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SAVANNA FIRE MANAGEMENT AND BUSHFIRE AND NATURAL HAZARD SCENARIO PLANNING FOR NORTHERN AUSTRALIA

Annual project report 2015-2016

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Cover: The Waanyi-Garawa Rangers organised for women to observe new fire scars from prescribed burning on Wuyaliya country, through their collaboration with the Carpentaria Land Council Aboriginal Corporation on their aerial burning program.

EXECUTIVE SUMMARY

The ***Savanna fire management and bushfire and natural hazards scenario planning for northern Australia*** project is part of a larger suite of Bushfire and Natural Hazards CRC projects being undertaken through Charles Darwin University focused broadly on '*Building community resilience in northern Australia*'. Collectively, these projects aim to promote enhanced understanding of the special circumstances concerning resilience issues in remote Indigenous communities, and identify culturally appropriate governance arrangements and enterprise opportunities that can contribute to enhancing community development and resilience.

We report here on activities undertaken in 2015-2016 for two active sub-projects: ***Savanna fire management***, and ***Gulf fire management***. A third sub-project; ***Management of flammable high biomass grassy weeds,*** will commence in July 2016, and a fourth sub-project addressing ***scenario planning*** issues for better informing and engaging remote communities with project outcomes will commence in early 2017.

The ***Savanna fire management*** sub-project (undertaken by Dr Andrew Edwards) commenced late in 2013. It builds upon satellite derived modeling of fire severity. These datasets, combined with fire history mapping, are being applied to assess fire risks to biodiversity, emissions and ecosystem services in general. Over the past year this sub-project has:

1. continued to develop and refine the fire severity mapping algorithm, particulalrly for environmental assessment and emissions accounting applications;
2. undertaken finer scale analyses of the fire mapping and ancillary spatial data for Indigenous land management applications across northern Australia (Kimberley's, Arnhem Land, Gulf region, Cape York); and
3. undertaken informal workshops with indigenous ranger groups to ascertain the use and utility of the mapping products.

The ***Gulf fire management*** sub-project has principally involved PhD studies (undertaken by Kate van Wezel) exploring Indigenous women's engagement and employment opportunities with fire management and emissions abatement projects being established in the remote NT / QLD Gulf region.

Both above sub-projects are proceeding exceptionally well. Findings from both sub-projects will be incorporated in a substantial final report addressing sustainable north Australian community development issues, due to be published as a book in mid-2017.

WHAT IS THE PROBLEM?

Australia's tropical savannas constitute the most fire-prone landscapes of a fire-prone continent—where ~20% of the 1.9 km^2 savanna region (a quarter of the Australian land mass) is currently burnt each year. Annual fire incidence is particularly frequent across higher rainfall (>1000 mm) far northern regions, where over half the landscape is burnt each year, mostly under relatively severe late dry season fire-weather conditions.

The problem for fire management personnel in northern Australia is a lack of resources. However, the lanscapes are extensive so that landscape scale mapping of the occurrence of fire and its many other effects can be very effective tools to assist in each step of the planning, mitigation and suppression processes.

Why is it important?

The current patterning of late dry season fires impacts on a broad range of issues, including community safety and health, production (e.g. pastoral enterprise), infrastructure and environmental values (e.g. soil erosion, stream health, biodiversity, greenhouse gas emissions).

How are we going to solve it?

As part of a suite of complementary projects being undertaken at Charles Darwin University for the BNH CRC, this project focuses on a number of issues broadly relating to identifying the extent and magnitude of risks to community, production and environmental values. The project currently has three sub-project components (with a fourth component, to be determined for commencement in 2017):

- Describing environmental risks across the north and providing mapping tools for remote community planning purposes in trial locations
- Quantifying the risks posed by large flammable exotic grasses (e,g, gamba and mission grasses)
- Exploring fire management risks and challenges in the NT / QLD Gulf region

A second suite of projects explores related issues pertaining to remote community resilience and governance, and the potential for environmental services projects to provide enhanced economic and community resilience. A major report addressing all above matters is due to be completed in 2017, and will include research undertaken in the north and nationally from the Scientific diversity, scientific uncertainty and risk mitigation policy and planning project in the Economics, Policy and Decision-Making cluster and the The Australian Natural Disaster Resilience Index: a system for assessing the resilience of Australian communities to natural hazards project.

END USER STATEMENT

Naomi Stephens & Felipe Aires, *National Parks & Wildlife Service, Office of Environment & Heritage, NSW*

The ***Savanna fire management and bushfire and natural hazards scenario planning for northern Australia*** *project and its various subprojects demonstrate the complexity of fire management in an extremely fire-prone landscape that dominates this part of the continent. Projects like this are critical not only to support improvement of fire management and the development of strategic landscape decision making processes but also to empower local communities, create opportunities and promote resilience.*

The ***Savanna fire management*** *sub-project has created an important network of fire managers and stakeholders across northern Australia and provided them with mapping tools to assess risks to various environmental and community values. The research developed new metrics to replace seasonal burnt area mapping with fire severity mapping. This removes the requirement to define the early/late dry season threshold, which is an important political and social issue in some areas. The fire severity maps have important implications in landscape risk assessment and on the analyses of greenhouse emissions and carbon sequestration for savanna regions and may help inform research on other grassy type vegetations across the country. The project also offered support data on potential conservation land and extent and level of pastoral activity for associated projects. The knowledge and data produced by this project has helped identify research gaps and may direct future research agenda proposals which are important for bushfire management and future development of north Australian communities.*

The ***Gulf fire management*** *sub-project has an important role in promoting Aboriginal women's inclusion in fire management in the northen savannas and identifying impediments, opportunities and challenges. Empowering women to participate in the fire management program, (re)building fragmented cultural knowledge and womens capability to manage fire in the landscape will add essential value to the fire management strategies on Waanyi and Garawa country. This project has potential to have a positive long term impact in the local community and on sustainable indigenous fire management.*

Both projects have helped connect an important network of fire managers, local community and other stakeholders. The detailed research results contribute important contemporary insights into different aspects of fire management in the savanna region of Northern Australia.

PROJECT BACKGROUND

The **Savanna fire management and *bushfire and natural hazards* scenario planning for northern Australia** project has four sub-project components: **Savanna fire management**; **Management of flammable high biomass grassy weeds**; **Gulf Savanna Fire Management** and ; **Major disaster scenarios planning**.

The ***Savanna fire management*** component builds on the substantial work previously undertaken within the Bushfire CRC's North Australian Fire Mapping project. The sub-project continues with this work by undertaking more detailed field and mapping assessments of fire metrics including fire severity in regions defined as being at greatest risk. This includes working with other Bushfire and Natural Hazards CRC projects, especially ARPNet and NAILSMA, to develop a network of indigenous people to assess the utility of mapping products and incorporating the fire severity mapping into carbon accounting methodologies.

Managing flammable high biomass grassy weeds: A range of invasive grasses have spread rapidly in tropical Australia over the past two decades, substantially altering the savanna, riparian and wetland ecosystems. The ecological, economic and social consequences of these grasses are so significant that many are now declared at the Territory and State level, have been listed as Weeds of National Significance, and listed as a Key Threatening Process under the EPBC Act. This sub-project will assess the social, environmental and economic risks associated with these invasive flammable species.

The ***Gulf savanna fire management*** sub-project focuses on applying market-based savanna burning greenhouse gas emissions abatement project opportunities in fire-prone northern lower rainfall (600-1000 mm isohyet) savannas (http://www.comlaw.gov.au/Details/F2015L00344). To date, substantial efforts have been made by Indigenous ranger groups operating in the Gulf, the Waanyi Garawa Rangers in the NT and Carpentaria Rangers in QLD, to develop landscape fire management programs mostly with ad hoc Indigenous funding (e.g. Working on Country, Indigenous Protected Area, programs). There is significant potential to develop more sustainable payment for environment services (PES) enterprises based on emerging carbon market arrangements

The ***scenario planning*** component is due to commence in early 2017. Previously, this sub-project was to focus on scenario planning for major disasters occurring in the north Australian region, and potentially include neighbouring countries to the north. Following recent reappraisal of the broader suite of BNHCRC projects being undertaken by CDU and partners focused on "Building community resilience in northern Australia", agreement-in-principle has been reached that this project component will use materials developed as part of that broader project to better inform and engage with select community groups and associated stakeholders (including EM agencies) across northern Australia through the undertaking of targeted scenario planning exercises.

WHAT THE PROJECT HAS BEEN UP TO

The project has four interrelated components as set out below

1. SAVANNA BURNING COMPONENT

Outlined here we provide detail of the components of the Savanna Burning sub-project, namely: the continued calibration and validation of the fire severity mapping; the ongoing assessment of landscape risk; and implications of fire severity data for savanna burning emissions abatement and sequestration methodologies. Additionally, we address future research requirements.

1.1 Fire Severity Mapping

Fire severity mapping was undertaken by applying methods developed through previous years of calibration with field and satellite imagery [1, 2]. (see Milestone Report "***3.2.4 Report on Fire Severity Models for 2015 Fire Season***"). Extensive calibration and validation field data were collected across north Australia including the Kimberley, the Top End of the NT and Cape York.

The ultimate aim of this research component is to develop a method to replace the contentious application of fire seasonality with fire severity mapping in the Savanna Burning Greenhouse Gas Emissions Abatement calculation methodology. (see Milestone Report "***3.1.2 Report-fire severity vs fire seasonality mapping assessment***").

Fire severity mapping for 2015

Summary

The 2015 fire season was again above average, with fire affecting 30% and 22% of the higher and lower rainfall regions of the tropical savannas, respectively. The fire season was dominated by early dry season fires, in terms of fire severity, 40% of fires were not-severe whilst 60% were severe (where fire affected the upper canopy). The seasonal occurrence of severe fires was 53% of all fires in the early dry season and 65% of all fires in the late dry season. This result is consistent with other published results describing the seasonal occurrence of severe fires [1].

Methods

Methods for mapping and discriminating fire severity on savanna vegetation are provided in detail in [1, 2]. In summary, a time series of MODIS satellite images is acquired every 5 to 10 days, the optimal acquisition difference being 7 days [4]. The pre and post difference in the reflectance of light from a fire affected area between two consecutive dates is calculated and compiled for each month. This layer is masked by the MODIS-derived burnt area mapping from North Australia Fire Information (NAFI – www.firenorth.org.au) for that month. The total mapping covers the area north of 20° S in Western Australia (WA), the Northern Territory (NT) and Queensland (QL), approximately 1.9 million km^2.

Results

The calibration data collected in previous years indicate a threshold proportional reflectance change value of ~20% for a binary classification differentiating severe from not-severe savanna fires, where a severe fire has affected the mid and upper canopy. This value was applied to the collated time series image, to produce a fire severity map for 2015, Figure 1.

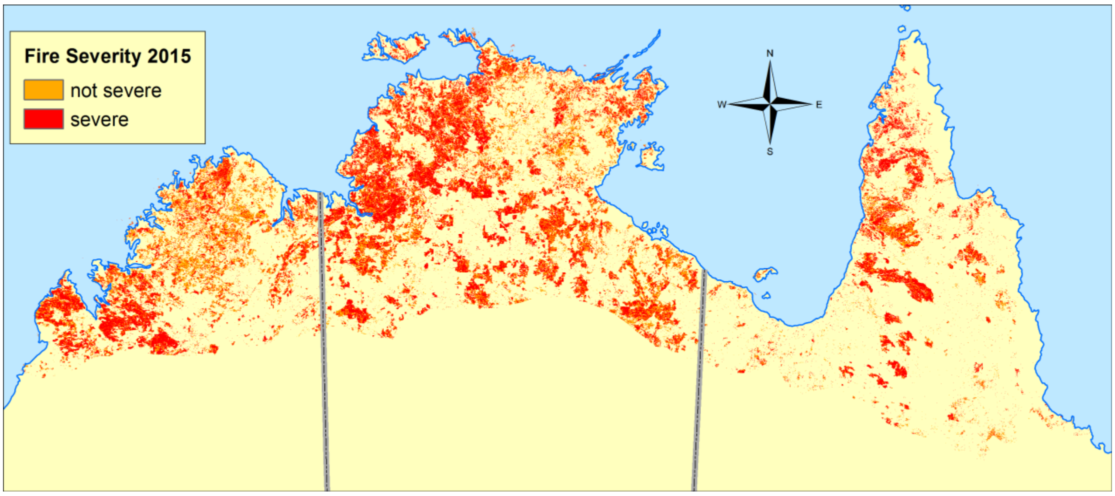

FIGURE 1. FIRE SEVERITY MAPPING, NORTH AUSTRALIA, 2015.

VALIDATION EXERCISES FOR 2015

In 2015, validation data were collected from helicopter for a total of 1,750 km^2 and a total of 4,369 waypoints, 15% of that number pertain to fire severity assessments, as the data are only collected over burnt areas, and very specifically in homogeneous patches for accuracy, Figure 2

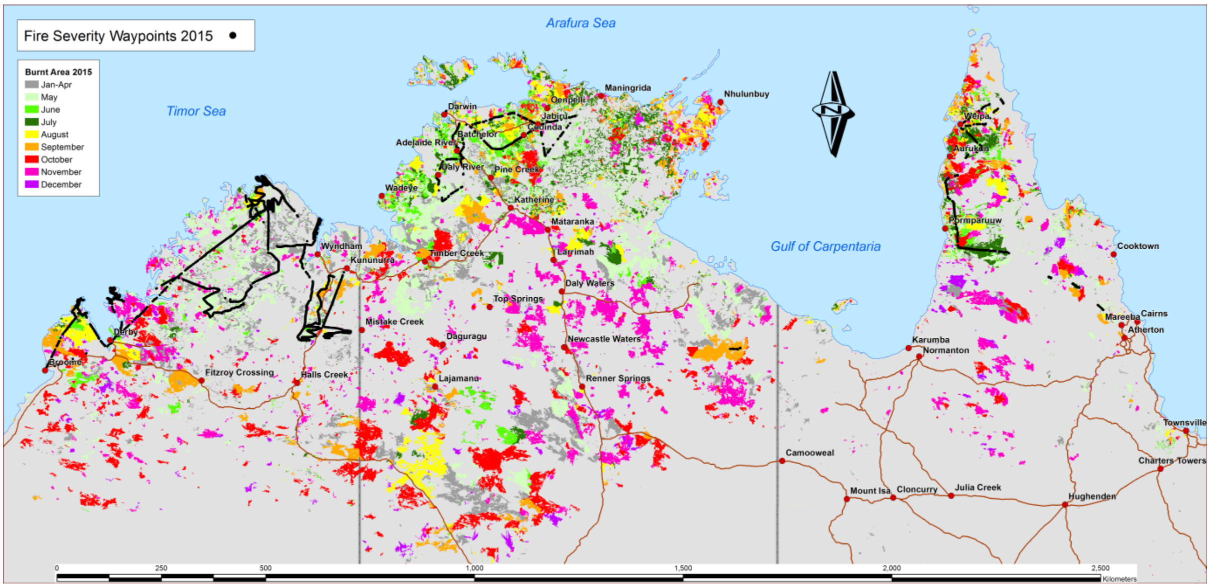

FIGURE 2 THE LOCATION OF THE CALIBRATION WAYPOINTS, NORTH AUSTRALIA, 2015.

Results of the validation for each survey are given in Table 1. The burnt area mapping has accuracies $\geq$ 85%, the fire severity mapping has overall accuracies ranging from an average of 74% in the EDs to 86% (for a single small site) in the LDS, with relatively similar accuracies for each area across the seasons.

TABLE 1 ACCURACY ASSESSMENT OF BURNT AREA AND FIRE SEVERITY MAPPING, 2015.

Survey	Date	# Burnt Area (# Fire Severity) Waypoints	Burnt Area Accuracy (%)	Fire Severity Accuracy (%)
Kimberley	12th-15th June 2015	4,759 (353)	86	75
Top End	24th June 2015	467 (39)	89	NA
Cape York	3rd August 2015	2,1802 (61)	87	73
Top End	11th August 2015	1,316 (85)	85	NA
NT Gulf	25th November 2015	14 (14)	100	86
Total	**2015**	**8,658 (552)**	**87**	**75**

1.2 Landscape risk

An assessment of previous published research [3] identified areas of aboriginal land deleteriously affected by contemporary fire regimes. Two key areas were identified with the assistance of indigenous partner agencies (nortn australia indigenous land and sea management alliance (nailsma)) and researchers (aboriginal research practitioner's network (arpnet)) and assessed in detail. (see milestone reports "***3.3.2 draft mapping and assessment of high risk regions***" and "***3.4.3 draft report mapping and characterisation of high risk landscape regions***")

in coincidence with fire severity field data collected across north australia, burnt area validation data were collected, and accuracy assessments of the north australia fire information (nafi) burnt area mapping were generated. These were reported on in a report to commonwealth department of the environment: "***nafi burnt area validation 2015***")

a number of assessments of various tracts of the indigenous and conservation estate were analysed for fire effects. Metrics include burnt area proportion, seasonality, frequency, age, and severity in various landscape and key habitat components. The methods and results of these analyses are provided in final reports to the relevant agencies (e.g. Fire monitoring reports to kimberley land council, kakadu national park, and arnhem land fire abatement project). These analyses are pertinent to the business of the relevant agencies and not publicly available.

Spatial analyses are required to assist the associated 'scoping resilience' project. Interim datasets have been collated and re-classified to provide: (1) the extent of existing and potential conservation land and; (2) datasets illustrating the extent and level of pastoral activity.

1.3 Implications for savanna burning methodologies

Summary

The current emissions abatement through Savanna Fire Management calculations use empirically derived data describing the proportion of fire severity classes within the early and late dry season periods to provide fire seasonality. Along with patchiness these define the burning efficiency factors. We re-analysed the field data used in the methodology, with the intention to replace fire seasonality with severity factors. This calculation process reduces a step, thus minimising error. However, this proposed methodology replaces seasonal burnt area mapping, with overall accuracies of ~90%, with fire severity mapping, with overall accuracies of ~72%. The conclusion of this analysis is a thorough error analysis must be undertaken to determine if there is a net benefit in accuracy. Aside from the numerical considerations, there are many savanna burning project proponents who are loudly opposed to the current seasonal threshold, for which this option is, foreseeably, the only solution.

Introduction

The current methodology for calculating greenhouse gas emissions abatement in the Savannas intersects: mapping of the seasonal occurrence of fire; fire history mapping to provide the year since last affected by fire and; vegetation fuel type mapping [5] for a given year of calculation. Tables for fuel accumulation for each fuel component of eligible fuel type (see Russell-Smith et al. (2009) for class descriptions) are applied. Variation in fire severity is assumed to be wholly inter-seasonal, the assumption being, for simplification and statistical robustness, that, the average early dry season fire is a low intensity prescribed burn, and late dry season fires are higher intensity wildfires [6]. The outcome being, that on average, nearly twice as much vegetation fuel is consumed by wildfire in the higher rainfall region. The various fuel components then use the seasonality of fire to provide early and late dry season Fire Patchiness, being the areal fire affected proportion of the ground fuels, and Burning Efficiency, being the proportion of each fuel component (Fine, Shrub, Coarse and Heavy fuels) consumed by fire.

Fire severity describes the proportion of biomass consumed by fire and thus not only describes the effect of fire throughout the fire season, but also, through Fire Severity Mapping, can be applied across the whole landscape where fire has occurred. As a field measurement in the savannas, it is equal to the mean height of scorched foliage (scorch height) as a proportion of the mean height of the vegetation [2], whereby low severity fires affect the ground lower of herbs/grasses and small shrubs and trees only, moderate severity fires affect the mid storey of shrubs and young trees, and high severity fires affect the upper canopy. This definition is readily applied in the field, and was developed with fire managers, it was published with tabular and graphical descriptions within the auspices of the Bushfire CRC [7]. However, the mid-storey canopy makes up less than15% of the total cover of both photosynthetic and non-photosynthetic vegetation in typical Eucalypt dominated higher rainfall savanna habitats [4], similarly in the lower rainfall region [8], confounding the remote detection of change in this stratum. This is reflected in the fire severity mapping, which has simply two classes, Severe and not-Severe, where fire affects the canopy or it does not, respectively.

Fire severity mapping has been developed over the last decade, initial research involved understanding the effect of fire on the reflectance of bands of electromagnetic radiation (light), [4]. A hand-held spectrometer measuring wavelengths 1 µm apart collected data which was then scaled up to apply to commonly available remotely sensed data, such as the Moderate Resolution Spectroradiometer (MODIS) used by North Australia Fire Information (NAFI) for burnt area mapping [9]. The mapping is extensively calibrated and validated by annual helicopter based GPS transects. The north Australian tropical savannas fire severity mapping product is available with accuracies approaching 72% overall accuracy [1].

The current methodology for calculating greenhouse gas emissions abatement uses the seasonal occurrence of fire early and late As well as the seasonal Fire Patchiness and Burning Efficiency Factors (BEFs). These are derived from large sets of field data [5] which are averaged for each fuel type for both the early and late dry seasons. The intention of this revision is to improve the National Greenhouse Gas Inventory as described in [5]. The defining changes are the refinement of fuels accumulation from a single value to multiple values representing time, habitat and fuel type, and in separating fire type through fire seasonality with the incorporation of a statistical description of the fire severity based on the research in Russell-Smith and Edwards (2006). The next step is to replace mapping of seasonal burnt area with a surface describing the spatial occurrence of fire severity. This will improve fire severity measures beyond mere seasonal inference, and the amount of fuel consumed to also, importantly, replace the requirement to define the early/late dry season threshold (currently 31 July / 1 August), which has not only been a contentious political and social issue in Cape York [10], but removes the need to undertake research to define fire seasonality across the whole of north Australia, as this has proven to be problematic [11].

Methods

In the current Emissions Abatement through Savanna Fire Management methodology the proportion of biomass pyrolised for a given project area is calculated in the first instance by intersecting 3 spatial layers: 1. mapping of the areas burnt in the early and late dry seasons for the given calendar year; 2. vegetation fuel classes mapping based primarily on overstorey structure, dominant overstorey species and grass habit and; 3. a layer, constructed from the previous five years of burnt area mapping, representing the number of years since a given area was last affected by fire. Each Vegetation Fuel type has a series of look up tables describing annual fuel accumulation (fine, shrub, coarse and heavy fuels) and burning efficiency seasonally (i.e. early versus late dry season). Replacing fire seasonality with fire severity requires a table derived from the empirical data that describes the burning efficiency of each fuel type in each habitat for each fire severity class.

Field data

Fuel accumulation and burning efficiency values were derived, from 255 and 42, 100 m transects, respectively, in the higher rainfall region [5] in west Arnhem Land, calculated separately for each season and habitat. To calculate the burning efficiency and patchiness, as they relate to fire severity, rather than fire seasonality, we correlated the proportion of each fuel type consumed by fires with measurements of fire severity per transect, where fire severity was derived from the proportion of the mean scorch height of the mean canopy height at each transect:

Fire severity ~ mean scorch height (m) / mean canopy height (m) (1)

Russell-Smith and Edwards [6] derived a fire severity history from annual photographs of 178 fire monitoring plots in the adjacent Kakadu and Nitmiluk National Parks. This fire history was then used to characterise the proportion of ***low***, ***moderate*** and ***high*** severity fires that occur in the early and late dry seasons, Table 2. We compared the severity based burning efficiency and patchiness from the vegetation fuels plots in west Arnhem Land with the probabilistic occurrence derived by Russell-Smith and Edwards (2006).

TABLE 2 THE EMPIRICALLY DERIVED SEASONAL PROPORTION OF EACH FIRE SEVERITY CLASS

Severity	EDS	LDS
Low	0.80	0.25
Moderate	0.15	0.45
High	0.05	0.30

The comparison is undertaken by converting the severity based burning efficiency and patchiness values to seasonal values using the probabilities in Table 2:

$$(BEF/P)_F = [\sum (Low(P, p, BEF), Moderate(P, p, BEF), High(P, p, BEF))]_F \quad (2)$$

Where P = the seasonal probability; p = the fire severity based patchiness; BEF = the fire severity based burning efficiency and; $_F$ = the fuel type. Similarly to derive the seasonal based factors is simply the product of the seasonal patchiness and burning efficiency factors for each fuel type, Table 3.

TABLE 3 BURNING EFFICIENCY AND PATCHINESS FACTORS FROM THE FIRE SEASONALITY BASED EMISSIONS CALCULATIONS METHODOLOGY

Season	Fine fuels	Coarse fuels	Heavy fuels	Shrub fuels	Patchiness
EDS	0.74	0.15	0.17	0.29	0.71
LDS	0.86	0.36	0.31	0.39	0.89

Results

A total of 42 of the transects were experimentally fire affected, Table 4, with an even distribution of ***low*** (n = 21) *versus* ***moderate/high*** (n = 21) fire severity transects.

TABLE 4 THE NUMBER OF FIRE AFFECTED TRANSECTS IN EACH FIRE SEVERITY CATEGORY

Severity	Count
Low	21
Moderate	9
High	12

Patchiness data were available for 30 of the transects, and resulted in a distribution with a standard error that clearly differentiated ***low*** from ***moderate/high***, Table 5.

TABLE 5 THE GROUND LAYER PATCHINESS OF EACH SEVERITY CLASS (SE = STANDARD ERROR)

Severity	Patchiness	SE
Low	74	5
Moderate	96	2
High	98	1

The burning efficiency factors were derived for each fuel type, for each fire severity class, Table 6. In this analysis they were averaged across all habitats for all 42 transects.

TABLE 6 THE BURNING EFFICIENCY FACTORS FOR EACH FUEL TYPE FOR EACH FIRE SEVERITY CLASS

Severity	Fine fuels	Coarse fuels	Heavy fuels	Shrub fuels
Low	0.60	0.08	0.10	0.25
Moderate	0.74	0.31	0.18	0.22
High	0.86	0.51	0.51	0.60

We calculated the combined effect of the new fire severity based burning efficiency factors and ground patchiness by using the probability scores from Table 2. The results are similar although slightly less, Table 7.

TABLE 7 (I) THE SUM OF THE PRODUCTS OF THE FIRE SEVERITY BASED BURNING EFFICIENCY FACTOR, PATCHINESS AND SEASONAL PROBABILITY OF THE OCCURRENCE OF EACH FIRE SEVERITY CLASS AND; (II) THE PRODUCT OF THE SEASONAL BASED BURNING EFFICIENCY AND PATCHINESS.

(i)	Season	Fine	Coarse	Heavy	Shrub
	EDS	0.51	0.12	0.11	0.21
	LDS	0.68	0.30	0.25	0.32
(ii)	**Season**	**Fine**	**Coarse**	**Heavy**	**Shrub**
	EDS	0.53	0.11	0.12	0.21
	LDS	0.77	0.32	0.28	0.35

Discussion

The data collected at the vegetation fuels transects across west Arnhem Land, contain all the necessary information to characterise the Ground Fuel Patchiness and Burning Efficiency Factors based on the quantitative assessment of the fire severity at each of the 42 transects treated with fire. In these analyses we have demonstrated the simplicity with which the existing methodology [12] can be converted from a seasonal based to a severity based classification of the ground patchiness and burning efficiency factors in the higher rainfall region. Similar data exist for the lower rainfall region and will be re-analysed. The conversion of the methodology provides for the replacement of the seasonal mapping of burnt area with mapping of fire severity. Hence, the removal of a processing step, and associated error, by replacing the empirically derived but statistically based calculation of the proportionality of the fire severity classes per season, in the emissions calculation process. Also, the fire severity mapping is equally appropriate throughout the fire season and across the geographical extent of the tropical savannas, removing the requirement for a seasonal threshold. The threshold date (31 July/1 August) has caused consternation amongst potential savanna burning project participants particularly in Cape York, where it is generally, felt that the threshold should be much later and therefore penalises their fire management efforts.

The linchpin in this proposed converted methodology is the fire severity mapping. As stated, many years of calibration data have been collected. The accuracy of the mapping overall is improving slightly such that in 2014 accuracy reached 72%. The next step is to undertake a thorough comparative error analysis of the emissions calculations to determine if the error introduced into the emissions calculation process from the mapping is equivalent to or better than the error associated with the application of the proportionality of the fire severity classes per season, and apply this process to the lower rainfall data and methodology.

1.4 Future research agenda`

The research undertaken through this project has provided many land managers with maps and other information relevant to fire management. Through consultation with stakeholders, key research gaps have been identified and a proposed future research agenda developed. This was presented to the relevant agencies and Indigenous groups at the North Australia Fire Manager's Forum in Alice Springs, 20-22 June 2016. Three proposals addressing technical research needs are itemed blow.

Research Proposal 1

Validation of satellite based measures for fire characterisation

Objective

North Australia fire managers and agency end-users require reliable fire mapping products to meet a variety of land and emergency management needs. This research will undertake a multi-scale calibration, from ground observations and UAV measurements applied to increasingly larger area satellite remote sensing images to improve the ability of the large area images to map fire effects. Resultant mapping surfaces will be made available on NAFI.

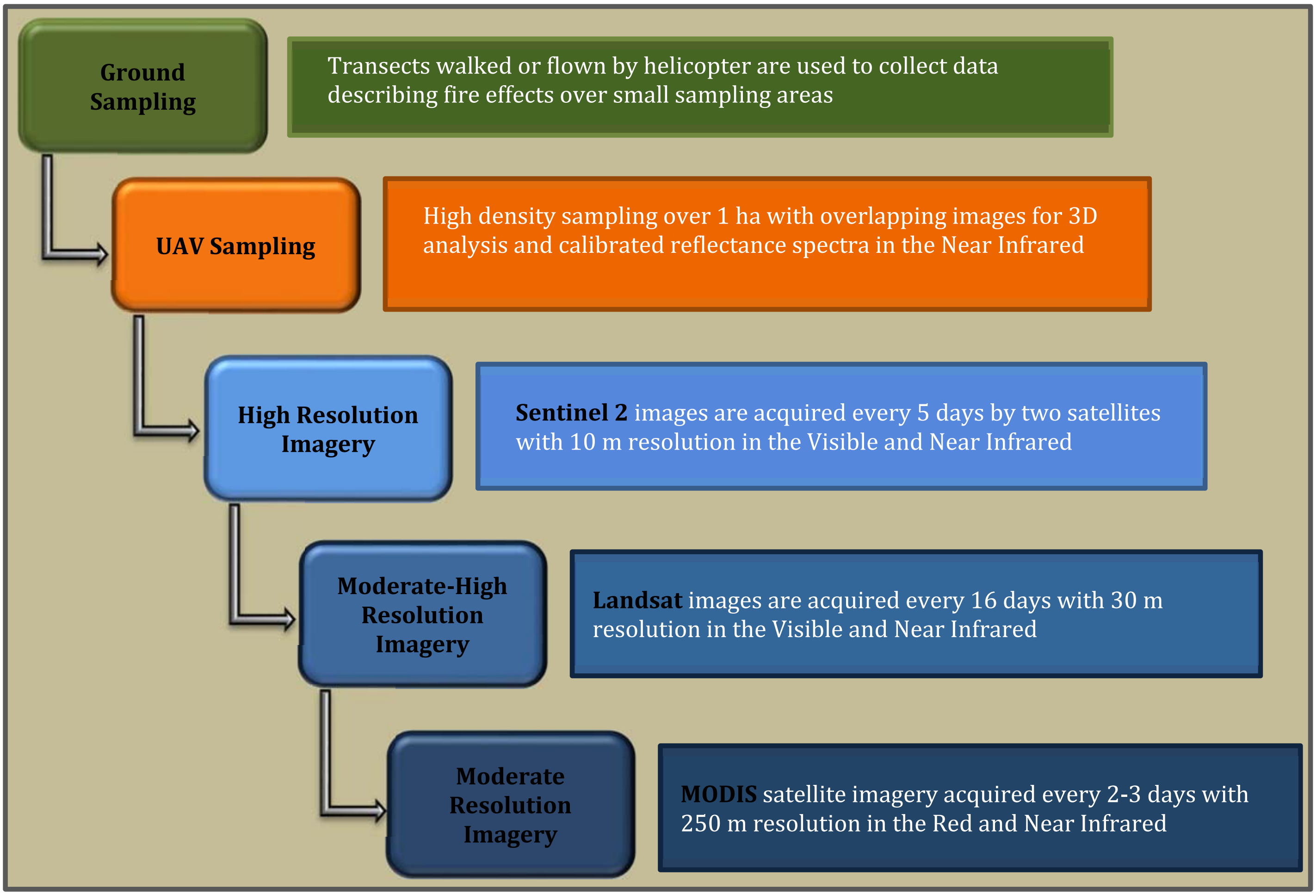

FIGURE 2. THE SCALE CONTINUUM: REPRESENTED BY STEPS OF DECREASING SCALE DESCRIBING FIRE EFFECTS; FROM GROUND AND AERIAL TRANSECT OBSERVATIONS TO CALIBRATE THE DRONE SAMPLING AT 1 HA; WHICH CAN THEN BE USED TO CALIBRATE HIGH THEN MODERATE-HIGH TO MODERATE RESOLUTION SATELLITE IMAGERY.

Research Proposal 2

Satellite sensor replacement research

Objective

To research and develop new and upcoming satellites to replace the MODIS satellite imagery

Background

The MODIS satellites (Moderate Resolution Imaging Spectroradiometer), referred to as Terra and Aqua, were launched in 1999 and 2002, respectively. These earth orbiting devices are prone to impacts from meteorites and other space debris, and, like all other machinery, they are also prone to entropy. In fact, the original specifications provide a design life of 6 years.

Research proposal 3

Fire Reporting

Objective

To improve and expand current fire reporting tools to enable users to incorporate further metrics

Background

A rudimentary but very useful reporting tool is currently available on NAFI. Many agencies require more detailed reporting to assist with fire management planning and strategies, and to subsequently determine budgets.

2. FLAMMABLE GRASSY WEEDS COMPONENT

At the time that this activity was commencing, the Project Leader Associate Professor Samantha Setterfield was offered a position at the University of Western Australia. Negotiations took place between CDU and UWA to ensure the research activity could be completed in collaboration between the two Universities. The contract between CDU and UWA was signed for project commencement on July 1, 2016. Therefore, there are no research activities or milestone to report in the 2015-16 period.

3. GULF FIRE MANAGEMENT COMPONENT

As outlined in last year's annual report, it was agreed that this project component would replace an earlier potential focus on developing market-based fire management in central Australian spinifex and mulga rangelands. The main focus of the research to date has been the undertaking of PhD studies by Kate van Wezel, looking at the potential for developing economic opportunities for fire management in the NT/QLD Gulf region--especially the engagement of women in ranger-based activities. Her report is given below.

Research Progress with the Gulf savanna burning project, June 2015-June 2016.

Upon completing milestones such as ethical clearance, a literature review, and confirmation of candidature, PhD candidate Kate Van Wezel based herself in Robinson River - a remote community on the Garawa Aboriginal Land Trust – to commence field work at the end of last year's dry season. As discussed with rangers and mentioned in the previous annual report, the research focus had shifted to women's fire management specifically. The intention was therefore to document women's traditional knowledge of fire, and to measure ecological outcomes together with female rangers of their burning practices to inform their adaptive fire management and to ultimately attract recognition and funding for their work.

During the wet season, initial interviews with community elders were conducted and a plot network was established to measure outcomes of different fire regimes on stand dynamics of a culturally significant sandalwood species (*Santalum lanceolatum*). However, attempts to collaboratively develop a theoretical framework for the research made it increasingly obvious that if this project is to truly support women's fire management over the long term, research objectives need to be reprioritised. Although documenting management outcomes is still essential to any form of adaptive management, building women's capacity for ecological research is futile in the face of major conflicts of interests in land use, governance, and access. While these issues affect the continuity of Waanyi and Garawa fire management as a whole, a range of compounding factors have lead these problems to affect women's involvement in a specific way. Women have now been excluded from fire management for so long that their customary knowledge of fire is highly fragmented, and only few feel confident enough to manage their country.

Based on these findings the project no longer aims to develop a sustainable fire management plan based on women's customary knowledge of fire. Rather, it aims to (re)build women's knowledge and confidence to manage fire as part of a broader development strategy for Waanyi and Garawa country. To this end, the Waanyi-Garawa rangers have started employing representative senior female land holders through the IPA program to participate in land use planning workshops structured around mapping provided by the Darwin Centre for Bushfires Research, as a part of this BNHCRC research project. These workshops are to be held out on country with custodians from all four Waanyi and Garawa clan groups; the Wuyaliya, Wudaliya, Rhumburriya, and Mabaliya. Participation in community life in Robinson River made it very clear that this is integral to fair representation in both the ranger program and in this BNHCRC research project. At the time of this report, a series of workshops on Wuyaliya country had just been completed, and workshops on Wudaliya and Mumbaliya estates were scheduled for early July.

Topsy Green, Iris Hogan, Kathleen O'Keefe, Margaret Cutta, Katie Seccin, Joy Seccin, and Maxine Wallace participate in land use planning workshops. They discuss landscape change and governance through a series of maps provided by DCBR as they are entering Waanyi country from the west on Creswell Downs station (top); and how women could work together with men through the ranger program in a way that is culturally appropriate while planning their involvement in a Bush Heritage biodiversity survey on the Waanyi-Garawa IPA (below). Photos courtesy of Harry MacDermott (top) and Karl Rann (bottom)

These fieldtrips are often the first time for participants to visit their country. This on itself is probably the most empowering aspect of the workshops, as many women understandably feel incapable of making land management descisions when they have never been to their country before. This is also an opportunity for them to observe fire management outcomes first hand.

The Waanyi-Garawa rangers organised for women to observe new fire scars from prescribed burning on Wuyaliya country, through their collaboration with the CLCAC on their aerial burning program.

During these fieldtrips senior women also met with the male Waanyi-Garawa rangers to familiarise themselves with the current collaborative fire management program with the Carpentaria Land Council Aboriginal Corporation (CLCAC). Here they discussed how a women's fire management program should intersect with the men's current work, and agreed that these senior women now have a responsibility to inspire younger Waanyi and Garawa women to get involved in fire management.

Women meet with Kevin Anderson (CLCAC fire project officer) , Billy Jackson (CLCAC head ranger), Jimmy Morrison (Waanyi-Garawa and Garawa ranger coordinator, NLC) and Donal Shadforth (Waanyi-Garawa ranger) at Wallace Creek outstation on the Waanyi-Garawa IPA. Photo courtesy of Karl Rann

Representatives from the Waanyi-Garawa rangers, the CLCAC, Bushfires NT, and project volunteers gather for a demonstration of modern equipment used in the prescribed burning program.

Joy Seccin, a senior traditional owner visiting Wallace Creek for the first time, is the first female Waanyi-Garawa ranger to practice using the new Pyro Shot, with instruction from Kevin Anderson (CLCAC) and Arthur Green (Waanyi-Garawa rangers).

However, agency-based training alone will be insufficient to instil confidence in women, as it cannot address site-specific cultural responsibilities inherent to Indigenous fire management. Some of this cultural knowledge of country is still held by women from other language groups who are sometimes more familiar with country than its traditional custodians through deployment in stock camps or through marriage. Fieldtrips were therefore not entirely restricted to traditional custodians of the visited estates; some women from neighbouring language groups were also employed through the IPA program as consultants to the Waanyi-Garawa rangers and the BNHCRC project. They contributed valuable reflections on landscape change, uses of natural resources, and also site specific cultural knowledge.

Consultants guide wuyaliya custodians to a women's sacred site on their estate on the Waanyi-Garawa IPA (sacred site is not in view). Knowledge of sacred sites is particularly important to including women in fire managent, with rangers fearing they could unknowingly damage sites during landscape-scale prescribed burning. Women also worry that their sacred sites have been desecrated by being left unburnt, or managed by men out of neccesity. Photo courtesy of Harry MacDermott

Sisters Margaret Cutta (left) and Kathleen O'Keefe (right) from the neighbouring Wambaya language group share their medicinal uses of Dradjula (Eremophilia longifolia) *with Waanyi woman Topsy Green (middle) during a foraging trip to Brunette Downs station.*

Although the surprising and immensly challenging context of my project has led to its (honestly daunting) reconfiguration, I am convinced that these changes are requisite to meaningful outcomes for all research parties. As of yet I do not forsee that these structural changes will result in a delay in my PhD progress, and for this I am grateful to have been hosted by Robinson River community during the wet season, allerting me early on to the reality faced by co-researchers. Furthermore, data collected prior to this understanding is still relevant. For instance, the sandalwood plot network can be incorporated into community-based natural resource mapping for the Garawa Land Trust. Ultimately, being confronted with obstacles to including women in fire management is frustrating but definitely generates insight into the impediments, opportunities, and key challenges to sustainable Indigenous fire management. I am therefore confident that this project will fulfil its purpose for the CRC, contributing a highly contemporary case study to the broader scope of BNHCRC research into savanna management in northern Australia.

4. SCENARIO PLANNING COMPONENT

This component is due to commence in January 2017. Ongoing discussions are being held with project partners about the appropriate formulation of this component, especially the need to build on work undertaken to date in both 'Savanna prescribed burning' and the complementary 'Scoping community resilience in north Australian remote community' projects as part of CDU's broader umbrella BNHCRC project, "Building community resilience in northern Australia".

Agreement-in-principle has been reached with project partners and the BNHCRC that this project component will use materials developed as part of the broader project to undertake scenario planning exercises with select community groups and associated stakeholders (including EM agencies) across northern Australia. Prof Douglas Paton (CDU) has agreed (in-principle) to lead this project component.

The project will be developed in partnership with the BNHCRC, research partners and communities over the next six months.

PUBLICATIONS LIST

Nil.

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