Northern Australia Environmental Resources Hub

National Environmental Science Programme

Supporting savanna fire management through carbon farming

Final report

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Cover photographs

Front cover: A small controlled early dry season fire in an open forest savanna (photo: Garry Cook 2012).
Back cover: A LIDAR image showing the difference in biomass of a plot between 2013 and 2017 (image: Shaun Levick).

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Acronyms

DAWE................Department of Agriculture, Water and the Environment

DISER................Department of Industry, Science, Energy and Resources

ERF.....................Emissions Reduction Fund

LIDAR.................Light detection and ranging

NESP ....National Environmental Science Program

NIR......................National Inventory Report

NOAA-AVHRR...National Oceanic and Atmospheric Administration Advanced Very High Resolution Radiometer

TRAPS ....Transect Recording and Processing System

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Executive summary

Savanna burning for emissions avoidance and carbon sequestration under approved accounting methodologies is now an established industry across northern Australia and supports improved management of about 334 000 km^2 of northern Australia's savannas. The project supported the Australian Department of Industry, Science, Energy and Resources improve parameterisation of a new Australian Government legislative instrument aiming to support emissions reduction and carbon sequestration through improved fire management in savannas (herein called the 'savanna burning methodology'). A published scientific paper (Cook et al. 2020) described the basis for including dead standing wood as a pool of carbon that had previously been excluded from the emissions and carbon stock calculations in the methodology. A table providing the new parameterisation based on currently available maps of savanna vegetation types is included in the paper. The approach has been described in a number of face-to-face meetings with departmental staff over several years.

In addition, the project supported ongoing development of new approaches for quantifying carbon stocks in savannas through use of LIDAR. We showed that LIDAR offers the ability to quantify previously unmeasurable attributes of vegetation structure to improve our understanding of the effects of fire management on vegetation and carbon stocks. This work was published in a scientific paper (Levick et al. 2019).

1. Introduction

The major vegetation classes of Australia's tropical savannas have fire frequencies ranging from 0.17 to 0.36 fires per year. In all cases, fires in the late dry season – that is defined as after 31 July – dominate. These fires produce substantial quantities of the strong greenhouse gases methane and nitrous oxide as well as reduce the amount of carbon stored in the landscape. Australia's Emissions Reduction Fund (ERF) exists to reduce greenhouse gas emissions. Projects under this fund cover 334 000 km^2 of northern Australia's savannas.

Fire management projects have been established in those parts of northern Australia that historically have had a greater frequency of fires and particularly of late dry season fires. A new legislative instrument aiming to include carbon sequestration in dead organic matter as well as emissions avoidance was enacted in 2018. This new approach ensured that the government was moving towards compliance with the 2006 guidelines for national greenhouse gas inventories (IPCC 2006). However, the parameterisation provided in supporting documentation to this legislative instrument did not include carbon in dead standing trees.

This project aimed to provide a new parameterisation table to support the ongoing improvement of the savanna burning methodologies and to take account of a previously unaccounted pool of carbon. As well the project supported further development of new approaches to quantifying carbon stocks using LIDAR imagery.

2. Methodology

The new Australian legislative instrument aiming to support emissions reduction and carbon sequestration through improved fire management in savannas includes an equation to calculate fuel loads in equilibrium with particular fire regimes. This equation is derived from Equation 15 of Cook et al. (2016). The fuel loads depend on inputs (L), decomposition rates (k) and characteristics of the fire regimes. For woody debris the parameter table invoked by the legislative instrument currently only includes onground dead wood. We developed and parameterised an approach to include the much larger pool in standing dead wood.

2.1 Introduction

The 2015 Savanna Burning methodology is consistent with the 1996 IPCC guidelines for national greenhouse gas inventories (IPCC 1996). This was a partical account that included methane and nitrous oxide emissions but did not include dynamics in carbon stocks. However, Australia needed to move to be consistent with the 2006 IPCC guidelines that included accounting of both emissions and carbon stock change (Paustian et al. 2006). The paper by Cook, Meyer, Muepu & Liedloff (2016) provided an approach for a consistent set of calculations of both emissions avoidance and carbon sequestration. Unfortunately, the field data used by Cook et al. (2016) and adopted in the new legislative instument only included dead wood on the ground. Thus, the key parameter L, which describes the rate of dead wood production only gave the amount for dead wood on the ground. Here we provide a way to calculate the inputs of total dead wood including both on-ground and standing dead wood. We apply it to provide a new parameter table based on existing knowledge of savanna vegetation types.

2.2 Sampling methods

The value of L, the input of dead wood was determined as the product of the woody component of live tree biomass and the average annual tree mortality rate.

We used existing and newly collected data to quantify tree stand structure relationships for all the vegetation types in the existing methodology exCept for the heathland communities for which there was insufficient information. For open forests in the high rainfall zone (>1000 mm) and woodlands in both the high and low (600 -1000 mm) rainfall zones, we showed that their stand structures were well described by negative exponential relationships. These curves indicated that a constant proportion of each size cohort of trees dies each year on average. The slope of these curves together with mean growth rates were used to calculate the mortality rates of trees. The mortality rates were greatest in high rainfall woodlands and least in high rainfall open forests. A lower mortality rate will lead to the open forests having a greater proportion of large trees in their stands than woodlands.

Data from the analysis of tree stands across the Northern Territory by Williams et al. (1996) allowed total basal area of trees to be calculated across northern Australia from data layers of soil type and rainfall. From this data layer, we use a vegetation fuel type map for Australia's northern savannas (Thackway, Auricht, Edwards, Lynch & Cuff 2014) to allocate each 0.01° X 0.01° grid cell to a vegetation class for which we could calculate stand biomass from the total basal area.

From the stand biomass in each grid cell, we calculated that amount comprising wood rather than leaves and twigs. By multiplying the woody biomass in each grid cell by the appropriate mortality rate, we produced a data layer of annual inputs of heavy fraction (>0.05 m diameter) dead wood. Inputs of course fraction (0.006 – 0.05 m diameter) dead wood were calculated from the total basal areas using a relationship based on measured data of Cuff & Brocklehurst (2015). These values were then averaged for each vegetation class.

3. Results

3.1 Values of annual inputs of dead wood

We found that the across the whole savanna zone, the annual mortality rate of trees was greater than 2%. We also showed that across the savannas, there were approximately 23 billion live trees with a stem diameter greater than 5 cm and a total above ground biomass of about 3.6 billion tonnes. Thus, in total, more than 400 million trees die each year with a total biomass of more than 72 million tonnes.

Nearly 80% of the dead wood in the savannas comprised dead standing wood, with the remainder being on-ground.

The values of L_h (heavy fuel input) and L_c (coarse fuel input) for each vegetation class along with the mean live biomass and mortality rates are given in Table 1. It can be seen that although the open forest has a larger biomass of live vegetation, due to its lower mortality rate the value of L_h is lower than that for the woodland classes in the high rainfall zone.

Table 1. Mean live biomass, mortality rates and annual inputs of heavy and coarse fraction dead wood in seven vegetation types in Australia's tropical savannas. The vegetation classes are either from high or low rainfall (h: >1000 mm or l: 600–1000 mm respectively) with tree structure being open forest (OF), woodland (W) or open woodland (OW), with mixed (Mi), hummock (Hu) or tussock (Tu) grasses.

Vegetation class	Mean live biomass ($t\ ha^{-1}$)	Mortality rate (yr^{-1})	L_h* ($Mg\ ha^{-1}\ yr^{-1}$)	L_c ($Mg\ ha^{-1}\ yr^{-1}$)
hOFMi	50.6	0.0215	1.09	0.18
hWMi	43.5	0.0270	1.16	0.17
hWHu	42.1	0.0270	1.12	0.16
lWHu	32.5	0.0224	0.72	0.12
lWMi	27.24	0.0224	0.61	0.1
lWTu	24.9	0.0224	0.56	0.09
lOWMi	26.3	0.0224	0.59	0.09

*: note, Values of L_h are taken from Table 4 of Cook et al. 2020. Slight discrepencies between those values and one calculated by multiplying the biomass by mortalility values in this table are due to rounding errors.

Modelling of the dynamics of dead woody biomass under different fire regimes was supported by field data. The data showed that the proportion of total biomass comprising dead wood increased with decreasing fire frequency. This demonstrated that there is opportunity to manage fire regimes to increase carbon stored in the landscape.

3.2 Historic fire regimes

We examined historic fire regimes (1988–2015) using NOAA-AVHRR data and found that across the nine defined vegetation types eligible for carbon farming projects in the savanna zone, the total fire frequencies ranged from fires in 16% of years to fires in 36% of years (Cook et al. 2020). Areas that have developed fire management projects had fire frequencies greater than the average for each vegetation type ranging from 26 to 37% of years. In all cases, late dry season fires dominated over early dry season fires at the scale of vegetation types.

3.3 Development of LIDAR as a tool to quantify the dynamics of carbon in savannas

LIDAR-derived canopy height and cover metrics showed that these attributes were higher in the absence of fire in a controlled experiment near Darwin (Levick et al. 2019). They were least in plots burnt late in the dry season every second year. Fire caused the greatest reduction in biomass on sites with shallower soil.

Figures 1 and 2 show how LIDAR data can be used to monitor vegetation and carbon stock change in savannas.

Figure 1. LIDAR scan of a patch of trees in 2013. Source: Shaun Levick.

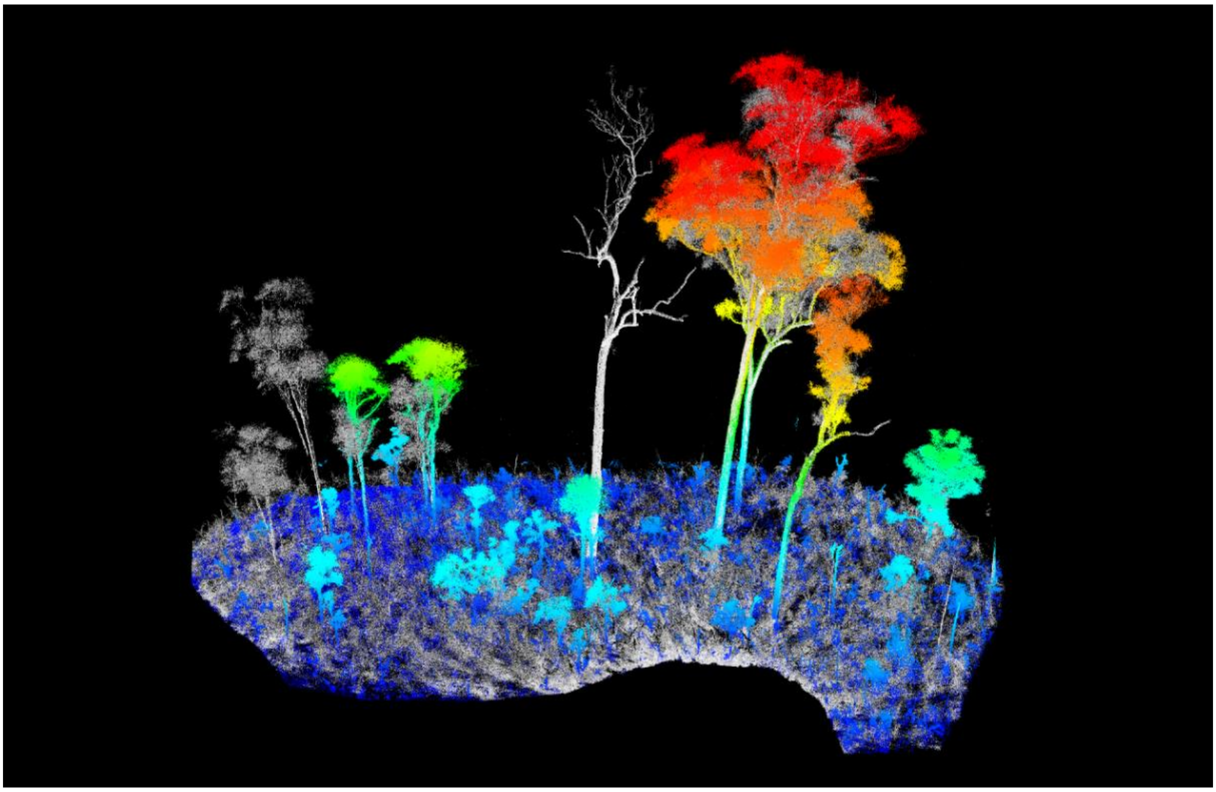

Figure 2. A difference image showing how the plot in Figure 1 has changed by 2017. Trees in grey have disappeared (through combustion by fire), while new growth on surviving trees is shown in colour with blue grading through green to red indicating increasing height. Source: Shaun Levick.

4. Discussion

4.1 Using fire to manage carbon in savannas

The following text has been taken from Cook et al. (2020).

At the scales of major vegetation classes, Australia's tropical savannas have fire frequencies ranging from,0.17 to 0.36 fires per year, with late dry season fires dominating in all cases. Emissions avoidance projects under Australia's ERF cover, 334 000 km^2 of northern Australia's savannas. Projects have been established in areas that historically have had more frequent fires, and more frequent late dry season fires, than the area overall. With the move to including carbon sequestration as well as emissions avoidance in ERF methodologies and in the National Inventory Report, it was important that fuel accumulation curves were robustly parameterised to produce valid carbon and emissions budgets. This ensured compliance with the 2006 guidelines for national greenhouse gas inventories (IPCC 2006). Regarding woody debris – important because of its biomass and high methane emission factors – the first step in this was the fitting of modified Olson curves to field observations. Fitting these curves supported estimates of carbon sequestration in new ERF methodologies and in the NIR. A further development has been the application of a mass balance approach to estimate the input parameters to the modified Olson curve from field data of tree stand structure, growth rates and woody combustion. These considerations allow the mortality rate of trees (and consequently the creation of dead wood) to be estimated. Across the whole savanna zone with more than 600mm rainfall, more than 2% of trees die per year. Thus, in total, more than 400 million trees with a stem diameter <0.05m and a total biomass of more than 72 Tg die per year. Previous estimates of greenhouse gas emissions from Australian savanna fires have not included standing dead trees. However, research from eucalypt woodlands in southern Queensland showed that they burn at rates similar to on-ground dead wood. New field data from semiarid savannas across northern Australia have confirmed that dead standing trees comprise most of the dead wood. Further, the proportion of total woody biomass comprising dead wood increases with decreasing fire frequency and a decreasing proportion of late dry season fires. This gives scope for increasing the carbon stock in the woody debris pool with improved fire management. New parameters are presented for calculating woody debris dynamics, including dead trees, in Australia's savannas.

4.2 Using LIDAR to assess vegetation dynamics in savannas

The following text is taken from Levick et al. (2019).

We quantified the magnitude of above-ground carbon reduction under different regimes by integrating airborne LIDAR, field surveys, and an ongoing fire regime experiment. Our results highlight the impact of late season burning on both carbon storage and canopy vertical profile structure. Clear relationships between biodiversity and fire regimes have proven difficult to establish in savannas, despite many attempts at linking floral and faunal diversity directly to fire regime patterns. The range of vertical profile responses that we have illustrated here under different experimental fire treatments could hold the key to unlocking stronger links between fire management and biodiversity responses. High-resolution LIDAR can expose the structural consequences of different management actions and make them more easily accessible for integration with biodiversity and ecosystem process studies.

5. Recommendations and conclusions

The published paper giving new parameters for annual inputs of dead wood has been presented to staff in the Agriculture Section, Land and Outreach Branch, Climate Change Division, Department of Industry, Science, Energy and Resources. The department will consider them and following review and consultation may use them to revise parameter tables that support the savanna burning calculations.

Research into the use of LIDAR as a tool for understanding and quantifying the dynamics of vegetation and carbon is ongoing.

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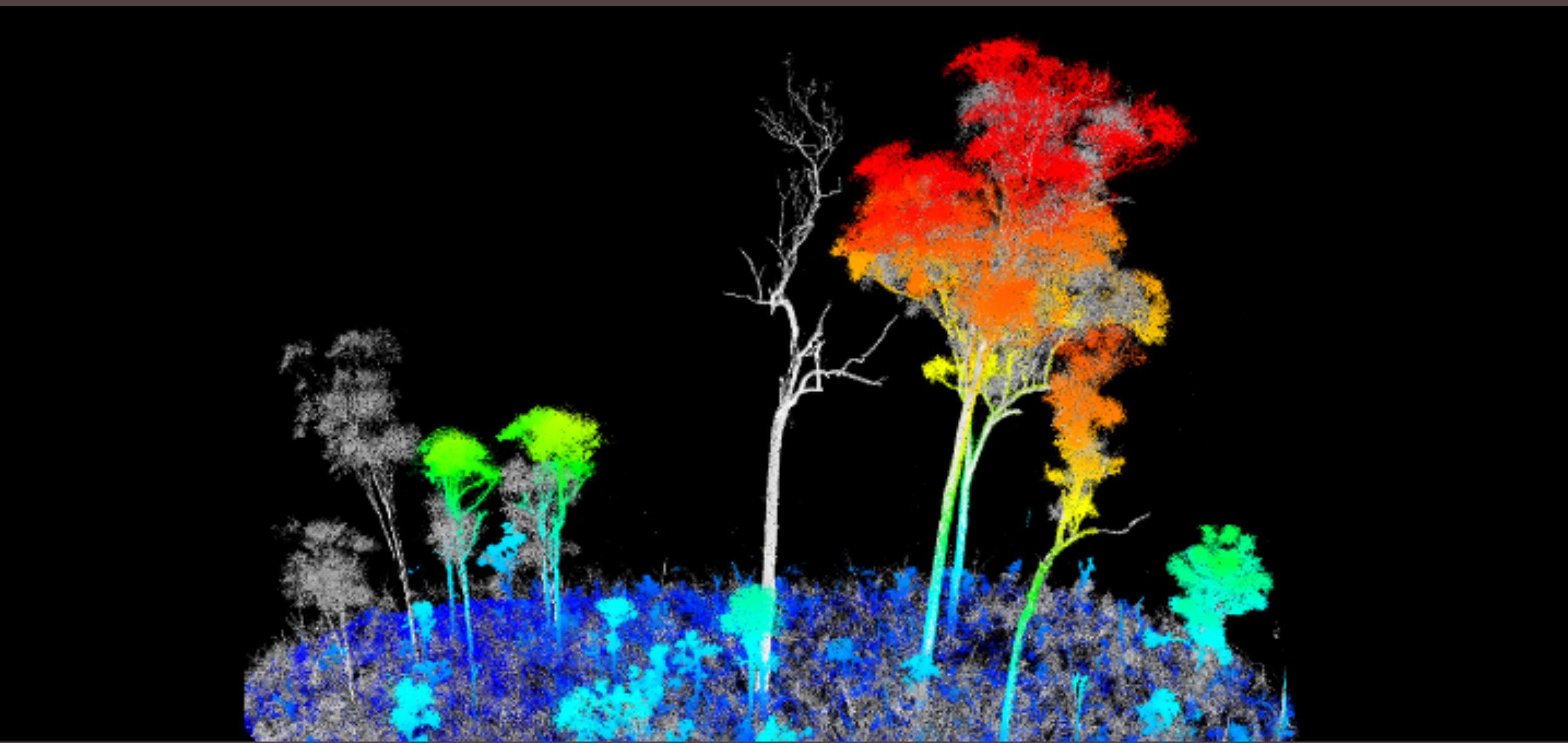

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