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The identification of rangeland regions where severe fire regimes affect cattle producers

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Abstract

This project identified cattle producing regions where the Australian Government's Carbon Farming Initiative (CFI) Savanna Burning Methodology to account for reductions in greenhouse gas emissions or a similar lower-rainfall methodology could be applied. Across seven bioregions in northern Australia where late dry season fires dominated, 73 properties with a total of 537 000 head of cattle had an average of 36% of their properties burnt annually. Only one of these bioregions had a mean annual rainfall greater than 1000 mm required for the current Methodology. The other bioregions may be able to use a lower-rainfall Methodology that is currently under development. In other bioregions, there may be individual properties that may find it advantageous to participate in savanna burning management under the CFI.

Recommendations are made for further research and development to facilitate producer's participation in the CFI. These include social research aiming to understand producers' attitudes to fire management, biophysical research to better understand the nature of fire regimes and their impacts on pasture and fuel dynamics in grazed landscapes and the development of business models that would facilitate individual or regional participation in the CFI.

Executive summary

Project background and aims: This project aimed to (1) define the areas of Australia's rangelands where the Savanna Burning Methodology under the Australian Government's Carbon Farming Initiative (CFI) could benefit red-meat producers and to (2) recommend further research. The CFI could enable producers to earn carbon credits by reducing the greenhouse gas emissions from fires on their land. The Savanna Burning Methodology requires this to be achieved by strategically burning early in the dry season to reduce the overall frequency of fires and particularly of late dry season fires.

Specifically the objectives of the project were to produce:

1. a report to MLA
2. a draft scientific paper that
    a. defines the relationships between fire regimes (defined as size, frequency and timing) and stock density for different rainfall zones across Australian rangelands
    b. identifies regions where improved fire management is likely to lead to reduced greenhouse gas emissions and benefit red-meat producers and therefore could lead to participation in the carbon farming initiative.

Achievements: We developed new maps describing the climate, fire regimes and cattle density across the rangelands at the scale of the Australian government's 51 defined bioregions within the Australian rangelands. These maps required collation of data on 16 million active NLIS devices on more than 13 000 properties, and of more than 145 000 individual fires from 1990 to 2011. We assumed that the NLIS devices could be used to infer cattle density. In keeping with conditions of access to the primary data, the analyses were conducted to ensure that individual properties could not be identified and that the fire data could not be reproduced.

We showed that fire frequency was greatest where rainfall was highly summer dominant. Across the rangelands, large fires burning in the late dry season accounted for the most of the total fire affected area. However in the north-west of the Northern Territory fire management using early dry season burning has resulted in a very low proportion of late dry season fires. In other areas, the major peak in fire activity is in the late dry season. Across the north, declining fire frequency on properties was associated with increasing cattle density. Nevertheless, there were 73 properties with more than 537 000 head of stock that were subject to late dry season fires. These fires affected on average 36 % of the area every year. About half of these stock were on 21 properties in the Gulf Plains, Sturt Plateau and Dampierland bioregions.

The CFI requires that methodologies be based on research published in peer-reviewed scientific literature. Accordingly, most of the analyses conducted for this project have been presented in a draft manuscript aimed at the journal *Rangeland Ecology and Management*.

Description of industry benefits: When, how and who?

In northern Australia, the late dry season is the time of the most severe fire weather. Fires at this time are typically large, intense and burn most of the available fuel. Uncontrolled fires damage infrastructure such as fences and bores and increase costs of production (Legge et al. 2011; Palmer 2004?). In the Kimberley, many agencies and land managers support the use of early dry season burning, but agree that despite its use late dry season wildfires are still very prevalent. Such as situation is likely to be common across much of the northern semi-arid grazing lands of Northern Territory and Queensland. Heckbert et al. (2012) estimated that at $23 per tonne of CO_2-e, fire abatement under the CFI could be economically viable across 51m ha and abate 1.6m t of emissions per year. Thus there is considerable potential to use the CFI to increase financial support for improved fire management across northern Australia.

Most cattle producing regions subject to frequent fires have less than 1000 mm annual rainfall and so cannot use the current Savanna Burning Methodology to generate carbon credits. For these regions, fire management supported by the CFI must await development of a lower-rainfall Methodology. Research is currently underway, but will take several years to lead to a methodology. Meanwhile, steps could be undertaken to facilitate participation in the CFI by industry when the lower rainfall Methodology is developed and approved. Research and development could focus on the three bioregions (Gulf Plains, Sturt Plateau, Dampierland) that have the greatest number of cattle on properties affected by frequent late dry season fires. Key research and development questions that need to be addressed include:

a. Social: What are the attitudes of cattle producers to current fire regimes and fire management on their properties and in their regions? Is the current fire regime perceived to be a problem? What are the limitations to better managing fires? Are there perceived trade-offs between the use of early dry season burning and maintenance of forage availability or is there a direct benefit from early dry season burning?

b. Biophysical: Are the assumptions that early dry season fires are more patchy and consume more fuel than late dry season fires valid in grazing lands of these bioregions? At the scale of paddocks and landscapes, what is the relationship between fire regimes and grazing regimes? Does less fire mean more consumption of grass by cattle? Do the least valuable grazing assets burn more frequently those than better grazing lands within properties? Could improved fire management focus on the least used parts of properties without affecting grazing practice on better value pastures?

c. Business development: What are appropriate models for CFI businesses about fire abatement in grazing lands? Can they be based on individual properties, or would a regional consortium be preferred? How could benefits and liabilities be distributed?

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1 Background

This report is provided in fulfilment of contract B. CCH. 2056 between CSIRO and Meat and Livestock Australia Limited (MLA): The identification of regions where severe fire regimes affect red-meat producers. This contract was issued in the context of the Federal Government's Carbon Farming Initiative (CFI). Under this scheme, the Savanna Burning Methodology was developed to support land managers in northern Australian regions who are affected by frequent late dry season fires. Through the strategic use of early dry season fires, property owners could claim carbon credits for the reduction in emissions of the greenhouse gases methane and nitrous oxide. This report has been conducted in the context that only 10 % of research papers on the subject of fires in northern Australia are pertinent to the effects and use of fire in pastoral areas (McIvor 2010).

The Savanna Burning Methodology has the potential to provide cattle producers with resources to manage fires on their lands better than has been possible in recent decades. More research is required to understand the interactions of cattle production with fire management, vegetation management and greenhouse gas budgets. However, the first step is to identify regions where cattle producers could benefit from improved management of frequent late dry season fires.

This project relates existing data on the occurrence, size, frequency and timing of fires across Australian rangelands to estimated data on cattle numbers and density. It is expected that for similar rainfall levels, fire regimes generally will become less severe as cattle density increases. Nevertheless, there are likely to be some regions with both a severe fire regime and high cattle numbers or density.

The analyses enabled the identification of cattle producing regions in which a reduction of fire frequency could benefit cattle producers and be supported by the CFI. The analyses were conducted and reported so that individual properties could not be identified.

The current Savanna Burning Methodology (Anonymous 2012) applies to four defined vegetation types in regions of northern Australia with a mean annual rainfall of more than 1000 mm. The Methodology requires that reductions in emissions from fires be achieved by planned and purposeful deployment of prescribed early dry season burns in combination with other natural and constructed barriers and active extinguishment to stop the spread of fire. It specifically excludes the use of increased grazing by cattle as a means of reducing emissions per unit area from fires. Research to develop a complementary methodology for areas with less than 1000 mm rainfall is underway.

2 Project objectives

The objectives as defined in the contract between MLA and CSIRO were to produce

1. a report to MLA
2. a draft scientific paper that
    a. defines the relationships between fire regimes (defined as size, frequency and timing) and stock density for different rainfall zones across Australian rangelands
    b. identifies regions where improved fire management is likely to lead to reduced greenhouse gas emissions and benefit red-meat producers and therefore could lead to participation in the carbon farming initiative.

The project used the National Livestock Inventory System (NLIS) data to estimate stock density across the Australian rangelands and compared it with existing data on fire occurrence over 21 years (1990 – 2011). The Australian rangelands region was defined according to the Australian Collaborative Rangelands Information Scheme (ACRIS). This region corresponds to that area deemed subject to savanna burning in the Australian National Greenhouse Gas Inventory. This region was divided according to rainfall zones that were identified by Russell-Smith et al. (2007) who analysed fire regimes across the continent. Using property and bioregional scale data, cattle density was related to various aspects of the fire regime such as mean fire size, fire frequency and mean fire timing.

Maps were produced to describe climate, fire regimes, and cattle density at bioregional scales across the rangelands. These and the underlying data were analysed to identify regions in which there are both a high density of stock and a severe fire regime that could be better managed under the CFI. Recommendations for further research were made. The analyses do not enable identification of individual properties or re-creation of the original fire dataset.

3 Methodology

3.1 Methodology – Overview of the data and its analysis

In order to identify regions where there are both high numbers of cattle and severe fire regimes and number of data sets need were collated into a Geographic Information System. Fire data had been obtained previously from Landgate and rainfall data from SILO and the Bureau of Meteorology. Data on Property Identification Codes (PICs) and the numbers of active devices on each under the National Livestock Inventory System (NLIS) were obtained from respective state agencies and NLIS Ltd by mid-October 2012.

The project sought to identify regions where there were both high densities of cattle on each PIC and severe fire regimes in each of four fire regions based on the analyses of Russell-Smith et al. (2007) but modified so that the Interim

Biogeographic Regionalisation for Australia (IBRA) provided the boundaries between fire regions. Property data was collated for each bioregion so that individual properties could not be identified.

3.2 Methodology – Assembling the data

The following data sets were collated for the analyses required:

1. The Australian rangeland boundary developed by the Australian Collaborative Rangeland Information System;
2. National Livestock Identification System (NLIS) data for Active Devices for each Property Identification Code on 1 Jan 2011 in Western Australia, South Australia, Northern Territory, Queensland and New South Wales;
3. Locations of each Property Identification Code provided by the relevant state agency as either shape files (WA, SA, Qld, NSW) or centroids (NT);
4. Rainfall history[1] ;
5. Interim Biogeographic Regionalisation for Australia (IBRA7);
6. Fire history from Landgate (http://www.landgate.wa.gov.au/corporate.nsf).

We firstly obtained data from NLIS Ltd of Active Devices for each PIC in the Australian rangelands. These data were used to indicate the number of cattle on each PIC. These data may overestimate or underestimate cattle numbers on particular properties, but should be useful regionally as an index of cattle numbers. These data comprised a list of the number of Active Devices registered to each Property Indentification Code (PIC) in the areas of interest. They were then matched against cadastral information linking the location and boundaries of each property to the PIC. These data were obtained separately from each state government. For the Northern Territory, only centroids of each PIC were provided and these were cross-matched with separate cadastral data to allow seamless integration with data from other states. Where relevant, large congregations of active devices within holding yards, feedlots and within town boundaries were removed so that the focus was on open rangelands. The relevant contacts and dates when the data was supplied and licence agreements finalised are given in Table 1. For this report, properties were defined as cadastres that had a Property Indentification Code (PIC) as recognised by the National Livestock Inventory System. Across the bioregions, there were varying proportions of the total area that were not within defined properties.

From the NLIS and PIC data, the density of cattle was estimated. The data on cattle density was compared with data on fire regimes stratified according to regions with similar fire climates.

[1] http://www.longpaddock.qld.gov.au/silo/

Table 1 Sources of Property Identification Code and Active Device data

Data	Supplier	Contact	Licence	Date supplied
Active Devices	NLIS Ltd	Stephen Doughty	Yes	17 Sept 2012
PIC boundaries WA	Department of Agriculture and Food, WA	Samantha van Wyngaarden	Yes	18 Sept 2012
PIC boundaries SA	PIRSA Biosecurity SA	Peter Zviedrans / Mark Langman	Approval given	19 Sept 2012
PIC boundaries Qld	Animal Industries	Chris Chilcott	Approval given	11 Sept 2012
PIC boundaries NSW	Department of Primary Industries NSW	Peter Worsley	Approval given	02 Aug 2012
PIC centroides NT	Department of Lands, Planning and the Environment	Andy Roberts / Adele Kluth	Yes	**19Oct 2012**

3.3 Methodology – Description of bioregional analyses

Most of the analyses conducted for this project used the Interim Biogeographic Regionalisation of Australia (IBRA) (http://www.environment.gov.au/parks/nrs/science/bioregion-framework/ibra/maps.html). This defines 89 bioregions. We used the rangelands as defined by the Australian Collaborative Rangelands Information System (ACRIS) (http://www.environment.gov.au/land/rangelands/acris/) to define the area of interest within Australia. There are 51 bioregions within the Australian rangelands, with each having a name and a three-letter code that can be interpreted at the IBRA website.

For our first analyses, we grouped these 51 bioregions into four climatic zones based on the RAINCLASS zones defined in an analysis of Australian fire regimes by Russell-Smith et al. (2007). These are shown in Figure 1. For the analyses, we considered the following rainfall class regions of Russell-Smith et al. (2007): (1) Southern arid; (2) Central arid; (4) Semi-humid; and (6/7/8/10) Humid zones.

We analysed fire regimes and cattle density at varying scales. Depending on the purpose, these could be at whole of bioregion, or at the scale of properties within bioregions.

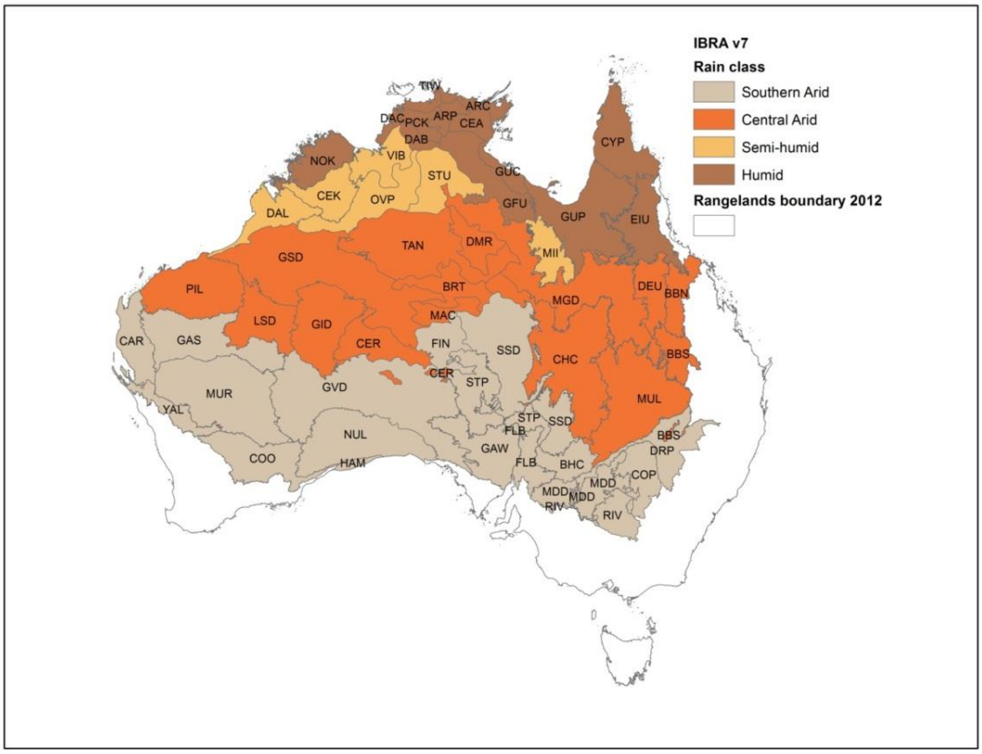

Figure 1 The 51 bioregions in the Australian rangelands grouped into four climatic zones based on the analyses of Russell-Smith et al. (2007)

4 Results and discussion

4.1 Results: The draft manuscript

The contract between MLA and CSIRO specified that a draft manuscript be produced. This was because of the requirement of the Carbon Farming Initiative that methodologies be based on research published in the peer-reviewed scientific literature. There has been much less published on the bio-physical aspects of fire in grazing lands of northern Australia than in non-grazing lands. The resultant scientific uncertainty is likely to impede acceptance of the application of CFI Savanna Burning Methodologies to grazing lands. This is particularly so given the specific exclusions within the Savanna Burning Methodology (Anonymous 2012) for increasing stocking rate as a means or consequence of reduced fire frequency. The draft manuscript gives the results and conclusions of the analyses conducted for this project and is included as Appendix 9.1. It represents a first step in addressing the uncertainties surrounding fire management for greenhouse gas abatement on grazing lands.

4.2 Discussion: Impacts on red-meat producers

Across the Australian rangelands, fire frequency is greatest in the north where the rainfall is highly summer dominant. In the southern and central arid zones, relatively high fire frequency only occurs in regions where cattle density is relatively low. In the northern semi-humid and humid rainfall zones, fire frequency on properties at a bioregional scale declines with increasing cattle density. Nevertheless, there are many individual properties in northern Australia where cattle density is relatively high and frequent fires occur.

Three northern Australian bioregions have significant numbers of cattle, very frequent fires, but already have fire regimes dominated by early dry season burning. These bioregions are Pine Creek, Darwin Coastal and Victoria Bonaparte. At a bioregional scale, application of the Savanna Burning Methodology would be difficult because these regions are already dominated by early dry season fires. Nevertheless, there may be individual properties in these bioregions where late dry season fires dominate and the Savanna Burning Methodology could support improved fire management. There may also be other means by which fire frequency could be reduced overall, but it would be challenging given the already extensive effort in fire management in these bioregions.

There are 11 bioregions that have significant numbers of cattle and have fire regimes with frequent late dry season fires (see Table 2 and Appendix). However, in four of those bioregions the number of properties and cattle affected by frequent fires is small. Across the North Kimberley, Ord-Victoria Plain, Gulf Coastal and Einasleigh Uplands bioregions only 6 properties with a total of 23 000 cattle are affected by frequent fires (average frequency = 39 %: Table 2).

Frequent fires, dominated by late dry season burning have the greatest affect on cattle producers across seven bioregions of northern Australia: Dampierland, Central Kimberley, Daly Basin, Sturt Plateau, Gulf Falls and Uplands, Gulf Plains and Cape York Peninsula. Across these bioregions, 73 properties with a total of more than 537

000 cattle have an average fire frequency of about 36 % (Table 2). This is equivalent to an average recurrence interval of about one fire every two to three years. The other properties in these bioregions have an average fire affected area of about 13 % or an average recurrence interval of about one fire every five to ten years. The properties subject to frequent fires represent 93 % of the total area of properties with more than 1000 head in the Daly Basin bioregion, 40 to 69 % of the Dampierland, Central Kimberley and Cape York Peninsula bioregions, and 19 to 30 % of the other bioregions.

The current Savanna Burning Methodology only applies to areas with more than 1000 mm mean annual rainfall. Of the seven bioregions mentioned above, only one – Daly Basin, has a mean annual rainfall of more than 1000 mm. In this bioregion, the fire regime includes a lot of early, middle and late dry season burning, and potentially the amount of late dry season burning could be reduced. For the other six bioregions where rainfall is less than 1000 mm, a future lower-rainfall CFI methodology may be applicable. The success of strategic fire management in the Ecofire project in Western Australia and the WALFA project in Arnhem Land indicates that fire frequency can be successfully managed (see Appendix). While research is currently underway to develop such a lower-rainfall methodology, there are a number of research questions around its application to grazing properties that would need to be addressed to facilitate adoption. These are discussed in draft paper in the appendix.

Table 2 Characteristics of properties with high fire frequency between 1990 and 2011 in northern bioregions

Bioregion	Total cattle ('000s)*	Properties with mean Fire Affected Areas (FAA) >25 % and > 1000 cattle				Properties with mean FAA <25 %
		Total cattle ('000s)*	Number of properties	Proportion of area (%)**	Mean FAA (%)	Mean FAA (%)
North-west Northern Territory						
Pine Creek	127	100	10	99	46	12
Daly Basin	177	135	14	93	43	14
Darwin Coastal	145	53	5	61	37	11
Victoria Bonaparte	159	16	6	36	44	17
North-east Northern Territory						
Central Arnhem	<5	<5	2	100	36	
Arnhem Coast	<5	<5	1	100	31	
Arnhem Plateau	<5	<5	1	100	31	
North Western Australia						
N. Kimberley	15	12	3	100	49	0
Dampierland	187	58	7	40	34	17
Central Kimberley	138	33	5	53	37	10
Contiguous bioregions between 17°S and 15°S in WA and NT						
Sturt Plateau	319	75	10	30	31	17
Ord Victoria Plain	433	8	1	1	40	12
Gulf Fall & Uplands	257	53	10	26	34	15
Gulf Coastal	119	2	1	41	37	21

North Queensland						
Mount Isa Inlier	383	0	0	0	-	4
Gulf Plains	1747	138	11	19	35	5
Einasleigh Uplands	1082	2	1	0	28	5
Cape York Peninsula	104	44	16	69	39	15

*NB: These numbers represent the total number of active NLIS devices in each bioregion and should be indicative of cattle numbers, but will not be exact. **of properties with > 1000 head.

5 Success in achieving objectives

In fulfilment of the objectives, the draft scientific paper reports an analysis of fire regimes and cattle density across the Australian rangelands. The annual extent of fire and its seasonality are described across the rangelands at the scale of four broad rainfall classes and at bioregional scales within those rainfall classes. Data from the National Livestock Inventory Scheme was used as an index of cattle density on properties and presented at the scale of bioregions to avoid breaching privacy obligations.

The following seven bioregions were identified as containing properties with medium to high cattle densities and a high frequency of late dry season fires: Daly Basin, Dampierland, Central Kimberley, Sturt Plateau, Gull Falls and Uplands, Ord Victoria Plains and Gulf Plains. Except for Daly Basin, the mean annual rainfall of all of these bioregions is less than 1000 mm so they are excluded from the current Savanna Burning Methodology. However, they could be included in a future lower-rainfall methodology.

6 Impact on meat and livestock industry

6.1 Now

As required, this project has identified regions where improved fire management is likely to lead to reduced greenhouse gas emissions and benefit red-meat producers. Seven bioregions identified in the draft manuscript where research into fire management for emissions abatement on cattle properties could improve participation in the carbon farming initiative. The specific research areas that could be investigated are specified in section 7.

6.2 In five years time

In five years, the cattle properties in northern Australia that suffer from relatively frequent late dry season fires could be accessing the carbon economy to support improved fire management and to reduce greenhouse gas emissions. Research supported by Meat and Livestock Australia could have led to reduced frequencies of wildfires for those properties and regions and led to reductions in greenhouse gas emissions. Such research would aim to reduce uncertainties that may restrict access to the CFI and would support business models for involvement in carbon trading through reductions in emissions from fires.

7 Conclusions and recommendations

1. The NLIS data has proven useful in deriving a fine-scale estimate of cattle density. The map of cattle density is consistent with others (e.g. Bastin 2008, http://www.environment.gov.au/soe/2006/publications/drs/indicator/162/).

2. The Darwin Coastal, Pine Creek and Victoria-Bonaparte bioregions have a high cattle density and a high fire frequency, but the fire regime is already dominated by early dry season fires. Hence for these bioregions there is little opportunity to reduce fire frequency by increasing the proportion of early dry season fires consistent with the Carbon Farming Initiative's Savanna Burning Methodology. It is possible that more strategic application of early dry season burning and adoption of other approaches, could reduce overall fire frequency, but the potential emissions abatement is much probably less than for other regions.
3. Within the seven bioregions identified in the appendix, there is evidence that early dry season burning is used to some extent, but late dry season fires are still extensive. There is potential to increase the use of strategic early dry season fires to reduce overall fire frequency. The success of the Ecofire project in the Kimberley and the WALFA project in Arnhem Land indicates that strategic fire management can reduce fire frequency at very large scales. Apart from the Daly Basin, these bioregions are excluded from the current Savanna Burning Methodology because their rainfall is too low. However they could be included following further methodology developments.
4. In order to give producers the best support to participate in the CFI Savanna Burning Methodologies, both current and future, further research is needed and it should focus on properties within the seven bioregions identified in section 4.2. Of these, 28 properties in the Gulf Plains bioregion in Queensland, Sturt Plateau in Northern Territory and Dampierland in Western Australia account for nearly half of the cattle numbers on properties with a very frequency of late dry season fires and could be the main targets for research.
5. The report on grazing and fire management practices in northern Australia by McIvor (2010) describes the knowledge about the effects and use of fire and raises a number of research questions. However, it lacks robust descriptions of fire regimes at regional, property and within-property scales that are critical to understanding and addressing fire management issues. This present report including the draft manuscript starts to address that key knowledge gap.
6. Key research and development questions regarding potential adoption of CFI Savanna Burning Methodologies on grazing lands fall into three categories: Social, bio-physical and business development
    a. Social: What are the attitudes of cattle producers to current fire regimes and fire management on their properties and in their regions? Is the current fire regime perceived to be a problem? What are the limitations to better managing fires? Are there perceived trade-offs between the use of early dry season burning and maintenance of forage availability or is there a direct benefit from early dry season burning?

b. Biophysical: Are the assumptions that early dry season fires are more patchy and consume more fuel than late dry season fires valid in grazing lands of these bioregions? At the scale of paddocks and landscapes, what is the relationship between fire regimes and grazing regimes? Does less fire mean more consumption of grass by cattle? Do the least valuable grazing assets burn more frequently those than better grazing lands within properties? Could improved fire management focus on the least used parts of properties without affecting grazing practice on better value pastures?

c. Business development: What are appropriate models for CFI businesses about fire abatement in grazing lands? Can they be based on individual properties, or would a regional consortium be preferred? How could benefits and liabilities be distributed?

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9 Appendices

Appendix 1: Draft Manuscript for Rangelands Ecology and Management

Interactions between fire and grazing in Australian rangelands: a continental scale analysis

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Abstract

The strategic use of early dry season fires has been advocated to reduce the greenhouse gas emissions from burning of savannas in Australia, but most of the research supporting this has come from outside of commercial grazing lands and in areas with more than 1000 mm rainfall. In this paper, we aimed to identify regions where examined commercial pastoral properties could alter fire regimes to reduce greenhouse gas emissions. We examined the interactions of fire regimes and cattle density across the 51 bioregions within the Australian rangelands. We showed that fire frequency increases greatly with increasing summer dominance of rainfall. Within the humid north of the rangelands where fire frequency is greatest, increasing cattle density is associated with declining fire frequency. Seven bioregions were indentified where at least some properties had both a high frequency of late dry season fires and relatively moderate to high densities of cattle. Adoption of approaches to reduce emissions from fires in these bioregions is contingent on further research into quantifying the impact of fire management on emissions at rainfall levels less than 1000 mm and understanding the interactions with cattle production.

Introduction

Fires burn across more than 300 000 km^2 of northern Australia's tropical savannas annually (Russell-Smith et al. 2007). The emissions of the greenhouse gases nitrous oxide and methane from Australian savanna fires comprise 2 to 4 % of annual accountable emissions (Cook and Meyer 2009). This is a uniquely high proportion for an OECD country. Much research has focussed on improving the accuracy of emissions estimates and on developing land management practices to reduce the pyrogenic emissions. These emissions were first quantified as part of the Kapalga Fire Experiment in Kakadu National Park Northern Territory (Hurst et al. 1994), which was established in response to frequent, widespread and intense late dry season fires in the Kakadu lowlands (Andersen et al. 1998). It was suggested that increased use of patchy early dry season fires could reduce overall fire frequency and fuel combustion and consequently reduce greenhouse gas emissions (Cook 2003; Cook et al. 1995). Following further research (Cook and Meyer 2009; Meyer et al. 2012; Russell-Smith et al. 2003a; Russell-Smith et al. 2009b), this approach was formalised as a methodology under the Australian Government's Carbon Farming Initiative (Anonymous 2012) and will be referred to herein as the Savanna Burning Methodology. Successful application of this methodology allows carbon credits to be issued which can be sold on a carbon trading market. Specifically the methodology requires that reductions in emissions from fires must be achieved by planned and purposeful deployment of prescribed early dry season burns in combination with other natural and constructed barriers and active extinguishment to stop the spread of fire. The methodology currently applies only to four specific vegetation types on areas with more than 1000 mm mean annual rainfall, but research is underway to extend it to other vegetation types in drier regions.

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