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# Post-fire hillslope erosion response in a sub-alpine environment, south-eastern Australia

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**Abstract**

This paper examines post-fire erosion response in a sub-alpine environment in south-eastern Australia for a period of 2.2 years. Few studies have examined fire impacts on sediment transfer in this environment. Erosion pins were used in grids located at upper, mid and lower slope positions on adjacent burnt and unburnt hillslopes to assess fire effects on the extent of surface level change. The results indicated that there was a significant difference between the surface level change regimes on the burnt and unburnt hillslopes. Estimated erosion rates for the burnt slope over the study period ranged from 2.7 to 94.3 t $ha^{-1}$, which could be considered low given the high slope angles, high precipitation and moderate fire severity. Slope position was critical in modifying post-fire erosion response, as it controlled slope angle and the rate of surface cover regrowth. Analysis of lower slope sites, for which more detailed data was available, indicated a second delayed erosion peak after the initial elevated post-fire response during the following spring snowmelt period. Surface recovery on the lower burnt site was slow, with vegetation cover still comparatively low 2.3 years after the fire. Evidence of post-fire sediment supply limitation was found on this site, with a declining rate of increase in the magnitude of total surface level change, despite limited regrowth and an increasing number of precipitation events >20 mm for measurement intervals since the fire. Modification of the hillslope surface by fire leads to changing hillslope erosion process dominance in this environment. The post-fire hillslope undergoes erosion by direct rain-drop impact and overland flow, whereas the unburnt slope rarely experiences overland flow due to the thick ground cover. As a result surface level change on the unburnt slope was largely influenced by wetting–drying effects rather than sediment transfer by surface flow. Downslope biotransfer appears to be the dominant sediment movement process in the unburnt sub-alpine forest environment.


*Keywords:* Wildfire; Soil erosion; Sub-alpine environment; Erosion pins

## 1. Introduction

Wildfire can be an important component in geomorphological change (Shakesby and Doerr, 2006). Modifications to the landscape by fire can lead to significant ongoing changes to erosion rates and the hydrological response of burnt areas (Cerdà and Lasanta, 2005). Fire effects contributing to altered surface processes include reduced ground cover (White and Wells, 1979; Prosser and Williams, 1998), changes to surface characteristics (Mitchell and Humphreys, 1987; Lavee et al., 1995), soil structure effects (Kutiel and Inbar, 1993; Rab, 1996), bioturbation (Dragovich and Morris, 2002b; Shakesby et al., 2006) and alterations to soil hydrophobicity and infiltration (Doerr et al., 1996; Shakesby et al., 2000; Martin and Moody, 2001). Variability in post-fire hydrologic and erosion response is further enhanced by the patchiness of fire severity (Kutiel et al., 1995; Dragovich and Morris, 2002a) and variation in environmental factors unaffected by fire (Kutiel and Inbar, 1993), including rainfall amount and intensity (Atkinson, 1984), slope and aspect (Marques and Mora, 1992) and vegetation type, affecting the rate of recovery (Kutiel and Inbar, 1993).

The complex interaction of the heterogenous fire alterations to the land surface and environmental factors contributes to the variety of post-fire erosion and hydrologic response observed in previous research (Shakesby and Doerr, 2006). The coincidence of large magnitude, high intensity rainfall events immediately

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after the fire is expected to produce the largest erosion response (Prosser and Williams, 1998). However the peak erosion response may be delayed or subsequent peaks may occur due to higher magnitude rainfall events occurring well after the fire (Inbar et al., 1998; Shakesby and Doerr, 2006). A delayed peak in post-fire erosion response has also been attributed to seasonally dependent soil moisture levels and changing surface characteristics (in the absence of significant regrowth) with time since the fire influencing post-fire runoff and erosion rates during the recovery period (Cerdà, 1998). The re-establishment of ground cover is probably the primary factor influencing the recovery time to pre-fire erosion rates (Benavides-Solorio and MacDonald, 2001). Variability in post-fire erosion response, including delayed peaks in erosion following fire, emphasises the need for longer term continuous monitoring. In particular, Shakesby and Doerr (2006) note that relatively few studies have undertaken continuous hillslope erosion monitoring beyond the first year after fire.

This study examines hillslope erosion response following fire in a sub-alpine environment in south-eastern Australia. Few studies have examined fire impacts on sediment transfer in this environment. Alpine and sub-alpine environments in Australia are limited in extent, occurring mainly in Tasmania and the Australian Alps in south-eastern Australia. Previous research in these environments has reported higher catchment runoff and sediment yields following fire, with a return to pre-fire hydrologic patterns within 4 years at the small catchment scale (Brown, 1972). Costin et al. (1960) noted the high hillslope erosion hazard following fire in sub-alpine woodlands when the ground cover of herbs and herbaceous litter had been destroyed. Good (1973), in a preliminary, largely qualitative survey of erosion after fire which burnt 12 000 ha above 1360 m noted some areas of severe erosion existed, but mostly only minor erosion was evident.

The fire which burnt through the study area occurred in January 2003 during a period of drought in eastern Australia. Severe electrical storms started 140 lightning strike fires throughout Victoria, New South Wales and the Australia Capital Territory (ACT); these eventually combined to burn 1.73 million hectares. This study investigates the erosion response following this fire in a sub-alpine environment by monitoring surface level change on adjacent burnt and unburnt hillslopes. It examines the erosion response for a period of 2.2 years (795 days).

## 2. Study area

The study area was located in the Snowy Mountains, an elevated plateau region ranging between 1500 and 2228 m. Deeply incised by rivers, there are extensive areas with steep slopes. Glaciation during the late Pleistocene affected only a limited area (Costin, 1954). The geology of the region is dominated by granites, with gneisses, porphyries and some Tertiary basalts and metamorphosed sediments (Costin, 1954). Shallow gravelly soils are common on steeper slopes and organic-rich humus and peaty soils mostly occupy flatter slopes and poorly drained areas. Areas classified as sub-alpine climate were defined by Costin (1954) as ranging from 1520 m to 1830 m, with the upper limit defined approximately by the tree line. Areas above this limit were classified as alpine. There is a large increase in annual precipitation between these areas, ranging from 760 mm in lower sub-alpine areas to 2286 mm in the higher elevations of the alpine zone (Costin, 1954).

The monitoring sites were located near Thredbo in Kosciuszko National Park, south-eastern Australia (Fig. 1). Thredbo is situated just below the sub-alpine zone and experiences warm summers (mean maximum and minimum temperatures of 20.8 and 6.8 °C in January) and cold winters (5.2 and −3.7 °C in July), when snowfalls are generally frequent. The mean annual precipitation is 1792 mm, with a seasonal peak during late winter and spring (Fig. 2). Vegetation changes with increasing altitude. Wet sclerophyll forests dominate at elevations above 1000 m up to approximately 1500 m, above which woodland and scrub is dominant to the tree line (Martin, 1986).

Sites were selected according to apparent similarities in fire severity between upper, mid and lower slope positions. Fire severity was determined on the basis of observed vegetation effects. High severity fires resulted in the loss of ground cover and canopy, moderate severity involved loss of ground cover and partial loss/browning of canopy, and low severity resulted in loss of most of the ground cover, with the canopy remaining unaffected (White and Wells, 1979; Prosser and Williams, 1998; Dragovich and Morris, 2002a).

Monitoring sites were established on adjacent burnt and unburnt hillslopes, which had similar elevation, slope, aspect, vegetation and proneness to snow cover. The two study hillslopes have a generally west-north-westerly aspect and are located on the southern side of the Thredbo River near Thredbo Village. Fire severity on the burnt sites was moderate, with the lower burnt site appearing to be the least intense of the three, with only partial scorching of the canopy. Slopes at the upper sites were less steep (13° and 12° for burnt and unburnt respectively) than mid slope

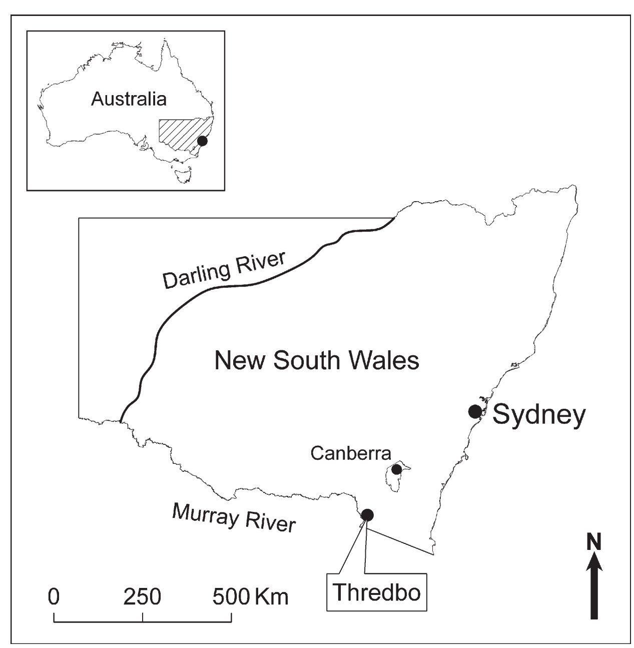


Fig. 1. Study area location near Thredbo in the Snowy Mountains in south-eastern Australia.