

The effect of time since fire on the cover and composition of cryptogamic soil crusts on a eucalypt shrubland soil

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D.J. Eldridge¹ & R.A. Bradstock² (¹Department of Conservation & Land Management, PO Box 77, Condobolin, NSW 2877* ²NSW National Parks & Wildlife Service, PO Box 1967, Hurstville, NSW 2220) 1994. The effect of time since fire on the cover and composition of cryptogamic soil crusts on a eucalypt shrubland soil. *Cunninghamia* 3(3): 521–527. We investigated the cover and composition of cryptogams at a number of mallee (*Eucalyptus* spp.) sites with different periods of recovery since fire. Total cryptogam cover increased with time since fire, and maximum cover of 52% occurred at sites with 16 years of recovery since fire. Increasing the interval since fire increased the contribution of crustose lichen to total cover and decreased the contribution by algae. The results suggest that fires less than ten years apart are generally likely to maintain cryptogam cover at low (< 20%) levels and lead to a dominance by algae.

Introduction

Eucalypt shrublands occupy an extensive area of Australia, and their ecological and economic significance is well established (Noble & Bradstock 1989). Mallee eucalypts (*Eucalyptus* spp.) are restricted to aeolian soils (Eldridge 1986), which are weakly structured, highly erodible by wind and water, and characterised by low levels of organic matter and available nutrients. In these communities, cryptogamic soil crusts occupy large areas of ground between individual shrubs. These crusts, which comprise mosses, lichens, algae and liverworts, help to stabilise the soil surface against water erosion (Fletcher & Martin 1948, Eldridge & Greene 1994). Their presence is linked to changes in vascular plant survival and nutrient cycling (West 1990).

Fires are a feature of many semi-arid landscapes, and occur regularly in eucalypt shrublands of eastern Australia (Bradstock 1989, Noble 1984). As well as altering the structure and composition of the shrub and herbaceous layers, fires affect the cryptogamic components of the soil surface. Studies on different soil types in other semi-arid grazing systems (e.g. Greene et al. 1990, A.M. Gill pers. comm. 1993), have shown that fire has the capacity to destroy gels and mucilaginous sheaths associated with cryptogams and fungal hyphae in the crusts. This results in a breakdown in the spatial integrity of the crust, increased erosion (Kinnell et al. 1990) and reduced infiltration through a decline in aggregate stability and density of fungal hyphae (Greene et al. 1990).

Although the rate at which cryptogamic surfaces recover after fire has been variously reported in the literature for some soil and rangeland types, there are no data for aeolian soils. Reported rates for complete recovery in other systems vary from 4 years (Greene et al. 1990) to more than 20 years (Callison et al. 1985). In January 1992 we commenced a study to investigate the rate of recovery of cryptogamic soil crusts after fire, on an aeolian soil dominated by mallee species at a range of sites with different intervals since fire.

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Methods

Study area

The study was conducted in eucalypt shrublands at Yathong, Round Hill and Nombinnie Nature Reserves in central-western New South Wales (Figure 1). The landscape is characterised by long undulating sandplains with slopes of $< 2\%$ on which are superimposed subdued low rises to 2 m in relief. Soils on the sandplains are predominantly calcareous sands (Uc5.12; Northcote 1979) and those on the rises an assortment of calcareous sands and siliceous sands (Uc1.13; Northcote 1979).

Vegetation was similar on the sandplains and rises, with a shrub overstorey dominated by stunted mallees (particularly *Eucalyptus socialis*, *E. dumosa*, *E. leptophylla* and *E. gracilis*) and a perennial shrub understory dominated by *Acacia rigens*, *A. wilhelmiana*, *A. triptera*, *A. havilandii* and *Melaleuca uncinata*. *Callitris preissii* subsp. *verrucosa* was more common on the low rises, and *Triodia irritans* was locally dominant at all sites. Recently burnt sites possessed a ground layer composed of ephemeral forbs and grasses (e.g. *Haloragis odontocarpa*, *Goodenia* species, *Stipa* species.)

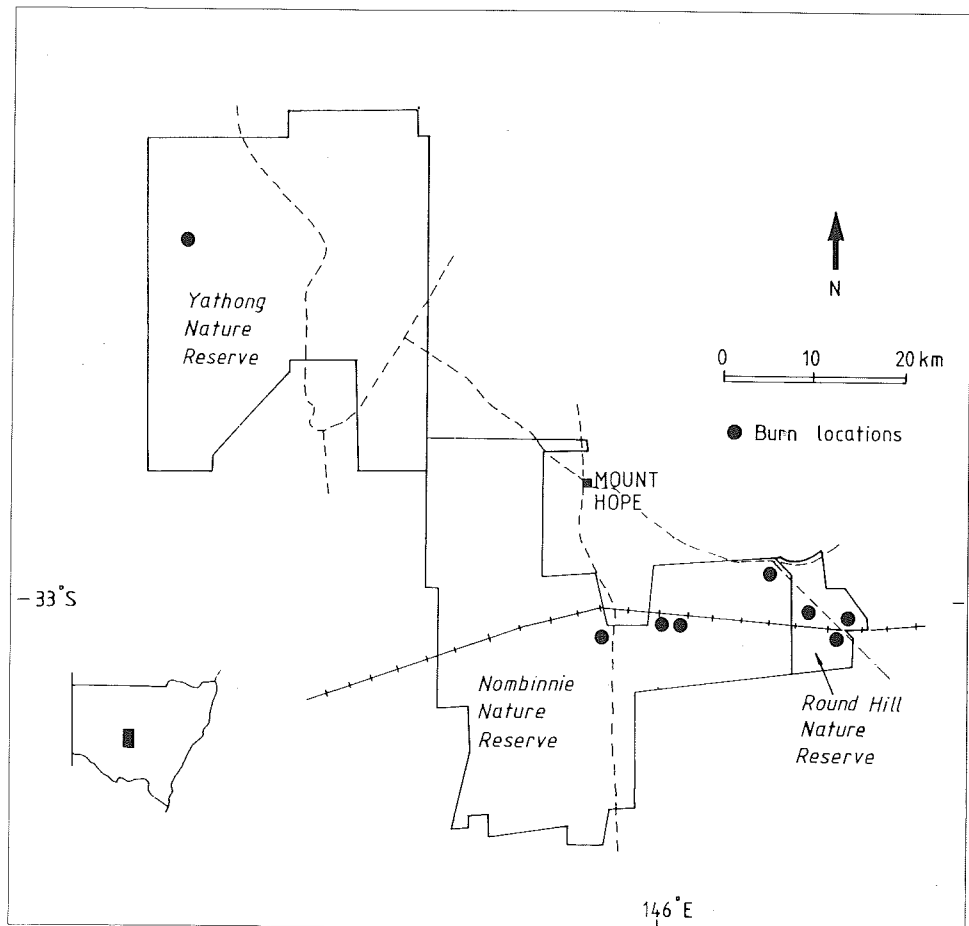


Figure 1. Location of the study areas in central-western New South Wales.

The fire treatments

In January and August 1992 we selected nine areas of mallee representing a broad range of fire histories. These areas represent times since last fire of 1, 3, 4, 7, 13, 16, 18, 35, and 100 years (Table 1). An additional block was measured 2 weeks after an experimental burn. Blocks varied in size according to fire history. Blocks at Yathong Nature Reserve (0, 1, 3 and 4 yrs) were either 100 X 100 or 200 X 200 m, and resulted from experimental fires (Bradstock et al. 1992). The 7, 13, 16, 18, 35 and 100 year fire histories were located on sites burned by wildfires and occurred over many hundreds of hectares. Fires in experimental blocks produced levels of fuel consumption and scorch in the vegetation that were visually similar to the study sites burnt by wildfires. Data for the 100 years since fire treatment were collected from three remnant areas of mallee dominated by *Callitris preissii* subsp. *verrucosa* located at Yathong (1 block) and Round Hill Nature Reserves (2 blocks). These remnant areas resulted from the progression of *Callitris preissii* subsp. *verrucosa* individuals from the understory into the overstorey, resulting in a diminution of fine fuel and hence fire frequency (Bradstock 1989, 1991). Time since fire in these sites was indirectly estimated from size measurements of dominant *Callitris preissii* subsp. *verrucosa* individuals relative to younger plants of known age at other nearby sites (Bradstock unpublished data).

Measurements

At each site a transect was laid out through a homogeneous area of mallee, along which 20, 0.25 m² quadrats were systematically sampled at 10 m intervals. On the smaller experimentally burnt sites, transects were laid out along the two plot diagonals. Transects were located on the sandplain units except for the 100 year treatments which traversed the small rises. One observer estimated the total cover of cryptogams, and the relative contribution to total cover of moss, algae and lichens. Previous studies (Eldridge 1993) have verified the accuracy of this method for estimating species composition. We have no data however on the composition of various taxa on

Table 1. Changes in the composition (%) of moss, algae and lichen with time since last fire (years). n indicates the number of quadrats used in the calculations and sem is the standard error of the mean.

| Time since fire (year) | Moss | | Algae | | Lichen | | |
|------------------------|------|------|-------|------|--------|------|-----|
| | n | mean | sem | mean | sem | mean | sem |
| 1 | 17 | 7.6 | 1.0 | 72.9 | 1.6 | 19.5 | 1.4 |
| 3 | 13 | 7.0 | 4.7 | 57.3 | 11.6 | 35.7 | 1.8 |
| 4 | 9 | 11.1 | 11.1 | 68.9 | 13.7 | 20.0 | 1.9 |
| 7 | 57 | 15.5 | 0.7 | 57.9 | 0.8 | 26.6 | 4.0 |
| 13 | 18 | 3.0 | 0.7 | 10.3 | 4.3 | 86.7 | 1.0 |
| 16 | 37 | 8.2 | 0.7 | 20.3 | 1.0 | 71.5 | 1.0 |
| 18 | 18 | 6.1 | 2.3 | 31.4 | 10.4 | 62.5 | 9.9 |
| 35 | 19 | 7.4 | 3.7 | 35.0 | 7.9 | 57.6 | 1.4 |
| 100 | 24 | 4.2 | 4.2 | 77.3 | 7.8 | 18.5 | 1.2 |

the plot at time zero. Apart from a general description of the main species found at the sites, we were only interested in broad cryptogamic taxa. Consequently cryptogams were pooled into either moss, lichens or algae.

Results

Fire resulted in a dramatic reduction in cryptogam cover from about 35% on a block last burned in 1985 (i.e. 7 years since fire) to 5% two weeks after fire. Cryptogam cover increased markedly with time since last fire, reaching a maximum of 52% at 16 years since fire. Cover then declined to < 2% at 100 years since fire. Within a single fire history, cryptogam cover was highly variable.

The moss flora at the sites was dominated by *Didymodon torquatus*, with smaller occurrences of *Bryum pachytheca*, *Desmatodon convolutus*, *Barbula hornschurchiana*, *Gigaspermum repens* and *Eccremidium pulchellum*. The lichen flora comprised *Endocarpum* spp., *Collema* spp. and *Psora decipiens*. Some other unidentified lichen and algae were present at the sites.

Mosses contributed very little to total cover, and their contribution to total cover was generally < 10% through time (Table 1). Composition of algae within the cryptogamic layer however was greatest shortly after fire (73% after 1 year), declining to low levels due to a gradual replacement by lichens (Figure 2). The 100-year-since-fire sites were dominated almost exclusively by algae, although total cover was < 2%. One-way ANOVA revealed no significant differences in composition of moss, lichen or algae due to the large spatial variation in composition between quadrats at any given site.

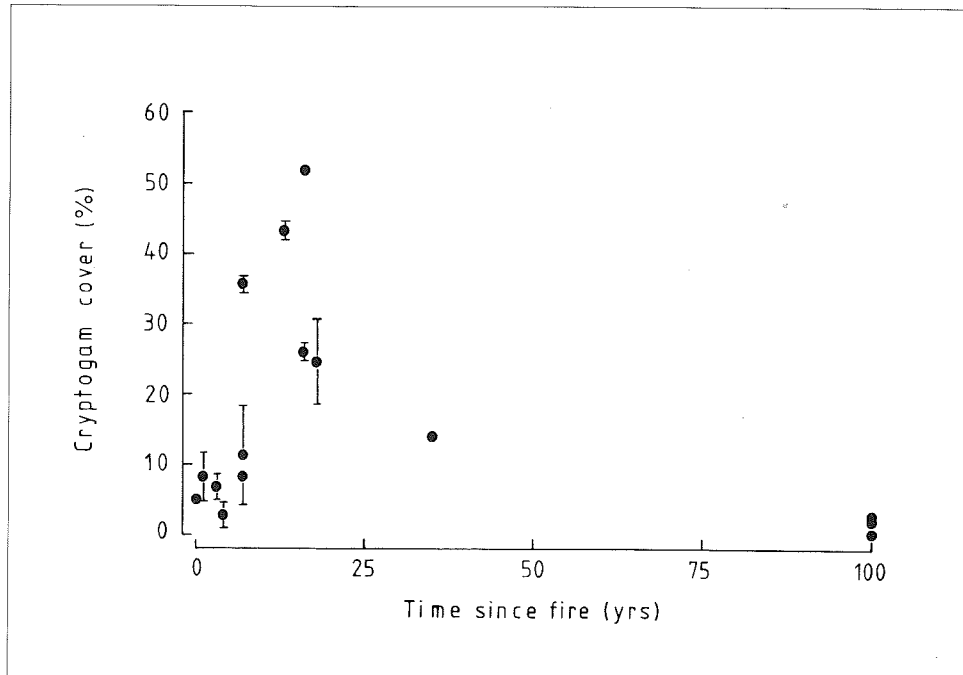


Figure 2. The relationship between total cryptogam cover (%) and time since last fire (years). Symbols enclose standard errors of the mean except where indicated.

Discussion

Non-vascular plants are primary stabilisers after major perturbations such as fire or grazing. In aeolian landscapes, where the post-fire soil surface is particularly unstable, largely due to saltating sand grains, little is known of the process of recolonisation by cryptogams after fire.

Effect of fire on total cover and composition

The results indicate that maximum cryptogam cover occurs 13–16 years after fire. At less than 7 years after fire, cryptogam cover is likely to be low (< 20%; Figure 1) and to be dominated by algae at the expense of lichen (Table 1). Fire failed to completely eliminate cryptogam cover on the plot measured two weeks after fire, as the main understory fuel *Triodia irritans* was only patchily distributed on the ground.

The only other data on post-fire recovery of cryptogams comes from studies on red earth soils in the semi-arid woodlands by Greene et al. (1990). These studies showed that cryptogam cover reached a maximum of about 60% four years after burning. This level probably represents the upper limit of cryptogam cover on red earth soils, and would be expected to decline in response to the development of stable cover of vascular plants. This maximum cover value is consistent with our observation of 52% for a sandy soil, but the time taken to achieve this was significantly greater in our study (13–16 years, Figure 1). Johansen et al. (1984) showed that there were still marked reductions in cover and frequency of moss, algae and lichen five years after burning. Similarly West and Hassan (1985) showed only partial recovery of moss and lichen from a Utah rangeland after 2 years. In a desert shrub community in Utah, Callison et al. (1985) reported that cryptogamic crusts had not recovered even 30 years after fire.

Greene et al. (1990) found that continual burning (yearly for 7 years) completely destroyed cryptogams. Micromorphological examination of the cryptogamic crust revealed that continual burning eliminated fungal hyphae and the gels cementing individual mineral particles together. In that study, fire led to a breakdown in the structural integrity and organic component of the soil crust, and to reductions in spatial heterogeneity at the soil surface. The slower recovery rates in our soils may have resulted from differences in lichen or algal taxa between the two sites (A. Downing pers. comm. 1993), due to different soil conditions between the two sites, or lower populations of fungi and blue-green algae in sandy soils. In a study of post-fire recovery of algal soil crusts in the USA, Johansen et al. (1993) observed that certain functional groups of algae were associated with specific soil pH levels. They postulated that these algal groups had different abilities to recover after fire. Differences in recovery might also have been due to the more hostile post-fire environment on the sandy soils which is dominated by wind-induced erosion.

The dynamics of cryptogam cover after fire is closely tied to their competitive advantage over vascular plants during the early stages of recovery, as well as their interaction with vascular plant recruits and the resprouting mallee shrub layer. During the first few years after fire in a eucalyptus shrubland, litter is generally low (Bradstock 1991), at which time algae are primary stabilisers of the soil surface. Blue-green algae have the capacity to fix atmospheric nitrogen, making this available to developing vascular plants (Rychert et al. 1978). Algal polysaccharides and fungal hyphae cement the soil particles into more stable units, providing a substrate for developing mosses and vascular plants. Coincident with an increase in nitrogen fixation and organic matter levels, mosses and lichens increase in cover. This increase in cryptogam cover up to

a maximum at 16 years corresponds with an increase in cover of understorey shrubs and *Triodia irritans* (Bradstock 1989). Despite the dominance of these shrubs in the lower strata, and the density of mallee eucalypts in the overstorey (Bradstock 1991, Bradstock & Gill in press), there are still large patches of bare ground between the shrubs for colonisation by cryptogams. However, after about 16 years post-fire, our results suggest that cryptogam cover begins to decline. This can be attributed to the spreading of litter from overstorey *Eucalyptus* species and *Callitris preissii* subsp. *verrucosa*, which, in the absence of fire, reduces the cover of bare ground and thus niches for colonisation by cryptogams.

As well as changes in total cover due to fire, we found differences in the relative composition of moss, algae and lichen, although these differences were not significant due to the high spatial variability. Our results suggest that frequent burning (i.e. less than once every 7 years) leads to the persistence of algae at the expense of moss or lichen (Table 1). This is consistent with work by Schulten (1985), who found that fire reduced the composition of mosses and lichens during the initial stages of recovery on a sandy soil in the Midwest of the United States.

Implications for management of mallee landscapes

As mallee landscapes support pasture plants of low grazing values, carrying capacities are as low as one sheep to 20 hectares (Noble 1984). The use of controlled burning in mallee shrublands is restricted under Regulation 50C(1)(j) of the Western Lands Act 1901. Current legislation, however, allows burning in eucalypt shrublands for the purpose of promoting the growth of pasture species or for reducing fuel loads, provided that the dominant eucalypt species are not killed. Similarly, fire is used by park administrators for hazard reduction and habitat manipulation. Our results suggest that the cover and composition of cryptogamic crusts will be dependent on the fire regime adopted by land managers, and this may affect the vulnerability of the surface to erosion. For example, under a regime of frequent fires where algae are dominant, wind and water erosion may increase, particularly in the absence of a high cover of vascular plants. Tchoupopnou (1989) showed that algal-covered surfaces were the least effective and lichen the most effective at reducing erosion. Increased diversity of cryptogamic flora on plots of 10–15 years since fire would result in an adequate cover of mosses and lichens, maximising soil microtopography, increasing surface detention, and decreasing rainsplash and erosion. There is value in the proposition of Good (1981) that management should be flexible, allowing for long fire-free periods in reserves, which would aid plant species conservation. An alternative strategy may be to proscribe certain events which are incompatible with the fundamental aim of conservation (e.g. frequent fires), but allow others to happen (e.g. wildfires or no fires) according to chance (Bradstock 1989).

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