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Preface

Fire and savanna landscapes in northern Australia: regional lessons and global challenges

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Introduction and background

Since the mid 1990s, a substantial research effort has addressed various aspects of the ecology and management of Australia's *ca*. 1.9 million km^2 tropical savannas region (an area encompassing a quarter of the continental land mass). Notably, much of the research has occurred under the umbrellas of two major collaborative research organisations, both based at the Northern Territory University, Darwin—the Tropical Savannas Cooperative Research Centre (TSCRC), and the Australian Research Council Key Centre for Tropical Wildlife Management (KCTWM). Major research themes undertaken through these centres relevant to this volume have included: developing a better understanding of spatial and temporal patterning of regional fire regimes at a variety of landscape scales; implications for savanna structure, carbon balance and biodiversity; and application of fire management in different extensive land use contexts—particularly pastoralism, conservation management, and indigenous practice.

As an important contribution to critical appraisal of this collective effort, an international conference was held in Darwin over the week 8–12 July 2002, co-hosted by the TSCRC and KCTWM. This combined volume (Volume 12, Numbers 3 and 4) of the *International Journal of Wildland Fire* comprises 17 invited papers from the first session of that conference, addressing the theme *Fire and savanna landscapes in northern Australia: regional lessons and global challenges*. As well as reporting major findings of their research, authors were asked to address key research challenges in their respective fields. Assembled papers from the second session, *Managing for heterogeneity: maintaining savanna wildlife*, are to be published in *Wildlife Research* in 2004.

As papers included in this volume (as well as others to be included in the companion *Wildlife Research* volume) attest, rapid progress has been made in our understanding of regional fire patterning, and in international savanna biomes generally, principally through the application of remote sensing and geographic information system (GIS) technologies. Such perspectives, in combination with a variety of experimental and modelling approaches, have provided landscape-scale frameworks, hitherto inaccessible, for application to pressing ecological, regional land management, and global climate issues.

An additional feature of current northern Australian applied fire research programs concerns a strong commitment to community participation in formulating, designing and implementing pertinent research. Indeed, both the TSCRC and KCTWM have embraced this approach as realistically being the only sensible way to assist and influence the development of improved natural resource management outcomes, especially for remote Aboriginal communities and pastoral enterprises that typically have limited economic, infrastructure and information resources.

The proceedings are, for convenience, presented in three sections as follows: *Fire patterns at the savanna-wide scale; Fire regimes and regional landscape dynamics; and Managing fire for desired landscape states.* Each section is introduced by at least one overview paper by a non-Australian author, the purpose being to give an international context to the Australian savanna papers that follow.

Fire patterns at the savanna-wide scale

It is now well recognised that the annual extent of biomass burning from savanna fires is the predominant source of global biomass burning and associated greenhouse gas emissions (Hao and Liu 1994; Andreae 1997). Such perspectives have been available only within the last 20 or so years, and particularly the last 10, principally as a result of advances in satellite-based remote sensing of fire occurrence and extent,

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and coordinated global atmospheric chemistry initiatives. Technological advances in both these research arenas are continuing at a frenetic pace.

The five papers included in this section document: (1) global initiatives towards developing a coordinated approach for providing consistent, timely, reliable, and readily useable fire information products derived from remote sensing (Justice *et al.*); (2) the current state of the art with respect to remotely sensed fire detection and mapping of savanna fires (Pereira); (3) recent studies of the extent and significance of emissions derived from biomass burning in the South-east Asian sphere (Kondo *et al.*); (4) implications of recent Australia-wide remote sensing studies of fire extent for understanding past and contemporary patterns of savanna biomass burning and emissions (Russell-Smith *et al.*); and (5) assessing the potential of remote sensing applications for monitoring of fuel curing states, and thereby informing improved fuel management at landscape-scales, in flammable Australian savanna systems (Allan *et al.*).

Fire regimes and regional landscape dynamics

The has been considerable research effort within the fire research and development community over the last 30 years directed towards understanding fire regimes—the landscape expression of temporal and spatial variation in fire interval, season of fire and fire intensity (*sensu* Gill 1975). Indeed, the concept of the regime—rather than individual fires—has become central to our understanding of the occurrence of fire in the landscape and its effects on ecosystems and the atmosphere (Bradstock *et al.* 2002). The seven papers in this section present approaches, tools and techniques for documenting fire regimes at regional scales (thousands to hundreds of thousands of square kilometers). Remote sensing, GIS and ecological modelling are all critical tools that allow us to track regional fire regimes, and extrapolate the results from local empirical studies to regional scales.

In the introductory paper to this section, Keane *et al.* argue that capturing fire regimes and their impacts on landscape dynamics is a difficult enough task, but that predicting them is even harder. Simulation modelling is one approach that can be used to explore the nature of variation in fire regimes.

Three papers discuss fire patterns and vegetation response at regional scales in north-western Australia. Fisher *et al.* discuss patterns of landscape fire and vegetation response for the vast landscapes of the north Kimberley region of Western Australia. Two papers explore spatial and temporal aspects of the fire regimes of a large, 900 000 ha property, Bradshaw Station. Yates and Russell-Smith document the variation in seasonality, frequency and return interval with respect to landscape units. The flora is attributed in terms of regenerative characteristics, and the analyses used to assess landscape fire sensitivity. Gill *et al.* explore the types and 'life histories' of patches that result from fire at Bradshaw, in particular the intervals between fires.

Two papers address the issue of change detection using remote sensing. Fensham and Fairfax assess change in woody vegetation cover over half a century using aerial photography in the Victoria River district. The study highlights the possibility that the average trend of vegetation thickening represents recovery during relatively wet times in the region after the 1970s, and is not exclusively or principally related to regional fire regimes. Bowman *et al.* tell a cautionary tale concerning the detection of fire scars using satellite imagery, based on a calibration exercise using the Kapalga Fire Experiment. Their methods show rapid fading of fire footprints; an observation underscoring the need for caution when applying fire mapping to fine-scale ecological studies.

Beringer *et al.* take a plant physiological approach to fire. They highlight the importance of fire in northern Australia for regional estimates of carbon and water exchange between savannas and the atmosphere, and the potential impacts of fire, through changes in energy fluxes, on regional climate.

Managing fire for desired landscape states

Improving capacity of land managers to use fire to achieve desired conditions in fire-prone savanna landscapes is the ostensible purpose of much of the research summarised in this volume and elsewhere. However, it would be a mistake to assume that there is unanimity about goals in landscape management or a dominant, widely shared view of what the desired states should be within, let alone across, community sectors. Uncertainty and contention extend beyond setting goals to include the suitability of different fire regimes for achieving sustainable production, maintaining landscape function and conserving biodiversity. Some participants in debates question whether we have the tools and human and other resources needed to implement particular regimes, widely endorsed or otherwise, at large spatial scales.

This group of papers explores all of these issues. A short history of fire management in South African conservation reserves illustrates the way in which objectives have changed and methods have shifted in tandem, often without much empirical assessment or justification (Bond and Archibald). Williams *et al.* summarise fire experiments in northern Australia and their implications, to identify areas where knowledge is perhaps robust enough to inform choice of methods, but also identify gaps that compromise our capacity to make good choices and then assert a useful level of control. Use of fire as a tool for pastoral production is examined by Dyer and Stafford Smith, who show that choices will be influenced by the time horizon of the manager. Longer-term economic outcomes may be very different from the immediate impacts of decisions about fire use. Indigenous perspectives are also informed by economics and tradition, and have been influential in shaping contemporary landscapes and their biota. Whitehead *et al.* discuss the match between Indigenous approaches to fire management and the expectations of conservationists, and the potential to identify and achieve shared objectives. The last paper, by Edwards *et al*., particularly focuses on ways of determining whether objectives have been achieved at both the operational level and in terms of conservation outcomes, drawing on a fire monitoring program from Kakadu National Park, a place managed jointly by Aboriginal landowners and a Federal Parks authority.

Synthesis—from regional lessons to global challenges

It is apparent from the scope of the papers in this Special Issue that great progress has been made in the past decade or so on understanding the nature of fire regimes in northern Australia, and the interactions between fire, people and the landscape. But what is our vision of the research and development needs of the next decade? What are the emerging issues, and what do the regional stories from northern Australia have to say about challenges and issues that will be faced by researchers and managers alike across the globe in the decades ahead?

Here, we provide some synthetic opinions of our own, as to how the regional lessons from northern Australia highlight current and emerging issues of global importance in fire ecology and management. For us, there are several issues that stand out. The first is the ongoing quest for enhanced remote sensing tools, and the associated need for improving the timeliness of remote sensing products, to better address fire management requirements at landscape scales, as well as facilitating improved quantification of the temporal and spatial components that lie at the heart of fire regimes. The second, which is partly dependent on the first, is the need for a better understanding of the role of fire patchiness, in terms of both fires themselves (both prescribed and unplanned) and implications for landscape function. And thirdly, there is a critical need for developing effective adaptive management models that take into account both bio-physical and socio-economic factors. These are explored further below.

Remote sensing tools and product management

Given the significance of rapidly developing continental, regional, and localised landscape-scale perspectives afforded by satellite-based sensing systems for monitoring of fire occurrence and extent detailed above, a first and somewhat obvious challenge is to better harness available instruments, at a variety of spatial and temporal scales. In the context of northern Australia, and savannas generally, the temporal resolution provided by current and near-operational geostationary satellite systems heralds varied and exciting opportunities for a multitude of research and management applications. Capabilities include real-time 'hotspot' detection, the availability of frequent (daily), complementary moderate- (MODIS) and fine- (ASTER) scale spatial data for fire mapping and associated validation purposes, and other instruments with potentialities ranging from monitoring of fuel load moisture content to emissions of gaseous species. As outlined by Justice *et al*., attendant critical challenges include developing collaborative partnerships between researchers and managers, and providing fire mapping and associated products in useful, readily accessed and down-loaded formats; a pertinent rapidly developing example of the latter is the North Australia Fire Information site at http://www.firenorth.org.au.

Remote sensing products come, however, with assorted, significant limitations (e.g. Allan *et al*.; Pereira; Bowman *et al*.), and there is a constant requirement both to better document these, and to better inform end-users. Nevertheless, it is salutary to reflect on how rapidly the integrity and reliability of fire mapping products derived from remote sensing have, in the main, progressed. A case in point is the observation made by Levine (1996: xxxvi) that '… perhaps the greatest single challenge to the scientific community studying biomass burning is to accurately assess the spatial and temporal distribution of burning over a given period of time, that is, weeks, months, or a year'. In fact, recent experience shows that the greater challenge for reliable estimation of biomass burning from tropical savannas clearly rests with fuels modelling (Russell-Smith *et al*.). Understanding fuels is also important for calculating emissions/carbon budgets (Beringer *et al*.; Kondo *et al*.; Fensham and Fairfax) and for understanding the regional health implications of biomass burning (Johnston *et al*. 2002).

Quantifying fire regimes—spatial and temporal components; ecosystem responses

There are two critical issues with respect to further understanding how fire regimes vary. The first is documenting the behaviour of individual fires, both prescribed and unplanned. The second is understanding the internal patchiness of burnt landscapes.

With respect to the first, we need to more fully understand the conduits of, and limitations to, fire spread in the landscape. This is a universal issue, as it is at the core of evaluating the behaviour of prescribed fires (starting and stopping where planned), and the effectiveness of prescribed fires in preventing unwanted fires. Here, managers and researches alike need products derived from sensors like MODIS, with useful spatial and temporal resolution, so that individual fires can be tracked from ignition to extinction.

It is clear we need to improve our understanding of the temporal and spatial components of the patches, or 'graininess', that constitute the expression of fire regimes in the landscape. This will involve quantitative analysis of patch types, configurations and sizes, over both longer and shorter timeframes. Gill *et al*. provide a framework within which to explore the properties of such patches, especially those that are cryptic, even 'invisible'. Products derived from sensors with spatial resolution at the sub-hectare scale (e.g. ASTER, SPOT, IKONOS), combined with species attribution (Yates and Russell-Smith) and/or exercises in ecological assessment (Fisher *et al*.), will be critical in this regard.

The relationships between patchiness and ecosystem health—especially in terms of the persistence of populations of plants and animals—will also require further research. Fire models that deal explicitly with these problems at a regional scale (e.g. Keane *et al.*) will become increasingly important, because much conservation planning and practice in coming decades will need to be at such scales.

The adaptive management model—the Holy Grail of fire management

To deliver on the above issues, we need workable adaptive management models. Such models must deal with multiple, complex and often potentially competing goals (Whitehead *et al.*), even within the one 'sector' (e.g. biodiversity conservation; Williams *et al.*). They must also be sufficiently robust and flexible to meet the diverse needs of communities of people at landscape scales. Northern Australia would seem to be the perfect testing ground for such a research and development adventure.

The adaptive framework implies that targets are set and management outcomes are monitored to evaluate both the appropriateness of the scientific predictions that may underpin the targets, and the effectiveness of the management processes in achieving those targets (or otherwise). The concept is not new (Holling 1978) but, because recent Australian texts on fire in the landscape (e.g. Bradstock *et al*. 2002; Dyer *et al*. 2002; Andersen *et al*. 2003) invariably conclude with a call for the application of such approaches, the implication is that there are no genuine working models for the fire community.

Target setting in itself is no easy task, because of inherent uncertainties. Management authorities in Australia have, for the most part, not addressed the challenge of uncertainty in fire management or many other areas of operation. Whatever the uncertainties, monitoring is crucial to both the setting and evaluation of targets. Edwards *et al*. present a pathway and methodology that can both detect environmental change (albeit coarsely) and, critically, engage researchers and managers in the evaluation process—the feedback loop. Flexibility and confidence in application may well also come from general acceptance of the philosophical position that nature is in flux, and that targets are best expressed in terms of ranges and thresholds rather than points, as argued by Bond and Archibald in their illustration of the influence of these shifts in conservation philosophy for management of national parks in southern Africa. These observations resonate in northern Australia, where the same issues create debate in park management circles, albeit in a less structured way.

Dyer and Stafford Smith provide a preliminary economic analysis of the tradeoffs involved in dealing with uncertainty in the pastoral industry. An important aspect of their analysis is the demonstration that adaptive management experiments may need to run for very long periods to test fully quantitative predictions about the economic consequences of fire management decisions, let alone interactions with other values.

Moreover, the economic context for any adaptive model for northern Australia is further complicated by the existence of dual economies—the Western, and the Indigenous customary economies (Altman 2000; Whitehead *et al.*). Indigenous people own much of the northern Australian land mass and the customary economy has achieved a measure of formal protection under the *Native Title Act* 1993. Continued use of fire to maintain that economy, both on and outside Aboriginal land, is therefore likely. Finding ways to maintain values important to Indigenous people on or adjacent to lands also used for other purposes poses a complex challenge for both the organisations representing Indigenous people and Government policy-makers and legislators, and may involve a unique hybrid economy that mixes customary, market and state support (Altman 2001). There is certainly no existing paradigm for this type of interaction; northern Australia is well-placed to provide globally relevant leadership on this issue.

In summary, then, we believe that the contributors to this volume have provided a strong platform on which northern Australia's adaptive fire managers can confidently build improved practice. They have provided a global and national context, and an appreciation of the state of the science for measuring operational performance and outcomes in sustainable use and conservation of savannas. They have provided examples of best practice in engagement of communities in fire management programs. Perhaps most importantly, they have shown how far understanding of fire management challenges, and our capacity to deal with both technical and socio-economic issues, have advanced in northern Australia in a few short years. Whilst they also clearly acknowledge remaining gaps and difficult challenges, our contributors have shown that great strides are possible through collaboration within and across sectors. We trust that our readers share that view and will be encouraged by this landmark volume to maintain focus on what is a critical issue for northern Australia, and savannas generally.

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