The vulnerability of peatlands in the Australian Alps

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Formation and function of peatlands

Peatlands are coupled to earth's wet climates (Whinam *et al.* 2003). They are formed when inundated plant material decomposes slowly relative to production, causing partially decayed organic matter to accumulate as soil. A high water table allows non-vascular *Sphagnum* moss species to prevail in many peatlands. Peatlands promote acidic soil conditions, produce decay-resistant biomass, reduce surface runoff and have an exceptionally high water holding capacity, features which stimulate further peat development. Lowering of the peatland water table can accelerate decomposition and cause a shift away from *Sphagnum* to shrubs or grass. Hence climatic drying or disturbance causing drainage can compromise organic soil accumulation. Hydrological disturbance from activities such as cattle or horse grazing can also damage peatlands through compaction of peat, increased drainage and runoff and soil erosion.

Drying also increases the impact of fire on peatlands. Fire won't burn waterlogged peats because high moisture content retards peat combustion. However, drying peats become vulnerable to smouldering ground fires, which consume the organic soil layer. Deep peat horizons are often a legacy of wetter climatic periods, when peat accumulation was rapid.

The positive feedbacks that help maintain subalpine moss cushion peatlands can be summarised as follows: saturation promotes *Sphagnum* growth and peat formation and protects from fire; upper peat layers provide good physical and chemical conditions for *Sphagnum* growth; *Sphagnum* produces resistant organic matter and chemical conditions that promote peat accumulation, and also confers fire protection; the high water storage capacity of *Sphagnum* and resulting peat soil slow runoff, promoting a high water table and saturation.

There is an opposite set of feedbacks that make it less likely for vegetation on mineral soils to convert to peatland: less organic matter reduces water retention during drought; this leads to loss of organic matter through oxidation, fire and erosion; mineral soils and drier conditions are more conducive to shrub and grassland development, less conducive to *Sphagnum* growth; vascular plants are less conducive to peat formation than *Sphagnum,* and drive higher fire frequency/severity; this leads to further loss of organic matter and promotion of mineral soils.

Together, these feedbacks reinforce the stability of the peatland/ mineral soil mosaic. However, when environmental conditions change sufficiently, or the landscape is subject to repeated and severe disturbance, the stabilising influences can be overwhelmed, and organic soils can be converted to mineral soils, or vice versa. Note, however, that conversion of organic to mineral soils can occur much more quickly than the opposite, because of the long time it takes for peat to accumulate, usually 2-5 cm per century in Australia (Hope and Nanson 2015).

Peatlands in the Australian Alps

In mainland Australia, moss-shrub peatlands are mostly restricted to the alpine and sub-alpine environments of the Australian Alps. The fact that these peatlands are constrained to poorly drained topographic positions and/or groundwater-fed systems indicates they are at the margin of climatic suitability. They are typically small (<1ha), and exist in a matrix of other vegetation types including grassland, heathland, and *Eucalyptus* woodland. They total around 7000 ha in the Australian Alps (Victoria, NSW and the ACT).

Despite their limited area, moss peatlands are highly valued, not least for their role in absorbing and releasing water into local catchments. They support numerous threatened species and contain valuable sediment records of past environmental conditions. Peat accumulation was well established in the region by 10,000 years BP, and was fastest during wet climatic periods. Charcoal throughout peat profiles indicates that fire has been common during their development, but there has been a clear increase following the change to European land management. Peatland area is estimated to have declined by at least 30% due to burning and grazing in the high country (Hope *et al.* 2012)

Management implications

The future of peatlands in alpine Australia under predicted warmer, drier climates is precarious given that they are already constrained to the wettest parts of the landscape. Predicted changes in rainfall and evaporation are likely to further reduce the area in which peat can accumulate, and will render peatlands more vulnerable to fire (McDougall 2007).

The recent string of particularly large, drought related fires in the Alps (Williams *et al.* 2008) is consistent with predictions of increased fire danger due to climate change. *Sphagnum* peatlands are the most fire-sensitive of the Alps vegetation communities; many have been burnt in recent fires, some repeatedly, with losses of peat and *Sphagnum*. Shifting fire regimes are recognised as the most rapid mechanism of degradation in drying peatlands and can potentially result in their loss (Kettridge *et al.* 2015).

Many peatlands in the region have also suffered hydrological disturbance from cattle grazing since the 1850s (McDougall 2007, Grover *et al.* 2012). *Sphagnum* is gradually recovering in some areas following cessation of grazing in 2005, but the legacy will endure for years, exacerbating the effects of a drying climate and increasing the flammability of Alpine areas.

The January 2003 fires burnt over 2.1 million ha of bushland in montane south-eastern Australia including 80% of the peatlands. The fires came after three years of drought and killed the peatland vegetation, especially the *Sphagnum* moss hummocks, whose living tissue is concentrated at the surface of the cushions. Figure 1a shows the pre-fire *Sphagnum*-shrub bog vegetation at Snowy Flat, ACT and 1b the post fire dead vegetation.
Figure 2 shows badly damaged vegetation at the Ramsar site of Ginini, ACT.
Figure 3: Peat that has been drained will burn away leaving brick-like clay, as at Top Flat ACT.
Figure 4: Alpine humus soils are particularly vulnerable, as seen at 1950 m on Mount Tate (NSW) where this picture was taken three years after the fire, with no regeneration evident and continuing wind erosion. Management here is restricted to planting tussock grass to establish some cover. Photos: G Hope.

Following disturbance, effective recovery of peatlands requires a high water table to be restored, and a disturbance-free period for *Sphagnum* to re-establish and peat to accumulate. Trials of these approaches have shown promise (Hope *et al.* 2005). Fire management targeted at conserving the least disturbed peatlands could also be effective. Regardless of the conservation strategy, optimising management requires a robust understanding of both the future fire risk and existing degradation of individual peatlands.

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The unique and surprising environments of Temperate Highland Peat Swamps on Sandstone (THPSS) in the Blue Mountains, NSW

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Introduction

The Blue Mountains region, around 80 km west of Sydney, conserves a variety of unique landscapes and ecological communities in a series of National Parks which are collectively listed as the Blue Mountains World Heritage Area. This World Heritage Area contains a relatively large number of mires which have been recognised as ecologically important, for example, Temperate Highland Peat Swamps on Sandstone (THPSS), is an Endangered Ecological Community listed under the *Environment Protection and Biodiversity Conservation Act* 1999 (*EPBC Act* 1999) in May 2005 and a Vulnerable Ecological Community under the NSW *Threatened Species Conservation (TSC) Act* 1995. In the Sydney Basin Bioregion this protection under the TSC Act also extends to the Blue Mountains Swamps and Newnes Plateau Shrub Swamps both Endangered Ecological Communities, and these all share characteristics with Coastal Upland Swamps in the Sydney Basin Bioregion, an Endangered Ecological Community occurring at lower elevations, which was listed under the *TSC Act* 1999 in 2012.

In 2011 an Enforceable Undertaking under Section 486DA of the *EPBC Act* 1999 was reached between the Federal Department of Sustainability, Environment, Water, Population and Communities (now Department of Environment) and two coal mining companies over their 'significant impact' on three swamps (see https://www.environment.gov.au/news/2011/10/21/centennial-coal-fund-145-million-research-program for more information). Although these companies did not concede that they had breached this (or any other) Act they contributed $1.45 million towards the establishment of the Temperate Highland Peat Swamps on Sandstone Research Program (THPSSRP). The THPSSRP, administered by the Fenner School of Environment and Society at the Australian National University, identified priorities, called