g. veldt and primrose) and crowns have mostly survived the fire, erosion will be reduced. If a rain event happens these areas will regenerate.
2. For small patches where sweeping wind erosion is occurring within a larger paddock that is mostly stable, consider topdressing with pig manure or similar to improve stability on these areas and protect rest of paddock.
3. If intending to clay the paddock, consider claying these areas with 100-200t/ha of clay as soon as possible. This will provide protection this year and strengthen the soil. Test clay before application to ensure it is suitable and modify the application rate according to clay content.
4. Summer emergency cropping is only an option on areas that have been regularly cropped and possible when a significant rain event happens (>50 mm). Sow immediately (with press wheels to pack sand while sand is wet) to enable sufficient plant growth for surface cover under high evaporation conditions after sowing. In pasture areas there might be enough cover from various seeds and crowns if a rain event occurs.

Sand over Clay

Image 4: Soil characteristics of a Sand over Clay profile.

Thick Sand Over Clay

Shallow Low Sand over Clay

Sand over Clay

Management control options for Sand Over Clay soils include:-

1. Do nothing: where some cover or crowns of plants persist it may be best to leave them untouched. Avoid grazing or vehicle movement. Sometimes shallow sands over clay will develop an armour or crust which has loose material above it and prevents further soil damage- see photo below. Where significant perennial grasses persist (e.g. veldt and primrose) and crowns have mostly survived the fire, erosion will be reduced and if a rain events happens these areas will self regenerate.

2. If intending to clay, areas can be delved or clayspread with 100-200t/ha of clay as soon as possible. Note delving is generally considered much cheaper than claying, but need to ensure clay can be successfully brought to the surface to provide soil protection – will need to patch areas out for delving. Deeper areas of sand (> 50-70cm) may need to be clay spread as well. This will provide immediate protection.

3. The shallow loamy sand shown above could possibly be ripped provided ripping tynes bring some clods of clay to the surface to protect against wind. Remove tynes to give a wider spacing if too much clay is brought to the surface.

4. Summer emergency cropping may be an option on areas which have been regularly cropped and possible when a significant rain event happens (>50 mm). Sow immediately (with press wheels to pack sand while sand is wet) to enable sufficient plant growth for surface cover under high evaporation conditions after sowing. In pasture areas there might be enough cover from various seeds and crowns if a rain event occurs.maybe possible if a significant rain event happens (>50 mm and comments as above for sand). In pasture areas may find enough cover from various seeds and crowns if a rain event occurs.

Examples of Soil Erosion Management Control Methods

Soil Armouring/crusting

Sometimes surface soil will develop an armour or crust below loose material, preventing further soil damage.

Emergency Tillage

May only be successful as a management control on areas with suitable soil depth and soil strength.

Clay Spreading

If intending to clay the paddock, consider claying these areas with 100-200t/ha of clay.

Pig Manure

Pig manure can be applied at 5-6 t/ha.

Further References

The Coorong District Council has established a Yumali fire recovery website. The following resources can be viewed at this weblink:

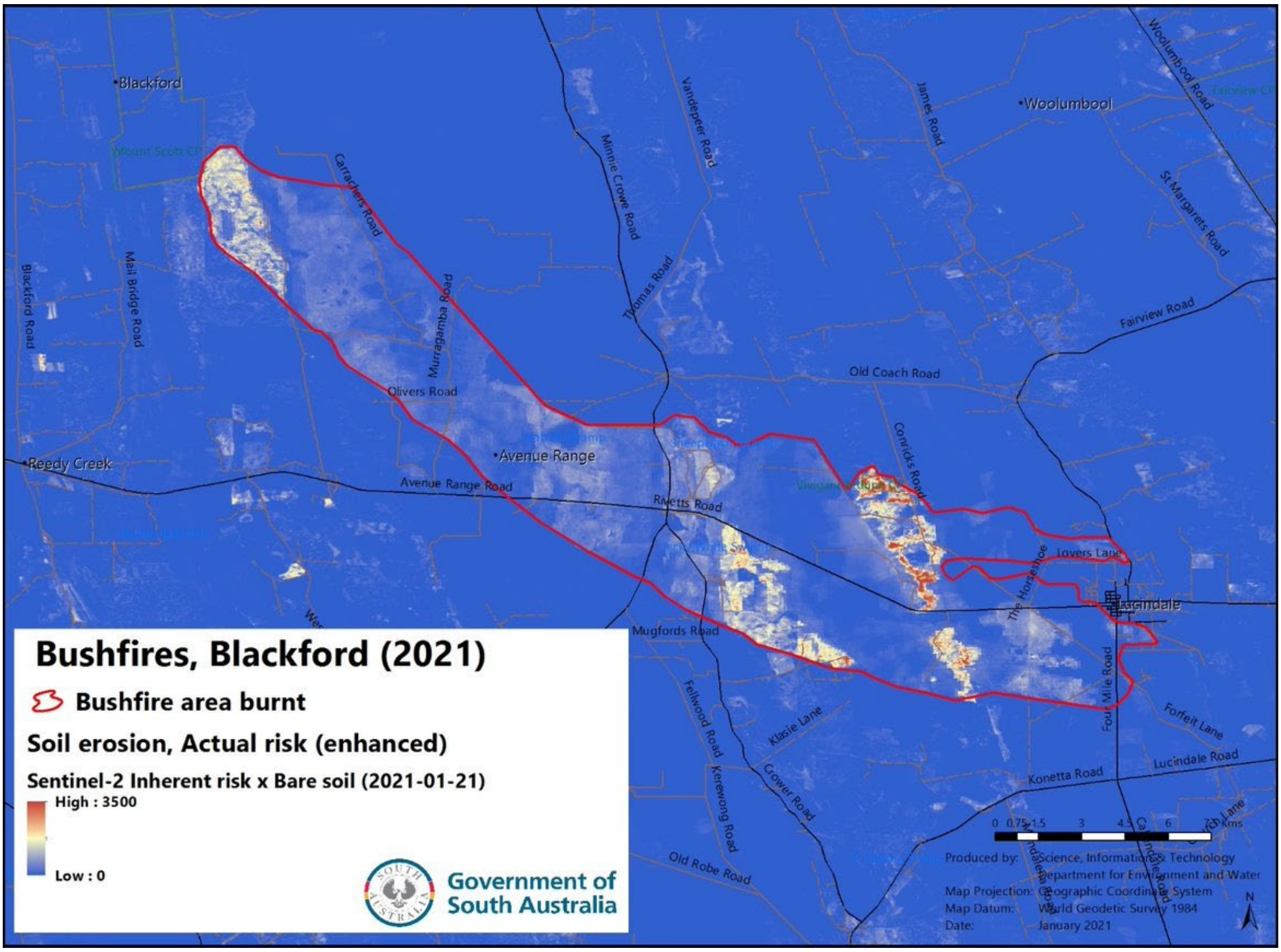
https://www.coorong.sa.gov.au/council-services/coorong-tatiara-local-action-plan/bushfire-recovery

- Murraylands and Riverland Landscapes SA - Post fire management in broadacre farming
- PIRSA – Emergency measures to curb wind erosion.

Blackford

Blackford	January 2021 14,100 ha
Land Use	Livestock grazing – perennial pastures Hay production – cereals, lucerne Cropping - cereals
Fuel load (type and amount) at soil surface	Bales of hay in paddock – high Perennial pastures e.g. Phalaris – moderate to high Crop residues - moderate
Effects of fire on soil properties	None apparent. Dung beetle numbers before and after fire were unchanged.
Effects of fire on land	Increased risk of wind erosion on sandy soils due to loss of surface cover.

A relatively small area of sandy soil was at high risk of wind erosion following the Blackford fire. Perennial pastures quickly started generating new growth, stabilising the soil surface. Areas of hot burns were noted under hay bales in paddocks so it is suspected that these areas will take longer to recover.



Appendix 2

Fact sheets related to soil management after fire.

Emergency measures to curb wind erosion

Wind erosion on agricultural land is usually avoided or mitigated by keeping soils covered by vegetation and minimising soil disturbance by machinery or animals.

Occasionally soils become bare of cover or are loosened to the extent they start to suffer wind erosion. This occurs at times such as during drought, after fire, following clover harvesting or on areas that have been heavily stocked for a length of time.

During these times “emergency” measures can be taken to prevent or check wind erosion. These are treatments that stabilise the soil until protective cover can be re-established on it.

The aim of these treatments is to roughen the soil surface, reduce the velocity of wind sweeping over it and deflect the wind upwards and away from the ground.

The importance of clay and clods

Soil texture, or more specifically the amount of clay in the soil, is a key factor in deciding which treatment to use.

The aggregation, or “cloddiness” of a soil is important in protecting soils from wind erosion. In a small clod of clay there are millions of particles bound together by ionic bonds, electromagnetic forces and organic matter. Clay also has the ability to store more water in its matrix thus making the soil heavier and harder to be picked up and carried by wind. Sandy soils are made up of singular, inert particles that are often only bound together by water.

Forming "ribbon" of soil to assess clay proportion

The texture of the soil at risk of erosion, both in the topsoil and layers beneath, can be determined by doing a field texture test. This is done in the paddock by dampening and moulding soil in the hand, then squeezing the soil between the thumb and forefinger. The length of the ribbon of soil formed indicates how much clay is present in the soil. (YouTube videos on the internet show how to assess soil textures in the paddock).

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Texture	Clay %	“ribbon” length
Sand	< 5	0
Loamy sand	≈ 5	5 mm
Clayey sand	5–10	5-15 mm
Sandy loam	10-20	15-25 mm
Loam	≈ 25	≈ 25 mm
Sandy clay loam	20– 30	25–40 mm
Clay loam	30–35	40-50 mm
Light clay	35–40	50-75 mm
Heavy clay	> 50	>75 mm

Select treatment based on soil type

Where soils have sufficient clay (> 20 %), wind erosion treatment measures involve roughening the soil surface by leaving clods of soil on the surface which slow and break up wind flow. This is done using tillage machinery.

In soils with very little clay, adding and mixing clay into the topsoil will help it aggregate and form clods of soil more resistant to wind erosion. Adding clay to sandy topsoils can also have long term benefits such as improved water holding capacity and fertility. However, the clay must not be sodic or high in carbonate as these attributes will cause problems in the topsoil.

Soil type	Treatment
Sandy loam to heavy clay	Rip or cultivate to leave clods on surface.
Sand over clay - clay within 60 cm of surface	Rip into clay layer; bring clay to surface; level and incorporate (delving).
Sand over clay – clay within 1m of surface	Remove surface soil to expose clay; extract clay; spread, level and incorporate into sand (clay spreading).
Sand, loamy sand, clayey sand > 1m depth	Do nothing. Import clay; spread, level and incorporate into topsoil (clay spreading).

“Do nothing”

Disturbing the soil will break up soil aggregates to some extent and dust rising from machinery, vehicle and animal movements is evidence of this.

Before deciding on what action to take, inspect the eroding area. Sandy soils can develop an “armouring” following wind erosion where the finer particles are winnowed out of the top few millimetres of soil. A thin layer of heavier, coarser particles that are more resistant to erosion, is left on the surface. Keeping this surface seal intact can provide some protection against wind however it will not withstand the erosive force of strong winds laden with dust. Care must also be taken that the surface layer is not disturbed by vehicles or animals.

“Doing nothing” is an option if surface armouring has developed, windy weather has abated, and it is likely that sufficient rains to stimulate plant growth will fall within a few weeks.

Ripping or cultivation

Cultivation can be implemented quickly although now that many farmers are practising no-till or zero-till farming, suitable machinery might not always be readily at hand. The most difficult matter to decide is whether to minimise disturbance of the soil as much as possible by cultivating sparingly in strips, or to roughen the whole area by cultivating it all.

If erosion is not already occurring, using a single tine ripper to create a deep furrow with high cloddy ridges might be sufficient as a preventative measure. Rip lines can be spaced 10 – 20 metres apart. On sloping land, rip lines on the contour of the land will reduce the risk of water erosion. Strips of rough cultivation can also break up wind sweep across bare, open areas and is often used after clover harvesting or stone picking.

Ripping after medic harvest.

Ripped furrows on pastoral land.

Where land is eroding, a cultivator to work strips of land or the whole area might be required. Cultivation should aim to make the soil surface as cloddy as possible. Digging below the usual tillage depth and travelling very slowly will bring more lumps to the surface. Working at normal tillage speeds tends to break clods up more and create more dust.

Strip cultivation on burnt land

On very clayey soils, one cultivation should be sufficient to reduce wind erosion and provide protection until enough rain falls to stimulate plant growth. However, the rough condition of the soil will make it difficult for spraying and seeding operations so some form of levelling (e.g. rolling) might be required. The ridges and clods on less clayey, cultivated soils will slump and furrows will fill with soil over time. Consideration will need to be given as to whether these soils should be cultivated again, based on the likelihood of windy weather and rain.

Loam soil cultivated with narrow points

Clay clods brought to surface by 15 cm depth cultivation

Sandy soil starting to slump and furrows filling within a few days of cultivation

Clay spreading and delving

Clay spreading and delving treatments require careful planning and implementation to ensure they work well. Special machines are needed that are not always readily available. Finding machinery or contractors to do the work takes time so wind erosion on sandy soils might not be able to be treated immediately.

Good analysis is required of the soil over the whole area to be treated, the clay to be used and calculation of rates to be spread or delved. Planning how the clay will be incorporated or the surface levelled is also necessary so that when rain falls, the treated area is ready to be sown.


Clay delved and spread over sandy rise.

Adding clays to sandy topsoils can improve soil fertility and water-holding capacity, and overcome non-wetting problems, leading to improved plant growth. If it is undertaken as part of an overall soil improvement program, it will also improve the soil's resistance to wind erosion.

Further information on clay spreading and delving is available in "Spread, delve, spade, invert: a best practice guide to the addition of clay to sandy soils" available from the Grains Research and Development Corporation's website and other websites.

Protecting assets from soil deposition

Severe wind erosion can lead to soil accumulating in, around or on top of buildings, fences, trees, roads, troughs, tanks, pipes and pumps. Temporary wind barriers can be made around or on the windward side of assets to trap soil before it reaches them. Barriers can be made of bales of straw or hay, shadecloth and iron droppers or other such materials. They will become buried under soil so must be able to be cleaned up and removed later.

Recovering after fires – Land management

There are a number of factors for landholders to consider when restoring their agricultural land and properties after fires.

Erosion risk

Burnt areas can be protected from further damage and assisted in their rehabilitation by minimising soil disturbance. Keeping stock and vehicles off, and fencing off particularly vulnerable areas such as sandy rises can stop the soil becoming loose and powdery. Temporary wind breaks using shadecloth and iron droppers or straw bales can be used to stop accumulation of soil around troughs or gateways.

Partially burnt paddocks can be protected by putting up temporary (e.g. electric) fencing to keep stock off burnt areas. Allow plants to establish and grow so that they can provide surface cover and anchor the soil. Herbicides can be used to control weeds when they are at a growth stage that provides surface cover but won't cause problems at sowing time.

Water erosion

The risk of water erosion is significant on bare sloping land especially on sandy loam to clay textured soils. Should heavy rain fall, it will tend to run off rather than soak in, particularly on slopes. Bare, hilly land upstream will shed water quickly so there is a potential for flooding.

Wind erosion

Roughening the surface of soils susceptible to wind sweep will deflect wind away from the soil surface and can be done using a tyned implement such as a seeder bar, cultivator or a pipeline-laying ripper. This will bring clods of soil to the surface to act as wind barriers on the soil surface. Ripping on sandy soils is ineffective unless subsoil clay is brought to the surface. Clay spreading or delving might be an option if suitable clay is available or present in the subsoil. More information on these measures to curb wind erosion is contained in the Fact Sheet Emergency Measures to Curb Wind Erosion.

Dams and Watercourses

Runoff from burnt sloping ground will carry debris into dams, fouling the water and making it undrinkable. Runoff will scour bare watercourses. Sediment traps in watercourses above dams in the water course

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can filter the runoff, allowing water to flow through to the dam while trapping silt and debris. Small hay bales pegged down with droppers, chicken wire or coco-fibre logs anchored across the watercourse, can be effective.

Re-fencing and re-establishment of watering points

These are often a priority for many landholders and the temptation is to get it done as quickly as possible. However, there are some risks and missed opportunities in rushing these tasks.

Along fence lines, dead trees and limbs from burnt trees will be falling for quite a while and heavy rain might wash fallen timber and other debris onto fences in creek lines.

The boundary fence is the only one that has to go back where it was. Do all the other fences have to go back where they were? Does it have to be the type of fence it was before? Take the opportunity to rethink paddock layout and improve it if possible. Consider fencing to soil types or production zones and using laneways for stock and machinery movement.

Review the location of water tanks, pipes and troughs – consider if putting these back in their original location is the best option.

NatureMaps is a South Australian government website where aerial photographs of properties can be viewed and used for planning layout of fences and watering points.

Livestock feeding

The broad options for maintaining livestock condition after a fire are the same as for a drought – sell, agist or confinement-feed.

Information on confinement feeding of stock is available in Feeding and Managing Sheep In Dry Times

If bringing in hay or grain from unknown sources, be wary of weed seeds. Feed stock in a small area so that weed seed distribution is limited.

Establishment of feed on burnt land

Plants that bury their seed or have growing points below the surface should be best able to survive the effects of a fire. Perennial plants with larger crowns (therefore more root mass underground) can be expected to survive therefore established phalaris, lucerne and native grasses should regenerate reasonably well.

Some annual grasses produce very little dormant seed. Eighty to ninety per cent of the seed in one season will germinate in the following autumn. Fire can therefore drastically reduce the number of these. Other grasses such as wild oats, brome grass and silver grass seed can persist for a long time in the soil so these are most likely to regenerate.

On land that is not cropped, Salvation Jane and Geranium can take advantage of the lack of competition on bare ground and grow prolifically.

Medic and clover seed on the soil surface will be damaged or destroyed by fire but buried seed will have some protection.

While fires can destroy all above ground vegetation, it does not necessarily mean that organic matter below the soil has been lost. Inspection of the ground surface and digging the soil will often reveal intact plant butts and roots.

Soils under areas that have been subjected to prolonged or very hot burns, such as under gum trees, haystacks or vigorous, ungrazed pastures, can suffer more damage. They can lose significant amounts of nitrate, some organic matter, be partially sterilised or lose soil structure.

Thoroughly soaking an area of burnt land to simulate rainfall and then observing what germinates following the “rain” can provide an indication of what is likely to grow in the paddock. A metal ring (such as a large steel can or a piece of bore casing) embedded in the soil and then filled with water can be used. The ring acts as a dam, allowing water to soak into the soil. Keeping the ring covered with a bag or shade cloth will reduce evaporation of water from the soil.

Feral pest control

Rabbit warrens and foxholes will have been exposed so will be more obvious. As debris is being cleaned up and fences renewed, there is also an opportunity to clean up warrens and foxholes.

Effect of fire on gypsum and lime stockpiles

Fire should not affect the effectiveness of lime and gypsum. However, the condition of the material and its ability to be spread should be checked to see that it has not become too hard or lumpy. Gypsum and lime piles in a paddock are more likely to be affected by rain than by fire. There is a risk that fine gypsum and lime spread on bare soil might blow away but this is balanced against the need to apply these products well before sowing crops and pastures to allow them to react in the soil.

Ash

Ash is alkaline and contains significant amounts of the essential plant nutrients phosphorus and potassium. Ash in soil samples can skew nutrient analyses so avoid including ash when collecting soil samples for nutrient analysis. The nutrients in ash will be readily taken up by new plant growth.