A Review of the Impact of Fire on Soil Erosion in the Tropical Savannas of Northern Australia

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Abstract

The tropical savannas of northern Australian are prone to fire due to the region's highly season rainfall. Fires are common, and most frequent late in the dry season when the fires are most destructive. A consistent finding of studies into the effect of fire on soil erosion in northern Australia is that the reduction in ground- and canopy-cover by late dry season fires increases soil erosion by a factor of 2-3. Early dry season fires, even after several years of fuel accumulation, can have undetectable impacts on soil erosion compared to unburnt areas. The effect of fire on stream bank erosion, caused by the reduction in riparian vegetation, however has not been examined, nor the longer-term implications of accelerated soil erosion on the integrity of the Australian tropical savanna landscape.

Introduction

The tropical savannas of Australia occupy almost 20% of the Australian continent (Fig. 1) an area of 1.9 million km^2, and are dominated by eucalypt woodlands with a continuous grass understorey on typically nutrient poor soils in a highly weathered landscape. The savannas are prone to fire due to northern Australia's highly seasonal rainfall. Wet season rains between December and March promote the profuse growth of vegetation, in particular annual grasses and herbs. Over the following dry season months, between May and September, these grasses and other vegetation material cure and become highly flammable.

Between 1997 and 2001, an average of 19% of the savannas were burnt annually [*Russell-Smith et al*. 2003]. In parts of northern Australia (Fig. 1), however, annual fire extent can exceed 50%. Most of these fires are human lit, with only a very small proportion caused by lightning strikes between October and December. The current frequency and extent of fire is believed to be considerably greater than traditional Aboriginal use of fire before European colonization, in particular the prevalence of fires late in the dry season.

The intensity of late dry season fires tends to be higher than fires earlier in the dry season [*Williams et al*. 1998]. At Kapalga in Kakadu National Park (Fig. 1), the intensity of fires late in the dry season (average 7700 kW m^{-1}, n=14) were three times more intense than fires in the early part of the dry season, due to the accumulation of leaf litter over the dry season, lower fuel moisture, and more favorable weather conditions. This trend for higher fire intensities later in the dry season however is influenced by the accumulation of fuel between years. Fire intensities in the tropical savannas of Australia are of lower

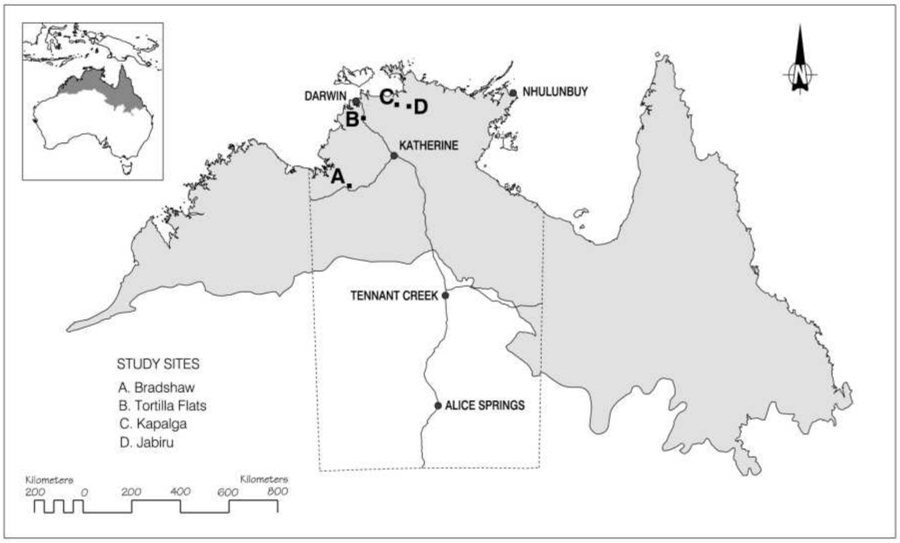

Fig. 1. Tropical savanna of Australia, and fire-soil erosion study sites.

intensity then the wildfires of southern Australian and rarely if ever include crown fires [*Williams et al*. 1998].

Review of fire and soil erosion studies.

Research into the effects of fire on the tropical savannas of northern Australia has mainly focused on the impact on biodiversity [e.g *Andersen et al.* 1996]. The impact of fire on soil erosion and the fluvial export of sediment is less well studied, but could be a major determinant of long-term changes in the savanna landscape. This extended abstract reviews the recent, albeit few, studies into the effect of fire on soil erosion in the Top End of the Northern Territory, Australian (Fig. 1).

Two approaches have been applied to evaluate the impact of fire on soil erosion in the tropical savannas of the Top End. These have been the use of erosion pins to directly measure soil loss or gain from a site within a catchment, and the collection of water samples for the determination of fluvial suspended sediment loads exported from catchments.

Erosion pin studies measure the soil surface relative to a pin set flush with the surface. Soil losses or gains are measured after a wet season with vernier calipers from the head of the pins. On lowland slopes of <1%, in open woodland and forest at Jabiru, Duggan (1988) reported a mean soil gain for all unburnt sites of +1.25 mm and +0.33 mm for burnt areas. Soil deposition was lower in the burnt areas due to increased surface mobility of gravel and sand that resulted in the net erosion in some sites. Duggan (1988) showed that soil deposition increased with pre-wet season litter and surface gravel cover. The main mechanism for soil movement was surface wash, rather than rain drop displacement. Leaf litter reduced surface water velocities whereas gravel dissipated the erosive energy of rain drops to reduce erosion. On steeper slopes (3-25%) at Tortilla Flats and Bradshaw, Russell-Smith *et al*. [2001] reported soil losses in areas burnt late in the dry season that were three times higher than unburnt areas, and they attributed this to the removal of almost all ground cover. Fires early in the wet season [*Russell-Smith et al.* 2001] on similar slopes also increased soil erosion.

As part of the Kapalga landscape-scale experiment (Fig. 1) on the effect of fire on the Top End savanna environment [*Andersen et al.,* 1996], the fluvial loads of suspended sediments were determined over three years for three fire regimes: fire exclusion (unburnt), early dry season (May, June), and late dry season fires (September) [*Townsend and Douglas,* 2000]. Sediment loads from the catchment burnt late in the dry season were on average 2.4 times greater than loads from the unburnt and early burnt catchments, which were both similar The catchment burnt late in the dry season featured episodic runoff events, before the stream commenced continuous wet season flow. These carried concentrations of suspended sediment of up to 1000 mg/L and were ten times higher than later wet season storm concentrations. Townsend and Douglas (2000) concluded that the high loads from the late dry season burnt catchment were due to reduced ground and canopy cover.

The significance of catchment cover in mitigating soil erosion was further demonstrated when the fire regime of the Kapalga catchment studied by Townsend and Douglas [2000] was changed from a late to an early dry season burn [Townsend and Douglas 2004]. In the year immediately following the introduction of the early dry season burn, the suspended sediment load of run-off events was halved, and decreased further over the next two wet seasons. Moreover, the frequency of early wet season episodic run-off events was reduced by 80%. This rapid catchment response to a regime of lower intensity dry season burns was attributed to a 25% increase in grass cover, 50% increase in canopy cover, and 15 fold increase in litter cover.

Areas not burnt for many years will accumulate fuel, increasing the likelihood of an intense fire. This scenario was examined for a Kapalga catchment that had been excluded from fire for 10 years, and was burnt in May, early in the dry season [*Townsend and Douglas,* 2004]. The intensity of this fire (estimated from the height of tree scorching) was slightly more than the average dry season fire intensity. There was no detectable effect on the stream suspended sediment concentrations compared to pre-fire data. The low fire intensity was attributed to relatively high fuel moisture content and less favourable weather conditions than those later in the dry season. Importantly, the retention of canopy cover and notably the accumulation of litter following the wildfire, as well as the catchment's relatively flat terrain, contributed to the negligible effects on stream sediment loads.

Conclusion

Although there are few studies into the impact of fire on soil erosion, a consistent finding is that the loss of ground and canopy cover by fire increases soil erosion, and that this impact is dependent on catchment slope. The effect of fire on erosion of stream banks, through the reduction in riparian vegetation [Douglas *et al.* 2003], has not been examined, but could be significant. Fires late in the dry season cause a marked reduction invegetation cover, and so increase soil erosion. The long-term effect on the ecological integrity of the savanna landscape of increased soil erosion and possible degradation of stream banks, caused indirectly by late dry season fires, however is not known.

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References

Andersen, A.N., Cook, G.D. and Williams, R.J. (Editors), 2003. Fire in Tropical Savannas: the Kapalga Experiment. Springer-Verlag, U.S.A.

Douglas, M.D., Townsend, S.A. and Lake, P.S., 2003. Streams. In: A.N. Andersen, G.D. Cook and R.J. Williams (Editors), Fire in Tropical Savannas; the Kapalga experiment. Springer-Verlag, New York, pp. 59-78.

Duggan, K., 1988. Mining and erosion in the Alligator Rivers Region of northern Australia. Ph. D. Thesis, Macquarie University.

Russell-Smith, J., Yates, C. and May, T., 2001. A comparison between the effects of late dry season (LDS) and wet season burning (WSB) on soil erosion, fuel loads, and species composition in sandstone-derived landforms of the Bradfield Training Area, Northern Territory. A report to the Department of Defence. Bushfires Council of the Northern Territory and Tropical Savannas Cooperative Research Centre, Darwin (Australia).

Russell-Smith, J. et al., 2003. Contemporary fire regimes of northern Australia: change since Aboriginal occupancy, challenges for sustainable management. *International Journal of Wildland Fire*, 12: 283-297.

Townsend, S.A. and Douglas, M.M., 2000. The effect of three fire regimes on stream water quality, water yield and export coefficients in a tropical savanna (northern Australia). *Journal of Hydrology*, 229: 118-137.

Townsend, S.A. and Douglas, M.M., 2004a. Catchment cover and stream water quality in an Australian tropical savanna: rapid recovery after a change to a less intensive fire regime. *Ecological Management & Restoration*, 5: 136-138.

Townsend, S.A. and Douglas, M.M., 2004b. The effect of a wildfire on stream water quality and catchment water yield in a tropical savanna excluded from fire for 10 years (Kakadu National Park, North Australia). *Water Research*, 38: 3051-3058.

Williams, R.J., Gill, A.M. and Moore, P.R.H., 1998. Seasonal changes in fire behaviour in a tropical savanna in northern Australia. *International Journal of Wildland Fire*, 8:227-39.