Fire and people in tropical island grassland landscapes:

Fiji and Madagascar

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Abstract

Little research has focused specifically on fire in Fiji's leeward grass-covered hills and mountains. In this paper, I review what is known about Fiji's grassland fires, what we can surmise from comparison with Madagascar (another frequently burnt tropical island landscape) and what questions deserve further research. Grassy biomes and fire were more common than previously thought in prehuman seasonally dry landscapes; Madagascar and Fiji are no exception. People burn in both places for diverse livelihood reasons, but in particular for pasture management and cropfield preparation. Fires, however, do escape control and damage property, and are also blamed for effects on health, climate and biodiversity. Government regulation of fire is difficult to enforce and often ignored. Given the danger of fuel build-up and the cost of other land management options, continued traditional burning is a realistic future outlook.

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Introduction

Fire is one of humanity's most ancient skills, yet it is also a significant challenge for the future. When people colonised new lands, they inevitably burnt (Bowman & Haberle, 2010; Pyne, 1995) and people around the world continue to set fires to manage landscapes. But fire is complex; it predates humans on the planet, it is not fully under our control and it elicits condemnation for consequences on property, biodiversity, health and carbon fluxes (Bowman et al., 2009).

Fire is widely present in the leeward grasslands of Fiji and other Pacific islands, yet it has not received much scholarly attention. Here I seek to open a window into a 'pyrogeography of the Pacific' using a comparative perspective from previous research on fire on the Indian Ocean island of Madagascar (Kull, 2002, 2004). I review what we know, suggest what we can surmise from comparison with places like Madagascar, and point out areas ripe for further research.

A comparison between Madagascar and Fiji begs mention of their similarities and differences (Table 1). The island nations share similar latitudes and exposure to southeastern oceanic trade winds, though Madagascar is some 50 times larger than Viti Levu and rises twice as high in altitude. Madagascar is an ancient piece of Gondwana, with some volcanism, while Fiji is of much more recent volcanic, sedimentary and limestone origin. Madagascar's flora contains circa 12,000 species; Fiji has just 827 native species (Daehler, 2006). Both islands were settled relatively late by humans, with Fiji occupied from circa 3000 years BP (Clark & Anderson, 2009; Kumar et al., 2006) and Madagascar visited from at least 2300 BP with permanent settlement from at least 1500 BP (Burney et al., 2004). A significant part of the prehistoric settlement of Madagascar was by Austronesian speaking people originating in Southeast Asia, making the country culturally comparable to the Pacific in some ways (Vérin, 1994). Fiji was a British colony (1874–1970) while Madagascar was French (1896–1960). In both countries, large areas of fire-affected land are effectively under the control of clan- and village-based groups (though in Madagascar the land is technically government controlled).

The intertwined histories of fire, vegetation and people

Fire predates humans. It is inevitable in areas where enough plants grow to become fuel, yet where seasonal dryness and lightning allow it to ignite. As a result, fire has shaped plant evolution and the development of biomes like tropical savannas. Humans, who evolved in such landscapes, have used fire for hundreds of thousands of years. While many grass-dominated environments would burn anyway, humans change the timing, frequency and intensity of fires. Human impact is more obvious in wetter areas where natural fire is rare, and where human fire contributes to wholesale ecological transformations (Bowman et al., 2011).

The origins of grasslands on both Fiji and Madagascar have been hotly debated, reflecting a century of reticence by scientists to accept grassy biomes as a 'natural' formation instead of as an early-successional stage (Bond & Parr, 2010). Colonial foresters, whose ideas were moulded by Europe's temperate humid environments, strongly shaped perceptions that fire is an external disturbance, rather than an inherent component of certain biomes (Kull, 2004; Pyne, 1997). However, evidence has accumulated from palaeoecological research in recent decades to counter this view in each of these island nations, yet many questions remain.

Table 1. Summary of key points of comparison regarding fire in Fiji and Madagascar.

	Madagascar	Fiji
Contextual similarities and differences		
Physical environment	large (587,000 km^2) mountainous Gondwanan island subject to tropical trade winds at 12° to 26° S latitude; ~12,000 native plant species	mountainous volcanic and sedimentary island chain (total land area 18,300 km^2) subject to tropical trade winds at 16° to 19° S latitude; 827 native plant species
Social environment	1500–2300 years of settlement; Austronesian language; former French colony; population 20,700,000; GDP (PPP) per capita $900	3000 years of settlement; Austronesian language; former British colony; population 860,000; GDP (PPP) per capita $4500
Fire history		
Pre-human leeward side vegetation	mosaic of forests, savannas, with megaherbivores	forest dominant but grassy vegetation in drier periods; no megaherbivores
Effect of human arrival	expansion of grassland at expense of woody vegetation; megafaunal extinctions; new plants and grazers	expansion of grassland at expense of forest; accelerated erosion; introduction of grazers and new plants like mission grass
Fire use		
Pasture management	for ~10 million cattle	for cattle, horses, goats
Field clearance and fertilisation	In both grass and forest zones; cause of deforestation	for hillside gardens
Wildfire prevention and control	embodied in need to keep landscape 'clean'	not mentioned in King's (2004) interviews
Other uses	pest control (ticks, locusts); hunting; clearance; cane harvesting	wild yam collection; pest control (pigs); hunting; clearance; cane harvesting
Modernisation	majority of livelihoods still based on farming and herding	increasing urbanisation and non-farming economies
Bad fire		
Accidental fires	1/30 of ignitions in Kull (2004)	2/3 of ignitions in King (2004); probably an exaggeration
Property damage	to tree plantations, standing crops and thatched roofs	to tree plantations, standing crops
Policies	strict yet unenforceable regulations largely ignored due to fire's utility; some village-based management schemes carry legitimacy and are effective	colonial era restrictions largely ignored; some village-based management schemes carry legitimacy and are effective

In Madagascar, evidence from archaeological deposits, sediment cores and comparative biogeography have built a picture that contradicts the assertions of colonial botanists that closed forest once covered the island. Prior to settlement, large areas of the drier leeward west were open grassland landscapes grazed and browsed by hippos, elephant birds, tortoises and giant lemurs, with periodic lightning fires. The arrival of humans (and their fires and cattle), perhaps together with climatic desiccation, led to major transformations over the last 2000 years, including the extinction of the grazing megafauna and the dramatic expansion of grassland at the expense of woody vegetation. Much of the central and western portion of the island today hosts diverse, specialised grasslands (Bond et al., 2008; Burney, 2003; Burney et al., 2004).

In Fiji, charcoal in sediments suggests that lighting fires occurred long before human settlement but, in contrast with Madagascar, megafaunal herbivores were absent (Hope et al., 2009; Nunn & Kumar, 2004). Palaeoecological analyses suggest that grasslands were present during the drier conditions of the last glacial, that grasslands were restricted or absent during the wetter, more forested early Holocene, and that forest–savannah mosaics possibly existed on the dry side of the large islands in the mid-Holocene (Enright & Gosden, 1992; Hope et al., 2009; Southern, 1986). Humans began spreading fire into burnable landscapes on the leeward sides of the islands from at least 2000 BP, increasing the presence of grassland. Nunn (1997, p. 7) specifies:

> Although most of the grasslands that developed under the arid conditions of the Last Glacial would have been replaced by forest once wetter conditions prevailed, it has become clear recently that many modern Pacific Island grasslands may have persisted since Last Glacial times . . . Notwithstanding this, the marked reduction in forest area and the proportional increase in grasslands during the thousand years or so following initial settlement of many islands is undeniable.

Increased settlement and clearance of the interior using fire led to accelerated erosion and coastal sediment deposits (Kumar et al., 2006; Spriggs, 2010). Anthropogenic fires are seen as the primary driver leading to the loss of Fiji's tropical dry forests (Keppel & Tuiwawa, 2007).

Humans shape fire not only through ignition, but also by introducing grazing animals and new plants. For instance, fire-dependent grasses may accumulate standing litter and compete with other species through the resultant shade and eventual fire, altering the fire regime (D'Antonio & Vitousek, 1992). While agricultural services introduced a number of grasses to Madagascar, research on introduced grass–fire cycle dynamics in Madagascar is limited (let alone on native grass–fire dynamics; Bond et al. 2008; Kull 2004). The same can be said for Fiji, where research has focused on pasture productivity for grazing (e.g., Partridge, 1986). However, the widespread mission grass (mauniba, *Pennisetum polystachion*), introduced into Fiji's grasslands from 1920 and now dominant, is known from elsewhere to alter fire dynamics (Douglas et al., 2004).

What we know. In both Madagascar and Fiji, humans significantly increased fire and grassland landscapes at the expense of woody vegetation. They also introduced new plants and animals that affect the fire environment.

What we surmise. Given the results of recent research in Madagascar, and the characteristics of Fiji's leeward environments (dry seasons, lightning, cyclonic disturbances) it appears likely that there

was more grassy vegetation in the prehuman past than commonly recognised (e.g., by Keppel & Tuiwawa, 2007; World Wildlife Fund, 2006).

What needs research. The history and ecological dynamics of Fiji's grasses, both pre- and post-settlement, require further evidence. While the dominance of an introduced species like mission grass may suggest an anthropogenic origin to the grasslands (Bond et al. 2008, p.10), Fiji's grasslands do host a variety of native grasses, including the misnamed 'reed' (gasau, *Miscanthus floridulus*) and the lemon grasses (coboi or bucago, *Cymbopogon* spp.) (King, 2004). What is the island's grassy biota, what kinds of communities does it form now and in the past, what is its relationship to fire and introduced species, where did it persist during wetter climatic periods and is it in need of conservation (Bond & Parr, 2010)? Such research would entail detailed, spatially explicit reconstructions of vegetation, herbivore, climate and fire history before and after human arrival; also relevant would be an assessment of lightning ignition likelihoods (Bowman, 2005).

People and their uses of fire

Fire can be an efficient and effective tool to achieve a number of vegetation management and livelihood goals. Before the advent of industrial agriculture, forestry and widespread urbanisation, people burnt wherever there was vegetation to burn (Pyne, 2001). The uses of fire in Fiji appear to reflect those in Madagascar, and indeed around the world.

The most extensive use of fire (in surface area) is for pasture management. In Madagascar, with some ten million cattle, fires in grassland areas fight bush encroachment and clear lignified, unpalatable standing grasses to make way for a 'green bite' of resprouts during the late dry season. A quarter to half of the island's grasslands are burnt annually (Kull, 2004). In Fiji, widespread fires in mission grass covered hills likewise serve to provide 'new grass' to village cattle, horses and goats (King, 2004).

Burning to clear brush, grass or trees for crop cultivation is equally common. While affecting smaller surface areas than pasture fires, such swidden fires are frequently more controversial, as they can be associated with deforestation and have, in the past, been seen as unsustainable. Farmers in Madagascar use swidden fires in both grasslands and forests to facilitate planting and provide an input of fertile ashes; swidden fires in the island's mature forests are the proximate cause of dramatic rates of forest loss (Kull, 2004). Fijian villagers also list the clearance of hillside gardens as one of the top three uses of fire (King, 2004).

The third most cited use of fire in Fiji, according to King (2004), is to clear vegetation on lower hillslopes for the collection of wild yams (*Dioscorea* spp.). This use is also known from the dry deciduous forests of western Madagascar (Bloesch, 1999).

Fire has many other uses, and frequently a single fire accomplishes several goals. Pest control is one benefit cited for Madagascar (ticks, locusts, crop-eating birds) and Fiji (crop-thieving pigs). Hunters use fire to flush out game. Fires clear overgrown tracks and roadsides; and, of course, in sugar cane fields in both countries, fires facilitate hand harvesting.

A use of fire observed in Madagascar but not cited in interviews with Fijian villagers (King, 2004) is for wildfire prevention and control. Frequent low-intensity burns reduce fuel loads and are easier to

control than infrequent hot fires in accumulated fuel. A mosaic of burnt areas serves as firebreaks for later fires. As a result, Malagasy farmers, like Malian herders and Australian Aborigines, appreciate a 'clean' landscape (Kull, 2004).

What we know. Fijian villagers utilise fire in ways that correspond closely with traditional uses in the rest of the world.

What we surmise. It is likely that fuel control is an unspoken outcome of Fijian burning practices. In leeward Fiji, where a generous wet season is followed by a dry period and where ignition sources are omnipresent (whether lightning or humans), there will eventually be fire; frequent grassland fires avoid potentially catastrophic, hotter, wildfires burning in accumulated biomass.

What needs research. The above hypothesis needs confirmation, possibly through both interviews and fire exclusion experiments. In addition, a fruitful research topic would centre on the impact of the modernisation of rural livelihoods on fire. In Fiji, more so than poorer Madagascar, urbanisation and economic development mean that 'traditional' rural livelihoods are changing. This has consequences on fire use, theorised by Pyne (2009) as a 'pyric transition' or by Bowman and co-authors (2011) as 'pyric phases'. How is fire use changing as Fiji develops?

Bad fire

While efficient and effective, fire can also be catastrophic and controversial. Fire may be appreciated by one person, but deplored by another. On top of that, unlike other land management tools like axes or bulldozers, fire often escapes human control or acts in the absence of humans.

Accidental fire ignitions from cigarettes, cooking fires and other sources are unavoidable. My monitoring of a year of fires in an 18 km^2 highland grassland zone of Madagascar showed accidental fires to be 3 per cent of ignitions, accounting for 10 per cent of area burnt (Kull, 2004). In Fiji, villagers reported to King (2004) that over two-thirds of fires were accidental (which, one should note, contrasts with their careful explanation of the reasons *for* burning, perhaps reflecting unease over admitting to too much fire lighting. This was frequently the case in Madagascar).

Fires also cause property damage. This may be due to escaped fires or straightforward arson. Farmer woodlots and industrial tree plantations are frequent casualties in both Madagascar and Fiji, occasionally due to tensions over land appropriation (King, 2004; Kull, 2004). Standing crops are sometimes damaged, including maize and cassava in Madagascar and kava in Fiji. Burnt houses are not uncommon in Madagascar, where thatched roofs still dominate. Other negative consequences of fire include the effects of smoke on public health (Johnston, 2009), the contribution of forest clearance fires to atmospheric carbon (Bowman et al., 2009) and mortality of individual plants and animals.

Given the various negative consequences of fire and the threat to assets dear to governments (like pine plantations), policy makers have sought to regulate and limit fires. In Madagascar, numerous laws and decrees make burning either illegal or subject to onerous restrictions. Enforcement has, however, always lagged far behind and burners have hardly been deterred by rules they do not see as legitimate (Kull, 2004). In Fiji, colonial fire laws have largely been ignored since Independence (King, 2004). In both countries, however, there are hamlets or villages with respected local institutions that appear to manage their fires more coherently.

What we know. Fire is an unfaithful servant that sometimes acts as a master. It can damage assets, hurt health, have an impact on atmospheric carbon and affect biodiversity. Anti-fire legislation is difficult to enforce and rarely effective.

What we surmise. Over time, the trend in many countries has been increased surveillance and control of fire, with a strong emphasis on property protection. This is particularly so in wealthy countries where residential housing increasingly abuts fuel-rich forests and scrublands, but also in poor Madagascar, where new governments repeatedly renew national anti-fire campaigns (though with little effect). Will Fiji follow suit?

What needs research. Decisions about fire are ultimately political balancing acts between different interests (farmers reliant on fire, health workers citing ill effects, foresters protecting plantations, environmentalists counting carbon). Research is needed to provide better evidence-based information for such decisions and to determine the appropriate institutional pathways such that decisions can be made with legitimacy and are likely to be enforceable.

Conclusion

In both Fiji and Madagascar, where fire use appears quite comparable (Table 1), the ancient solution with respect to fire was to burn the landscape for uses sanctioned through local social norms and institutions. Can this solution, a continuation of 'traditional' approaches, meet the future challenges of fire management? The general global trend is, increasingly, for rural people to gain their livelihoods from economic activities outside semi-subsistence agro-pastoralism, focusing on more intensive, market-oriented agricultural production or urban incomes. As a result, the future may see less close management of fire on the hills and less tolerance of such 'traditional' approaches.

If policy or rural livelihood changes reduce burning, is Fiji ready for whatever dynamic 'new' ecology asserts itself in the grassy hills and mountains of the leeward side of its islands? Mission grass might gradually be replaced by different weedy woody pioneers. It may be a fuel-rich, wildfire disaster in the making. Other alternative management strategies in such 'grasslands without fire' would mean further expansion of pine plantations, with attendant social and hydrological consequences (Waterloo et al., 2007); attempts at a costly re-establishment of tropical dry forests along the lines of restoration ecology (Keppel & Tuiwawa, 2007); or promotion of an expansion of sustainable smallholder agroforestry gardens (Clarke & Thaman, 1997) into the hills. In the absence of any of these major (and largely unrealistic) undertakings, the 'traditional' approach of continuing to burn may actually be the most appropriate and realistic.

References

Bloesch, U. (1999). Fire as a tool in the management of a savanna/dry forest reserve in Madagascar. *Applied Vegetation Science,* 2, 117–124.

Bond, W.J. & Parr, C.L. (2010). Beyond the forest edge: Ecology, diversity and conservation of the grassy biomes. *Biological Conservation*, 143(10), 2395–2404.

Bond, W.J., Silander, J.A., Jr., Ranaivonasy, J. & Ratsirarson, J. (2008). The antiquity of Madagascar's grasslands and the rise of C4 grassy biomes. *Journal of Biogeography,* 35(10), 1743–1758.

Bowman, D. (2005). Understanding a flammable planet: climate, fire and global vegetation patterns. *New Phytologist,* 165, 341–345.

Bowman, D.M.J.S., Balch, J.K., Artaxo, P., Bond, W.J., Carlson, J.M., Cochrane, M.A. et al. (2009). Fire in the Earth system. *Science,* 324(5926), 481–484.

Bowman, D.M.J.S., Balch, J.K., Artaxo, P., Bond, W.J., Cochrane, M.A., D'Antonio, C.M. et al. (2011). The human dimension of fire regimes on Earth. *Journal of Biogeography*, 38, 2223–2236.

Bowman, D.M.J.S. & Haberle, S.G. (2010). Paradise burnt: How colonizing humans transform landscapes with fire. *Proceedings of the National Academy of Sciences*, 50, 21234–21235.

Burney, D.A. (2003). Madagascar's prehistoric ecosystems. In S.M. Goodman & J.P. Benstead (Eds), *The Natural History of Madagascar* (pp. 47–51). Chicago: University of Chicago Press.

Burney, D.A., Burney, L.P., Godfrey, L.R., Jungers, W.L., Goodman, S.M., Wright, H.T. et al. (2004). A chronology for late prehistoric Madagascar. *Journal of Human Evolution,* 47(1), 25–63.

Clark, G., & Anderson, A. (Eds.). (2009). *The Early Prehistory of Fiji.* (*Terra Australis* 31). Canberra: ANU E Press.

Clarke, W.C., & Thaman, R.R. (1997). Incremental agroforestry: enriching Pacific landscapes. *The Contemporary Pacific,* 9(1), 121–147.

D'Antonio, C. & Vitousek, P.M. (1992). Biological invasions by exotic grasses, the grass/fire cycle, and global change. *Annual Review of Ecology and Systematics,* 23, 63–87.

Daehler, C. (2006). Invasibility of tropical islands by introduced plants: partitioning the influence of isolation and propagule pressure. *Preslia,* 78, 389–404.

Douglas, M.M., Setterfield, S.A., Rossiter, N.A., Barratt, J. & Hutley, L.B. (2004). Effects of mission grass (*Pennisetum polystachion* (L.) Schult.) invasion on fuel loads and nitrogen availability in a northern Australia tropical savanna. In B.M. Sindel & S.B. Johnson (Eds), *Proceedings of the Fourteenth Australian Weeds Conference* (pp. 179–181). Sydney: Weed Management Society of New South Wales.

Enright, N.J. & Gosden, C. (1992). Unstable archipelagos: south-west Pacific environment and prehistory since 30,000 B.P. In J. Dodson (Ed.), *The Naive Lands: Prehistory and Environmental Change in Australia and the South-West Pacific* (pp. 160–198). Melbourne: Longman Cheshire.

Hope, G., Stevenson, J. & Southern, W. (2009). Vegetation histories from the Fijian islands: alternative records of human impact. In G. Clark & A. Anderson (Eds), *The Early Prehistory of Fiji (Terra Australis* 31*)* (pp. 63–86). Canberra: ANU E Press.

Johnston, F.H. (2009). Bushfires and human health in a changing environment. *Australian Family Physician,* 38, 720–725.

Keppel, G. & Tuiwawa, M.V. (2007). Dry zone forests of Fiji: species composition, life history traits, and conservation. *New Zealand Journal of Botany,* 45(4), 545–563.

King, T.G. (2004). *A burning question? Fire, livelihoods and sustainability in the Navosa region of the Fiji Islands.* Unpublished PhD thesis, Massey University, Palmerston North, New Zealand.

Kull, C.A. (2002). Madagascar's burning issue: the persistent conflict over fire. *Environment,* 44, 8–19.

Kull, C.A. (2004). *Isle of Fire: the Political Ecology of Landscape Burning in Madagascar.* Chicago: University of Chicago Press.

Kumar, R., Nunn, P.D., Field, J.S. & de Biran, A. (2006). Human responses to climate change around AD 1300: A case study of the Sigatoka Valley, Viti Levu Island, Fiji. *Quaternary International,* 151(1), 133–143.

Nunn, P.D. (1997). *Human and Nonhuman Impacts on Pacific Island Environments* (3rd edn). Suva, Fiji: SSED, University of the South Pacific.

Nunn, P.D. & Kumar, R. (2004). Alluvial charcoal in the Sigatoka Valley, Viti Levu Island, Fiji. *Palaeogeography, Palaeoclimatology, Palaeoecology,* 213(1–2), 153–162.

Partridge, I.J. (1986). Effect of stocking rate and superphosphate level on an oversown fire climax grassland of mission grass (*Pennisetum polystachyon*) in Fiji. *Tropical Grasslands,* 20(4), 166–180.

Pyne, S.J. (1995). *World Fire: The Culture of Fire on Earth*. New York: Henry Holt.

Pyne, S.J. (1997). *Vestal Fire: an Environmental History, Told through Fire, of Europe and Europe's Encounter with the World*. Seattle: University of Washington Press.

Pyne, S.J. (2001). *Fire: A Brief History*. Seattle: University of Washington Press.

Pyne, S.J. (2009). The human geography of fire: a research agenda. *Progress in Human Geography,* 33(4), 443–446.

Southern, W. (1986). The Late Quaternary environmental history of Fiji. Unpublished PhD thesis, Australian National University, Canberra.

Spriggs, M. (2010). Geomorphic and archaeological consequences of human arrival and agricultural expansion on Pacific islands: a reconsideration after 30 years of debate. In S. Haberle, J. Stevenson & M. Prebble (Eds), *Altered Ecologies: Fire, climate and human influence on terrestrial landscapes* (*Terra Australis* 32) (pp. 239–252). Canberra: ANU E Press.

Vérin, P. (1994). *Madagascar* (3rd edn). Paris: Karthala.

Waterloo, M.J., Schellekens, J., Bruijnzeel, L.A. & Rawaqa, T.T. (2007). Changes in catchment runoff after harvesting and burning of a *Pinus caribaea* plantation in Viti Levu, Fiji. *Forest Ecology and Management,* 251(1–2), 31–44.

World Wildlife Fund (2006). Fiji tropical dry forests. In C. J. Cleveland (Ed.), *Encyclopedia of Earth* http://www.eoearth.org/article/Fiji_tropical_dry_forests, (retrieved 3 Aug. 2011). Washington: Environmental Information Coalition, National Council for Science and the Environment.