

Drivers of landscape change

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Tropical savannas extend across nearly one third of the Earth's – and Australia's – surface. Although the biome is principally defined by a climate condition – highly seasonal but regular rainfall patterns – the name “savanna” is also given to the dominant feature of tropical savannas – open woodlands characterised by the coexistence of grasses and trees. Under classical successional theory this is a paradox: either conditions do not support trees, or trees eventually supplant grasses. There has been much debate over the factors that lead to grass-tree coexistence in savannas, but a consensus is forming that disturbance, particularly from grazing and fire, is the key structuring factor. Because tropical savannas are disturbance dependent systems, they can be particularly impacted by seemingly subtle changes in disturbance regime.

Tropical savannas communities exhibit great diversity in both composition and disturbance regime, and it is helpful to think of savanna ecosystems in terms of resistance and resilience. “Resistance” refers to the capacity of a system to resist change in the face of disturbance, while “resilience” is the capacity of a system to return to its former state after a disturbance. For example, woodlands are a highly resistant ecosystem that can withstand repeated disturbance, particularly very frequent fire regimes, but under particularly severe disturbance can irreversibly shift to an alternate state. Floodplains are resilient on an annual scale, as they change in composition between wet and dry seasons, but also appear to change rapidly in response to shifts in grazing or fire regime and to have some capacity to revert if the prior regime is restored.

The contrast between resistant and resilient ecosystems is highlighted by the ecological legacy of feral water buffalo in Kakadu National Park. Buffalo reached carrying capacity in Kakadu by the 1960s and the impact of buffalo on floodplain hydrology and vegetation was immediately apparent. By the 1970s many floodplain vegetation communities had all but disappeared and saltwater channels had expanded markedly throughout the Alligator Rivers/Mary River region. Although there were some permanent shifts, the freshwater ecosystems largely returned to their original state soon after the removal of buffalo from Kakadu in the 1970s and 1980s.

The impact of buffalo on woodlands was less apparent during the buffalo era, and only now are we beginning to understand the legacy that some two decades of high density grazing pressure has had on the structure and function of woodland ecosystems. Buffalo had a substantial negative impact on understory vegetation in woodlands, and the rapid removal of buffalo released annual grasses, particularly annual sorghum (*Sorghum intrans*). The increase in sorghum abundance was likely enhanced by frequent fires, locking some portions of the Kakadu savanna into an alternate ‘grass-fire’ state where an understory dominated by sorghum promotes frequent fires that decrease competition between sorghum and perennial vegetation, and has led to the long term decline in woodland cover in some areas. Moreover, an overall increase in fire frequency has been linked to the decline of small mammals across Kakadu.

In the past fifty years, there has been a consistent expansion of closed forest vegetation across Kakadu. This seems somewhat counterintuitive given that closed forest vegetation is particularly susceptible to damage from both fire and buffalo (i.e. it is both less resistant and resilient than floodplains and woodlands). Increasing rainfall, particularly within the past decade, has likely contributed to this expansion. Also, buffalo grazing may have reduced fire frequency at closed forest margins. Finally, the removal of buffalo coincided with an increasingly vigorous fire management program within Kakadu that focused both on early dry season, high frequency but low intensity burning of woodlands, and the protection of closed forest vegetation margins.

The introduction of feral animals and changes in fire regime in Kakadu National Park illustrate the sorts of management changes that can have long term consequences for ecosystem structure and function within tropical savannas. Grazing and fire are the key disturbances in savanna systems and decisions about fire management, the introduction of large grazing animals, and the introduction of exotic grasses all have the capacity to profoundly change savanna ecosystems. The sustainable management of tropical savannas relies upon knowing the limits of resistance and resilience within ecological communities. It would appear that the chief danger lies in underestimating the capacity of highly resistant, but low resilience ecosystems such as woodlands to withstand changes in disturbance regime. The impact of change may not be immediately apparent, but the legacy of change may last many decades.