Case study: The 2019–2020 Black Summer in Australia

The 2019–2020 wildfires in Australia were exceptionally severe, burning ecosystems that typically do not burn, including the World Heritage-listed Gondwana rainforest (Nolan et al. 2020). The most extensive of the wildfires occurred in the south-eastern corner of the continent, although south-western ecosystems and northern rainforests were also affected. It is estimated that 3 billion animals were killed or displaced, including an estimated 143 million mammals, 180 million birds, 51 million frogs and a staggering 2.5 billion reptiles (van Eeden et al. 2020).

The fires burnt the habitat of 832 of Australia's native animal species (Ward et al. 2020) including 21 "threatened with extinction" under Australia's Environment Protection and Biodiversity Conservation (EPBC) Act. These include the Kangaroo Island dunnart (*Sminthopsis griseoventer aitkeni*) and the long-footed potoroo (*Potorous longipes*), which had more than 80 per cent of its habitat impacted by the fires. Furthermore, almost a quarter (272) of the 1,180 listed threatened plant species had >10 per cent of their known distribution within the fire footprint (Wintle et al. 2020).

Many native Australian species have been historically maintained within specific fire regimes. Altered frequency, severity, or timing of extreme events such as wildfire can increase their extinction risk and encourage threats such as invasive species. Many species and ecosystems are known to be at risk because of multiple, interacting disturbances (Didham et al. 2007; Foster et al. 2016).

Fire effects on soil and erosion

Fire is often considered an important soil-forming factor, influencing soil development and sediment production (Certini 2005). The heat transfer from the combustion of biomass directly impacts soil properties, and indirectly affects erosion rates and sediment production (Robichaud et al. 2016; Pingree and Kobziar 2019). At lower temperatures (below 200°C), essential biological properties are affected, in particular there is a significant reduction in the microbial community, biomass, and seed bank. At higher temperatures (above 200°C), physico-chemical properties of soil are modified through the combustion of soil organic matter and the production of pyrogenic compounds. Physical transformations include the breakdown in soil structure and aggregate stability, reduced moisture retention capacity, and development of soil hydrophobicity (soil repellency to water that hampers soil wetting). Chemically, fire-affected soils undergo changes in nutrient cycling rates and pH. These changes typically lead to more brittle and erodible soil (Shakesby 2011; Wittenberg 2012). This may cause the accelerated loss of topsoil after the fire, with published rates of 0.1–41 Mg ha^{-1} per year after moderate to severe fires compared with 0.003–0.1 Mg ha^{-1} in unburnt landscapes (Shakesby 2011; Santín and Doerr 2016). It is estimated that more than 70 per cent of the total annual erosion in the MCRs is caused by wildfires (Swanson 1981). Using a combination of climate, fire, and erosion models, one study in the western USA estimated that by 2050 post-fire sedimentation rates would increase by more than 100 per cent in over 30 per cent of the watersheds due to increased fire activity (Sankey et al. 2017).

Soil erosion is a problem worldwide. The loss of topsoil – where organic substances and vital nutrients are stored – results in decreased soil fertility. However, post-fire increases in erosion rates are often limited to a short period following the fire. They usually decrease at larger spatial scales (basins) due to local redeposition of sediment and rapid regrowth of vegetation (Zituni et al. 2019).