
Charles Darwin University

Scenario Planning for Remote Community Risk Management in Northern Australia Final project report

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FINAL PROJECT REPORT

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SCENARIO PLANNING FOR REMOTE COMMUNITY RISK MANAGEMENT IN NORTHERN AUSTRALIA

Final project report

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Darwin Centre for Bushfire Research, Charles Darwin University
Bushfire and Natural Hazards CRC





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Cover: Researchers Dr Kamaljit Sangha and Dr Andrew Edwards and the Garawa & Waanyi Garawa Rangers, Borroloola, at the Scenario Planning workshop. Source: Charles Darwin University



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EXECUTIVE SUMMARY

The 'Scenario planning for remote community risk management in northern Australia' project is part of CDU's northern hub second round suite of projects, commencing in July 2017. The hub involves collaborations between the Darwin Centre for Bushfire Research (DCBR) at Charles Darwin University (CDU), the North Australia Indigenous Land & Sea Management Alliance Ltd (NAILSMA), the Aboriginal Research Practitioners Network (ARNet) also based at CDU, and regional stakeholders including north Australian Fire and Emergency Management agencies, conservation agencies and remote Indigenous communities. In this report, we provide summaries of the work undertaken over the project period in the two main components of the Northern hub's scenario planning project.

Firstly, we have been developing a framework for the Fire & Emergency Services agencies to engage with remote Indigenous communities to potentially improve Emergency Services delivery. The agencies recognise the need to improve the services provided remotely, but also recognise that some jurisdictions (particularly the NT) are not adequately resourced to achieve this. The classic model of volunteering does not suit remote significantly disadvantaged Indigenous community members in remote communities. However, the expanding Indigenous Ranger program is a potential means to more appropriately engage with local Indigenous people to build local emergency management (EM) capacity, preparedness, resilience and disaster response.

This research has developed a suite of case studies. In each case, interviews/workshops have been conducted with members of the, now, widespread Indigenous Ranger Groups (IRGs) to ascertain the aspirations, willingness and capacity of the Indigenous Rangers to engage in EM activities. In this report, we provide summaries of the activities undertaken and information gathered to date at Hermansberg and Yuendumu in Central Australia, Broome, Beagle Bay and Bidyadanga in the Kimberley, Galiwinku on Elcho Island off Arnhem Land, in Bulukhuduru, Ramingining and Ngukkur in Arnhem Land, and Borroloola on the Gulf of Carpentaria. Main identified issues across the selected remote communities include little engagement of locals, if any, in managing emergency situations around the community, inappropriate placement of EM plans in police stations, lack of resources and services in remote communities, broader recognition of IRGs capacity to deliver EM services, and willingness of IRGs to participate in EM services.

Secondly, this research continues the service delivery program of land management, monitoring and evaluation tools to assist fire managers in remote north Australia. To develop "Improved Fire Management Regimes", we provide information with respect to the spatial distribution, and effects of fires on tropical savanna and rangeland habitats through the Savanna Monitoring & Evaluation Reporting Framework (SMERF). In particular, we include the development of a fire severity map product, not only to inform land management, but to improve Savanna Burning greenhouse gas emissions calculations.

Finally, this report addresses ongoing priorities identified by partner agencies and community stakeholders requiring further action-based research and implementation, especially addressing:



- Understanding the full “costs and benefits” of engaging with IRGs in delivery of effective EM in remote community settings;
- Full accounting of the costs of natural hazards and disasters in northern Australia and;
- Ongoing development of tools to assist savanna fire managers, for example: fire behavior models, improved fire mapping resolution, curing mapping.



END-USER PROJECT IMPACT STATEMENT

Ken Baulch, *Bushfires NT, Department of Environment and Natural Resources, NT*

The scenario planning project has focused on opportunities for engaging with and utilising the emerging capacities of IRGs in emergency management (EM) in remote community settings. There are many opportunities offered by government agencies and shire councils for IRGs to develop fee-for-service and contracted arrangements, for example: undertaking bushfire preparedness and management activities around towns and out-stations; tree clearing and a variety of response activities after big storms, cyclones and floods. As a rural fire management agency, we can foresee many benefits from local, well-trained individuals for emergency management primarily in mitigation but also in responding to wildfires.

Volunteering is a very worth-while activity, for the community and for the mental and physical health of the people involved. However, there are barriers to involvement for people living in remote areas, such as maintaining car registration and drivers' licenses, especially where there is endemic poverty and disadvantage. The work that the Darwin Centre for Bushfire Research (DCBR) team has undertaken with the IRGs has been crucial in identifying these issues and instigating the changes needed to involve local people in local EM activities.

The DCBR team members have, so far, developed a rough model outlining the development of two very successful IRGs and their involvement in volunteering in Bidyadanga and Beagle Gulf in the Kimberley in Western Australia. The salient points our agency will be able to take away from the DCBR analyses includes: the importance of providing long-term agency support from trained personnel with appropriate cross-cultural training; the provision of regular, flexible and appropriate training and resourcing; respectful collaboration with communities and traditional owners; and to engender fee-for-service arrangements within the shire councils, agencies and other land owners/managers to help support the IRGs.

Over the years, DCBR have developed a number of irreplaceable tools that are used widely and regularly by land managers right across the NT and the rest of northern Australia, such as the North Australia Fire Information (NAFI) web portal, the Greenhouse Gas Emissions calculator (SavBAT), Infonet for our reporting needs, and now they are reporting on the development of the Savanna Monitoring & Evaluation Reporting Framework (SMERF) and fire severity mapping. SMERF will greatly increase our capacity to analyse past fire regimes to assist with planning. Fire severity mapping will take this one step forward providing us with more detail regarding the real distribution of hot fires.

The DCBR team have performed well, having published papers of international significance, and patiently working towards the development of remote Indigenous community resilience. They have provided insights into the potential for Indigenous Ranger Group involvement in remote community EM activities, and assisted rangers to better understand their aspirations in this space. The Leadership and Governance training is new and exciting, the results thus far have been very positive, generating a lot of interest in similar future events.



PROJECT TIMELINE

The 'Scenario planning for remote community risk management in northern Australia' (hereafter called the Scenario Planning [SP]) project was a continuing component of CDU's 'northern hub' suite of projects that commenced in 2014, collectively addressing '*building capacity in north Australian remote communities*'. The SP project commenced in July 2017. The main objective of this project was to enhance the capability of and empower vulnerable north Australian communities to better plan for and address EM issues.

This core objective has been addressed through the undertaking of targeted SP and other activities during 2017-2019 at selected participatory remote communities including Hermannsburg and Yuendumu in Central Australia, Beagle Bay and Bidjardanga in the Kimberley, Galiwinku on Elcho Island off Arnhem Land, in Bulukhuduru, Ramingining and Ngukkur in Arnhem Land, and Borroloola in the Gulf of Carpentaria. With this on-ground collaborative research, the CRC researchers were able to assess and report on the current situation of EM in remote communities, and have identified gaps, resources needs, and IRGs capacity and aspirations. Our cases studies, recognising lack of information on EM in remote communities, offer the main sources of information for the EM agencies and related policies across the north. The key lessons learnt from this project include: recognition of IRGs as potential players in EM planning and service delivery in remote communities; the need to build effective partnerships with IRGs; assessment of the total (monetary and non-monetary) benefits of involving IRGs in EM to find cost-effective and long-term solutions; and assessment of the capacity of IRGs to effectively manage EM situations across northern Australia.

In the first year of the SP project, we had several meetings with the EM agencies in the NT to select remote vulnerable communities for case studies. These communities were then approached for initial consultations to seek their interest and participation in SP workshops. The ethics approval was obtained through CDU-Human Research Ethics Committee (approval number H17134). The first round of workshops commenced in early 2018 with Borroloola, Hermannsburg, and Yuendumu communities, and later in 2018-19 we expanded to few other remote communities in the Kimberley and Arnhem Land. After the two rounds of workshops in all the selected communities, we started reporting back to the communities in 2019 to confirm and update our project findings. This was followed by multi-stakeholder workshops with the EM representatives and the IRGs/Traditional Owners (TOs) in the NT to collectively explore sustainable solutions/alternatives to better manage and mitigate natural hazards in remote locations.

To encourage policy decision makers to invest in building the capacity of IRGs in EM, and to draw their attention to the true costs of natural hazards, we assessed total costs (tangible and intangible) from wildfires in the NT (estimated at \$150 million per year, and for Indigenous people alone at \$272 million per year). We further expanded this analysis in 2020 to include all the major and minor natural hazards in the NT over the last 10 years.

From 2019 onwards the SP project has also developed a fire severity map product through SMERF (a focused utilisation project funded through the CRC), that



informs land managers as well as contributes to improving Savanna Burning greenhouse gas emissions (GHG) calculations, thus directly informing Australia's GHG emissions inventory.



KEY FINDINGS

1 BUILDING THE CAPACITY OF INDIGENOUS RANGER GROUPS TO DELIVER EFFECTIVE EM IN REMOTE COMMUNITY SETTINGS

In summary, a model for effective engagement and partnership with remote Indigenous communities can be guided through the following salient points:

1. Long-term agency support is required from trained personnel with appropriate understanding of and consideration for the social, economic and cultural issues.
2. The classic model of volunteerism has limited applicability in remote Indigenous communities for various social, economic and cultural reasons
3. That support needs to build on foundations of mutual respect.
4. A collaborative model of managing EM in remote communities, developed in consultation with local members, is vital to improve the current situation.
5. Implementing a multi-sector targeted approach for generating new opportunities to reduce the risk of natural hazards in remote settings, offering a cost-effective way to mitigate and manage natural hazards.
6. EM can be undertaken as part of activities addressing broader landscape and community management.
7. Agencies need to be patient in their support for, and provide regular, flexible and appropriate training, mentoring and resourcing assistance.
8. Significant efficiencies can be gained through developing contracted, fee-for-service arrangements—especially where agencies have limited or no capacity to deliver required services themselves.

2 FULL ACCOUNTING OF THE REAL COSTS OF NATURAL HAZARDS AND DISASTERS IN NORTHERN AUSTRALIA

A detailed assessment of total, monetary and non-monetary, costs associated with natural hazards in the NT suggests that:

1. Natural hazards in the NT cause total losses > \$150 million on average per annum (2010-2019), with monetary losses comprising only \$53 million per annum, typically only considered for policy decision making.
2. Non-monetary losses, estimated at \$103 million per annum (accounting mainly for bushfires and cyclones), constitute two-thirds of total losses that remain - largely omitted in our current natural hazard-related assessments and policies.
3. Minor, yet frequent, events such as monsoon troughs, floods, cost >\$7 million per annum for the NT, need to be considered in national disaster datasets—AUS-DIS and the Australian EM Knowledge Hub disaster events data (<https://data.gov.au/dataset/ds-dga-26e2ebff-6cd5-4631-9653-18b56526e354/details?q=Disasters>).



4. Effective partnerships with remote communities, and cross-sectoral engagement, especially with the environmental sector, is essential for building resilience to natural hazards across northern Australia.

3 DEVELOPING TOOLS FOR SAVANNA FIRE MANAGERS

Due to the findings from extensive consultation of fire management personnel, SMERF has developed in 3 directions:

1. In response to a nearly standardised need for high level reporting and planning requirements, the initial SMERF report provided a thoroughly sophisticated and complete range of fire metrics presented as maps, graphs, tables and long-term trend analyses, and is referred to simply as the **“SMERF Report”**;
2. Further consultation led us to understand the requirement of a web-site with a simple map, graph and longer-term trend graph for each year, at a regional and property level, known as the **“Dashboard”**, set up at user-request to provide a simple overview of a property or region, and;
3. A **“Fire Community”** report for specific habitats subsetting from project areas. The report is based on the assessment of one or two metrics, combined with thresholds of effectiveness provided by the user.



RESEARCH IMPACT

The SP project has led to a significant impact on highlighting EM issues in remote communities for EM agencies and Indigenous stakeholders across the north, including:

1. This project has initiated a dialogue across the north among the EM agencies (NTES/FRS, DFES, & QFES) and senior TOs/Elders (from the NT and north Qld) to look for community-based solutions to effectively manage and mitigate natural hazards in the region;
2. It has led to discussions among Indigenous stakeholders from participating remote communities to discuss EM issues and to realise that their involvement is valuable and critical for their own communities;
3. It has helped inform EM agencies, particularly the NTES, to learn about various EM issues directly from the IRGs and TOs from remote communities;
4. Detailed cost analyses, including tangible and intangible losses from wildfires and all the major and minor natural hazards from 2010-2019, directly informing EM agencies in the NT;
5. Map products from the SMERF project are proving valuable for a wide range of northern land managers, including pastoralists, and Indigenous and conservation land managers;
6. The SMERF map product also informs the National GHG emissions inventory through SavBAT (Savanna Burning Abatement Tool);
7. For the first time, this project has generated detailed information to understand EM situations in remote northern communities;
8. The SP project has led to production of >25 research publications (see page 24)



ACHIEVEMENTS

1 BUILDING THE CAPACITY OF INDIGENOUS RANGER GROUPS TO DELIVER EFFECTIVE EM IN REMOTE COMMUNITY SETTINGS

Workshops and meetings

Case study groups were selected through consultation with NTES/NTFRS at the beginning of the project. Significant meetings and workshops then included:

1. A high-level multi-stakeholder meeting with EM agencies, Indigenous Rangers and senior Indigenous leaders from the Top End, NT;
2. Several meetings/workshops/multi-stakeholder meetings to gauge the interest of Indigenous Rangers and other community members in EM planning and service delivery;
3. Meetings with Central Australian groups including the Tjuwanpa Rangers in Hermannsburg, NT and the Warlpiri Rangers in Yuendumu, NT;
4. Interviews with Bidjyadanga Aboriginal Community Council, Karajarri Rangers, Traditional Owners, and Police Officers in Bidjyadanga, WA;
5. Interviews with Nyul-Nyul Rangers in Beagle Bay, WA.

Summaries of the Workshops and Interviews are provided in [Appendix 1](#). In addition, we provide here a succinct summary of Indigenous Community member interviews outlining key messages for appropriate engagement:

Key messages

1. There has been minimal involvement from Indigenous community members, nor consideration of cultural protocols in local EM-service delivery models, under current EM arrangements;
2. There is distinct willingness amongst community members, traditional owners (TOs), and rangers to be part of EM planning/management/service delivery for building resilience in their communities;
3. There is clear recognition of the need for involving local community members among the EM agencies in north QLD, the NT and Kimberley;
4. Evidently there are insufficient resources and infrastructure to support effective EM activities in remote communities;
5. Due to the poor economic and social status, and available skillsets, of remote communities, there is a lack of interest among many local community members to volunteer for EM services;
6. Often there is a poor understanding of the cultural protocols required from EM personnel for engagement with Indigenous community members;
7. There is a need for developing a collaborative platform among the EM agencies and remote community members to improve EM arrangements in remote communities;



8. There is a need to develop cost-effective mechanisms to improve EM and build resilience in remote Indigenous communities.

2 REAL COST ANALYSIS OF NATURAL HAZARD RELATED LOSSES FOR THE NT

We conducted a detailed total assessment of natural disaster related monetary and non-monetary losses for the NT over the last 10 years, using a number of data sources ([Sangha et al. 2019](#)). This assessment builds on current available ND accounting methods which do not effectively account for marketable as well as non-marketable losses. We propose to extend this assessment to consider more realistic and comprehensive accounting of NDs across the north Australian jurisdictions.

The key points of this assessment are:

1. NDs cause an estimated loss of AUD 156 million per year (on average, from 2010-2019);
2. Intangible losses from bushfires and cyclones alone account for AUD 103 million per year, comprising two-thirds of total disaster-related losses;
3. Minor NDs such as frequent floods, storms, and monsoon troughs cost up to AUD 6-7 million per year;
4. A single flooding event can cause losses up to AUD 3 million per year; and there are several remote communities that experience frequent floods every year;
5. There is a need to recognise all minor, yet frequent ND-related losses, for remote locations such as floods and monsoon troughs; currently these are overlooked in our national databases such as AUS-DIS/EMA;
6. Estimated cost-savings for involving community members in EM services can be >AUD 30 million per year (assuming part-time employment of four members in major remote communities across the NT);
7. There is a need to develop effective partnerships for improved EM services in regional northern Australia.

3 BUILDING EFFECTIVE PARTNERSHIPS

High-level multi-stakeholder workshops leading towards transitioning the current EM arrangements

Under the CRC funded utilisation project to “Build effective EM partnerships in remote Indigenous communities”, we were due to hold a workshop in April 2020, involving senior representatives from north Australian end-user agencies and Indigenous remote community stakeholders, the Red Cross and other national research and implementation partners. The workshop was to identify challenges and opportunities for developing more effective EM partnerships between EM agencies and remote north Australian communities. Unfortunately, due to the pandemic, such a face-to-face workshop was not possible. However, our



conversations have evolved over the last 4-5 months, and have led to the proposed development of two allied multi-stakeholder workshops:

1. Darwin, NT -13th August 2020, involving rangers and senior community members from 10-12 different communities across the NT, and the local EM agencies;
2. Burketown, Queensland - 3rd September 2020, involving rangers and senior community members from the Gulf country, QFES, including the regional office in Townsville and the Deputy Commissioner, and other local organisations.

The intent is that these workshops will help inform the now-postponed April workshop when it finally can be convened.

4 DEVELOPING TOOLS FOR SAVANNA FIRE MANAGERS

Fire Severity Mapping

Fire severity mapping underpins the assessment of fires and fire management with respect to key ecological fire effects. Unlike simple fire mapping, it is very difficult to interpret directly from high resolution aerial photography, or its equivalent, and nearly impossible using moderate resolution satellite imagery. A program has been in train for several years to continually improve the automated algorithms. Here we provide background on the project and updates on the latest research effort. – [Appendix 2.1](#)

Savanna Monitoring and Evaluation Reporting Framework (SMERF)

The development of SMERF commenced as a Utilisation Contingency Funded project in late 2018. The CRC then kindly provided a second installment to continue the development. There has been very positive feedback toward the first version of SMERF which included all available metrics as maps, graphs and tables. Since then there have been two new versions, a lighter version with a cut down set of metrics available as an on-line dashboard and, a version that relates to specific fire communities mapping. Ostensibly this third version relates to the conservation estate and has been borne out of research undertaken with Parks & Wildlife in the Northern Territory, Kakadu National Park (Parks Australia) and the Queensland Parks & Wildlife Service. – [Appendix 2.2](#)

The main utilities of SMERF:

1. Monitor the effects of fires through a multitude of effects models;
2. Analyse the effects of past fires, through the assessment of an extensive fire history and
3. Improve planning capacity through analysis of past fire effects.

Through an extensive consultation process, SMERF has branched in 3 directions:

1. The thoroughly sophisticated and complete range of fire metrics presented as maps, graphs, tables and long-term trend analyses, referred to as the “**SMERF Report**”;



2. A web-site with a simple map, graph and longer-term trend graph for each year, at a regional and property level, known as the “**Dashboard**”, set up at user-request to provide an overview and;
3. A “**Fire Community (ecosystems)**” report for specific habitats subsetted from project areas. The report is based on the assessment of one or two metrics combined with thresholds of effectiveness provided by the user.



FUTURE RESEARCH PRIORITIES

On the basis of substantial research and implementation undertakings to date (as outlined elsewhere in this report), and advice and recommendations received from agency partners and remote community stakeholders, a number of core research activities have been identified for future actioning:

1 UNDERSTANDING THE FULL “COSTS AND BENEFITS” OF ENGAGING WITH INDIGENOUS RANGER GROUPS IN DELIVERY OF EFFECTIVE EM IN REMOTE COMMUNITY SETTINGS

It is quite evident that IRGs provide a currently untapped resource for delivering EM services in remote communities. Discussions with key agency partners and remote community stakeholders have emphasised the need to undertake a thorough “cost-benefit” study, involving both Indigenous and non-Indigenous research partners, to explore and provide a compelling case to better advocate for this proposition—noting that costs and benefits apply to the accounting of a variety of socio-cultural (e.g. health, well-being) and conventional financial values. Such a study would feasibly address a variety of related questions:

- How do EM agencies engage effectively and build long-term relationships with remote communities—especially in the absence of adequate knowledge concerning the importance of engaging with Indigenous ‘informal’ community governance arrangements?
- Conversely, how do local communities develop and build effective long-term partnerships with EM agencies?
- In the experience of northern EM agencies and remote communities, are there good examples of effective EM partnerships and delivery, what are their characteristics, and how transferable are such models more broadly?
- How can EM arrangements better utilise remote community resources, skills and capabilities (e.g. IRGs)—especially given that EM agencies typically do not have the resources to effectively service the PPRR needs of many dispersed remote communities?
- How appropriate and effective are standard Volunteer models for engaging and retaining remote community members—what are the experiences of EM agencies operating across the North?
- What are the associated costs and benefits (including for community health, well-being; savings to government; financial and intangible) of different volunteer or alternative (e.g. fee-for-service) engagement models—what is the evidence?
- How do above matters relate to ongoing national discussions addressing evolving EM community engagement and Volunteer models? Who might they inform and be informed by?



2 ASSESSING THE FULL COSTS OF NATURAL HAZARDS ACROSS NORTHERN AUSTRALIA

Building on the methodological approach adopted in the recent paper outlining the full costing of natural hazards in the Northern Territory (refer [Publication](#)), including both monetary and non-monetary losses, there is an opportunity to apply the same approach for assessing such costs across other jurisdictions. Assessing both the monetary and non-monetary losses is essential to appropriately inform policy decision making and to develop effective EM measures. No current assessment in Australia, including a recent detailed assessment by the Australian Business Roundtable for Disaster Resilience and Safer Communities (ABRDRSC 2017), estimates the loss of natural systems due to cyclones or bushfires, both of which are extensive and frequent in north Australia where Indigenous cultural footprints are widespread. Moreover, since Indigenous communities have imbued relationships with land across the north, estimating the real costs using community-based case studies helps develop effective measures and partnerships across multiple sectors at a local scale. For example, engagement with Indigenous Rangers to deliver effective EM arrangements. Such an integrated understanding of real costs enhances the development of long-term programs to build resilience in hundreds of remote communities across the north.

3 ONGOING DEVELOPMENT OF TOOLS TO ASSIST SAVANNA FIRE MANAGERS

Fire management in north Australia has improved alongside our capacity to provide more and more detailed analyses of the fire mapping information, including tools to support better fire management planning. To that end, we are regularly surveying our vast user-network to best utilise improved satellite and other spatial and ecological information for their use.

We have compiled the following list of user needs for development in the near-future:

1. Fire behavior simulations for engaging with communities to build resilience. For some time, DCBR have been working with many north Australian communities to better understand fire behavior through 3-D modelling; **An on-line 3-D modelling system** would aid many more communities;
2. The NAFI and SMERF information rely upon moderate resolution fire mapping (currently derived from the MODIS satellite with 250 m pixels, although a post-MODIS succession plan is in development). Development of **Savanna-wide high-resolution mapping** systems is now far more accessible and considered the most appropriate scale now that fire management in savanna burning projects is creating very fine prescribed burning mosaics;
3. The development of high-resolution fire mapping offers the opportunity to improve the assessment of fire patchiness. Fire monitoring and evaluation techniques now require development of **a patchiness algorithm from**



high-resolution fire mapping to improve temporal and geographical attribution of burnt patches;

- The SMERF system has demonstrated its utility to scrutinize fire management for improved fire management planning. Users in other Rangelands zones of Australia require the development of **a National Rangelands Fire Information system**, that is, geographical expansion of existing NAFI into NSW and Victoria rangelands;
- Similarly, for operational purposes, to inform fire managers of the best time to undertake prescribed burning in large regions requires the development of **Savanna/Rangelands-wide mapping of grass curing**;
- In the past 18 months, since the first work on the creation of SMERF, there have been many advances stemming from advanced technologies, but mostly from user-feedback. We expect that this kind of iterative improvement will support continued development of monitoring and evaluation tools (SMERF) such as:
 - improvement of the dashboard to allow for assessment at the fire community level;
 - more user-engagement to ascertain appropriate fire regime evaluation thresholds;
- **High biomass grassy weeds:**
 - mapping of occurrence;
 - calculating rates of spread;
 - field assessments to characterise fuel accumulation and;
 - rates of curing and;
 - impact on fire danger warning systems.



KEY PROJECT MILESTONES: 2017-2020

1.1.1: Discussions with potential remote community participants undertaken, with final site selection completed

We had several meetings with the NT emergency management representatives (involving NT Emergency Services (NTES), Fire and Rescue Services (NT FRS), and Bushfires NT) to identify key vulnerable remote communities in the NT. As per suggestions, we contacted those identified communities to seek their participation in the SP project.

1.1.2: Report on status of high resolution fire mapping

A report was submitted to the CRC.

1.1.3: Posters and/or conference papers for CRC Conference

We submitted two posters and papers for the CRC conference in 2017.

1.1.4: Quarterly report

This report summarised the initial process of engaging with the key stakeholders, i.e. remote communities and the EM agencies.

1.2.1: Undertake submission for ethics approval for work in remote Indigenous communities.

We submitted our ethics application to CDU-Human Research Ethics Committee, which was approved under H17134, in early 2018.

1.2.2: Quarterly report

This report summarised the ethics approval process, and our further conversations with the participatory remote communities.

1.3.1: Scenario Planning workshops undertaken in selected remote indigenous communities

First round of SP workshops started early in 2018 with ethics approval, in remote communities of Hermannsburg, Yuendumu, and Borroloola.

1.3.1: Journal article submitted for CRC approval on “Application of new fire metrics for environmental assessments ”

Paper submitted.

1.3.2: Quarterly report

This report provided a summary of SP workshops with the participatory remote communities, highlighting key issues specific to each community settings.

1.4.1: Reports distributed to communities summarising Scenario Planning workshops.

We visited the selected communities to report back, and held another round of discussions to gauge IRGs interest and to understand the barriers for rangers to join EM services.

1.4.2: Report on the applicability and utility of new fire monitoring framework for regional planning



Report submitted to CRC

1.4.3: Quarterly report and annual report

These reports summarised SP workshop activities particularly in Borroloola, Hermannsberg and Yuendumu, and highlights main EM issues and processes including resources, and lack of engagement of local people in EM service delivery.

2.1.1: Scenario Planning workshops in selected remote indigenous communities

During this quarter, we visited the Garawa & Waanyi Garawa Rangers in Borroloola, The Tjuwanpa Men Rangers in Hermannsberg and interviewed Benji Kenny, the Tjuwanpa Men Rangers Coordinator. We undertook a series of interviews with each of the groups as part of scenario planning.

2.1.2: Posters and/or Conference Papers for CRC Conference

We supplied the AFAC conference with a paper and posters outlining our work over the past year.

2.1.3: Quarterly Report

The quarterly report summarised the various interviews, meetings and publications we undertook or produced in the period.

2.2.1: Reports distributed to communities on Scenario Planning workshops

In this quarter, we were invited over to Broome by Grant Pipe and Lee Vallance from DFES WA, to undertake interviews with two of the local IRGs who have successfully integrated their work programs into the local Volunteer Brigade.

We have since summarised the processes and conditions that have made this program successful.

2.2.2: Report on the assessment of the multi-scaled calibration of high resolution burnt area and fire severity mapping

In this report we collated and distilled all of the available information required to undertake high resolution burnt area and fire severity mapping for the; savanna regions of Australia.

2.2.3: Quarterly Report

The quarterly report summarised the various interviews, meetings and publications we undertook or produced in the period.

2.3.1: Consultations with remote Indigenous communities and end-users about planning activities to date

In this quarter, we reported on the consultations undertaken with the Galiwinku community on Elcho Island. The Galiwinku community is in the unique position to have been impacted on by two Tropical Cyclones in a short period. Their journey from having little recognised role in the disaster response to now has seen significant change in the way they represent their governance to the government and similar institutions.



2.3.2: Journal articles submitted for CRC approval on “Multi-scaled calibration of burnt area and fire severity mapping” & “Preliminary findings from scenario planning activities in remote Indigenous communities of north Australia”.

In this quarter, a paper was developed and submitted for submission to the Australian Journal of Emergency Management. Entitled “Long-term solutions to improve emergency management services in remote communities in northern Australia” this seminal paper sets out a framework for engaging with remote Indigenous Australians to improve emergency management capabilities.

2.3.3: Quarterly Report

The quarterly report summarised the various interviews, meetings and publications we undertook or produced in the period.

2.4.1: Analysis of the feedback provided from the Scenario planning workshops in remote Indigenous communities.

In this period, we continued the development of the scenario planning strategy for the Garawa and Waanyi Garawa Rangers in Borroloola. We have worked with the rangers for a number of years and seen many set-backs due to inter-family fighting, particularly to do with mustering on the Nicholson Block, with respect to the Section 19 process undertaken by the Northern Land Council. Also, earlier in the year, Borroloola had been impacted by a cyclone.

3.1.1: Preliminary assessment of utility and effectiveness of community case studies

3.1.2: Progress report on analysis of community planning workshops

The main event to report on was the Leadership Training course held for 20 Indigenous participants from across the Top End.

3.1.3: Posters and conference papers for CRC conference

A poster was submitted to the annual conference highlighting a summary of the work undertaken in 2018/19

3.1.4: Quarterly report

The quarterly report summarised the various interviews, meetings and publications we undertook or produced in the period.

3.2.1: High level workshops reporting back the findings of the scenario planning to senior management in agencies

NT EM Agency staff participated in a one-day workshop with the 20 participants of the Leadership Training course. This report summarised the workshop.

3.2.2: Journal article submitted to CRC outlining the final findings of the scenario planning workshops

An article entitled “Methodological approaches and challenges to assess the environmental losses of natural disasters” was submitted for assessment.

3.2.3: Quarterly report

The quarterly report summarised the various interviews, meetings and publications we undertook or produced in the period.



3.3.1: Report on feedback from senior agency management

The workshops proposed for this period have been delayed due to Covid-19.

3.3.2: Final report on the calibration and validation of higher resolution fire mapping products

See this report.

3.3.3: Quarterly report

The quarterly report summarised the various interviews, meetings and publications we undertook or produced in the period.

3.4.1: Synthesis report summarising key findings and outcomes from all project deliverables

See this report.

3.4.2: Final report

See this report.



OTHER ACTIVITIES COMPLEMENTING SP PROJECT

AIDR TRAINING FOR REMOTE COMMUNITY MEMBERS

A consortium of Charles Darwin University researchers from the Aboriginal Research Practitioners Network (ARPNNet), the School of Humanitarian Response & Disaster Management Studies, and the Darwin Centre for Bushfire Research, have been working together with NT EM agencies (Bushfires NT, NT Emergency Services and the NT Fire and Rescue Service) and the Indigenous Land & Sea Corporation to develop workshops to enhance remote Indigenous community capacity. An initial training program, funded by the Australian Institute for Disaster Resilience, was undertaken in Noonamah, outside of Darwin, in August 2019. Run over 5 days the event was hosted by the Darwin Centre for Bushfire Research and the School of Humanitarian Response & Disaster Management Studies at CDU; the Leadership component was delivered by Australian Forensic Sciences, and other certifiable components by St John Ambulance; other non-certifiable components included Scenario Planning with EM Agency staff and, the use of GIS and other on-line spatial tools (NAFI/SMERF/SavBAT) tailored for fire management.

UTILISATION PROJECTS

The Northern Hub of researchers have applied for 3 separate projects through the Utilisation Contingency Funding that we hope will greatly advance the research we've undertaken to date:

1. **A new version of the very popular Savanna Burning Book:** First developed by the Tropical Savannas CRC and published in 2001, this volume was developed before any extensive long-term monitoring programs had been developed, and although it provided great ideas for improved fire management, little or no research had been undertaken with respect to carbon.
2. **North Australia workshop addressing challenges and opportunities for developing effective EM partnerships in remote communities:** Based on preliminary discussions with EM agency end-users, the Red Cross, community stakeholders, and research partners, the DCBR team planned to organize a multi-stakeholder workshop (2-3 April 2020) under a CRC funded 'Utilisation project', to address EM partnership arrangements across northern Australia. The aim of the workshop was to collectively identify challenges and opportunities for developing more effective EM partnerships between EM agencies and remote north Australian communities. However, due to Covid-19 that workshop could not materialize, but ongoing discussions over the last 4-6 months have led to the development of two allied multi-stakeholder workshops: the first one is planned in Darwin, to be held from 10-14 Aug, and the second workshop will be held in Burketown, Qld, 31 Aug-4 Sept, 2020. At both these workshops, EM agency personnel, rangers and TOs, CDU researchers, local Aboriginal council members and other interested local parties will discuss gaps in the current EM arrangements while collectively discussing



solutions to better manage emergency situations and build resilience in remote locations.

- 3. The Savanna Monitoring and Evaluation Reporting Framework (SMERF):** SMERF has undergone significant development in the past twelve months. A thorough quality assessment process was undertaken with Queensland Parks & Wildlife Service operational personnel from Far North Queensland. Funding obtained through the CRC Utilisation Contingency Fund allowed us to create an automated on-line reporting tool. Through user surveys we determined that a simpler dashboard was also required to more simply demonstrate property-scale fire management to a more general audience.



TEAM

The Scenario Planning project is part of the larger Northern hub group of projects working with remote Indigenous communities in the NT to develop appropriate community-based training, providing economic opportunities to enable community engagement with emergency management and land management agencies, and community engagement.

RESEARCH TEAM

Professor Jeremy Russell-Smith – Project Leadership.

Jeremy is project leader for the suite of Northern Hub projects. Jeremy has long been involved with research to understand, monitor and evaluate the effects of fire in the tropical savannas. This has involved research on Indigenous land and with Indigenous people to meet their aspirations to provide economic opportunities to live back on country and manage it.

Dr Kamaljit K Sangha – Ecosystem/Economic Evaluation.

Kamal uses data to value ecosystems and the services they provide to calculate the economic opportunities available. In this project, Kamal is looking at the various fee-for-service and other economic opportunities for remote Indigenous communities to be involved in emergency management.

Dr Andrew Edwards – Spatial Science.

Andrew works with maps and spatial information to illustrate and assess fire effects in the tropical savannas. Deriving burnt area mapping from satellite imagery he has created fire history mapping and collected field data that he has used to develop ecological models. In this project, Andrew is further developing tools to assist with bushfire monitoring and evaluation.

END-USERS

Queensland Parks & Wildlife Service: Michelle Ibbett; Chris Kinnaird; Marty McLaughlin; Nathan Connor.

Queensland Rural Fire Service: Tony Hazell

WA Parks and Wildlife Service: Phil De Bruyen; Ben Corey; Ian Radford.

Bushfires NT: Mark Gardener; Andrew Turner; Rhys Swain and Ken Baulch.

Parks & Wildlife NT: Jonathon Vea; Liesl Wilson; Belinda Oliver; Lisa Lemcke, Lincoln Wilson; Sarah Kerin.

Garawa & Waanyi Garawa Rangers: Jack Green; Donald Shadforth; Robert O'Keefe;

WA Department of Fire & Emergency Services: Lee Vallance; Grant Pipe. x



LIST OF ALL PUBLICATIONS (2017-2020)

- 1 Russell-Smith, J., Sangha, K.K., James, G., 2017. Scoping remote North Australian community resilience and developing governance models through action research: Annual Report 2016-17, Melbourne, VIC, Bushfire & Natural Hazards Cooperative Research Centre (CRC), 24.
- 2 Sangha, K., Russell-Smith, J., 2017. Towards an Indigenous Ecosystem Services Valuation Framework: A North Australian Example. *Conservation and Society* 15, 255-269.
- 3 Sangha, K.K., Russell-Smith, J., Morrison, S.C., Costanza, R., Edwards, A., 2017. Challenges for valuing ecosystem services from an Indigenous estate in northern Australia. *Ecosystem Services* 25, 167-178.
- 4 Sangha, K.K., Sithole, B., Hunter-Xenie, H., Daniels, C., Yibarbuk, D., James, G., Michael, C., Gould, J., Edwards, A., Russell-Smith, J., 2017. Empowering remote Indigenous communities in northern Australia. *International Journal of Mass Emergencies and Disasters* 35, 137-153.
- 5 Buergelt, P., Paton, D., Sithole, B., Sangha, K.K., Prasadarao, P.S.D.V., Campion, O.B., Campion, J., 2017. Living in harmony with our environment: A paradigm shift. Chapter 16, in: Paton, D., Johnston, D. (Eds.), *Disaster resilience: an integrated approach*. Charles C Thomas: Springfield, Illinois., pp. 289-307.
- 6 Chambers, I., Russell-Smith, J., Costanza, R., Cribb, J., Kerins, S., George, M., James, G., Pederson, H., Lane, P., Christopherson, P., Ansell, J., Sangha, K., 2018. Australia's north, Australia's future: A vision and strategy for sustainable economic, ecological and social prosperity in northern Australia. *Asia & the Pacific Policy Studies* 5, 615-640.
- 7 Russell-Smith, J., Sangha, K.K., 2018. Emerging opportunities for developing a diversified land sector economy in Australia's northern savannas. *The Rangeland Journal* 40, 315-330.
- 8 Russell-Smith, J., Sangha, K.K., Edwards, A.C., 2018. Scoping scenario planning for remote community risk management in northern Australia, Melbourne, VIC, Bushfire & Natural Hazards Cooperative Research Centre (CRC), 17.
- 9 Sangha, K.K., Edwards, A., Russell-Smith, J., 2018. Emergency management Opportunities for remote Indigenous communities in Northern Australia, Bushfire & Natural Hazards Cooperative Research Centre (CRC) and AFAC conference proceedings., Perth, pp. 373-383.
- 10 Archer, R., Russell-Smith, J., Kerins, S., Costanza, R., Edwards, A., Sangha, K.K., 2019. Change and continuity: the North Australia cultural landscape, in: Russell-Smith, J., James, G., Pedersen, H., Sangha, K.K. (Eds.), *Sustainable land sector development in Northern Australia: Indigenous rights, aspirations, and cultural responsibilities*. CRC Press, Florida, USA, pp. 9-34.
- 11 Russell-Smith, J., Edwards, A., Sangha, K.K., 2019. Savanna fire management and bushfire and natural hazard scenario planning for north Australia. Bushfire & Natural Hazards Cooperative Research Centre (CRC), Melbourne, VIC. Pp. 57.
- 12 Russell-Smith, J., James, G., Pedersen, H., Sangha, K.K., 2019. Sustainable land sector development in Northern Australia: Indigenous rights, aspirations, and cultural responsibilities. CRC Press (Taylor and Francis Group), Florida, USA.
- 13 Russell-Smith, J., James, G., Sithole, B., Sangha, K.K., Edwards, A.C., 2019. Building emergency management capacity in remote north Australian communities—status report, November 2019, Published by the Darwin Centre for Bushfire Research, Charles Darwin University, Darwin, NT, and CRC, Melbourne, VIC.
- 14 Russell-Smith, J., Sangha, K.K., 2019. Beneficial land sector change in far northern Australia is required and possible – a refutation of McLean and Holmes (2019). *The Rangeland Journal* 41, 363-369.
- 15 Russell-Smith, J., Sangha, K.K., 2019. Submission to the Senate Select Committee Inquiry into the "effectiveness of the Australian Government's Northern Australia Agenda". Submission 11. https://www.aph.gov.au/Parliamentary_Business/Committees/Senate/NorthernAustraliaAgenda/NorthernAustraliaAgenda/Submissions.
- 16 Russell-Smith, J., Sangha, K.K., Costanza, R., Kubiszewski, I., Edwards, A.C., 2019. Towards a Sustainable, Diversified Land Sector Economy for North Australia (Chapter 5), in: Russell-Smith, J., James, G., Pedersen, H., Sangha, K.K. (Eds.), *Sustainable Land Sector Development in Northern Australia: Indigenous rights, aspirations and cultural responsibilities*. CRC Press. Florida, USA, pp. 85-132.
- 17 Sangha, K.K., Edwards, A.C., Russell-Smith, J., 2019. Valuing the North Australian conservation estate (Box 4.5 in Chapter 4), in: Russell-Smith, J., James, G., Pedersen, H., Sangha, K.K. (Eds.), *Sustainable land sector development in northern Australia: Indigenous rights, aspirations and cultural responsibilities*. CRC press (Taylor and Francis Group), Florida, USA., pp. 78-79.
- 18 Sangha, K.K., Edwards, A.C., Russell-Smith, J., 2019. Long-term solutions to improve emergency management services in remote communities in northern Australia. *Australian Journal of Emergency Management* 34, 62-71.
- 19 Sangha, K.K., Evans, J., Edwards, A.C., Russell-Smith, J., 2019. Measuring environmental losses from natural disasters: a case study of costing bushfires in the Northern Territory. *Australian Journal of Emergency Management* 34, 32-40.
- 20 Sangha, K.K., Gerritsen, R., Russell-Smith, J., 2019. Repurposing government expenditure for enhancing Indigenous well-being in Australia: A scenario analysis for a new paradigm. *Economic Analysis and Policy* 63, 75-91.
- 21 Sangha, K.K., Lynch, D., 2019. Land sector opportunities in the Gulf region (Box 7.2 in Chapter 7), in: Russell-Smith, J., James, G., Pedersen, H., Sangha, K.K. (Eds.), *Sustainable land sector development in northern Australia: Indigenous rights, aspirations, and cultural responsibilities*. CRC press (Taylor and Francis Group), Florida, USA., pp. 189-193.
- 22 Sangha, K.K., Russell-Smith, J., Costanza, R., 2019. Mainstreaming indigenous and local communities' connections with nature for policy decision-making. *Global Ecology and Conservation* 19, e00668.



- 23 Russell-Smith, J., 2020. Submission to the Royal Commission into National Natural Disaster Arrangements. Submission Number: NND.001.00636.
- 24 Russell-Smith, J., Edwards, A.C., Sangha, K.K., Yates, C.P., Gardener, M.R., 2020. Challenges for prescribed fire management in Australia's fire-prone rangelands – the example of the Northern Territory. *International Journal of Wildland Fire* 29, 339-353.
- 25 Sangha, K.K., Russell-Smith, J., Evans, J., Edwards, A., 2020. Methodological approaches and challenges to assess the environmental losses from natural disasters. *International Journal of Disaster Risk Reduction* 49, 101619.
- 26 Yin, C., He, B., Yebra, M., Quan, X., Edwards, A.C., Liu, X., Liao, Z., 2020. Improving burn severity retrieval by integrating tree canopy cover into radiative transfer model simulation. *Remote Sensing of Environment* 236, 111454.
- 27 Goldbergs, G., Maier, S.W., Levick, S.R., Edwards, A., 2019. Limitations of high resolution satellite stereo imagery for estimating canopy height in Australian tropical savannas. *International Journal of Applied Earth Observation and Geoinformation* 75, 83-95.



ABSTRACTS OF RELEVANT KEY PAPERS PUBLISHED DURING 2017-2020

1 REMOTE INDIGENOUS COMMUNITIES

Empowering remote Indigenous communities in northern Australia

Sangha, K.K., Sithole, B., Hunter-Xenie, H., Daniels, C., Yibarbuk, D., James, G., Michael, C., Gould, J., Edwards, A., Russell-Smith, J., 2017. International Journal of Mass Emergencies and Disasters 35, 137-153.

Abstract

Risks and challenges associated with recurring natural hazards (especially wet season cyclonic and flooding events; dry season extensive savanna fires) facing remote north Australian Indigenous communities are well recognised. Less well appreciated are longer-term challenges required for building community resilience in the face of responding to natural hazards. We report on detailed surveys of community perceptions of resilience undertaken in two communities, Ngukkurr and Gunbalanya, in northern Australia. This assessment highlights the critical challenge for government authorities to effectively engage with remote communities. We then address the equally challenging issue of enhancing resilience through building enterprise opportunities. Currently, only few employment opportunities exist in either community. Based on experience with market-based savanna burning greenhouse gas emissions abatement projects in north Australia, we illustrate the potential for ecosystem service-based enterprises to deliver culturally appropriate employment, which offers evident benefits for local communities in preparing for, responding to, and recovering from major natural disaster events.

Long-term solutions to improve emergency management services in remote communities in northern Australia

Sangha, K.K., Edwards, A.C., Russell-Smith, J., 2019. Australian Journal of Emergency Management 34, 62-71.

Abstract

Despite frequent exposure to extensive bushfires, tropical cyclones and floods, remote Indigenous communities across northern Australia typically have little engagement in managing, mitigating or planning for such natural hazards. This scenario planning project explores how remote communities, through engagement of IRGs, can contribute effectively to sustainable natural hazard mitigation and delivery of emergency services. This research emphasises the importance of developing effective partnerships between Emergency Management (EM) agencies and remote communities, to integrate and analyse EM related resources and services available through the agencies responsible in the Northern Territory. Using three remote communities as case studies we explored potential engagement opportunities with ranger groups to offer solutions to deliver efficient, cost-effective, and culturally appropriate emergency services. A collaborative policy framework is proposed involving EM



agencies and Indigenous communities to mitigate and manage disaster incidents while meeting Indigenous protocols, and recognising and taking advantage of community networks and knowledge of local socio-cultural and natural systems. This research offers practical insights into the delivery of cost-effective and improved emergency services that can empower vulnerable remote communities.

2 DISASTER RESILIENCE

Measuring environmental losses from natural disasters: a case study of costing bushfires in the Northern Territory

Sangha, K.K., Evans, J., Edwards, A.C., Russell-Smith, J., 2019. Australian Journal of Emergency Management 34, 32-40.

Abstract

Natural hazards cause sustained loss to the environment, yet the economic costs are largely not accounted for due to a lack of market measures. This research applies methods of global and national costing and proposes an integrated framework that incorporates marketable and non-marketable losses including those to the environment. These methods are applied to bushfires in the Northern Territory for estimating the cost of loss of ecosystem services as a surrogate. These fire events affect 20 per cent of the total land area annually (based on 18 years average from 2000–2018) and cost ~\$150 million per annum. Losses were greatest on the Indigenous lands, followed by pastoral and conservation areas. It is calculated that the effect of bushfires on 'loss of wellbeing' for the remote Indigenous population is, conservatively, \$272 million per year. An understanding of the costs of loss of environment is essential to develop emergency management policies that are effective in enhancing the resilience of communities.

Methodological approaches and challenges to assess the environmental losses from natural disasters

Sangha, K.K., Russell-Smith, J., Evans, J., Edwards, A., 2020. International Journal of Disaster Risk Reduction 49, 101619.

Abstract

Disasters cause enormous damages to the natural environment which underpins human survival, yet we largely fail to account for the loss of services from the damaged environment when it comes to accounting for disaster-related costs. This is mainly due to lack of conventional market price-tag for the services that are readily obtained from the natural environment. This study presents a costing framework, following the World Bank (2010), and a set of methodologies for how to measure such losses. A key focus of proposed methodologies is to assess these losses in terms of their impacts on human well-being, applying both the monetary and non-monetary measures. This paper further demonstrates the application of the proposed framework and methodologies for assessing the loss of ecosystem services from bushfires in the Northern Territory (NT), Australia, where wildfires are frequent, extensive, and often destructive. The total bushfires-related loss was



estimated at AU\$95-132million per year. Evaluating such costs for loss of Indigenous peoples' well-being who reside in remote parts of the NT, presents an estimate of AU\$272 million/yr. It discusses the key challenges to evaluate environmental losses, particularly the importance of applying local values, and understanding the local context and intricacies between social and economic systems. The framework and methodologies presented here to evaluate environmental losses can be useful to inform policy planning in natural disaster management.

Assessing the real costs of natural disasters: a case study of Australia's Northern Territory

Sangha, K.K., Russell-Smith, J., Evans, J., Edwards, A. (in preparation).

Abstract

Natural Hazard induced Disasters (NHD) cause a wide range of losses to built and natural environments, the latter often being beyond measurable yardsticks. Accounting for the exact amount and kind of losses can help in developing effective management and adaptive policies to build resilient communities. This study applies trans-disciplinary approaches to assess total, monetary and non-monetary, NHD-related losses estimated at AUD 156 million per year (on average, from 2010-2019), in the Australia's Northern Territory (NT) where bushfires, cyclones, storms and floods are often destructive and frequent events. Non-monetary losses, which are often overlooked/omitted, were estimated at AUD103 million per year, accounting for two-thirds of total disaster related losses. The marketable losses were inferred, using standard and non-standard datasets, from the Australian Government's Natural Disaster Relief and Recovery Arrangements (NDRRA), insurance costs (Insurance Council of Australia database), and other relevant sources. Non-monetary losses were accounted for by the loss of ecosystem services from natural systems caused by cyclones and bushfires only, applying ecological economics approaches, but without considering long-term losses over the duration of recovery. This study informs policy makers and disaster managers to invest in collective emergency and environmental management planning for not only reducing the risk of NHDs, but also building resilience of local communities to manage and prepare for changing climates.

Fire regimes in transition: incentivising fire management in fire-prone Australian savannas

Andrew Edwards, Jennifer Ansell, Shaun Ansell, Ricky Archer, Philip De Bruyn, Jay Evans, Ben Lewis, Tom Vigilante, Sandy Whyte, Dean Yibarbuk and Jeremy Russell-Smith (Submitted, Journal of Environmental Management).

Abstract

Savannas are the most fire-prone of Earth's biomes and currently account for most global burned area and associated carbon emissions. In Australia, savannas likewise constitute the most fire-prone biome of a notoriously fire-prone continent, with most fire extent and emissions resulting from late dry season wildfires. From the early 2000s substantial development of emissions accounting methods has been undertaken in Australia to incentivise more conservative



savanna fire management. Since inception of Australia's formal regulated savanna burning market in 2012, today 25% of the 1.2M km² fire-prone northern savanna region is managed under such arrangements. Although savanna burning projects generate significant emissions reductions and associated financial benefits especially for Indigenous landowners, various biodiversity conservation considerations, including fine-scale management requirements for conservation of fire-vulnerable taxa, remain contentious. For the entire savanna burning region, here we compare outcomes achieved at 'with-project' vs 'non-project' sites over the period 2000-19, with respect to explicit ecologically defined fire regime metrics, and assembled fire history and spatial mapping coverages. We find that there has been little significant fire regime change at non-project sites, whereas, at project sites under all land uses, since 2013 there has been significant reduction in late season wildfire, significant increase in prescribed early season mitigation burning and patchiness metrics, and seasonally variable changes in extent of unburnt (>2, >5 years) habitat. Despite these achievements, it is acknowledged that savanna burning projects do not provide a fire management panacea for a variety of key regional conservation, production, and cultural management issues. Rather, savanna burning projects can provide an effective operational funded framework to assist with delivering various landscape-scale management objectives. With these caveats in mind, significant potential exists for implementing incentivised fire management approaches in other fire-prone international savanna settings.

Adaptive prescribed burning in Australia for the early 21st Century – context, status, challenges

Jeremy Russell-Smith Lachie McCaw and Adam Leavesley. 2020. International Journal of Wildland Fire 29: 305-313.

Abstract

Despite evident advances in knowledge and understanding concerning the application of prescribed burning for delivering benefits in wildfire control and a variety of sociocultural, economic and environmental outcomes, the practical application of prescribed burning in Australia is increasingly administratively and logistically complex, often controversial and climatically challenging. This series of papers does not address the merits or otherwise of prescribed burning – we accept the lessons from antiquity and recent history that the use of prescribed fire in contemporary Australia is essential for reducing, although not always being able to deliver on, wildfire risks and meeting a variety of societal and environmental needs. This special issue focuses on several fundamental adaptive management and monitoring questions: are we setting appropriate management targets? Can these targets and associated indicators be readily measured? Can we realistically deliver on those targets? And if so, what are the costs and/or trade-offs involved? The 10 solicited papers included here provide a sample illustration of the diversity of approaches currently being undertaken in different Australian regions to address complex adaptive management and monitoring challenges.

Challenges for prescribed fire management in Australia's fire-prone rangelands – the example of the Northern Territory



Jeremy Russell-Smith, Andrew C. Edwards, Kamaljit K. Sangha, Cameron P. Yates and Mark R. Gardener. 2020. *International Journal of Wildland Fire* 29: 339-353.

Abstract

Northern Australia comprises by far the most fire-prone-half of a fiery continent, where fire frequencies range from annual in the tropical savannas to periodic very-extensive fire events following above-rainfall conditions in the central Australian rangelands. As illustration of the challenges facing effective fire management in Australia's 5.7 _ 106 km² rangelands, we examine the status of contemporary prescribed burning activities in the Northern Territory, a 1.4 _ 106 km², very sparsely settled (0.18 persons km⁻²) jurisdiction characterised by vast flammable landscapes, few barriers to fire-spread, predominantly anthropogenic ignitions, and limited institutional resources and capacity. Unsurprisingly, prescribed-fire management is shown to be restricted to specific locales. For more effective, landscape- scale fire management, potential solutions include engagement with dispersed remote communities and incorporation of IRGs into the fire-management network and building on the success of savanna-burning greenhouse gas emission projects as an example for incentivising landscape fire and emergency management services generally. Recently, significant steps have been taken towards implementing formal regional fire-management planning processes involving inclusive community-stakeholder engagement, and the setting of clearly defined time-constrained objectives and targets.

Emerging opportunities for developing a diversified land sector economy in Australia's northern savannas

Jeremy Russell-Smith and Kamaljit K. Sangha. 2018. *The Rangeland Journal* 40:315-330.

Abstract

We explore sustainable land sector opportunities for Australia's 1.2 million km² northern savanna rangelands where extensive beef cattle pastoralism is the predominant contemporary land use. Our focal region is characterised by mean annual rainfall exceeding 600 mm, ecologically bountiful wet season water availability followed by 6-8 months of surface water deficit, mostly nutrient-poor soils, internationally significant biodiversity and carbon stock values, very extensive dry season fires in pastorally unproductive settings, a sparse rural population (0.14 persons km⁻²) comprising a high proportion of Indigenous people, and associated limited infrastructure. Despite relatively high beef cattle prices in recent seasons and property values escalating at a spectacular ~6% p.a. over the past two decades, long-term economics data show that, for most northern regions, typical pastoral enterprises are unprofitable and carry significant debt. Pastoral activities can also incur very significant environmental impacts on soil and scarce dry season water resources, and greenhouse gas emissions, which currently are not accounted for in economic sustainability assessments. Over the same period, the conservation sector (including National Parks, Indigenous Protected Areas) has been expanding rapidly and now occupies 25% of the region. Since 2012, market-based savanna burning projects aimed at reducing greenhouse gas emissions occur over a further 25%. Returns



from nature-based tourism focused particularly on maintaining intact freshwater systems and associated recreational fishing opportunities dwarf returns from pastoralism. The growth of these latter industries illustrates the potential for further development of profitable 'ecosystem services' markets as part of a more environmentally and socially sustainable diversified regional land sector economy. We outline some of the imminent challenges involved with, and opportunities for developing, this new industry sector.

Beneficial land sector change in far northern Australia is required and possible—a refutation of McLean and Holmes (2019)

Jeremy Russell-Smith and Kamaljit K. Sangha. 2019. *The Rangeland Journal* 41:363-369.

Abstract

In a recent paper we set out a case for extending current and emerging ecosystem services enterprise opportunities to support sustainable land sector development in far northern Australia (Russell-Smith and Sangha 2018: *The Rangeland Journal* 40, 315–330. doi:10.1071/RJ18005). In that paper we illustrate very significant economic viability and environmental sustainability issues associated with the current dominant land use, the extensive rangeland beef cattle industry. Our beef enterprise economic assessments drew heavily on reports by Ian McLean, Phil Holmes and colleagues, as well as various other authoritative studies. In a detailed response, McLean and Holmes outline their concerns that, in various instances, we misrepresented their data and that our assessment 'does not accurately portray the economic performance and contribution of the pastoral sector in northern Australia, nor justify the conclusion that fundamental land sector change is required' (McLean and Holmes 2019: *The Rangeland Journal*, in press. doi.org/10.1071/RJ18098). While acknowledging the singular contributions of those authors for our understanding of the enterprise characteristics and challenges faced by northern beef producers, we: (a) for context, demonstrate the magnitude of the economic and sustainability challenges faced by the majority of northern beef producers as described in a range of pertinent studies including their own; (b) provide a detailed refutation of all eight of their listed concerns; and (c) conclude that available evidence does in fact strongly support the need for exploring diversified enterprise opportunities towards developing a sustainable and inclusive far northern land sector.

3 MAPPING TOOLS

Improving burn severity retrieval by integrating tree canopy cover into radiative transfer model simulation

Yin, C., He, B., Yebra, M., Quan, X., Edwards, A. C., Liu, X. and Liao, Z., 2020. *Remote Sensing of Environment* 236: 111454.

Abstract

Burn severity mapping greatly informs fire management and can be used to predict post-fire vegetation recovery. Satellite remote sensing is a cost-effective



method for estimating burn severity, providing a comprehensive spatially explicit view of whole landscapes. However, the proportion of tree canopy cover (TCC) affects the reflectance signal, obscuring background char and ash. Consequently, traditional optical satellite remote sensing methods that do not account for variation in TCC misclassify burn severity, especially in areas with extremely low or high TCC. In this study, TCC data served to parameterize and constrain the inversion of the Forest Reflectance and Transmittance (FRT) radiative transfer model (RTM) to alleviate spectral confusion when retrieving burn severity. The methodology was evaluated using field measurements of burn severity for a series of wildfires in the fire-prone tropical savannas of northern Australia and the western United States. Burn severity classes were used for Australia while the Composite Burn Index (CBI) for US. Reflectance data from Sentinel-2A Multi-Spectral Instrument (MSI) and Landsat-5 Thematic Mapper (TM) corresponding to post-fire field survey dates were used to retrieve burn severity using FRT RTM (with and without using TCC information in its parameterisation and inversion) and two standard empirical burn indices, dNBR and RdNBR, for comparison. Using FRT RTM without TCC constraint produced an overestimation for low burn severity in regions with low TCC and an underestimation for moderate and high burn severity in regions with high TCC. Burn severity estimation accuracy significantly improved by integrating TCC in the parameterisation and inversion of FRT RTM. The overall accuracy in northern Australia increased from 65% to 81%, and the kappa coefficient increased from 0.35 to 0.55. In the western United States, R2 between estimated and observed CBI, increased from 0.33 to 0.54, root mean square error (RMSE) reduced from 0.53 to 0.43, and in all instances, the method performed better than dNBR and RdNBR. The method used in this study achieved more accurate burn severity mapping, thus assisting land managers to better understand post-fire vegetation resilience and forest management.

A comparison and validation of satellite-derived fire severity mapping techniques in fire prone north Australian savannas: Extreme fires and tree stem mortality

Edwards, A. C., Russell-Smith, J. and Maier, S. W., 2018. *Remote Sensing of Environment* 206: 287-299.

Abstract

Severe fires in tropical savanna systems are recognised as incurring significant impacts on a variety of ecological attributes, including woody vegetation structure and greenhouse gas emissions. However, knowledge of the frequency and extent of severe fires is restricted given challenges associated with the development of reliable remotely sensed mapping procedures. This study takes advantage of three wildfires, 900–5300 km² in extent, containing very severely affected areas, occurring in semi-evergreen, eucalypt-dominated, tropical Australian savanna, which resulted in significant areas of complete canopy scorch, very significant tree stem mortality (24–55%), and associated loss of living above ground biomass (47–69%) at respective sites. Although increased map scale is generally considered to improve the reliability of fire severity mapping, our analysis found > 90% agreement between Landsat and MODIS-derived burnt area mapping, and > 80% for binary (severe vs. non-severe) fire severity



mapping. Mapping of internal fire (unburnt) patchiness was enhanced with finer resolution Landsat imagery, but the much longer orbital return cycle precluded its use at two of the three sites given extended cloudy conditions. Application of an automated MODIS-derived fire severity mapping algorithm (overall reliability in 2015 = 75%) calibrated for generalised north Australian savanna conditions, suggests that 15% and 12% of Australia's 1.3 M km² tropical savannas region were burnt by severe fires in 2015 and 2016, respectively. The study illustrates the potential for MODIS-derived fire severity mapping, the impacts of very severe fires on stand structure, and ongoing challenges associated with deriving reliable fire severity mapping products in Australian savanna systems.

Development of the Australian Savanna & Rangeland Monitoring and Evaluation Reporting Framework (SMERF)

Andrew Edwards, Anna Pickworth, Peter Jacklyn, Mark Gardener, Ken Baulch, Ben Corey, Grant Pipe, Aidan Joseph, Michelle Ibbett, Marty McLaughlin, Chris Kinnaird, Nathan Connor, Geoff Lundie-Jenkins, Jennifer Ansell, Patrice Weber, Cameron Yates, Jeremy Russell-Smith (In press, International Journal of Wildland Fire).

Abstract

Since 2006, payment for environmental service (PES) enterprises in north Australia have prospered, using internationally ratified Savanna Burning methodologies to calculate abatement of greenhouse gas emissions, thus earning Australian Carbon Credit Units. Land management groups from Aboriginal resource agencies, conservation agencies and pastoral enterprises have adopted techniques, based on traditional Aboriginal land management principles, reducing the overall biomass affected by fire, through strategic burning in the most benign periods of the year. The system delivers environmental benefits, and generates local employment, with improved health, cultural and social co-benefits.

Initially, the PES projects, covering large areas (10-20,000 km²) set about to reduce the total area burnt and overall severity of fire, vastly improving fire regimes of the recent past. After 5 to 10 years, in most regions, fire management planning is sophisticated, collaboration is regional, and high levels of fire management skill and capacity have been developed. Furthermore, the foundations of sustainable ecological restoration have been established.

Web-based tools have provided regular and timely satellite derived burnt area mapping, playing an unparalleled support role for planning, implementation, and monitoring the occurrence of fires, and biodiversity assessments. However, criticism of savanna burning projects has led to the need for greater scrutiny of the environmental benefits. In response, researchers and land managers have developed a suite of metrics to evaluate the effects of fire on biodiversity elements, to assist land managers to better undertake and improve their fire management.

In this paper, we outline the process to develop meaningful and easy to use metrics to measure environmental benefits, including a suite of metrics, derived from the scientific literature, collated from existing monitoring and evaluation reports, and workshops and interviews with land and fire managers. In this paper,



we detail the metrics, provide an interpretation of their application and utility, and describe thresholds for evaluation. Through this process we intend to develop a standardised and readily accessible Savanna-Rangeland Monitoring and Evaluation Reporting Framework (SMERF) for land managers in fire prone north Australia.

Delivering effective savanna fire management for defined biodiversity conservation outcomes: an Arnhem Land case study

Jay Evans and Jeremy Russell-Smith, 2020. International Journal of Wildland Fire 29: 386-400.

Abstract

Given the recent history of frequent and extensive late dry season wildfire in Australia's fire-prone northern savannas, regional conservation-based fire management programs typically aim to mitigate wildfire through the use of strategic prescribed burning during the cooler early dry season. However, it remains unclear as to the extent such environmental management concerns are being addressed by these renewed fire management efforts. This study documents changes in fire regime in the western Arnhem Land region of northern Australia associated with the implementation of active fire management since 2006. Over a 12-year period, the regional fire regime has transitioned from late dry season, wildfire-dominated to being characterised by a majority of fires occurring as small early dry season prescribed burns. Although overall area burnt has not significantly decreased, most ecological threshold metrics have improved, with the exception of those describing the maintenance of longer-unburnt habitat. Challenges involved with defining, delivering, monitoring and evaluating heterogeneity targets are discussed.

Limitations of high-resolution satellite stereo imagery for estimating canopy height in Australian tropical savannas

Grigorijs Goldbergs, Stefan W. Maier, Shaun R. Levick and, Andrew Edwards. Journal of Applied Earth Observation and Geoinformation 75: 83-95.

Abstract

Obtaining reliable measures of tree canopy height across large areas is a central element of forest inventory and carbon accounting. Recent years have seen an increased emphasis on the use of active sensors like Radar and airborne LiDAR (light detection and scanning) systems to estimate various 3D characteristics of canopy and crown structure that can be used as predictors of biomass. However, airborne LiDAR data are expensive to acquire, and not often readily available across large remote landscapes. In this study, we evaluated the potential of stereo imagery from commercially available Very High Resolution (VHR) satellites as an alternative for estimating canopy height variables in Australian tropical savannas, using a semi-global dense matching (SGM) image-based technique. We assessed and compared the completeness and vertical accuracy of extracted canopy height models (CHMs) from GeoEye 1 and WorldView 1 VHR satellite stereo pairs and summarised the factors influencing image matching effectiveness and quality. Our results showed that stereo dense matching using the SGM technique severely underestimates tree presence and



canopy height. The highest tree detection rates were achieved by using the near-infrared (NIR) band of GE1 (8-9%). WV1-GE1 cross-satellite (mixed) models did not improve the quality of extracted canopy heights. We consider these poor detection rates and height retrievals to result from: i) the clumping crown structure of the dominant Eucalyptus spp.; ii) their vertically oriented leaves (affecting the bidirectional reflectance distribution function); iii) image band radiometry and iv) wind induced crown movement affecting stereo-pair point matching. Our detailed analyses suggest that current commercially available VHR satellite data (0.5m resolution) are not well suited to estimating canopy height variables, and therefore above ground biomass (AGB), in Eucalyptus dominated north Australian tropical savanna woodlands.

Efficiency of Individual Tree Detection Approaches Based on Light-Weight and Low-Cost UAS Imagery in Australian Savannas

Grigorijs Goldbergs, Stefan W. Maier, Shaun R. Levick and, Andrew C Edwards. Remote Sensing 10(2): 161.

Abstract

The reliability of airborne light detection and ranging (LiDAR) for delineating individual trees and estimating aboveground biomass (AGB) has been proven in a diverse range of ecosystems, but can be difficult and costly to commission. Point clouds derived from structure from motion (SfM) matching techniques obtained from unmanned aerial systems (UAS) could be a feasible low-cost alternative to airborne LiDAR scanning for canopy parameter retrieval. This study assesses the extent to which SfM three-dimensional (3D) point clouds—obtained from a light-weight mini-UAS quadcopter with an inexpensive consumer action GoPro camera—can efficiently and effectively detect individual trees, measure tree heights, and provide AGB estimates in Australian tropical savannas. Two well-established canopy maxima and watershed segmentation tree detection algorithms were tested on canopy height models (CHM) derived from SfM imagery. The influence of CHM spatial resolution on tree detection accuracy was analysed, and the results were validated against existing high-resolution airborne LiDAR data. We found that the canopy maxima and watershed segmentation routines produced similar tree detection rates (~70%) for dominant and co-dominant trees, but yielded low detection rates (<35%) for suppressed and small trees due to poor representativeness in point clouds and overstory occlusion. Although airborne LiDAR provides higher tree detection rates and more accurate estimates of tree heights, we found SfM image matching to be an adequate low-cost alternative for the detection of dominant and co-dominant tree stands.

Hierarchical integration of individual tree and area-based approaches for savanna biomass uncertainty estimation from airborne LiDAR

Grigorijs Goldbergs, Shaun R. Levick, Michael Lawes and, [Andrew Edwards](#). Remote Sensing of Environment 205: 141-150.

Abstract

Understanding the role that the vast north Australian savannas play in the continental carbon cycle requires reliable quantification of their carbon stock at



landscape and regional scales. LiDAR remote sensing has proven efficient and accurate for the fine-scale estimation of above-ground tree biomass (AGB) and carbon stocks in many ecosystems, but tropical savanna remain under studied. We utilised a two-phase LiDAR analysis procedure which integrates both individual tree detection (ITC) and area-based approaches (ABA) to better understand how the uncertainty of biomass estimation varies with scale. We used estimations from individual tree LiDAR measurements as training/reference data, and then applied these data to develop allometric equations related to LiDAR metrics. We found that LiDAR individual tree heights were strongly correlated with field-estimated AGB ($R^2 = 0.754$, $RMSE = 90$ kg), and that 63% of individual trees crowns (ITC) could be accurately delineated with a canopy maxima approach. Area-based biomass estimation (ABA), which incorporated errors from the ITC steps, identified the quadratic mean of canopy height (QMCH) as the best single independent variable for different plot sample sizes (e.g. for 4 ha plots: $R^2 = 0.86$, $RMSE = 3.4$ Mg ha⁻¹; and 1 ha plots: $R^2 = 0.83$, $RMSE = 4.0$ Mg ha⁻¹). Our results show how ITC and ABA approaches can be integrated to understand how biomass uncertainty varies with scale across broad landscapes. Understanding these scaling relationships is critical for operationalising regional savanna inventories, monitoring and mapping.



APPENDIX 1: WORKSHOPS AND INTERVIEWS

1.1 BACKGROUND

The Scenario Planning project has focused on engaging with IRGs (IRGs) working in remote communities. The Darwin Centre for Bushfire Research (DCBR) have a long-standing relationship with many of the IRGs, the Rangers are skilled land managers, relative to most remote Indigenous community members, and therefore are some of the most-ready people to be able respond to bushfires and emergencies. We commenced our research by interviewing the Rangers to determine their willingness to engage in ES, to assess their interest, skills and training. We then determined the requirements of the agencies for the Rangers to successfully engage in ES.

The expected life span of Aboriginal Australians is much less than non-Aboriginals, “the gap” in health is recognised by the Australian Government as an issue of national significance (ABS & AIHW, 2008). Studies demonstrate a positive correlation describing the connectivity between land management involvement and the health of remote aboriginal people (Garnett & Sithole, 2007), particularly through the outstation movement (Morice, 1976) and the formation of IRGs (Russell-Smith *et al.*, 2009c). It is also suggested that any level of involvement in land management is important in addressing some factors affecting aboriginal health and therefore their vulnerability/resilience (Campbell *et al.*, 2011).

The main hazard for indigenous communities is their forced dependence on welfare which has been subject to a top-down approach in government policy. For example, the impact of the NT Emergency Response Intervention was the humiliation and demoralisation of indigenous communities. It undermined the existing functional governance structures, instantly, and without warning nor consultation a large suite of employment activities were removed through the cessation of the CDEP program (Edmonds, 2010). The “intervention”, by name and by nature, demonstrates a one-way, non-collaborative, stock-standard government approach. Fundamentally Australian Aboriginal people, like many other indigenous people around the world (Tousignant & Sioui, 2009), require a far greater level of independence to improve their community resilience. Therefore, the intention of the Northern Hub projects has been to characterise a diverse range of economic situations and compare them in consult with members of the remote communities.

Over the course of the project we have worked with and interviewed a number of IRGs in the NT: Hermannsburg, Yuendumu, Galiwinku, Borroloola, Ngukurr, Maningrida, Bulukhuduru, Malnjanaganak, Nitmiluk, and in WA: in Broome, Beagle Bay and Bidyadanga. We interviewed the Rangers to ascertain their perspectives on the emergency services (EM) needs in their communities, and their willingness and capacity to fill the EM gaps they identified.

We have spoken with NT Emergency Services (NTES), Bushfires NT (BFNT) and the NT Fire & Rescue Service (NTFRS) and WA DFES to determine the potential for the Rangers to work in EM, whilst reporting to them our findings from the interviews with Indigenous Rangers and others in remote Indigenous communities.



Study region

Aboriginal people live in many large parts of remote Australia, unmanaged by the Land Management and Emergency Services Agencies, and yet they have a long history (millennia) of successful land management. They are the creators of Australia's modern biodiversity.

There is very little policy and no formal framework that engenders the involvement of remote Aboriginal people in fire and emergency management, and, in part, that stems from the lack of trained personnel in Indigenous communities, but also poor and improper engagement by government agencies with remote communities.

The advent of the IRGs has created well-trained Land Managers living within many Indigenous communities, with appropriate skills and experience to deal, most particularly, with prescribed burning implementation and wildfire suppression, and additional skills with machinery and tools to enable post-event repairs and maintenance.

Context

The north Australian population is approximately 900,900 (ABS 2016) with Indigenous people comprising ~ 14%, and the largest proportion residing (30%) in the NT alone. Outside the major cities and towns, Indigenous people comprise >90% of the total population. Many of these remote northern communities are in naturally hazard-prone areas that experience frequent and extensive bushfires in the dry season, and cyclones and floods in the wet season, Figures 1-3. Typically, there are limited EM resources, operational infrastructure, government support and service delivery (Sangha et al. 2017 and 2019; NAILSMA 2014; Russell-Smith et al. 2019).

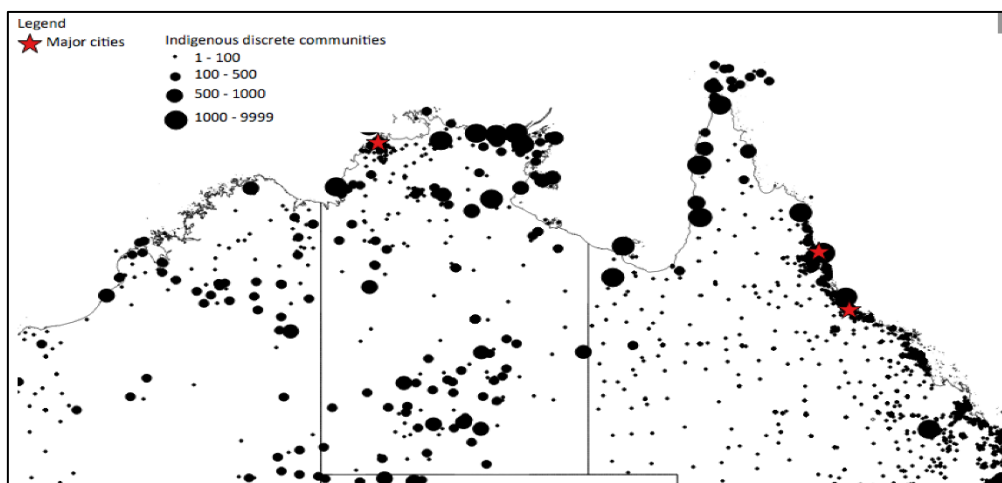


FIGURE 1. DISTRIBUTION OF DISCRETE INDIGENOUS COMMUNITIES ACROSS NORTHERN AUSTRALIA. (SOURCE: AUSTRALIAN BUREAU OF STATISTICS 2016).

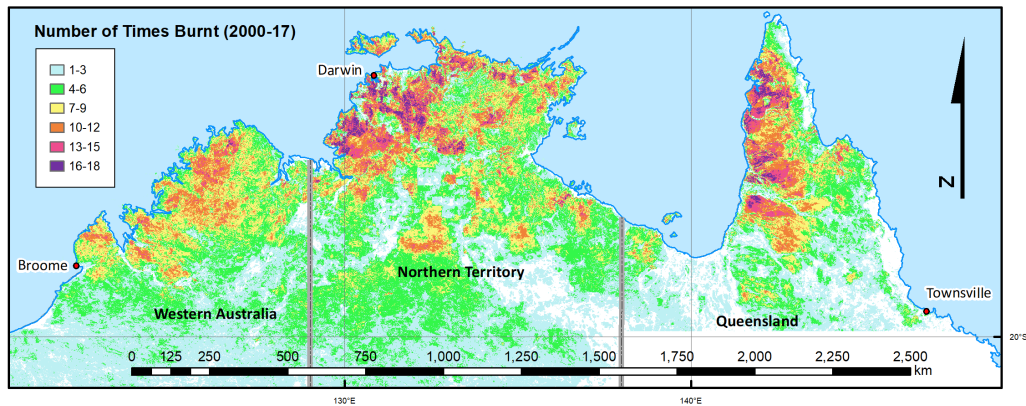


FIGURE 2. NORTH AUSTRALIAN FIRE FREQUENCY, 2000 TO 2017 (DERIVED FROM NORTH AUSTRALIA FIRE INFORMATION – WWW.FIRENORTH.ORG.AU).

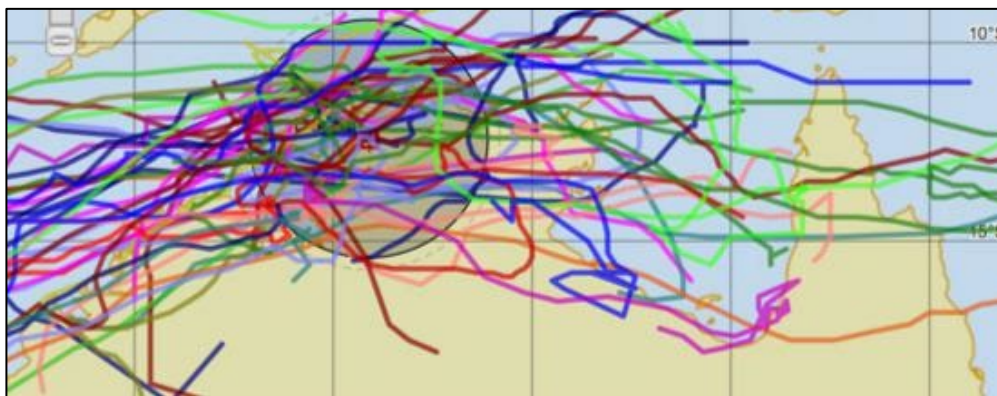


FIGURE 3. NORTH AUSTRALIAN CYCLONE TRACKS, 1970 TO 2015.

1.2 COMMUNITY MEETINGS AND INTERVIEWS

Borroloola

The initial interview with the Garawa & Waanyi Garawa (G&WG) Rangers in Borroloola revealed an interest but lack of knowledge of the NTES volunteer program. Therefore, we invited the Captain of the FERG, Nathan Eames, to visit the Garawa & Waanyi Garawa (G&WG) Rangers. He gave an inspirational talk about his fulfilling life as a F&ES volunteer. Nathan stated that there is not only a great deal of personal benefit, but also kudos from the community. As volunteers they will also receive extensive training, have access to personal protective equipment (PPE) and EM equipment. The Northern Land Council (NLC) management agreed to allow the Rangers to “volunteer” with the FERG as part of their ranger duties. There are, however, other barriers to volunteering for the Rangers, with respect to extensive availability, a driver's licence, a criminal check, and a much greater level of responsibility they've not had before. To date, none of the Rangers have submitted the volunteer application forms to NTFRS, due to either a lack of a drivers licence or fear of the responsibility. We attempted to remedy this second condition, through funding from the Australian Institute of Disaster Resilience, to undertake Leadership Training.

We spoke to the Regional Council's (Central Desert and Roper Gulf) with a CDEP1 work force, generally undertaking Council activities (such as rubbish removal, weed removal, and infrastructure maintenance). However, colleagues in BFNT informed us that the Central Desert Regional Council have employed a fire management officer to train and deploy a bushfire mitigation workforce through the CDEP program. Tamara Rolph (BFNT) was involved in the training and provided us with information to take the program to other jurisdictions. We have spoken to the Roper Gulf Regional Council CDEP program coordinator who is very interested in implementing the program.

Galiwinku community

In Galiwinku, Cyclone Lam in 2015 was the impetus for the community to create their own governance structures, transparent to Government and other non-local agencies, through the establishment of reference groups. These governance structures existed formally within the clan structures before colonisation and still exist today.



GALIWINKU WORKSHOP PARTICIPANTS

Galiwinku Reference group – Elcho Island

Topics discussed included: how to effectively engage and partner with Galiwinku community; what are the local structures and aspirations; and how CRC projects can support or empower the locals.

Tjuwanpa Men Rangers - Hermansberg

After our visit and interview with the Tjuwanpa Women Rangers Group in Hermansberg we were directed to the Men Rangers Group. The coordinator, Benji Kenny, is a local man, and very keen to advance the standing and capacity of the Rangers. Benji invited us to their biannual Traditional Owner/Ranger Advisory Committee meeting (TORAC). He was also interviewed with regard to Emergency Services in Hermansberg and the capacity and willingness of the rangers to be involved.

The team met at the Tjuwanpa Men Rangers' office. AE and KKS informed Benji about the project in detail including what it involves for the rangers to participate in the project.

Benji shared some of his experiences such as occasional flash flooding in the Finke river and how people on the other side of the river get cut off from basic services such as food, medical supplies etc. Land searches are another important issue in the community. He also described his aspirations for rangers



involved in Emergency Management for further employment opportunities around the community.

After introductions, the NAILSMA CRC project team member provided an overview of the project and the work that Galiwinku mob is doing to build their governance.

Yuendumu

Preliminary Ranger Survey 27 March 2018

Following on from our introduction to the Walpiri Rangers at the Central Land Council meeting in Tennant Creek, we decided to visit them at the rangers station in Yuendumu to conduct a more formal interview to determine the capacity of the group and impediments to volunteering.

Attendees

Rangers: Nelson Tex and Max Kennedy. Warlpiri Traditional Owners: Harry Jones, Roslyn Jones, Harry Nelson, Nellie Wayne, Maisey Wayne and Lorraine Granites. CDU Researchers: Kamal Sangha, Judith Lovell, Andrew Edwards. CDU PhD student: Claire Hawkes.

Background

The team including KS, JL, CH, and AE drove from Alice Springs in the morning. We firstly visited the Central Desert Regional Council office and met with Allan Hawke (Council Services Manager, Yuendumu). A summary of that conversation is provided below. A structured survey was then undertaken with Central Land Council Warlpiri Rangers and Yuendumu Traditional Owners, in the CLC offices at 1.00 pm Tuesday 27th March 2018, organised by Nick Ashburner, the IPA coordinator for the CLC. AE introduced the group from DCBR/CDU, describing our involvement in NAFI and the Savanna Burning projects in the north, particularly in Arnhem Land. The Rangers recalled our earlier conversation at the fire meeting held in Oct 2017 in Tennant Creek, as did one or two of the TOs. The team then surveyed the group using the Emergency Services questionnaire.

Summary

The survey questions regarding Emergency Services were asked by JL, KS and AE, whilst CH scribed. Discussion occurred over approximately 1 hour with the Rangers responding to most of the questions, Nelson periodically translated some statements and questions, and the TO's commented from time to time.

Key points in discussion with Warlpiri Rangers and TOs

People in the community will often light a fairly big fire ('Signal fire') on the roadside when they are broken down. They tend to try to get it to go in a windward direction to make it big. To their knowledge, the police are not aware of the need for this kind of burning, they probably only see it as arson. Generally, they do not respond to break downs. It is usually the community or the Rangers who respond. If a big fire does come towards the community, they back-burn to stop it.



House fires are just left to burn. There are no resources to put it out. The Council (CDRC), roads department own the fire truck, but they are not pro-active. However, the town infrastructure Department of the Council are pro-active, the group felt the truck should be with them, and listed people who they believe would be responsible enough.

The Rangers have access to a 1,000 L tank on a trailer.

The police are notably under-resourced, thus offers only limited help to the locals who need to be retrieved.

There are a number of out-stations serviced by the town (JL collected the names).

After a long conversation suggesting that the rangers are not engaged in emergency response, they then stated that unofficially the rangers respond to most of the quasi-Emergency Services tasks, usually out of town in the out-stations, and for breakdowns of Aboriginal people.

The rangers stated they were concerned about the lack of succession. They had had a couple of young people start working with them, but who then take their first pay and head off in to town, where they ended up getting locked up.

Key points in discussion with Alan from the Council

Alan does not believe there are any serious emergency response needs for the town in terms of floods or wildfires:

- Fuel loads around the town are too low for bushfires to be a problem. There is a lot of Buffel Grass, but it is not continuous.
- Flooding occurs but is short lived, that is, hours or at most, a day.
- There is no FRS presence nor is it really required.
- The Council have NTES/FRS PPE training and resources, so Council staff (including CDEP) would do any call-outs if required.
- Upon reflection Allan suggested it would be good to have a FRS position possibly attached to the police. Currently, the Police are called for all car accidents.

1.3 REMOTE COMMUNITY ENGAGEMENT CASE STUDY

Background

Here we provide a description of the development of fire management capacity in remote Indigenous communities through IRGs (IRGs) supported by the Department of Fire and Emergency Services Western Australia (DFES).

DFES have undertaken an 8-year program to develop community-based “volunteer” bushfire brigades initially mandated for 8 remote Indigenous communities, 3 in the west-Kimberley region. Chosen because their English language skills and education levels were the highest, and they were the most socially stable. This task has been driven by the Broome-based District Fire Officer, Lee Vallance, with support from the Superintendent and other DFES personnel.



The main lesson being that simply throwing money and equipment at a community has not worked.

To date, the two communities, Bidyadanga and Nyul Nyul, have reached a phase where the IRGs have working brigades and, at Bidyadanga, this includes local council employees. DFES have provided sheds containing functioning fire units on working vehicles, and associated fire management resources, including a communications room, used to undertake a strategic prescribed burning program, and have provided training to respond to wildfire.

Darwin Centre for Bushfire Research staff based at Charles Darwin University, Kamaljit Sangha and Andrew Edwards, travelled with Lee Vallance in September 2018 on one of his weekly visits, to undertake a series of interviews with key personnel at the two communities. The intention of the research was to document the approaches taken to develop the current fire management capacity in these communities to then communicate a model to implement in remote, predominantly Indigenous, communities in other parts of the country and perhaps elsewhere.

In summary, a model for engagement can be guided through the following salient points:

Long-term agency support is required from trained personnel with the right understanding and consideration for the social, economic and cultural issues.

Agencies need to be patient in their support, and provide regular, flexible and appropriate training and resourcing.

Agency representatives need to seek the permission of traditional owners and other community elders, as it shows respect. Give the proper respect, and it will be returned.

The classic model of volunteerism has limited applicability in remote Indigenous communities for various social, economic and cultural reasons.

Fire management can be undertaken as part of the activities of broader landscape and community management. Some of these activities on some land should be fee-for-service.

Interview outlines

DCBR researchers, Drs Sangha (Kamal) and Edwards (Andrew), flew from Darwin to Broome. Lee Vallance, District Officer from DFES, drove the team to the community of Bidyadanga, Figure 1. The group arrived as the Broome Shire Council were conducting an open meeting with the community, including the Mayor of Broome, the CEO of Bidyadanga Aboriginal Council, other key Broome Council staff, and members of the Bidyadanga Aboriginal Council. This provided the researchers with some insight into the local council structure, local government issues, a perspective from the nearby Broome (predominantly non-Indigenous) community, and locals who spoke up at the meeting.



FIGURE 4. THE EXTENT OF INDIGENOUS PROTECTED AREAS AND LOCATIONS OF KEY TOWNS AND COMMUNITIES IN THE WEST KIMBERLEY.

The group then went to the Police station and interviewed the Sergeant and Assistant Sergeant. The police are generally the first respondents to most incidents, especially a 000 call. Therefore, the interview was undertaken to ascertain the influence the Brigade might have had on emergency services and social issues, from their over-arching perspective.

The group then met with and interviewed the CEO of Bidyadanga Aboriginal Council (BAC), who is coincidentally the Captain of the Bidyadanga Volunteer Fire & Emergency Services Brigade. Most of the brigade are staff in the Municipal Services branch of the Council. The CEO is in the unique position to provide staff, who are volunteers, with flexible work hours to meet the demands of volunteering, particularly when she herself, as captain, is involved.

The group then met and interviewed the IPA coordinator with the Karajarri rangers, managing the Karajarri IPA, covering 32,000 km², around Bidyadanga, Figure 1. The coordinator and the rangers are part of the brigade, having solely managed fire in the community until recently.

On Day 2, the group went to Beagle Bay to interview the Nyul Nyul Rangers. The Rangers included the Head Ranger, two Senior Rangers, and another Ranger. The rangers undertake all their own planning, prescribed burning and wildfire suppression. In consultation with the rangers, Lee has transformed a nearby shed for the Brigade. It contains a communications room, personal protection clothing, a truck with a slip-on fire unit and fuel.

Interview methods

Lee Vallance introduced us to each of the interviewees and attended each interview. Although his presence may normally have introduced bias into the responses, the trusting relationship he clearly demonstrated with each person or group, his capacity to kindly receive criticism, and his additional knowledge from the departmental perspective, lead us to believe that his presence was more valuable to the interview than not.



Interviews were undertaken in the form of a conversation based on the questions in Table 1, however a single line of questioning was often pursued, or allowed to flow, to allow the interviewees to relax and express a broader opinion.

The questions were separately asked by Drs Sangha and Edwards. Both researchers took notes of the conversations, Dr Edwards collated the notes at the end of each day with Dr Sangha.

TABLE 1. QUESTIONS FOR THE BIDYADANGA AND BEAGLE BAY INTERVIEWS.

1	What is your role in the community, at work, and within the Brigade?
2	Describe your organisation, its roles and the number of personnel.
3	Describe the development of the Brigade, and your role in that process.
4	Describe the EM issues the brigade has dealt with, and any other issues you feel should/could be addressed.
5	Describe your challenges in joining and continuing the Brigade.
6	Rate community preparedness.
7	Suggestion how to develop Brigades in other Indigenous communities.

Interviews

Bidyadanga Police – Senior Sergeant and Sergeant.

The Senior Sergeant described the fire coordination effort, prior to the establishment of the Karajarri Rangers and, more recently, the Bidyadanga Volunteer Brigade (BVB), as “a loose band of people who, at one point, had attended a house fire with a garden hose.”

Since the implementation of the Brigade, their combined ability to protect the community from wildfire has increased 100-fold. Previously, there was no coordination, no one to communicate with. Now, they contact the CEO of the Bidyadanga Aboriginal Council and Volunteer Brigade Captain, and she coordinates the response. The brigade has had the truck and shed for approximately 18 months, supplied by DFES, replacing a small red troopie and a busted radio. The two Ranger groups in the community have mostly undertaken certificate 4 in Land Management, providing them with fire management training. An example was described, however, of a recent category 2 cyclone, where the only initiative for clean-up was made by a bunch of New Zealanders visiting family who worked for the BAC, who had access to a chain saw, some of those people have stayed on in the community.

The community have only relatively recently started to take on their more serious social issues, it was felt that it was a “long step” to being able to undertake an EM response role. Police have applied for a grant for 2 community members to work on domestic violence. The monies would provide training and a salary. This is to work on prevention rather than arrest.

Police hold the incident plans for Land Search and Rescue, and Road Crash, and the guidelines for cyclone/storm arrangements. Police assist through communications and coordination, they feel they are very pro-active in the community in terms of their communication. Police are first response, they contact the clinic for the ambulance, then the Council CEO, as she has the volunteer phone list, then she contacts the volunteers to assist.

Bidyadanga Aboriginal Council – Chief Executive Officer



The CEO of the Council is also Captain of the Volunteer brigade. She has been Captain for a year, coordinating the volunteers. Lee works between the Volunteers and the Rangers. The Rangers will respond out of town, otherwise the volunteers will respond in town, although the Rangers undertake much of the town response. There are a total of 15 volunteers from 5 different groups. The CEO described the previous situation as "winging it". Municipal services team would show up to a fire in the little red truck, with assistance from local people with cultural training, then Lee showed up and said, "get your act together". Currently they have a non-bespoke shed and one fire unit, and they're soon to acquire a light tanker. The CEO stated that their main limitation is the number of vehicles, which can only carry 4-7 people.

The CEO can provide flexibility to her staff to undertake their volunteer activities. They have all undertaken some Bushfire Fighter training, but she would like them all to do a lot more training, and get more exposure to fires, for experience and to build resilience in the community generally. The CEO felt the volunteer group were ready for some equipment upgrades, she would like a big truck, their activities are limited to the community, but she felt they could help other communities around them and undertake other EM activities such as attending accidents. She felt that unlicensed drivers were a limiting factor, and that perhaps there could be a bit more dispensation for remote community people with criminal records, as there was no need for a licence in town for instance.

The CEO felt that the most valuable aspect was that she and her colleagues were assisting on the front-line, not waiting for others from outside the community to come and help, "I'm part of the community preparing, not reactive. The homes and the community have been, and can be, threatened, you have to do something".

The CEO was grateful to Lee, stating that he has built good relationships with the community and the Council. He's involved the various community groups, not just the rangers, including the Council staff, such as herself.

Karajarri Rangers – IPA Ranger Coordinator

The Karajarri Rangers have been involved in prescribed burning on the Karajarri Indigenous Protected Area (IPA) for many years. The landscape wide burning program occurs through management of the Indigenous Protected Area and Working on Country funding through the Kimberley Land Council, there is no Savanna Burning project to support them, as the IPA is located south of the 600 mm mean seasonal rainfall boundary.

There is a Cert. 3 (Land Management) module for fire suppression that all the Rangers have studied, "but the best training occurs on the ground". 12 of the 15 Rangers are volunteers, the KLC has encouraged their involvement with the volunteer brigade, however the brigade and the rangers do not work together. The IPA Coordinator sees the value of the volunteer brigade as enhancing the overall capacity of the community, provides, through DFES, access to more equipment, and helps to free up more of Rangers' time. A limitation is the lack of integration between the rangers and other volunteers, they require more collective planning.



Most of their fire management work is out and about on the IPA. They don't feel that the community burning is too much work, they do it "out of necessity". They are seen as role models, appreciated by the community, Council, the Shire Council and even the neighbouring pastoralists. They are now at the fore-front of bushfire response in their region.

Although they don't have enough training now for cyclone response, The IPA Coordinator felt that they were ready to take on a significant recovery role. They have had some experience in Land Search and Rescue, an example was given of a lady lost at the lagoon nearby that they tracked.

The brigade has a fire trailer and 2 x slip-on units, but they're not able to be permanently attached, therefore they are slower to respond to a wildfire, whereas the DFES truck and unit are (sometimes) ready to go. There have- been recent instances where they've gone to get the DFES unit and it has had no fuel or water, although they are very appreciative for the access to the truck. The wildfire season has been very busy this year. The rangers plan to set up a late dry season roster, to make sure that the same people aren't being used all the time.

The Rangers would like to have more consultation from the agencies (DFES), especially considering the recent big fire in the north of the IPA, they would have liked to have been consulted more, although Lee suggested that there wasn't enough time, he had to make a very quick decision. Lee also stated he was concerned about the rangers staying out on the fire line overnight.

The Ranger Coordinator felt that anywhere where there is a ranger group it would be possible to set up a volunteer group. Other volunteers tended to be less trained than the Rangers. The rangers care more about country as they're managing it more broadly than town-centric volunteers. The Rangers give 100%, an example was given of local volunteers fighting a fire while the rangers were away but left it before it went out, this they felt was due to a lack of commitment and probably training.

Nyul Nyul Rangers, Beagle Bay - Head Ranger (Volunteer Brigade Captain); Ranger coordinators, volunteers; Ranger, volunteer

The Ranger Group consists of 9 rangers, 8 are volunteers, there are 8 other volunteers from the community in the brigade.

The Rangers undertook the burning previously. But now they have better resources. They only had 1 slip on unit. Rangers have undertaken training in prescribed burning, and response to, and suppression, of bushfires. The Head Ranger has completed the Sector commander training with KTI.

In the last couple of years, the group have been involved in the Dampier Peninsula fire working group. However, DPAW are an annual problem and won't work well with the other groups and won't let the other groups do any burning.

A Senior Ranger said they love using the leaf blowers, example of one bloke with a blower can do the work of a crew with backpacks and rake hoes. Blowers can be readily used around houses to move away the leaf litter.

Recently native title has been handed down in the area, but previously the rangers did the burning on those lands. The Jaba Jaba people now want to do their own burning. Nyul Nyul would be prepared to do it or even provide training,



but they want their own people to do it now, the Nyul Nyul want to support that, but in 2018, "Country lost out", that is, there were huge fires, as a consequence. DPAW are also supposed to work with Jaba Jaba more they don't.

Although no one was given permission to do prescribed burning, but then when there was a wildfire, permission was given in 1 day. The Rangers were excluded, they felt the fire could have been suppressed but instead the government staff did a huge back burn for safety's sake. "They killed all the Bilby's those bastards". A big easterly was obviously coming and DFES undertook a big roadside burnt hat burnt out a lot of country. This area is important country to local people, this was not considered, it was all about the supposed safety. They mentioned the District Manager from Parks & Wildlife. They're not listening to people who know country". The road works that were being undertaken were more important than looking after country.

The volunteers are involved as casuals, if rangers are short of staff and they need extra staff for an emergency, then the Head Ranger, as Brigade Captain, will press others in the community to assist by using the Bushfires Act. He will take someone and assess the fire (as there's only one seat in the vehicle). Mostly this kind of thing falls to the Head Ranger or he might pass it on to the Senior Rangers. There have been a few structural fires in town, but they are not allowed to do anything, as they do not have the required level of training. Many have advanced first aid training, but not had a call to a car accident, probably due to the proximity to Broome.

The Rangers would like to put a siren near the brigade shed for cyclone warnings. Rangers are involved in Land SAR, or they assist with bogged vehicles. But if it's not an emergency then they won't respond.

They rated the preparedness of the community to deal with the Bushfires issues as 8/10, but still felt there was room for improvement. They did not feel there were any other, as cyclones never hit the community, and anyway, they said "the old people wouldn't leave".

They suggested improvements could be made with more resources, more capacity for vehicles to carry people like the twin cab trucks, that they could do with a light truck. They would like to train more people up, undertake training and be resourced for structural fire training, however they felt they were capable to deal with structural fire. They said they'd like a washing machine and more leaf blowers.

They felt that the weather criteria for permits to burn were not appropriate. That the council need to change the allowable wind speeds to burn on the ground, currently it's 25 km/hr but that's at 8 m not on the ground where wind speeds are much lower.

Although the group said that in the whole there are no real barriers for people to join the volunteer brigade, they believed that there should be some sort of fitness test.

They felt that belonging to the brigade had provided a stronger relationship between the Rangers and DFES (primarily Lee), it had given them much greater capacity and knowledge, and consequently much more confidence as a group. The Rangers liked the fact that the school kids get really involved in ranger



stuff and it provides opportunities to get out on country, as they feel this important, they want to take the kids out to do burning, to teach them traditional knowledge and good fire management.

The Rangers felt that to improve the establishment of volunteer units in other communities that the agency representatives need to speak to the Traditional Owners first and explain what they want to do. They could then feed off existing nearby Ranger or volunteer groups to assist with mentoring and training, roll the program out along a line. This is important as you are getting the right permissions, and it shows respect. Then you need a reliable and committed Ranger crew. They gave the example of the Head Ranger, who can be called away by DFES elsewhere, he will go even if he doesn't want to, because of his commitment to the brigade.

Department of Fire and Emergency Services - Lee Vallance (District Officer)

Lee visits the communities weekly, checks vehicles, replaces equipment where he can, and provides training during working hours (not after hours like other brigades). Lee believes this regular contact is important to their relationship.

There is expansive, almost uncapped, funding available for suppression. The prescribed burning budget is mostly for mitigation on pastoral properties. They must sign up for Aerial Controlled Burning. This is just policy, not part of the Bushfires Act. It is felt that if this wasn't available most of the pastoralists wouldn't do any mitigation work, they are required to have fire breaks, although this is not very practical and not enforced. Local government is supposed to enforce it. Lee is also required to go around to local councils to make sure they're undertaking mitigation activities around the towns, basically to protect WA government infrastructure.

Each of the groups have planning meetings in November/December, neighbouring pastoralists also come to the meetings. In the plans, importantly, Lee wants to know where not to go, e.g. sacred sites/areas, so as not to offend, and if he needs to enter an area and is not sure, then they will ask the right Traditional Owner. In the planning, they use NAFI burnt area mapping to draw lines for proposed burn lines. A permit to burn around town is required from the Local Council, the groups must submit a plan, including road management and all other risks.

Bidyadanga Aboriginal Council sit within the Broome Shire Council. They provide a lot of local employment, unlike Beagle Bay where they outsource a lot of the municipal services.

Lee is conscious not to ruin programs already in communities by coming in and running over them or rebadging them. Example of kids bush rangers WA program, run through schools, while the Emergency Services cadets are run similarly. There are 3 different groups with different governance and other structures. Lee is key to understanding this about each group, developing the relationships to be able to make the assessments and support the right people.

There is often concern from some of the volunteers in terms of their availability, but Lee assures them that they can only do what they can do and tries to visit at times when they're around. An example is that many remote people go to town



on the weekends and are not available to do training. Lee is not aware that there are any issues to do with gender separation, and actively discourages it.

"We have to be prepared as an organisation to take risks with remote communities and give them equipment and training", Lee gave the example of where sheds have been broken into, mostly, it seems, it is just curiosity by young people to see what is in there".

Lee has always had dealings with Aboriginal communities, but it has only been the last 8 years he's been working on developing the brigades. It hasn't been done in this manner before, usually only ever in an emergency. Trying to do things differently by setting up brigades.

1.4 SCENARIO PLANNING: BORROLOOLA

Background

We had a whole-day meeting with the Garawa & Waanyi Garawa rangers from Borroloola on the 11th of June 2019. Since September 2018, a few meetings were planned but cancelled at the end due to several unfortunate incidents in the community, the wet season, and a cyclone that hit the region earlier in 2019.

The purpose of this meeting was:

- To learn about, discuss, and help revive the rangers' interest to participate in emergency management at a community level;
- To inform and discuss DFES's Broome model of volunteer brigades in the Beagle Bay and Bidydanga communities;
- Undertake a Scenario planning workshop – Business-As-Usual vs. Future Directions;
- To learn about the rangers' experience before and after cyclone Trevor;
- To seek the rangers' interest and participation in an EM-related multi-stakeholder workshop to be organised in August, in Darwin.

Participants

Rangers: Donald Shadforth, Peter Green, Robert O'Keefe, Jack Green, John Green, Karen Davey and Josie Green

Ranger Co-coordinator, Ed Slade, and the IPA coordinator, John Smith.

CDU researchers: Drs Andrew Edwards and Kamaljit K Sangha.

Outcomes

Ranger participation in Emergency Management (EM) services

The rangers expressed interest participating in EM and related community support services. The community experienced the category 3 cyclone "Trevor" that landed in the region hitting Borroloola on the 23rd of March 2019. The lack of involvement before and after the event, yet again, made the rangers rethink the role they can play in EM planning and support. The EM agencies in the NT do



not recognise the role these rangers can play in EM unless they are registered as volunteers, having the appropriately certified training.

A senior ranger and others felt that they could do a good job, saying “we should be going and talking to our people...before EM agencies come ...we should be informed beforehand”. This instigated thinking among the rangers as to how they could be involved and become part of the EM activities that happen in the community. At this stage, the main option is to join the local volunteer brigade. All the rangers agreed that to help their own community, they need to become members of the brigade.

The CDU researchers contacted the main station officer in Katherine and the Captain of the Volunteer Brigade in Borroloola. We hoped to organise a meeting soon with the rangers and the Captain of the Brigade to understand the obligations of joining a brigade and related paperwork.

Joining a volunteer brigade was also discussed in a workshop last year but due to lengthy and cumbersome procedures, and requirements for photo ID, police checks, and constant availability of a phone number for the members, the rangers withdrew. We hope to discuss some alternatives for those concerns with the Captain this time.

Analysis: Beagle Bay and Bidyadanga volunteer brigade models

To help improve emergency management and service delivery in Borroloola where locals (and the rangers) are hardly consulted, the researchers shared their knowledge of DFES's (Department of Fire and Emergency Services, WA) volunteer brigades that are established in the Beagle Bay and Bidyadanga communities in the Kimberley. Those brigades are currently operating quite well in participation with the rangers, locals, and other community organisations.

These remote community volunteer brigades were established after 8-9 years of persistent, ongoing and dedicated involvement of a district officer and superintendent from DFES to work with the community members. Each brigade includes a building (shed), a fire-truck, uniform and regular training for the volunteers, in each of the community. As a result, the local communities are reliable and confident to manage emergency situations, particularly bushfires, in their local regions.

This model provided some ideas and thoughts for the Garawa & Waanyi Garawa Rangers regarding involvement in emergency management planning and services. However, it is obvious that accessing brigade resources like in Beagle Bay and Bidyadanga is still a long way off for the Rangers. In Borroloola, there are some resources such as a boat, a fire truck, etc. managed and housed by the Council and the local Sea Rangers with Mabunji, as discussed in the earlier meetings, with limited access to any outside organisation/person. To access the resources, one has to be a member of the brigade.



IMAGE 1. MEETING WITH THE WAANYI-GARAWA RANGERS IN BORROLOOLA.

Analysis: Beagle Bay and Bidyadanga volunteer brigade models

DCBR researchers conducted a Scenario Planning workshop with the Garawa and Waanyi Garawa Rangers, based on their recent experience of cyclone Trevor, and interest to do better in emergency services for their community. For this, we discussed two scenarios, Business as Usual (BAU), and Future Directions (FD).

The BAU scenario was based on emergency planning, management and services currently being delivered by the NTES/FRS/Police, with no involvement by the Rangers nor access to resources. This top-down approach is delivered by agency protocols. To illustrate the current situation, a senior ranger gave a few examples: "the Council burns the town area but without consulting people in the camp where some Aboriginal families live, and some of them suffer from asthma...who could be taken out to safe places". Currently, there is no community consultation for burning around the town.

Alternatively, the FD scenario involved discussions around what the rangers could do to bring a positive change to the community. One key aspect that all the rangers mentioned was the need to involve young people, especially in the ranger program, with a hope to make them responsible. In the future, the rangers are looking for a female ranger coordinator, a ranger-base at Nicholson block, recognition of their work in the community, and taking a lead role in the event of bushfire threats. From an EM perspective, the rangers see themselves burning around the community, contacting and informing the locals to prepare for emergency events, and helping in the clean-up process after the event. However, this may require establishing fee-for-service arrangements for the rangers to be able to do that work.

The Garawa & Waanyi Garawa Rangers demonstrated an interest in the implementation of the FD scenario, particularly in the EM context. The next step is to consult with the other organisations/stakeholders in the town such as the Council, NTES/FRS, Police, via a multi-stakeholder scenario planning workshop



which can help to highlight the benefits of involving and working in participation with the rangers and traditional owners in the Borroloola community.

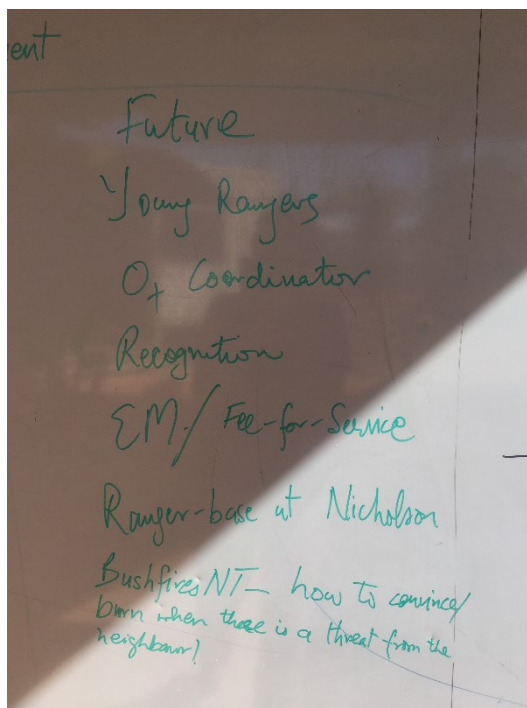


IMAGE 2. SCENARIO PLANNING WORKSHOP – 'FUTURE DIRECTIONS' – SCENARIO DISCUSSIONS WITH THE RANGERS IN BORROLOOLA.

Cyclone Trevor: The Ranger experience

Cyclone Trevor landed in the Gulf region on the 23th of March (Saturday) 2019 as category 3 and then was downgraded to a Tropical Low soon after. The Borroloola community was evacuated before the cyclone on Friday, the 22nd of March 2019– some drove in their own cars to Katherine, and others were transported to Darwin via Australian Defence Force planes. Camp sites were set up at Katherine and in the Marrara auditorium in Darwin.

The rangers realised that the EM agencies didn't check the outstations properly. The agencies contacted the ranger coordinator to ask if there is someone at the Nicholson block outstation on the 23nd of March, the day cyclone Trevor landed, while the community was already evacuated. The rangers felt that "we should be going and talking to our people...before EM agencies come and talking to people...", and even "afterwards, we should be utilising our chainsaw skills, not the contractors from Katherine. We could help them clean-up. We want to be part of the team, with support from Mabunji- Sea Rangers." The rangers felt that nobody from the EM agencies asked for their help, instead the contractors were brought in from Katherine. During the clean-up, the ranger coordinator and a ranger met with a person who was involved in clean-up, he said they will get back to them...but that never happened. In fact, during recovery, contractors cut down trees without consulting the locals. In Robinson river, the contractors cut all the big old trees, upsetting a lot of people. Some junior rangers from Robinson River laboured with the clean-up team but none of the senior rangers were involved in consultation.



The experience before and after cyclone Trevor made the Rangers feel that it's important for them to be involved in emergency management and service delivery around the community, and now want to join the volunteer brigade, although there are issues with the procedure and paperwork required to fill-in the forms to become a volunteer. Along with that, the CDU team will liaise with the NTPFES, the main EM agency in the NT, to express the community concerns. There is a plan to hold a multi-stakeholder workshop, including the rangers and the NT EM agencies, in Darwin from 19-23 August 2019.

Multi- stakeholder EM workshop, Darwin, 19-23 Aug 2019

We organised a 5-day workshop in August 2019 that included leadership training in the EM sector for upskilling and encouraging Rangers to participate in EM planning, culminating in multi-stakeholder workshop focused on building resilience in remote Indigenous communities.

Participants included 27 Indigenous Rangers and other community members representing seven groups from the Top End of the NT, and senior staff from Bushfires NT, NT Emergency Services (NTES) and NT Fire & Rescue Service (NTFRS). The workshop participants explored:

1. The good and bad of current Emergency Management Preparedness and Response in their community?
2. Improvements to meet community needs?

The rangers highlighted the importance of, and re-enforced the need for, community member involvement in EM activities in remote communities. The EM agencies acknowledged that improvements in emergency services delivery and engagement of community members is essential.

This opportunity was probably the first of its kind where community members and EM personnel had the opportunity to discuss community-related EM issues within a scenario planning framework. The EM personnel had first-hand opportunity to learn about community-based

EM issues. Lack of consideration of Indigenous perspectives into EM policy planning/service delivery and effective communication were key concerns. A follow-up meeting was planned, specifically focusing on developing effective partnerships between the EM agencies and remote community representatives, in April 2020 but it did not happen due to Covid-19.



FIGURE 6. PARTICIPANTS AT THE AIDR SPONSORED LEADERSHIP AND AGENCY NETWORKING WORKSHOP, AUGUST 2019.

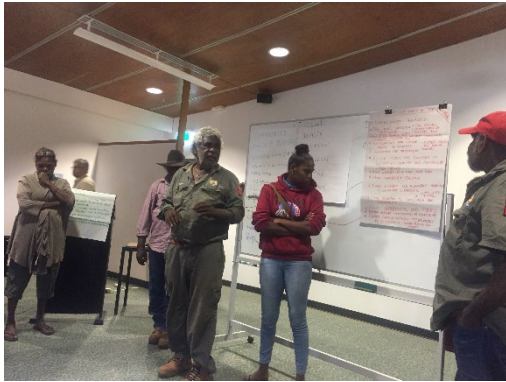


FIGURE 5. ELDERS AND YOUNG PARTICIPANTS ENGAGING IN EMERGENCY MANAGEMENT SCENARIOS AT THE LEADERSHIP WORKSHOP.



APPENDIX 2: TOOLS

2.1 FIRE SEVERITY MAPPING

Summary

The mapping of the level of effect of fire on vegetation, referred to as fire severity, has the potential to increase the accuracy of greenhouse gas emissions and carbon sequestration calculations. However, unlike burnt area mapping, it is not readily discernible from a satellite image, meaning that it cannot be manually mapped by a human operator. Automated burnt area mapping has yet to demonstrate the accuracy of semi-automated methods, improved by the complex interpretive capabilities of a human mind, with its abilities to discern context, colouration and texture, unlike any automated algorithm available today. Unfortunately, the intervention of a trained human mind is not possible with fire severity mapping as there are few direct optical links available through the bands available in an image derived from a satellite-borne sensor, particularly at moderate resolution. The challenge for fire severity mapping then is to develop an automated mapping system that can be improved by ground observation in a pure machine learning environment, accounting for seasonal changes such as curing, soil moisture and deciduousness.

The Bushfire and Natural Hazards CRC has funded research into the development of a fire severity mapping system. We've undertaken extensive field survey, assessment of different types of satellite imagery and the various bands of the electromagnetic spectrum to determine the most accurate means of mapping.

We undertook a workshop with a large group of international participants, leaders in the field of remote sensing, from NASA, the European Space Agency and leading Australian agencies. The outcome of the workshop was to continue to develop collaboration, and the opportunity to develop meaningful spatially explicit fire severity outputs to improve carbon farming opportunities.

Background



FIGURE 7. ILLUSTRATION OF MEASUREMENTS MADE AT 30 SITES IN TROPICAL SAVANNA WOODLAND AND OPEN FOREST IN THE TOP END OF THE NORTHERN TERRITORY. EACH PIE REPRESENTS A PORTION OF THE CANOPY (NOTED ON THE LEFT) AND THE FIRE EFFECT (NOTED ACROSS THE TOP). EACH PORTION OF EACH PIE REPRESENTS THE PROPORTION OF THAT PHENOMENON: MID-BLUE = OPEN SKY BETWEEN CANOPIES, LIGHT BLUE = OPEN SKY WITHIN CANOPY, BROWN= NON-PHOTOSYNTHETIC VEGETATION (E.G. TWIGS, STEMS, BRANCHES), GREEN = PHOTOSYNTHETIC VEGETATION (I.E. FOLIAGE), WHITE = OPEN AIR IN THE MID AND LOWER STOREYS, ORANGE = SCORCHED/DEAD LEAVES, YELLOW = CURED GRASS, LIGHT YELLOW = BARE GROUND, LIGHT GREY = WHITE MINERAL ASH, DARK GREY = CHARCOAL OR CHARRED LEAVES/STEMS.

Efficacy of fire severity mapping

Members of the National Greenhouse Gas Inventory team and Darwin centre for Bushfire Research undertook an assessment of the various parameters of the greenhouse gas emissions calculations of the abatement methodology that would be improved by replacing fire seasonality with fire severity, Figure 8.

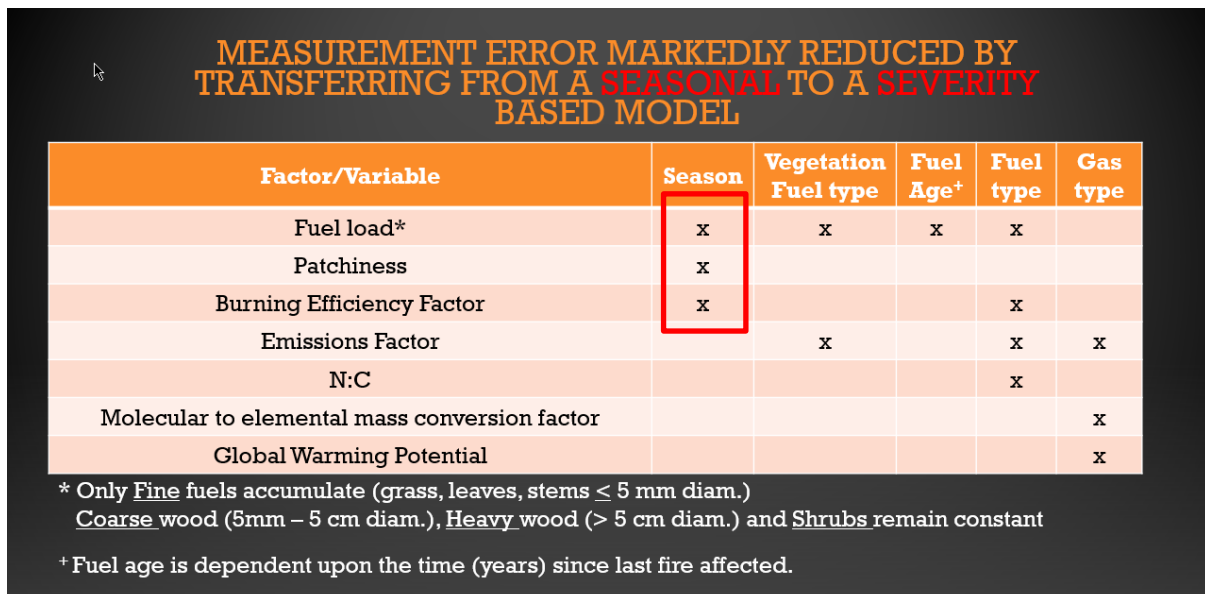


FIGURE 8. ASSESSMENT OF THE PARAMETERS INVOLVED IN GREENHOUSE GAS EMISSIONS CALCULATIONS.



The latest Methodology, however, attempts to model the accumulation of coarse woody debris and includes this in the summary calculations for greenhouse gas emissions, unlike the former methodologies that could not find significant relationships between coarse woody debris and the time since last burnt in the higher rainfall region and therefore used only a mean value measured at all sites, and although significant relationships were found for coarse woody debris in the lower rainfall region, again averages were used to be consistent with the high rainfall region.

A proportion of the study sites were burnt and biomass re-measured post-fire. Fire severity was scored according to the field guide, (Edwards, 2009), but also scorch height (the strongest relative indicator of fire severity according to the findings of the field guide) and the height of all stems (thus providing mean tree height). Therefore, it is possible to determine the relative proportion of the canopy affected by fire, and a quantitative measure of the fire severity. This then can be applied to develop a relationship between fire severity and biomass burnt (fuel load), for different vegetation fuel types, in different seasons under the various climatic conditions. Similarly, for patchiness and, consequently, burning efficiency.

Summary

Fire Severity Mapping Methods

Further development of a range of automatable processes to create a fire severity mapping methodology based on globally available and regionally created datasets, calibrated by local information was implemented in late 2019. Due to the temporal availability, or not, of various satellite image datasets, it was viewed that a number of methods should be developed that could be later integrated to provide a complete fire severity map history, albeit with varying levels of accuracy, but providing the best available fire severity mapping where and when we could.

Methods

Fire severity classes, unlike burnt areas, are not readily discernible from satellite imagery, relying on algorithms using satellite imagery, ancillary and calibration data. Accuracy using traditional methods is notoriously low (see Table 1 in (Edwards *et al.*, 2018)), whereby modern sophisticated machine learning algorithms require thousands of points for reliable and acceptable classification accuracy (O'Connor *et al.*, 2017).

An extensive series of 6,478 waypoints were collected via aerial survey across regions of north Australia from 2011-1. The standard survey method (Edwards & Russell-Smith, 2009) was applied at all times, flying in a helicopter (R44) at approximately 400 feet Above Ground Level, travelling at approximately 70 knots. These data, when randomly split, provide both calibration and validation data for the fire severity map classification. At each waypoint the level of fire effect, the severity, was assessed for an area approximating 3 ha, approximately half the area of a MODIS 250 m pixel (6.25 ha), in a detailed range of fire severity classes from patchy through to extreme.



Two image products will be derived. The first is the relative difference in the near infrared (RdNIR) developed in previous research to incorporate the highest resolution MODIS image data, the NIR with 250 m pixels, whilst encapsulating the greatest, and most parsimonious, spectral information discriminating fire severity. The second product will assess the pre-fire BRDF modelled image and a series of post-fire high-look-angle images, as a means of minimising the ground layer whilst maximising the canopy layer to look for change in known burnt areas, with the expectation that if no change is detected then the canopy has been minimally, or not, scorched, whilst a change would indicate fire effect in the canopy, and thus a severely burnt area.

To determine the most appropriate geographical stratification, within which we will derive separate RdNIR thresholds, we are creating ancillary surfaces, including a burnt area mask from NAFI. The NAFI mapping is highly regarded by the fire management community who monitor the mapping in the field and has annually achieved overall mapping accuracy > 90% for many years using independent and extensive aerial observations, often in conjunction with the fire severity calibration/validation data, to purposefully assess it. Stratification will also be assessed using a fire radiative power surface derived from the edited active fire waypoints, and Landsat-scale derived multi-year foliage projective cover (FPC) surfaces (<https://www.longpaddock.qld.gov.au/forage/report-information/foilage-projective-cover/>).

The outputs will be a combination of the stratification layers, the multiple RdNIR layers (3, 5 and 7 days) and the Δ BRDF layers to ascertain, with the validation subset of the field observations, the most accurate fire severity mapping algorithm.

Result

The last, but by no means the simplest, phase of the project will be the automation of the best result of the processes. Dr Patrice Weber has been employed to work with the assessment team, Drs Stefan Maier and Andrew Edwards, to automate many of the processes described in the above methods. But also includes the processes undertaken by the BAM team from NAFI to select and tabulate the BAM images used to delineate fire scars and the multiple products derived (annual fire frequency, late dry season fire frequency, time-since-last-burnt, patch size distribution, patchiness indices etc.)

Discussion

The potential for these methods to be globally adaptable depends on either the utility of the Hot Spot surface information or the pre-fire BRDF versus post-fire off-nadir analyses to characterise the fire severity.

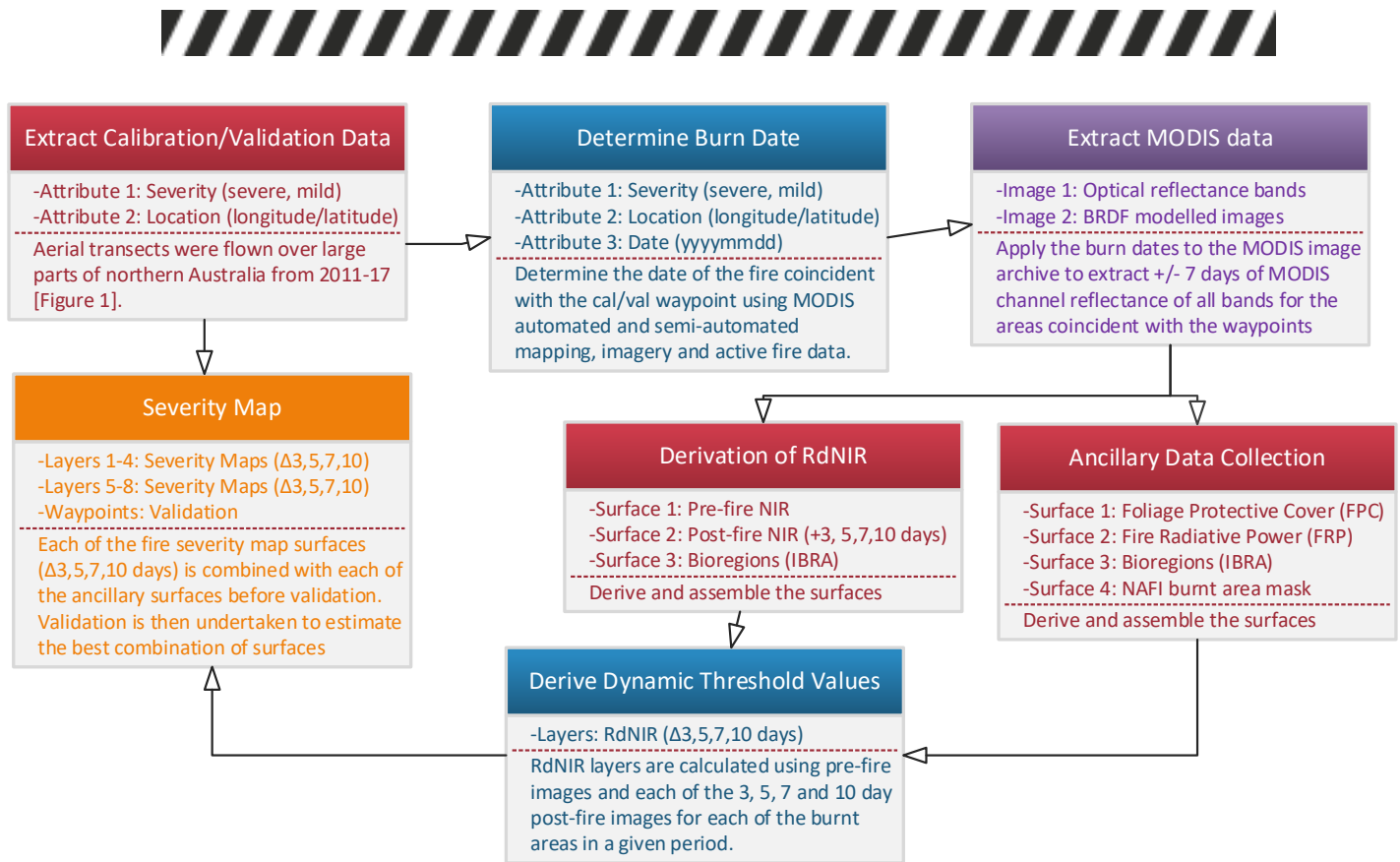


FIGURE 9. THE METHODS: FROM TOP LEFT, “EXTRACT CALIBRATION/VALIDATION DATA”, MOVING CLOCKWISE TO THE FINAL “SEVERITY MAPS” AND THE VALIDATION

2.2 SAVANNA MONITORING & EVALUATION REPORTING FRAMEWORK (SMERF)

Summary

The main outputs of SMERF:

1. Maps, graphs and tables of annual fire effects such as fire seasonality, fire frequency, fuel age, fire patchiness and more;
2. Graphs and maps illustrating the changes in the fire metrics through time using an extensive fire history;
3. Downloadable reports, tables of information and a simple dashboard.

The main utilities of SMERF:

1. Monitor the effects of fires through a multitude of effects models;
2. Analyse the effects of past fires, through the assessment of fire history info and;
3. Improve planning capacity through analysis of past fire effects.

Through extensive consultation, SMERF has branched in 3 directions:



4. The thoroughly sophisticated and complete range of fire metrics presented as maps, graphs, tables and long-term trend analyses, referred to as the **“SMERF Report”**;
5. A web-site with a simple map, graph and longer-term trend graph for each year, at a regional and property level, known as the **“Dashboard”**, set up at user-request to provide an overview and;

A **“Fire Community”** report for specific habitats subsetted from project areas. The report is based on the assessment of one or two metrics combined with thresholds of effectiveness provided by the user.

Abstract

Since 2006, payment for environmental service (PES) enterprises in north Australia have prospered, using internationally ratified Savanna Burning methodologies to calculate abatement of greenhouse gas emissions, thus earning Australian Carbon Credit Units. Land management groups from Aboriginal resource agencies, conservation agencies and pastoral enterprises have adopted techniques, based on traditional Aboriginal land management principles, reducing the overall biomass affected by fire, through strategic burning in the most benign periods of the year. The system delivers environmental benefits, and generates local employment, with improved health, cultural and social co-benefits.

Initially, the PES projects, covering large areas (10-20,000 km²) set about to reduce the total area burnt and overall severity of fire, vastly improving fire regimes of the recent past. After 5 to 10 years, in most regions, fire management planning is sophisticated, collaboration is regional, and high levels of fire management skill and capacity have been developed. Furthermore, the foundations of sustainable ecological restoration have been established.

Web-based tools have provided regular and timely satellite derived burnt area mapping, playing an unparalleled support role for planning, implementation, and monitoring the occurrence of fires, and biodiversity assessments. However, criticism of savanna burning projects has led to the need for greater scrutiny of the environmental benefits. In response, researchers and land managers have developed a suite of metrics to evaluate the effects of fire on biodiversity elements, to assist land managers to better undertake and improve their fire management.

In this paper, we outline the process to develop meaningful and easy to use metrics to measure environmental benefits, including a suite of metrics, derived from the scientific literature, collated from existing monitoring and evaluation reports, and workshops and interviews with land and fire managers. In this paper, we detail the metrics, provide an interpretation of their application and utility, and describe thresholds for evaluation. Through this process we intend to develop a standardised and readily accessible Savanna-Rangeland Monitoring and Evaluation Reporting Framework (SMERF) for land managers in fire prone north Australia.

Introduction



North Australia landscapes are extremely fire-prone with extensive areas of high natural and cultural value (Woinarski *et al.*, 2007), covering an area of approximately 2 million km². Prior to British colonisation of Australia, and the subsequent introduction of disease, massacres and removal of the Indigenous inhabitants from the landscape (Bottoms, 2009; Cooke, 2009; Reynolds, 2006), the ecosystems were shaped by a human imposed fire regime (Gammage, 2011). Fire management was integral to subsistence, and developed strong cultural and spiritual significance (Russell-Smith *et al.*, 2009b). Today the region is a matrix of marginally economic pastoral enterprises whose economy relies mostly on an over-inflated real estate market (Sangha *et al.*, 2017) and; conservation reserves, generally occurring on lands handed back to Indigenous collective-ownership, generally deemed unsuitable for pastoral or other economic activity, in joint-management arrangements with government conservation agencies, and consequently of the highest conservation significance (Director of National Parks, 2016). Fire regimes on conservation and Indigenous lands, until recently, have been dominated by wildfire, deleteriously affecting tens of millions of hectares annually (Yates *et al.*, 2008).

Since 2006, PES enterprises have expanded, predominantly on Indigenous owned lands (Sangha *et al.*, 2017; Walton *et al.*, 2014). Land management groups from Aboriginal resource agencies, conservation agencies and pastoral leases have adopted techniques based on traditional Aboriginal land management principles, to reduce the overall biomass affected by fire over an area, currently, of 300,000 km², through strategic burning in the most benign periods of the year (Murphy *et al.*, 2015a). These fires are smaller, patchier, and affect less of the biomass (~50%). They kill far fewer trees (Edwards *et al.*, 2018) and reduce, at a landscape scale, the ground fuel, halting the passage of wildfires. Therefore, they are coincidentally environmentally beneficial, affect less infrastructure, and generate local employment also providing health (Burgess *et al.*, 2005), cultural and social co-benefits.

Active burning, rather than wildfire suppression, is contentious (Willis, 2017). It seems that, “natural” disasters caused by lightning, or arson, in very high fuel, as compared to a period of controlled burning, are preferable in the minds of some. The distinction between the effects of planned versus wild fires is highlighted by a plethora of research illustrating markedly reduced biodiversity impacts from prescribed burns (Burrows & McCaw, 2013; Murphy *et al.*, 2015b; Russell-Smith & Thornton, 2013; Woinarski & Legge, 2013). Unless prescribed burning is properly planned, highly strategic, and backed up with mitigation strategies, the total area burnt is not markedly reduced (DCBR (Darwin Centre for Bushfire Research), 2014). The paucity of available resources, including personnel, means that prescribed burning needs to be highly strategic, requiring intra-regional pre-planning and iterative management. A strategic distribution of prescribed burnt areas, Figure 10, is now applied through Savanna Burning project areas across much of the region.

Fire regimes were previously so poor, that simply reducing burnt area, and instigating early dry season dominated regimes in appropriate habitats, was a vast improvement. The success of Savanna Burning projects to meet these goals has now, quite rightly, led many, including Indigenous and conservation land managers, to question the longer-term effects. Increasingly, therefore, the Savanna Monitoring & Evaluation Reporting Framework (SMERF) is being



developed, to provide greater scrutiny of the effects of the improved fire regimes, and the fire managers of this new carbon-based industry requires a standardised means of reporting.

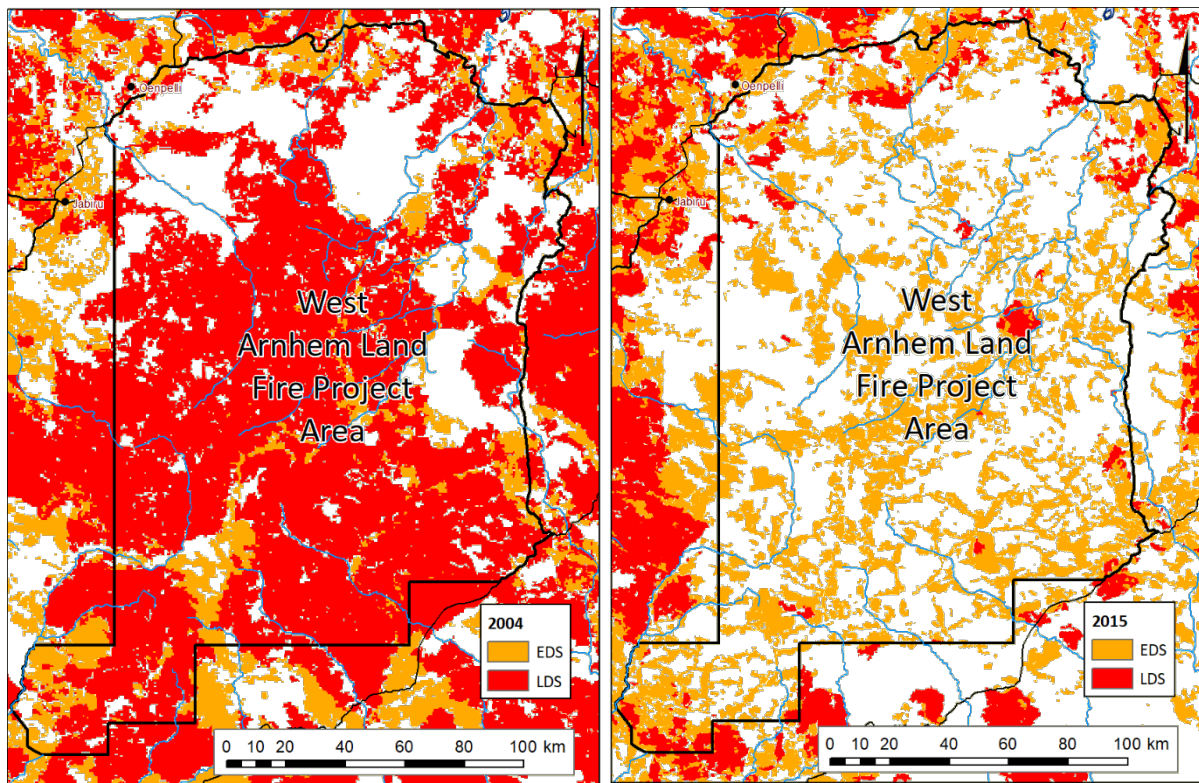


FIGURE 9. BURNT AREA MAPPING OVER THE ~28,000 KM² WEST ARNHEM LAND FIRE ABATEMENT (WALFA) PROJECT AREA. EARLY DRY SEASON (EDS) BURNT AREAS ARE ORANGE, LATE DRY SEASON (LDS) BURNT AREAS ARE RED: (A) 2004 FIRE SEASON, PRIOR TO THE COMMENCEMENT OF IMPROVED FIRE MANAGEMENT, SOME EDS BURNING HAS BEEN UNDERTAKEN. LARGE LDS FIRES SWEEP ACROSS THE ARNHEM PLATEAU, DEVASTATING BIODIVERSITY AND; (B) A MORE RECENT, AND NOW TYPICAL, IMPROVED FIRE MANAGEMENT OUTCOME, DEPICTING STRATEGIC FIRE BREAKS LARGELY ABLE TO CONTAIN LDS IGNITIONS TILL SUPPRESSED THROUGH HUMAN INTERVENTION. AVAILABLE AT WWW.FIRENORTH.ORG.AU. REGIONAL CENTROID: 133E, 13S.

Study purpose

In this research, we have collated and distilled current reporting metrics deemed indicative of fire effects to one fire management group or another. Information was gathered through a series of workshops with Federal, State and Territory government conservation, fire management, and Indigenous land management, agencies. We have also derived metrics from modelling provided in the scientific literature. The aim being to develop an on-line monitoring and evaluation reporting tool with standardised reports of simple metrics, and a range of more sophisticated outputs, describing fire effects.

Study area

The expansion of improved fire management has mostly occurred with the emergence of the Carbon industry in the fire-prone northern savannas and rangelands. However, the SMERF tool can be applied across a much broader area, where burnt area mapping (BAM) derived fire histories are available. The region of BAM derived from MODIS 250 m satellite data covers the entire tropical savannas including the 1.2 million km² Savanna Burning high and low rainfall zones (HRZ and LRZ); the savannas and rangelands of Western Australia (2.28 M km² – 90%); the entire Northern Territory (1.35 M km²), Queensland (1.75 M km²)



and the northern half of South Australia (0.46 M km² – 46%), Figure 11, a total mapped area of 5,818,519 km² or 76% of Australia's mainland and islands.

The northern mapping region of Queensland, near 20° S, includes the southern extent of the LRZ, to meet the requirements of Australian Commonwealth Law (Commonwealth of Australia, 2015) for Savanna Burning GHG emissions abatement calculations. Mapping in southern Queensland, was limited, 2008-16, due to funding, although there are plans through Queensland Government colleagues to complete and continue the program. The mapped region of northern South Australia is desert, fires, and therefore burnt area mapping, are intermittent, but predictably occur after one or two years of good summer rain.

Existing tools

The improvement in fire management in the region (Edwards *et al.*, in press), has been aided primarily by two important web-based tools:

1. The North Australia Fire Information (NAFI) web site (www.firenorth.org.au) and;
2. The Savanna Burning Abatement Tool (SavBAT – savbat.net.au).

Both tools were developed with the assistance of a range of stakeholders through the NAFI network and are freely available on line. The NAFI data underpin most calculations undertaken to assess and report on fire effects in the NAFI mapping region, Figure 11. They are also exclusively used by SavBAT to undertake Greenhouse Gas emissions abatement calculations (Commonwealth of Australia, 2015). Extensive validation is undertaken in each of the three jurisdictions both in the early and late periods of the dry season. Totalling > 4,000 validation waypoints, annually, along > 2,500 km of aerial transect. All map data are scrutinised extensively by the network of users; aerial transects digitally depicting prescribed burning are provided to the mapping team to assist the classification and editing processes (Fisher & Edwards, 2015).

Infonet

Infonet is an on-line map interface available through NAFI, with M&E reporting outputs:

- a. Fire Scars by Year Report - after selecting the reporting area, the tool requires the user to select the years for the assessment, generating a report including a simple location map of the study area, summary climate statistics, tables and a line graph of the annual area and percent burnt per month;
- b. Fire History Report – after selecting the reporting area, the tool requires the user to select the Fire History period (full record back to 2000 or most recent 10 years) and generates a report including a simple location map of the study area, summary climate statistics, a table, a map and a graph of the area and proportion of the selected area affected by fire including i. annual fire frequency, ii. late dry season fire frequency, and iii. years since last burnt.

Savanna Burning Abatement Tool

SavBAT uses the Carbon Credits (Carbon Farming Initiative-Emissions Abatement through Savanna Fire Management) Methodology Determinations (Commonwealth of Australia, 2012, 2013, 2015) (the "Determinations") to calculate emissions abatement for a given project area, outputting a



standardised report, based on a report first produced by the Indigenous Land Corporation, and ratified by private auditors and the Australian Government's Clean Energy Regulator (www.cleanenergyregulator.gov.au).

Literature

The body of research describing the decline in small mammals, most significantly in the World Heritage Listed Kakadu National Park (Woinarski *et al.*, 2010; Woinarski *et al.*, 2011), is not separate from the demise elsewhere in the region (Ziembicki *et al.*, 2015). The research consistently suggests the need to reduce the area and severity of fire (Radford *et al.*, 2014), to increase the area of longer unburnt habitat by reducing the total area burnt annually to 40%, and reburning 25% annually (Andersen *et al.*, 2012). Implicit in this, is the reduction, or removal, of wildfires. (This is a demonstrable achievement in some, albeit more remote, project areas. For example, Warddeken Indigenous Protected Area incurred wildfire covering 0.1% of the region in 2017, 1.2% in 2016, and 3.3% in 2015, compared to the 2000-2005 mean of 32%).

These metrics are simple to derive and sensibly indicative. Spatially explicit analyses provide a more advanced two-dimensional modelling approach (Lawes *et al.*, 2015) whilst highlighting the inadequacy of simple point-based models. The metric referred to as Fire Extent integrated fire size and frequency, by measuring the mean distance from each burnt pixel to the nearest unburnt pixel, within a given radius around a monitoring site, averaged for the monitoring period, usually 5 years. The conclusion is that large fires (> 1,000 ha) appear to be burning small mammals out of the landscape. This metric provides a model explicitly describing small mammal species richness and abundance (Lawes *et al.*, 2015).



Applicable habitat modelling has been undertaken in the region using data acquired from long-term fire monitoring plots, measuring changes in vegetation at five year intervals, sampling and photographing the plots annually to characterise the occurrence/severity of fire (Russell-Smith *et al.*, 2014; Russell-Smith *et al.*, 2009a). Derived from these data were significant models pertaining to indicator functional vegetation groups or species occurring in each of the major landscape units (Russell-Smith *et al.*, 2012). Relevant significant models, pertain to: savanna woodland sapling density for Eucalypts, non-Eucalypts, and the tropical pine (*Callitris intratropica*), a long-lived obligate seeder strongly indicative of fire regime (Trauernicht *et al.*, 2016); and obligate seeder taxa, distributed in the savannas generally, but specifically and importantly in refugia in the extensive rugged sandstone heathlands of the Kimberley and the Top End.

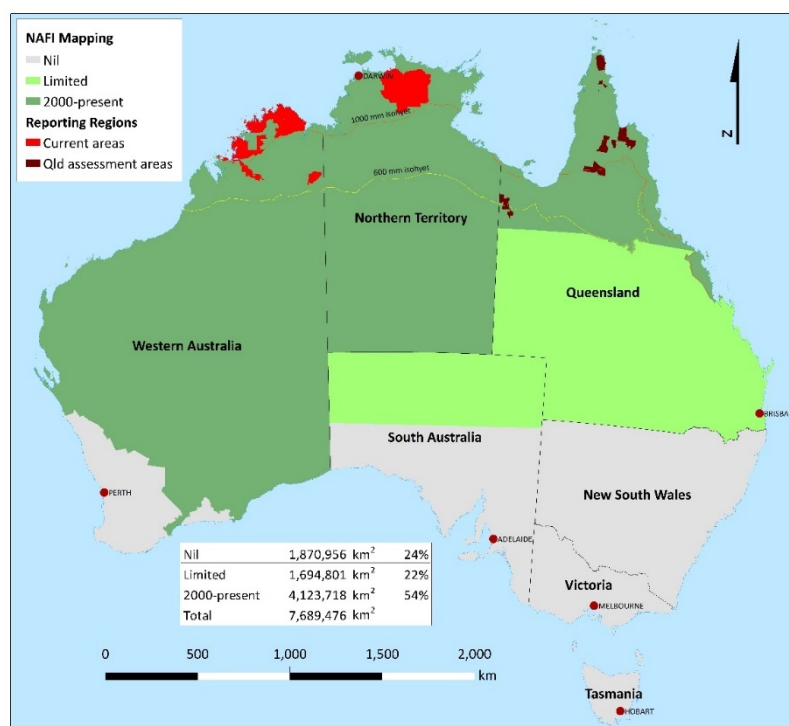


FIGURE 10. THE GEOGRAPHICAL AND TEMPORAL EXTENT OF NAFI MAPPING: (1) IN THE NORTHERN TERRITORY, THE KIMBERLY AND RANGELANDS OF WESTERN AUSTRALIA, AND NORTH QUEENSLAND - FROM THE YEAR 2000 TO THE PRESENT; (2) IN SOUTHERN QUEENSLAND 2007-2016; AND (3) IN NORTHERN SOUTH AUSTRALIA, 2012-2014 AND 2017-2018 HAVE BEEN MAPPED FOR SOME MONTHS OF EACH YEAR.

TABLE 1. SIGNIFICANT SPATIAL MODELS PERTAINING TO FIRE METRICS IN SAVANNA LANDSCAPE UNITS [35].

Landscape unit	Model of functional group/species	Fire metrics
Savanna woodlands	Sapling density (All species)	Fire frequency
	Sapling density (Non-Eucalypts)	Frequency of low severity fires
	Sapling density (<i>Callitris intratropica</i>)	Time since burnt severely
	Adult stem density (<i>Callitris intratropica</i>)	Frequency of severe and very severe fires
Savanna and Heathland	Number of shrub taxa (obligate seeders)	Minimum inter-fire interval
	Number of long maturing (> 3 yrs) obligate seeder shrub taxa	Frequency of early dry season fires
	Shrub density (resprouters)	Frequency of severe and very severe fires



The models provide a relative indication of the effects of fire regimes, although derived from data collected in specific habitats and regions, they can then be more widely applied if the user understands the limitations, bias and errors.

We spent considerably more time consulting with fire management personnel involved with planning, implementation, assessment and reporting, to ascertain the metrics and indicators they were currently using, and their conservation, or other, land management questions, so as to apply or develop metrics we could derive from the burnt area mapping information.

Consultation

Four groups, representing substantial geographical areas, had been creating reports that included fire effects landscape metrics, Table 1, at various resolutions. The 4 organisations coincidentally represent substantial Savanna Burning project areas. The NT projects, Kakadu National Park (KNP) and the West Arnhem Land (WAL) Fire Management Agreement, represent nearly 25% (~49,000 km²) of the HRZ in the NT, while the Kimberley Land Council (KLC) and Department of Parks and Wildlife in Western Australia (DPaW) represent 66% (~44,000 km²) of the HRZ in WA. In total, the 4 projects represent nearly 20% of the HRZ.

TABLE 2. FIRE RELATED LANDSCAPE EFFECTS REPORTING, RECENTLY UNDERTAKEN IN NORTH AUSTRALIA, USED TO DERIVE THE INITIAL SET OF METRICS.

Organisation	Location/Coverage	Resolution
Kakadu National Park ¹	Central Top End, NT; ~20,000 km ²	Landsat (30m)
West Arnhem Land Fire Abatement Project ¹	Central Top End, NT; ~29,000 km ²	Landsat (30m)
Kimberley Land Council ²	East and west Kimberley, WA; ~40,000 km ²	NAFI MODIS (250m)
Department of Parks and Wildlife	North-West Kimberley, WA; ~65,000 km ²	NAFI MODIS (250m)

¹ Report undertaken by Darwin Centre for Bushfire Research, Charles Darwin University

² Spatial analyses undertaken by Darwin Centre for Bushfire Research, Charles Darwin University

This excerpt from the North Kimberley Fire Abatement Project's Monitoring and Evaluation Report, describes the meaning of their evaluation process:

Each objective is measured and monitored... The next step is to evaluate how well we are going with meeting our objectives. A range of values are allocated when evaluating each objective. These ranges allow us to quantify the success of the project in meeting the objectives as; Very good, Good, Fair and Poor. These categories link directly back to the Healthy Country Plans of the Native Title Groups and allow groups to track the progress of the targets identified in their Healthy Country Plans.

As previously stated, fire regimes till recently have been unmanaged, and dominated by regular wildfires. As a result, the reports of these four large project areas contained similar metrics, with evaluation thresholds to inform stakeholders



of the fundamental improvements, or otherwise, instigated through improved fire management, Table 2, utilising the power of the burnt area mapping derived either from MODIS (250m pixels) or Landsat (30m pixels).

Agency consultations

A series of workshops were undertaken with fire officers and senior managers of the rural fire and conservation agencies from each of the 3 main jurisdictions of north Australia: Western Australia, the Northern Territory and Queensland. With respect to the environment, the rural fire services are required to report quite simply, regarding a general inter-annual comparison of fire affected area, usually for each of the regions/sub-regions of their State/Territory. However, the most significant metrics pertain to the number of call-outs to fires, the numbers of personnel, work-hours, vehicles and fire effects on infrastructure, such as fences, sheds, bores, homesteads and stock; as these can be costed to determine agency budgets. Aspirational metrics pertain to the multi-tenure nature of fire affected areas, that is, how many properties and of what tenure type were affected and how many of these incidents occurred in each region.

The Fire & Carbon Forum

In February 2018, the Fire & Carbon Forum (DCBR (Darwin Centre for Bushfire Research), 2018) was held in Darwin, NT. The forum was focused on supporting operational best-practice in fire management and cohesive development of the Savanna Fire and Carbon industry. A session on “Monitoring and Evaluation in north Australia” contained presentations from four key groups: the Australian Wildlife Conservancy, AWC manage the largest private conservation estate in Australia (4.6 million ha); the Department of Parks and Wildlife, Western Australia, manage National Parks in the Kimberley covering 2.7 million ha, Wunambal Gaambera Aboriginal Corporation are also in the north Kimberly managing 2.5 million ha; and Warddeken Land Management represent and manage an Indigenous Protected Area in west Arnhem Land covering 1.4 million hectares.

M7E Reporting examples

In the KLC M&E reports, each of the metrics were evaluated by comparing the most recent year, with the preceding few years of improved fire management, and the longer-term fire history (a baseline), illustrated through a map, a graph, and a table, Figure 12. The evaluations were an estimate based on the knowledge of the manager of the fire program having consulted with Indigenous traditional owners, experienced fire management colleagues and scientists. The fire component of the WA Parks & Wildlife analyses, used the MODIS-derived NAFI data to compare the most recent year with a pre-management period (2000-07), a transitional period (2008-19) and the management period (2011- the present year), applying a directional objective, i.e. a decrease or increase in the metric, to quantitatively assess the fire management. The Bushfires NT Research Group used higher resolution (30 m) data in the WAFMA report to compare metrics from a baseline (1995-2004), the project period and the most recent year of fire management. Similarly, for KNP they assessed long-term (from 1980) fire histories to illustrate the fire management trends. The higher resolution fire history data allowed for detailed analyses of finer habitats, in closed forests such as narrow strips of riparian vegetation (10-100 m wide) and monsoon jungles (mean



= 7 ha), and in The Nationally Protected Arnhem Plateau Sandstone Shrubland Complex (Australia), 2012).

TABLE 3. SUMMARY OF SIMPLE METRICS DERIVED FROM REPORTING OVER THE FOUR SUBSTANTIVE PROJECT AREAS.

Metric	Description	Objective
Total Area Burnt	A calculation of the proportion of the project area affected by fire.	The fire affected proportion of the project area should decrease.
Area Burnt by late Dry Season (Wild) Fires	The proportion of the project area affected by late dry season fire.	The dry season (~April to October) is characterised by little or no rain. Wildfires dominate in the latter half of the dry season (typically post-July) (Russell-Smith & Edwards, 2006), causing massive destruction to biodiversity in most but not all habitats. The area affected by wild fires should decrease.
Fire Frequency	The calculation of the proportion of the number of times an area has been burnt in a period.	The higher the proportion of high fire frequency the worse the effect on biodiversity. Mean fire frequency should decrease.
Frequency of Late Dry Season (Wild) Fires	The calculation of the proportion of the number of late dry season fires in an area over a period.	The higher the proportion of higher frequencies of late dry season (wild) fires the worse the effect on biodiversity. Mean LDS fire frequency should decrease.
Area of longer unburnt vegetation	An overlay of the previous years of burnt area mapping, back through time, to calculate the area and age of previously burnt areas.	Fire frequency in the tropical savannas has been high in past decades. Improved fire management should mean an increase in the area of longer unburnt vegetation (> 3 years, > 5 years, etc) in most habitats.
Minimum inter-fire interval	An intersection of the fire layers to determine the minimum time (years) between fires.	If the interval between fires in an area < the minimum interval required for obligate seeder plant species to grow from seed, mature and set seed then one can expect local extinctions.
Patchiness	Various metrics have been calculated that describe the landscape pyro-diversity: 1. Heterogeneity indices (Price <i>et al.</i> , 2005); 2. Mean distance from burnt to unburnt patches (Legge <i>et al.</i> , 2011).	These mean index value should increase under improved fire management. The heterogeneity indices are averaged over five-year periods to indicate the longer-term trend. The mean burnt to unburnt patch distance index should improve indicating fire patch sizes are decreasing.
Area/Perimeter Ratio	The ratio of the average perimeter / average area burnt per patch	The ratio is relative, indicating an improvement in patch size and shape, that is, longer narrower patches relate to more strategic fires as compared to large patches of wildfire.

The Fire & Carbon Forum

AWC are beholden to benefactors to report on the conservation significance of their investments. Probably more than any other group, they have undertaken extensive biodiversity assessments of habitats, functional groups and species (AWC (Australian Wildlife Conservancy), 2018), with over 30 peer-reviewed journal articles, 2008-17, related to fire effects in north Australia, summarised and presented at the forum. There was a strong interaction between many species and fire, particularly with respect to cat predation. The key metric for most species related to patchiness, including the late dry season, creating a mosaic of fuel ages.

The Wunambal Gaambera Aboriginal Corporation have created an adaptive management framework using Healthy Country Planning (Austin *et al.*, 2017). They have an M&E committee, useful in developing the discipline of undertaking M&E, and state that the framework is essential for developing co-benefits. Their main target for fire management is to reduce wildfires, however the framework integrates all aspects of land management with the key attribute: Traditional

Owners are decision makers and are undertaking the burning on their own country.

The Western Australian Parks & Wildlife Service, see Existing M&E Reporting section, undertake extensive monitoring through a suite of sites across their estate. The highest impact on small mammal abundance is from frequent hot fires. Sites that never burnt late had the highest diversity and abundance.

Interestingly mammal abundance and diversity in the absence of fire is less than if affected by multiple small patchy fires and is higher at sites that have a higher than average number of vegetation ages within a 3km radius.

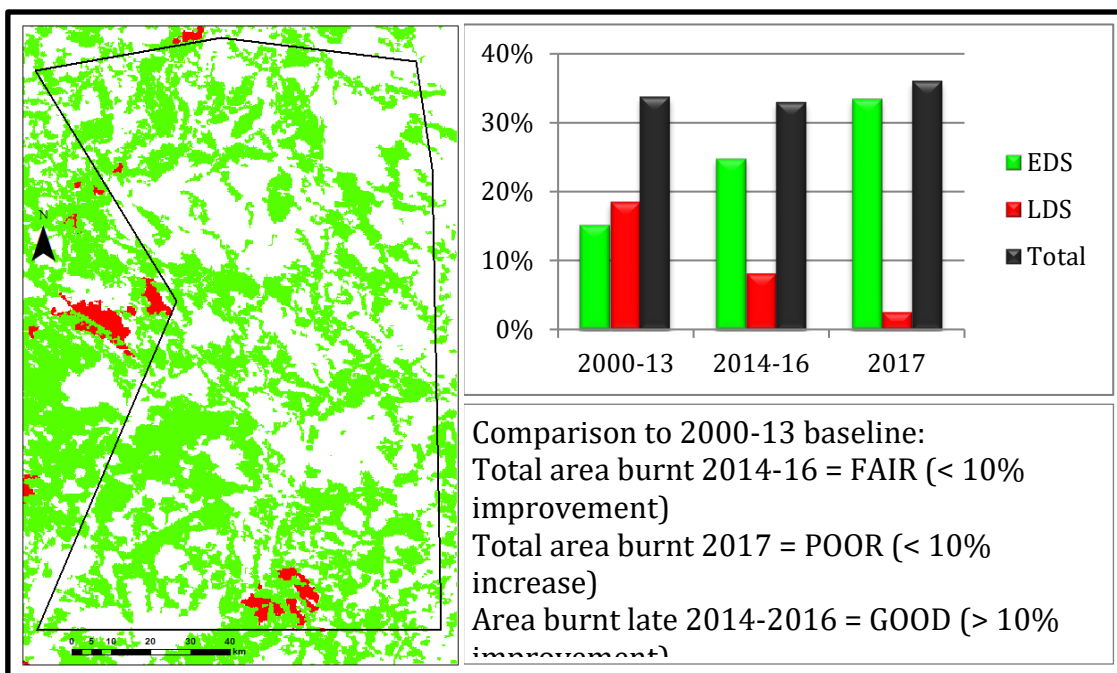


FIGURE 11. EXAMPLE OUTPUT OF THE AREA BURNT METRICS CALCULATED FOR A FICTITIOUS PROPERTY BOUNDARY: (A) A MAP ILLUSTRATING THE MOST RECENT YEAR OF BURNT AREA MAPPING; (B) A GRAPH ILLUSTRATING THE MEAN AREA BURNT FOR A BASELINE PERIOD (2000-13), THE MOST RECENT YEARS OF IMPROVED FIRE MANAGEMENT (2014-16), AND THE ASSESSMENT YEAR (2017) IN THE EARLY DRY SEASON (EDS), LATE DRY SEASON (LDS) AND WHOLE YEAR (TOTAL); (C) A COMPARATIVE TABLE USING A PRESET LIST OF THRESHOLDS BASED ON SCIENCE AND LOCAL KNOWLEDGE.

Warddeken Land Management Ltd, manage an IUCN Category 6 Protected Area. Carbon abatement commenced there in 2006, they have improved markedly over time, creating a mosaic of fuel ages, and all but suppressing wildfire. Their current M&E reporting, see Existing M&E Reporting section, examines the suite of standard fire metrics, including the integration of traditional and scientific knowledges, known as the “Two Toolboxes”, the use of which they also monitor.

Discussion

The metrics detailed in this research were collated and distilled for their appropriateness to the scale of landscape-wide habitat and burnt area mapping, readily calculated using MODIS satellite-derived burnt area mapping from NAFL, with 250 x 250 m pixels. Improving the scale of the mapping would



provide more detailed analyses of fire effects on fine scale habitats, more indicative of the sophistication required of fire regimes to properly emulate Indigenous traditional burning and therefore maintain, or re-create, ecosystems containing pre-colonial biodiversity.

Performance thresholds

The most recent summary of the literature outlined performance thresholds for associated fire metrics (Russell-Smith *et al.*, 2017). This body of work provided an ecological basis, summarising the substantial literature, for a list of criteria meeting the requirements of the Australian Government's Plan of Management for the World Heritage Listed Kakadu National Park. The analyses used Landsat-derived (30m pixel) burnt area mapping, summarised the fire metrics overall, and mapped them in 5 x 5 km cells to illustrate the geographical distribution in terms of the performance thresholds for each metric. There are two notable issues with respect to the metrics:

1. the current technical difficulties of identifying individual patches of burnt area, important in the assessment of fire patch size for fauna with restricted home ranges and narrowly dispersed obligate seeder plants, informing 3 of the 14 modelled criteria. The suggested solution was to apply patchiness metrics, Table 2.
2. the lack, yet importance, of fire severity mapping, informing 4 of the 14 models. Although, there is a substantial body of MODIS and Landsat-derived fire severity mapping algorithms for tropical savannas in the literature (Edwards *et al.*, 2015; Edwards *et al.*, 2013; Edwards *et al.*, 2018), the product has yet to achieve sufficient spatial accuracy. Surrogates using modelled seasonal proportions of low, moderate and high severity were utilised (Russell-Smith & Edwards, 2006).

The other key issue is the scale of the assessment. As stated, high resolution habitat and burnt area mapping were used. Similar data are not available across most parts of north Australia. However, many project areas already involved in Savanna Burning have a Vegetation Fuel Types map, used to upload to SavBAT to derive the GHG emissions abatement (offsets) report.

Conclusion

Many land management groups and government agencies have a requirement to report on the effects of their fire management efforts either to benefactors, land owners, government officers or politicians. There were many metrics in common from the interviews and workshops, the assessments of existing M&E reports and the scientific literature. However, some groups produced an interesting and unique metric that demonstrated the utility of a wide-sourcing program for this research.

The spatial scale of the MODIS-derived burnt area mapping from NAFI, as compared to aerial photography or Landsat derived mapping, limits the possibility to assess fire effects on culturally significant sites, infrastructure (fences, bores, buildings) and some habitats (riparian habitats on high order streams, monsoon jungle patches, sandstone heath complexes) significant to assessing biodiversity. However, the NAFI data are the best available for assessment of fire regimes across the whole savanna and rangelands region (75% of Australia). We have seen the cost benefits of standardisation in the NAFI mapping and reporting



and the SavBAT reporting and can only surmise a similar cost saving for the Savanna Monitoring & Reporting Framework (SMERF).

The SMERF tool will generate standard outputs, see Appendix 1, it will also have to generate non-standard reports, enabling the selection of a suite of metrics; it will have to have the capacity to upload a pre-made landscape (“habitat”) map for analysis of sub-components of the assessment area, as for SavBAT; and it will have to have the capacity to readily incorporate new metrics. Thus, all users will be able to acquire a report suitable to their reporting requirements.

Products

To date, three main SMERF Products have been identified through the survey and interview processes:

1. The full SMERF report containing maps, graphs and tables for all identified fire metrics; [This report will be used for detailed analysis and fire planning].
2. The SMERF dashboard; [The dashboard contains a lighter simpler version, illustrating the key fire metrics: Area Burnt by season, Fire Frequency, Late Dry Season Fire Frequency and, Years Since Last Burnt – with simple maps and dynamic graphs].
3. The third version illustrates the results of one or two metrics for Fire Communities within a Conservation Reserve. [This version was initially developed with Parks & Wildlife Commission NT planning staff in response to their Integrated Conservation Strategy for their 6 key parks, which provides thresholded values indicating the fire management for various fire communities].



APPENDIX 3: SUMMARY TABLES

KEY STAKEHOLDERS CONSULTED AND MEETINGS HELD ACROSS NORTHERN AUSTRALIA DURING THE SCENARIO PLANNING PROJECT

TABLE 1. KEY STAKEHOLDERS CONSULTED TO DATE FOR WORKSHOPS AND MEETINGS WITH REMOTE INDIGENOUS COMMUNITIES ACROSS NORTHERN AUSTRALIA.

Region / community	Key stakeholders consulted to date
Borroloola (NT Gulf)	<p>Waanyi Garawa Rangers</p> <p>Lianthawiriyarra Rangers (marine)</p> <p>Northern Land Council</p> <p>Department of Chief Minister, NT;</p> <p>PM&C & Borroloola Interagency Secretariat;</p> <p>NT Fire and Rescue Services (NTFRS), NT Emergency Services (NTES) and Bushfires NT offices in Darwin</p> <p>Rangers and Traditional Owners from seven different communities across the Top End, NT</p>
Central Australia	<p>Warlpiri Rangers (Yuendumu)</p> <p>Tjuwanpa Women Rangers (Hermannsburg)</p> <p>Central Land council</p> <p>Centralian Land Management Association</p> <p>NTES- Alice Springs; Bushfires NT- Alice Springs</p> <p>MacDonnell Regional Council</p> <p>Central Desert Regional Council</p>
Kimberley, WA	<p>Bidyadanga and Beagle Bay communities</p> <p>Local land councils, police, and the ranger groups (Karajarri and Nyul Nyul) rangers in both the communities, in consultation with the Department of Fire and Emergency Services (DFES), Kimberley Region, WA</p>
North Queensland	Carpentaria Land Council Aboriginal Corporation, and rangers
Key EM agencies involved/consulted	<p>NT—BFNT, NTES, NTFRS, DCM</p> <p>WA—DFES, Kimberley Regional Office, Broome</p> <p>QLD—QFES, North Regional Office, Townsville, Queensland</p>

TABLE 2. A LIST OF VARIOUS MEETINGS AND WORKSHOPS HELD SINCE 2017 TO DATE, INVOLVING VARIOUS EM AGENCIES AND REMOTE COMMUNITIES ACROSS NORTHERN AUSTRALIA.

Communities /towns and multi-stakeholder meetings	Emergency Management agencies (EM)	Other local and regional agencies	Discussions/meetings since 2017 to date
Borroloola, NT		Waanyi Garawa Rangers, Elders, and Traditional Owners	Several meetings, following discussions from the previous CRC funded project, to gauge rangers' interest in EM planning and service delivery, and conducted surveys/interviews with the community members, and held several workshops with the rangers.



	Fire and Emergency Response Group (FERG) unit, NTES from Borroloola	Borroloola Town Council	2-3 meetings with the service manager from Town Council, FERG unit Captain in 2018 and 2019 to discuss how rangers could assist in EM arrangements/planning in the community
	Fire and Rescue Services (FRS), NT Katherine		NT FRS organised two meetings in Borroloola town inviting local council, FERG unit Captain, Police and other agencies. The CRC researchers participated along with Waanyi Garawa Rangers to discuss how to be involved.
	Local Police Station, Borroloola		Met 2-3 times in a multi-stakeholders and FRS meetings in the town to understand EM concerns around the community.
	Bushfires NT (Darwin and Katherine)		Several meetings in the town and also in Darwin during 2018-2020
		A multi-stakeholder meeting including Roper Gulf Regional Council, Department of Prime Minister and Cabinet, Department of Chief Minister, NT, and several other local agencies	<p>Representatives from various agencies met in 2018 to discuss how to improve emergency service delivery in Borroloola. CRC researchers then followed up with the local council, police, and the ranger groups.</p> <p>Town Council recognises rangers' skills and knowledge in managing bushfires, however there were legal issues about changing the current protocols of burning around the community due to set standards by the Department of Infrastructure, Planning and Logistics, NT.</p> <p>However, this meeting did lead to explore a fee-for-service opportunity for the Waanyi Garawa Rangers to burn around outstations, in collaboration with Mabunji Aboriginal Corporation.</p>
		Mabunji Aboriginal Corporation	CRC researchers met with the CEO 2-3 times in 2018-19 to discuss a collaborative (fee-for-services) model for involving Waanyi Garawa rangers in fire management around the outstations, which was realised for about one year, but later abandoned due to change in management.
		Waanyi Garawa Rangers, Northern Land Council	<p>Several meetings since 2017 to date. Our recent meeting was in Feb 2019 at the Savanna Fire Forum. Rangers reiterated their interest to join EM services as volunteers but lack motivation to complete the paperwork required for FRS volunteers.</p> <p>Later in Aug 2019, during a high-level meeting with the EM agencies in the NT, the rangers provided very constructive feedback to the agencies on how to improve current EM arrangements in their community.</p>
Hermannsburg, NT	Regional Office of the NT Emergency Services (NTES), Alice Springs		Three meetings in 2017-2018 with the representatives from NTES, that later led to a collaborative meeting with Tjuwanpa Women Rangers to discuss their possible involvement in EM arrangements and some of the women rangers were already NTES volunteers.
	Tjuwanpa Women Rangers		Two meetings in 2018, including a multi-stakeholder meeting involving police, NTES, researchers, and the rangers. All the parties discussed the main EM-related issues concerning Hermannsburg community, and the needs of the women rangers to improve their current capacity. Due to workload, women rangers were unable to take more active role in EM service delivery but suggested the CRC researchers to talk with Men's Rangers.
	Men's Rangers		Two meetings with the group in 2018 to discuss their interest and availability to involve in EM services. This group expressed interest, but was too busy with their land management work.
Yuendumu, NT		Warpiri rangers	<p>Had a meeting in 2018 to discuss EM situation in the town and the rangers' interest/role in managing emergencies.</p> <p>They suggested involving young kids from the community.</p>



		Town council and CLC manager in Yuendumu	Met in 2018 to discuss about the existing EM arrangements.
Bidyadanga, WA	Local Police, Department of Fire and Emergency Services (DFES)	Bidyadanga Aboriginal Community Council, Karajarri rangers, and Traditional Owners	A multi-stakeholder meeting with all the listed parties in 2019, later a follow-up meeting with the CEO, local council in Feb 2020. This meeting was to understand and explore the current EM arrangements, i.e. Volunteer Brigades established by DFES in remote communities.
Beagle Bay, WA	Department of Fire and Emergency Services (DFES)	Nyul-Nyul rangers	Two meetings, earlier in 2018 and recently in Feb 2019 to learn about local EM concerns and existing DFES—Volunteer Brigade arrangements.
High-level multi-stakeholder meeting in the NT	Bushfires NT, FRS NT, and NTES	About 30 rangers from seven communities in the NT	A multi-stakeholder Scenario Planning workshop in Aug 2019 among all the listed parties to discuss community level EM-related issues and possible solutions.
Meetings with the Aboriginal Research Practitioners' Network (ARPNet), and NAILSMA (North Australia Indigenous Land and Sea Management Alliance, Ltd.)		ARPNet researchers including TOs from Ramingining and Maningrida; and NAILSMA led community participation in Galiwinku, NT	Several meetings since 2017 to date to discuss EM arrangements in the communities where ARPNet and NAILSMA researchers are involved in EM-related research. The CRC researchers have planned a scenario planning workshop in Galiwinku to add value to the existing project however, it's been delayed due to COVID-19 situation.
A multi-stakeholder utilisation workshop (but postponed due to Covid-19)	Invited agencies for the workshop include representatives from: Bushfires NT, FRS NT, and NTES from the NT; DFES from the Kimberley and Perth office, WA; and Queensland Fire and Emergency Services, Townsville, Qld.	Invited Indigenous communities include: Cardwell, Wujal Wujal, Torres Strait Island, Kowanyama, Burketown from Qld; Galiwinku and Ramingining from the NT; and Bidyadanga and Beagle Bay from the Kimberley, WA	This multi-stakeholder meeting was postponed due to Covid-19. This will occur once the situation returns to normal.



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