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Improved Fire Scar Mapping for Queensland

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Abstract

Satellite-based MODIS fire scar mapping accessed through the North Australia Fire Information (NAFI) website is an important tool for graziers who use these maps to monitor and manage fire. Use of the site has spread across Queensland in recent years and accuracy needs to be improved in some landscapes.

Given the data available, the accuracy of the fire scar mapping is difficult to quantify. In the northern and western bioregions (Western Cape York Peninsula, Gulf Plains, Northwest Highlands, most of the Einasleigh Uplands, Desert Uplands, Mitchell Grass Downs) the MODIS fire scar mapping has relatively few omission and commission errors at the scale needed by managers of landscape-scale fires and the map products are operationally very useful. In the more eastern and southern bioregions (Eastern Cape York Peninsula, Wet Tropics, eastern parts of Einasleigh Uplands, Central Queensland Coast, Brigalow Belt , South East Queensland, New England Tableland) the mapping can be subject to significant omission errors largely due to cloud cover, canopy cover and the small size of fires.

Options for overcoming these issues include increasing the time available for mapping, incorporating more user feedback, and including other data such as hotspots in the mapping process. Such changes should see accuracy improve as early as the coming (2011) fire season.

It should be possible to conduct regular quantitative validation of MODIS fire scar mapping based on existing State Government databases of fire occurrence, but these databases need to be made more consistent. The longer-term solution is to ensure that mapping meets national priorities and so attracts sufficient funding to cover transect-based validation and production of the required mapping resources.

If such a transition can be made while retaining links with graziers, the grazing industry will reap substantial benefits from an improved capacity to achieve desirable fire regimes and to reduce losses from wildfire. It may also allow the industry to capitalise on potential opportunities in the emerging carbon economy to earn income from changed fire management practices.

Executive Summary

Why the work was done
Digital state-wide maps of fire scars (areas of burnt country) and hotpots (locations of active fires) derived from satellite images and delivered via the North Australia Fire Information (NAFI) website, www.firenorth.org.au, are an important tool for Queensland graziers particularly those in northern regions. The maps allow graziers to better monitor fires on large properties, to better protect their infrastructure and fodder from wildfire, and to better plan their fire management. Many graziers see these maps as being as vital to their operations as the weather information from the Bureau of Meteorology site.

The 2009 fire season saw the use of these maps increase dramatically in Queensland and extend into central and southern grazing regions - there were 376,639 map requests in 2007, 471,649 in 2008 and 988,887 in 2009. As the geographical extent and use of these remotely-sensed map products has increased, issues have emerged around the accuracy of the fire scar mapping. Reports from users suggested that some fires were missed (omission errors) with estimates in some southern and eastern regions indicating that such errors represented up to 25% of the area actually burnt. Conversely, there were reports that extra 'fires' were being mapped in some regions (commission errors) but the areas involved in these cases were relatively small. The NAFI fire scar maps (250m resolution from the Moderate Imaging Spectroradiometer - MODIS - sensor) were seen as superior to the earlier remotely-sensed maps (1km resolution from the Advanced Very High Resolution Radiometer - AVHRR - sensor) by end users, but little work had been done in validating this perception. Nor was much known beyond anecdotal reports of how the accuracy of the mapping varied across different landscapes and why such variation occurred. Without this information it was difficult to improve the accuracy of the mapping in a systematic way.

What was achieved?
Transect-based surveys, usually by air, are the standard way to validate remotely-sensed fire-scar maps. State-wide transect surveys were beyond the scope of this project, however. Instead a more operationally-relevant assessment was done by using existing fire occurrence data held by State Government Departments and other end-users, and by directly consulting with landholders. The study set out to achieve the following objectives:
1. Review the accuracy of fire scar mapping in each of Queensland's 13 bioregions through on-the-ground consultation with key stakeholders and produce a table for each bioregion showing estimates of the commission/omission error;
2. Identify the major issues affecting data quality in each bioregion and the options for accommodating or overcoming these issues during the processing of satellite images;
3. Improve the reliability of the NAFI website fire scar maps for Queensland grazing areas;
4. Provide a mechanism for ongoing improvement of NAFI fire scar maps for Queensland.

Regarding objectives 1 and 2, the current State Government fire occurrence databases (held by QFRS and Qld Parks and Wildlife Service (QPWS)) were not in a suitable format for a standardised, quantitative assessment of the fire scar mapping. The QFRS database was largely focused on urban and roadside fires and the QPWS data were not stored with sufficient consistency to permit efficient queries. Instead, a state-wide bioregional assessment was compiled from interviewing key fire managers across each region. The findings confirmed earlier less structured evidence from end-users:

1. In the more northerly and north western regions (Western Cape York Peninsula, Gulf Plains, Northwest Highlands, most of the Einasleigh Uplands, Desert Uplands, Mitchell Grass Downs), with open landscapes, largely cloud-free fire seasons, and with more established networks between end users and fire mappers, the fire scar mapping is generally accurate.

Evidence suggests that in relatively clear conditions omission errors (actual burnt areas that were mapped as unburnt) account for <10% of the total area burnt in these regions. Similarly, commission errors (actual unburnt areas that were mapped as burnt) are estimated to account for <2% of the area burnt.

2. In the more eastern and southern regions (Eastern Cape York Peninsula, Wet Tropics, eastern parts of Einasleigh Uplands, Central Queensland Coast, Brigalow Belt, South East Queensland, New England Tableland), the fire scar mapping is less reliable. Based on feedback from fire managers, evidence suggests omission errors can account for >10% of the area burnt in a fire season. Commission errors were rarely reported from these regions. These areas tend to have more cloud cover in the fire season, many areas are more heavily vegetated, and the areas tend to be more closely settled with smaller and less frequent fires. These areas therefore tend to have more omission errors than areas in the far north and north-west of the State.

Regarding objective 3, and using the results above, improvement in fire scar accuracy in grazing areas will be significantly enhanced by increasing user feedback to mapping personnel, increasing the hours available for mapping, accessing improved hotpot data, and using hotspot and other data more methodically in the mapping process. The following specific improvements should occur over time: (a) more accurate mapping of patchy fires, particularly in the northern and north-western bioregions; (b) fewer omissions of large fires across all areas; and (c) elimination of significant mapping omission errors in fire history data, particularly in the northern and north-western bioregions. Enabling more effective use of the fire scar data by end-users is being improved by adding extra tools and clearer instructions on the NAFI website, and by raising awareness of the site and its use amongst grazing land managers.

Regarding Objective 4, efforts will be made to institutionalise processes that improve the fire scar mapping, primarily by developing a network for end-user feedback to mappers and by investigating new sources of remotely sensed data.

When and how Industry can benefit and who can benefit?
The benefits from this work should flow through to the grazing industry in the coming 2011 fire season, as improvements to the mapping are already being implemented. All other things being equal, this should see grazing land managers in fire prone areas of Queensland in a position to better manage and plan for wildfires - with losses to wildfire subsequently reduced. The main benefits to industry will be realised over the next five years or so, as feedback networks mature and new sources of remotely-sensed data are incorporated. In five years time, grazing land managers in the far northern fire prone savannas will be in a better position to capitalise on emerging opportunities to earn income from better fire management, such as through wildfire abatement and Greenhouse Gas reduction.

In 2006 the Centre for International Economics estimated that use of the NAFI website by fire managers across north Australia, most of whom were pastoralists, saved between $1M - $2M per year just in reduced monitoring costs. This did not include reduced damage to infrastructure or fodder. Since then use of the site has more than doubled with a dramatic increase in use in central Queensland. Implementing the measures above will result in income opportunities and savings conservatively estimated at many millions of dollars per year. The cost of operating the site and providing maps is around $350,000 a year.

Contents

1 Background

1.1 Development of the North Australia Fire Information (NAFI) service and current service delivery

The NAFI website, www.firenorth.org.au, was developed by the Tropical Savannas Cooperative Research Centre and north Australian fire managers, and is an important tool for land managers and Rural Fire Brigades for monitoring, recording and analysing fire activity across their regions.

The site displays maps derived from satellite images: locations of actively burning fires (hotspots) in close to real time (updated four times per day on average) together with maps of burnt areas (updated every week in the fire season). Hotspot data are sourced from Landgate Western Australia (NOAA and NASA satellites) and Geoscience Australia (NASA satellites). Firescar data are sourced from Bushfires NT (for Western Australia and Northern Territory) and Cape York Sustainable Futures (for Queensland). The fires scars are mapped from MODIS (Moderate Imaging Spectro-radiometer) images. The NAFI site is the only website that provides this fire scar data and is the only fire tracking website developed specifically for north Australian rural and remote area fire managers. It is the major fire-tracking website used in the region.

The website is hosted by Charles Darwin University, and has been funded by the Federal Government's Natural Heritage Trust program, through the NT NRM Board, and by Bushfires NT.

At the project's commencement it was known that the satellite-derived fire data on the website was widely used across rural and remote Queensland. The near real-time observations of active fires and fire scar maps via NAFI are used to help landowners monitor and detect fire outbreaks, fine tune fire responses, plan back-burns, plan aerial incendiary burns, and to avoid becoming trapped in fires (1) (2).

The NAFI site has been particularly useful for grazing land managers. Having a 'remote' view of the very large and often inaccessible areas they manage has helped to eliminate long vehicle drives and aircraft flights chasing smoke plumes on the horizon. The NAFI site provides an effective early warning system and a visual aid for planning fire responses, which helps to reduce damage to buildings, fences and fodder. The Centre for International Economics estimated that savings on monitoring alone averaged between $1M - $2M per year (3) across the north - this is probably a conservative estimate given the increase in use of the site since 2006.

The following comment on the role of the NAFI site in grazing operations is typical of many remote users:

"John Colless from Wetherby Station in Far North Queensland says NAFI is as important to him as the Bureau of Meteorology website. Mr Colless says his grazing operation would suffer if he couldn't access the website anymore." ABC Radio (Adam Stephen and Penelope Bergen) 2009.

(1) P. Thompson. Pers. comm.
(2) Manson, G. (2010). The Value of the Sentinel Hotspots System to Emergency Managers and the Australian Community. Unpublished Report for Geoscience Australia.
(3) Centre for International Economics (2006) Evaluation of the CRC for Tropical Savannas: Looking Back, unpublished report.

The Rangelands Fire Management Project Report (4) state that NAFI satellite data are relied upon for determining future fire management plans in many Queensland bioregions, including Cape York Peninsula, the Brigalow Belt and in central and southern Queensland. Of key importance is the access it gives to past and present fire history information for specific areas, allowing fire management on a property to be interpreted in context with the surrounding landscape.

From previous work it was known that the satellite-based fire scar mapping missed some fires, but it was unclear whether this was caused by landscape-related factors, land management practices, or issues inherent to the fire scar mapping process. The area serviced by NAFI has grown over time, especially in Queensland and now includes areas where grazing land management is the major economic activity. More people are using the site and data of high quality are required as people are making land management decisions based on the information. It is therefore timely that these problems are clearly identified and fire scar mapping is improved across the State. This in turn should improve fire monitoring and management, leading to tangible savings for grazing land managers.

2 Project objectives

By the completion of the project on 31 March 2011, the Project will have:

1. Reviewed the accuracy of fire scar mapping in each of Queensland's 13 bioregions through on-the-ground consultation with key stakeholders and produced a table for each bioregion showing estimates of the commission/omission error;

2. Identified the major issues affecting data quality in each bioregion and the options for accommodating or overcoming these issues during the processing of satellite images;

3. Improved the reliability of the NAFI website fire scar maps for Queensland grazing areas;

4. Provided a mechanism for ongoing improvement of NAFI fire scar maps for Queensland.

3 Methodology

3.1 Context

The standard approach to gauge the accuracy of remotely-sensed fire scar mapping is to fly or walk transects across the landscapes of interest and ground-truth the mapping against observed burns. This methodology produces a measure of omission errors (not mapping fire scars where there are fire scars) vs. commission errors (mapping fire scars where there are no fire scars) based on the lengths of transect that intersect burnt or unburnt country compared to the same transect drawn across the mapping (5). To do this for the whole of Queensland would require considerable resources and was beyond the scope of this project.

(4) Cape York Peninsula Development Association (2007) Rangelands Fire Management Project Report 2006-2007; Cape York Peninsula Development Association (2008) Rangelands Fire Management Project Final Report 2008

(5) Yates C, Russell-Smith J (2002) An assessment of the accuracy of DOLA's Northern Australia NOAA-AVHRR Fire Affected Area (FAA) map products. Australia State of the Environment 2nd technical paper series (Biodiversity), Department of the Environment and Heritage. Canberra, Australia.

The objective here was to produce estimates of omission vs. commission errors, based on significant fire events that were not mapped or significant mapping patches that were not actually fires, gauged through surveys of end-users and existing fire occurrence data. This measure of mapping accuracy is coarser and harder to standardise than transect-based estimates. However there are certain advantages. The results are easier to interpret in terms of implications for fire management, since operationally relevant aspects of fire mapping are captured. Transect based studies may miss considerations such as performance across all landscapes at all times of year. The approach used here also builds on existing data, thus requiring fewer resources than transect studies and can more easily be repeated to provide regular assessments of mapping effectiveness. To be reliable, such a measure needs to use standard criteria for defining significant fire events and also needs to be applied uniformly across the area of interest. Four techniques for assessing fire occurrence were used to determine which technique or combination of techniques could produce an effective standard measure: 1) interrogating fire-related government datasets; 2) using other remotely-sensed records of fire occurrence; 3) interviewing key bioregional fire managers; and 4) interviewing pastoralists.

The more general objective of identifying major issues regarding mapping quality in each bioregion would be achieved through an analysis of the omission/commission errors and through the interviews with key bioregional fire managers and pastoralists.

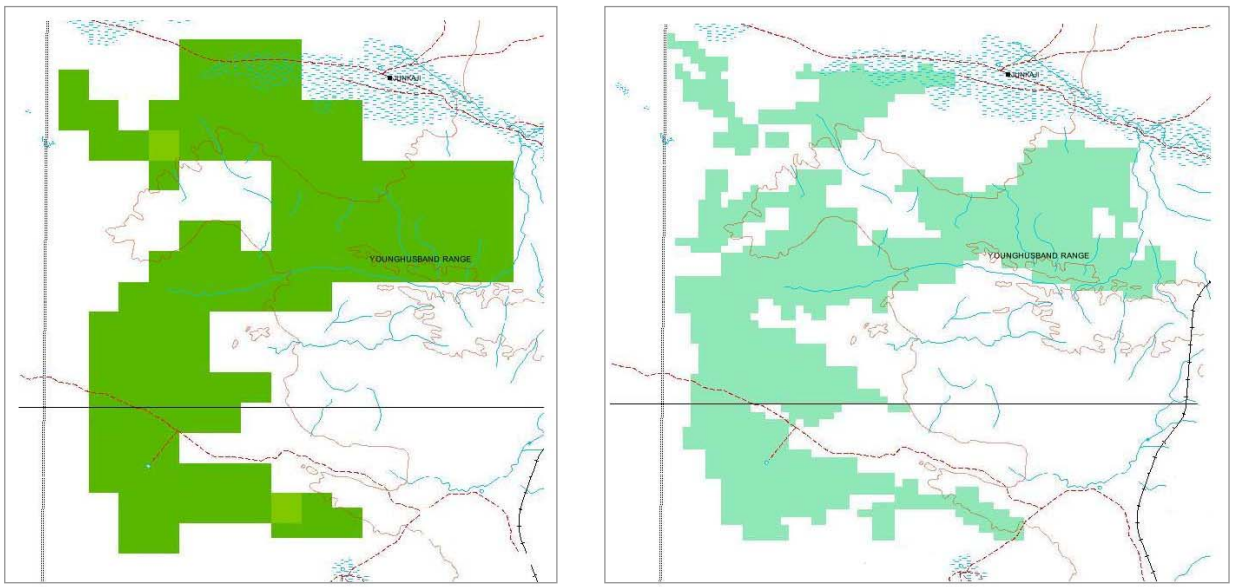
Once the data had been analysed a workshop that brought together the MODIS fire scar mappers, remote-sensing specialists and the NAFI website manager would be held to develop solutions to overcome the data quality issues and to improve the reliability of the fire scar maps for Queensland grazing areas. This workshop would also develop a mechanism for ongoing improvement of the mapping.

Before describing the detailed methodology it is useful to summarise the known limitations and data quality of the MODIS fire scar mapping to better place the methodology in context.

3.2 Known Issues and Limitations

3.2.1 Background to MODIS fire scar mapping

Mapping fires scars across the landscape using 250m resolution MODIS imagery was first trialled in the early 2000s. This was seen as an improvement on the existing 1km resolution fire scar mapping based on Advanced Very High Resolution Radiometer (AVHRR) Imagery (Figures 1 & 2). However the MODIS product has not had the same level of standardisation and assessment as the 1km product and remains a local, operational application rather than one that applies nationally. AVHRR has been used to map fire affected areas in Australia since the mid 1990s with the imagery sourced from satellites operated by the US National Oceanic and Atmospheric Administration (NOAA). With the launch of the NASA Earth Observing Satellites, Terra and Aqua, at the turn of the century, imagery from their MODIS sensors became a viable alternative to the AVHRR imagery for fire scar mapping. Not only was it also available free of charge, but it had a higher resolution, and the orbit of the NASA satellites meant that fire scar maps could be updated each week - as opposed to roughly fortnightly for the AVHRR imagery.



Figures 1 & 2 AVHRR fire scar map (left) The same fire scar mapped by MODIS imagery right

MODIS fire scar maps, delivered through the NAFI website, have been used since 2003 to assist fire operations across northern Australia. These maps are useful when viewed together with locations of "hotspots" or currently burning fires, in helping to predict the path of a fire. As shown below (Figure 3), the blue and red spots show a spreading wildfire (red spots more recent), and the coloured patches show the scars of recently burnt areas, coded by month.

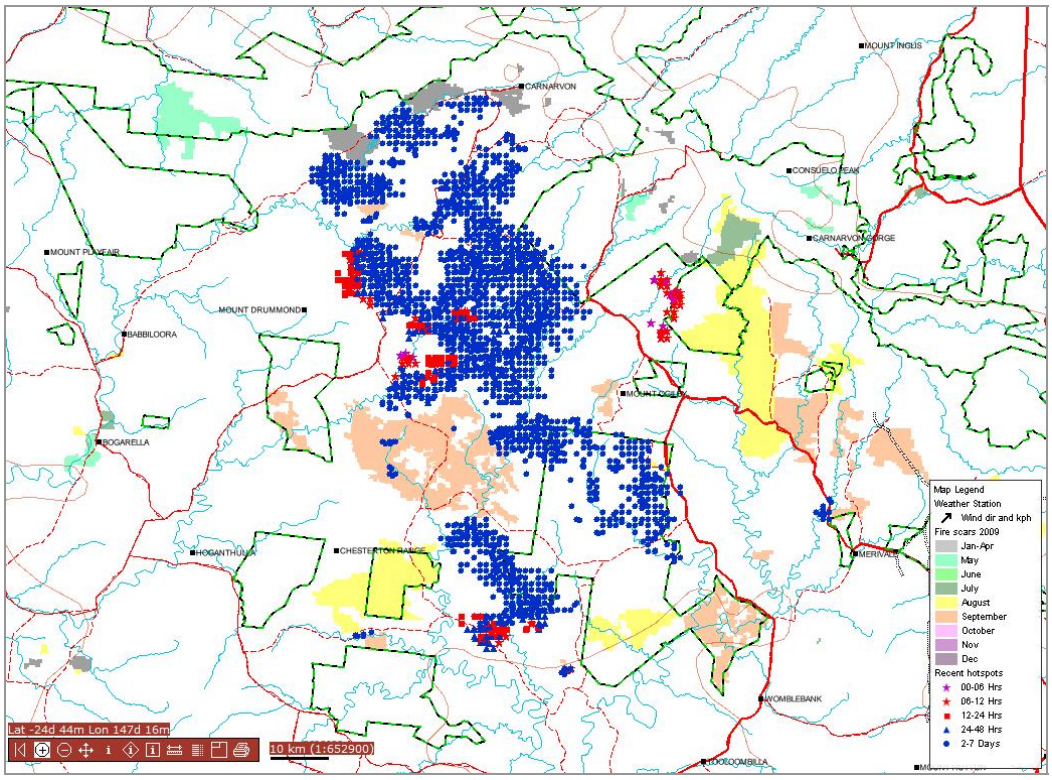


Figure 3. MODIS fire scar map showing previously burnt areas and active hotspots (blue and red dots)

Recently burned areas have less fuel (usually grass and/or litter) so these areas will often stop the further spread of a fire. Thus the fire scar mapping allows fire managers to focus their attention on areas they know have not been recently burnt, when predicting where a wildfire will travel. The fire scar data can also be used to create fire frequency and other fire history maps which can be useful for property planning (Figure 4).

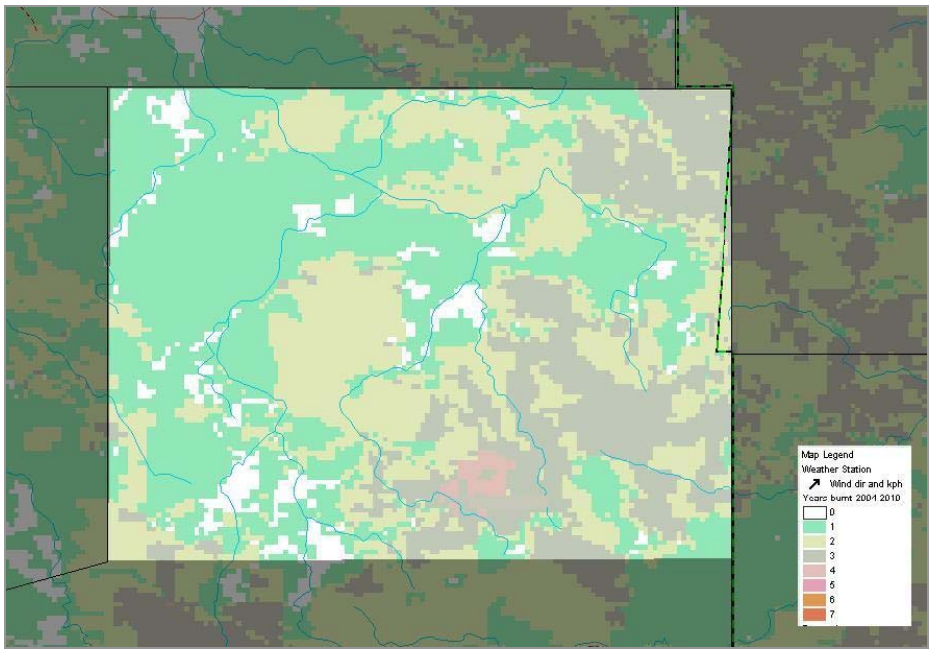


Figure 4. Fire scar data accumulated over time to show fire frequency in different areas

In both these cases, the utility of the data depends on accurate fire scar mapping - not just recent fire scars but fire scars for the whole year in the case of wildfire response, and for the previous several years for fire planning on the property.

The MODIS fire scar mapping has been restricted to northern Australia, currently extending to 20 degrees south in WA, and to the southern borders of the NT and Qld. Mapping for northern WA and the NT has been produced by Bushfires NT and for Queensland by Cape York Sustainable Futures, with the two datasets combined for display and distribution on the NAFI website. These data are produced by a combination of manual inspection of cloud-free MODIS imagery and the use of neural network pattern-matching software (www.firenorth.org.au/nafi2/about/faq.pdf).

There are two other MODIS fire scar coverages available for northern Australia: an automated 250m MODIS fire scar product developed at Charles Darwin University (CDU) and distributed by Landgate WA and the NAFI website (6) (7) and a global 500m MODIS fire scar product MCD45 (8).

(6) Maier, S. W. (2005). Automatic burnt area mapping with MODIS. In WASTAC Annual Report 2005, Western Australian Satellite Technology and Applications Consortium (WASTAC), Perth, Australia.
(7) Maier, S. W. (2010). Fire induced changes in surface reflectance on the Australian continent as measured with MODIS. International Journal of Remote Sensing 31, 3161-3176. doi:10.1080/01431160903154408
(8) Roy, D.P., Boschetti, L., Justice, C.O., and Ju, J. (2008) The Collection 5 MODIS Burned Area Product -Global Evaluation by Comparison with the MODIS Active Fire Product. Remote Sensing of Environment 112, 3690-3707.

Despite its operational significance across fire-prone northern Australia, there has been limited formal assessment of the accuracy of MODIS fire scar mapping due to the limited resources and institutional support available in far northern Australia. The assessments to date are reviewed below.

3.2.2 Existing assessments of the accuracy of MODIS fire scar mapping

Transect-based validation

There have been no published assessments of the accuracy of any of the three MODIS mapping products for northern Australia. However an unpublished assessment was carried out in the Kakadu/West Arnhem Land Plateau region of the Northern Territory where the manually mapped MODIS products and the CDU/Landgate automated MODIS mapping were compared with a visual inspection of burnt country by air (Stefan Maier, CDU). The map below shows the helicopter-flown transects involved (Figure 5) and Table 1 shows the results.

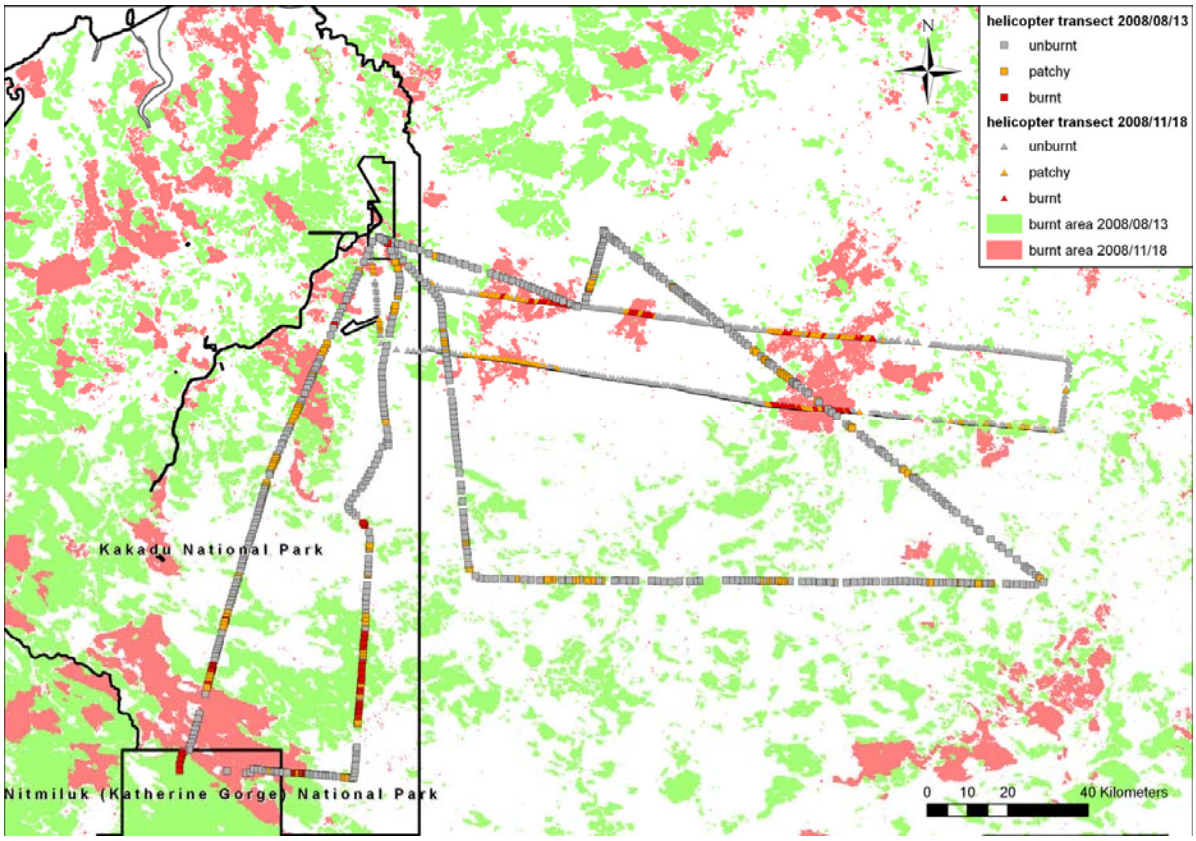


Figure 5. Transects flown by helicopter to compare mapping accuracy between automated and manual mapping processes in the West Arnhem Land Plateau region of the Northern Territory (source: S. Maier, CDU)

Table 1. Omission and commission errors for CDU/Landgate automated and NAFI manual fire scar maps based on MODIS imagery

	Early Dry Season (green scars)		Late Dry Season (red scars)	
	auto	**manual**	**auto**	**manual**
Commission error	0.1%	0.5%	0.9%	3.5%
Omission error	14.1%	7.1%	6.8%	3.4%
Omission error without patchy burns	10.9%	3.8%	1.2%	0%

For early dry season fires, which are of lower intensity and often leave lighter scars on the landscape, both techniques have low commission errors but higher omission errors. The automated technique in particular had large omission errors where fires were "patchy" and covered very small areas. For late dry season fires, which often produce darker scars, the manual technique produced more commission errors, though still less than 5%. The level of omission error was smaller than for early burns for both techniques, but it was greater for the automated technique.

Significant limitations in Queensland landscapes

The transect based study can be used as a broad guide to the accuracy of the MODIS fire scar mapping in similar open, sparsely vegetated landscapes in Queensland. Regular feedback from end-users across northern Australia supports the idea that in such landscapes, for the late dry season fires, the manual mapping is reasonably accurate and that the automated mapping consistently has greater omission errors - automated fire scars often look like a slightly contracted version of the manual fire scar. This feedback also supports the finding that both techniques, but particularly the automated technique, regularly miss less intense, patchy, early dry season fires.

Major errors, such as the 14% omission error for early dry season burns by the automated fire scar technique in the study above, cause particular problems. Some major errors only occur in certain situations, but such errors not only lead to erroneous management, they can also erode trust in the mapping as a whole (see Figure 6). These significant errors have not been precisely quantified but can be detected without having to conduct transect-based studies in each landscape type. Table 2 lists known errors based on user feedback across Queensland over the last eight years.

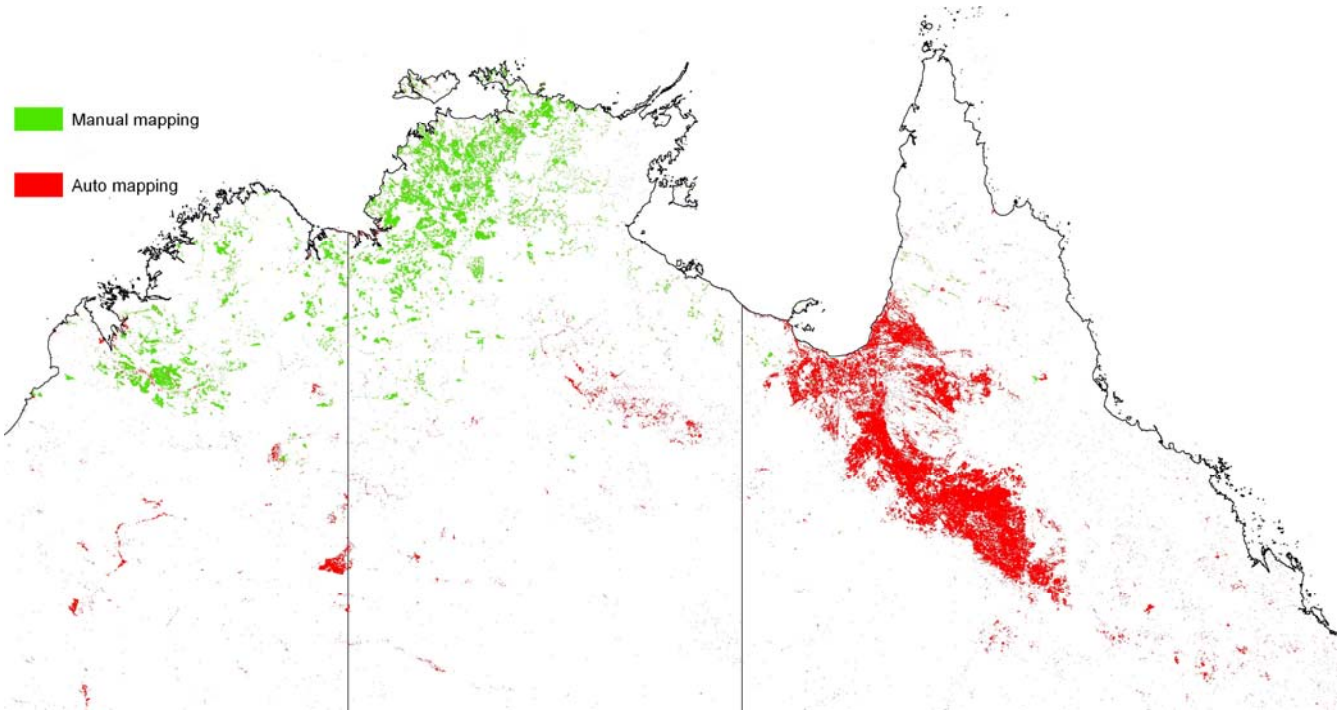


Figure 6 Manual vs. Autoscar mapping for early dry season (until end of July) 2006. The manual mapping is overlaid on top of the Autoscar mapping. In this year the Autoscar mapping picked up more fires in south east Queensland than the manual fire scar mapping, but this advantage was outweighed by the massive commission error (in red) in the Gulf Plains and eastern Mitchell Grass Downs. The Autoscar mapping algorithm has been improved since 2006, but major commission errors are still a problem.

Table 2. Known errors associated with automated and manual fire scar maps derived from MODIS imagery

Manual mapping	CDU/Landgate automated mapping
Significant commission errors in moist and inundated areas. In these instances the fire scars could not be separated from similar signals given by bodies of water, floodplains or from the black basaltic soils, particularly in the Brigalow Belt bioregion.	Major commission errors in moist and inundated areas - often entire riparian areas or floodplains would be identified as fire scars after rain events. Particularly seen in the Gulf Plains and Channel Country
There are omission errors in mapping small fires (< 20 ha). Therefore the area burnt by early season fires may be underestimated; the area burnt may also be underestimated if fires are of low intensity with little canopy scorch. The inability to detect small fires limits the use of the NAFI site in closely settled areas (e.g. rural residential areas in South East Queensland and other coastal bioregions)	Similar but more significant omission errors with mapping small fires, with such errors occurring across a broader range of landscapes
Problems associated with cloud cover in images, particularly in the wet season in some bioregions (e.g. the Wet Tropics and Cape York Peninsula). The clouds sometimes obscure fires and cloud shadows may result in miss-identification of fire scars. This problem is part of the limitation of working with satellite imagery and the end user should be made aware of this. (In the longer term, pending research, mapping fire scars from radar data could overcome cloud cover issues).	Similar problems with cloud cover - but in some cases the automated technique can cope slightly better with intermittent cloud cover.
Omission errors due to human error. Occasionally large fire scars or portions of scars may be missed through human error, particularly if a fire scar straddles two separate images.	Numerous small commission errors in the form of point scars that can be widely scattered across the landscape.

The major errors associated with the CDU/Landgate automated mapping, while not seen in all landscapes and seasons, do significantly erode trust in the mapping because of their magnitude: whole floodplains being mapped as fire, or whole landscapes being covered in small point scars. A problem here is that adjusting the algorithm to reduce the commission errors in one situation can then increase the omission errors in another situation. The MCD45 automated algorithm has yet to be compared to the other methods in Australian landscapes - this will be done by Dr Stefan Maier of CDU later this year - but it would be expected to have broadly similar issues to the CDU/Landgate algorithm.

The comparative lack of major errors and the absence of systemic errors of omission in the manual mapping mean that this method is preferred for the immediate future. It is important

therefore to try to further clarify the significant inaccuracies in the manual fire scar mapping that do occur in some landscapes and at certain times of year.

The role of hotspots

MODIS and AVHRR data are also used to produce hotspot maps (the location of active fires as shown in Figure 3) for northern Australia. These data are automatically generated by algorithms that analyse the pixel values for different wavelengths of the imagery. As such, hotspots form a partly independent estimate of fire activity from the fire scar mapping process. The NAFI website displays hotspot data sourced from Geoscience Australia and Landgate WA that are produced by a range of algorithms based on NASA's MOD-14 global algorithm and Landgate WA's SRSS algorithm. Feedback from users and mapping experience indicate that in conditions where the MODIS fire scar mapping misses fires, these fires can often be identified by hotspot clusters. Given the useful role hotspots could play in complementing and improving fire scar mapping, it was decided to also investigate the accuracy of the NAFI hotspot data.

3.3 Surveying Fire Occurrence Data and End-Users

3.3.1 Interrogating government data

While the accuracy and effectiveness of the fire scar mapping for grazing land managers was the main focus of the project, the fire scar data are used in a similar way by other remote area land managers such as park rangers and fire agency staff. The Queensland Parks and Wildlife Service (QPWS) and Queensland Fire and Rescue Service (QFRS) had centralised records of all fires on the park estate and all fires attended by fire units respectively. It was considered that these data could provide a standardised record of fire occurrence that covered all of Queensland's 13 bioregions.

Leasie Felderhof of Firescape Science commenced this aspect of the project while organizing a state-wide multi-agency fire coordination meeting. Subsequent meetings were held with personnel from Queensland Fire and Rescue Service, Department of Environment and Resource Management (QPWS) and some Natural Resource Management groups.

QFRS data

The Brisbane office of QFRS was visited in October 2010 to consult with their GIS unit staff on the use of the NAFI site and their requirements for fire map data. The QFRS keeps point-location records of all fires attended by an appliance along with the fire type (e.g. vegetation, structural fire etc). The intention was to compare QFRS fire location data with hot spot and fire scar data from NAFI, as well as the automated fire scar product. After selecting for vegetation fires only, data from across Queensland were qualitatively interrogated by viewing data layers on the GIS and checking for correlation between the data sources.

Fires attended by Rural Fire Brigades, or lit under the Permit to Light system, were not recorded in a format readily accessible for display using a GIS.

QPWS data

Similarly, the Brisbane office of QPWS was visited in October 2010 to consult with fire management and GIS staff. QPWS keeps records of all fires on the national park estate, whether they were intentionally lit or caused by wildfire. A detailed fire recording system is in place and includes details such as cause of fire, vegetation types burnt, area burnt and indicators of fire intensity or management success. In terms of mapping, information on map reliability is kept, including whether the burnt area was mapped from the ground using a GPS, mapped from

the air using aircraft, mapped from memory, or mapped using NAFI data. The intention was to compare QPWS records from across the state with hot spot and fire scar data from NAFI, as well as the automated fire scar product. After selecting for 2009 fires only, data from across Queensland were qualitatively interrogated by viewing data layers on the GIS and checking for correlation between the data sources. Comments on fire behaviour and on-ground monitoring results were read in conjunction with map comparisons to investigate usefulness of the data for further investigation.

3.3.2 Interrogating other remotely-sensed records of fire occurrence

To clarify the role that hotspots could play in assessing and/or improving fire scar mapping accuracy, the project undertook surveys of hotspot and fire scar mapping vs. roadside surveys and Landsat imagery.

Hotspot occurrence and fire scar mapping
NAFI hotspots were checked on a daily basis during the 2010 fire season (between 30/7/2010 and 26/11/2010) to identify areas of active fire and were compared with fire scars published on NAFI. A sample of these hotspots was also selected for confirming fire occurrence with landholders (via telephone interview).

Hotspot occurrence, fire scar mapping and roadside surveys
Existing data from a road survey undertaken in 2008 that traversed five bioregions and recorded evidence of fire activity were compared with hotspot and fire scar data from the NAFI site.

Hotspot occurrence, fire scar mapping and Landsat imagery
A Landsat scene (30m pixel resolution) of south east Queensland was analysed for evidence of fire activity from 2006 - 2010 by identifying burnt areas. This record was then compared to both the NAFI hotspot record and the MODIS fire scar mapping. A south east Queensland scene was chosen as it represents a closely settled landscape in which the fire scar mapping has reportedly experienced large omission errors (see Table 2).

3.3.3 Bioregional Contacts

From the discussions with landholders, QFRS and QPWS, a network of contacts across Queensland's 13 bioregions was established to assist with NAFI verification. The information flow for the bioregional feedback is summarised in Appendix 1. Digital maps were sent out so participants could assess recent fire history data from NAFI and report back to Firescape Science based on their local knowledge of fire occurrence. Several respondents expressed interest in continuing to assist in improving NAFI services.

3.3.4 Pastoralist feedback

Originally face-to-face meetings with pastoralists were planned for late 2010, however the logistics of conducting such interviews across Queensland was deemed inefficient due to travel distances, travel time, availability of interviewees and co-ordinating visit times with large numbers of busy people. The majority of information gathering was therefore conducted by telephone and email, with face-to-face meetings where opportunities arose. The interviews were conducted by a former pastoralist experienced in fire management. The main purpose of the interviews was not to arrive at a quantitative estimate of fire occurrence vs. fire scar mapping, but to help identify the major issues affecting data quality and reliability in each bioregion (objectives 2 and 3).

An initial phone survey was undertaken in November 2010 using a standard data collection sheet (Appendix 2). Forty persons were contacted with seventeen participating in the questionnaire. Most of these contacts were made through initial contact with Rural Fire Service personnel and these were generally graziers who were known to have an interest in fire management, often through involvement with their local Rural Fire Brigade.

The initial survey was interrupted by significant flood events across Queensland and the perception that there would be a corresponding lack on interest in fire at that time. The phone survey was continued in March 2011 using the same questionnaire. This was conducted by 'cold calling' graziers' selected at random from the phone directories. Out of thirty calls, 27 people responded in this phase of the survey. Data were recorded on separate data sheets for each respondent. A generalised list of property locations and survey effort is given in Appendix 3.

3.3.5 Initiating actions with fire mappers and remote sensing specialists

In November 2010 a group of fire mapping technicians from Bushfires NT, Cape York Sustainable Futures and Firescape Science together with remote-sensing specialists and the NAFI website manager from CDU met in Cairns to discuss NAFI accuracy and verification. The meeting had the following aims:

1. To identify the major operationally significant shortcomings of the fire scar mapping;
2. To develop new fire scar mapping techniques to help overcome these shortcomings, particularly in grazing areas, and to plan their trialling;
3. To update the documentation of the manual mapping process to reflect current practices;
4. To develop a mechanism for ongoing improvement of NAFI fire scar maps for Queensland.

4 Results and discussion

4.1 Interrogating QFRS and QPWS data

Review of data held by QFRS did not yield as much quantitative data as anticipated. Records were restricted to locations where appliances had been dispatched, therefore were predominantly related to roadside fires near urban areas. This was not useful for verifying the mapping of rangeland or rural fires. Very little additional data were collected; without metadata of any type, rigorous analysis was impossible. However reviewing the data on a state-wide scale, and for an entire calendar year, demonstrated conclusively that the automated map product consistently underestimated fire extent. Waterways, seasonality and cloud cover strongly influenced the automated mapping results.

Reviewing reports of fires on national parks supplied by Rangers of the Queensland Parks and Wildlife Service to their central office was also of limited value. It was anticipated that these data would provide good coverage of fires across the state, represent all 13 bioregions, and provide detailed on-ground records of fire occurrence. The exercise highlighted deficiencies related to consistency in data entry and storage (e.g. different date formats were used by the many different staff entering data). While records were available for a very large number of fires, it could not be sorted efficiently for detailed or rigorous interrogation. Data clean-up of such a large database was considered beyond the scope of the project. QPWS are addressing the issue and a process is in place to improve future record keeping. This will not necessarily fully address the issues around validating NAFI fire scar mapping.

The lack of standardised fire occurrence data at a State-wide scale severely limited the chances of developing a quantifiable and reliable measure of fire scar mapping accuracy as originally planned.

4.2 Interrogating other remotely-sensed records of fire occurrence

4.2.1 Hotspot occurrence vs. fire scar mapping

The daily check of hotspots for the last six months of the 2010 fire season were compared with fire scars published on NAFI.

* Generally there were good matches between hotspots and fire scars for Cape York Peninsula, North-west Highlands, the Einasleigh Uplands, Gulf Plains and Desert Uplands.

* Because the season was particularly cloudy, there were very few hotspots recorded in the Wet Tropics (and correspondingly, no fire scars).

* Only minor fire activity occurred on the Central Queensland Coast, Brigalow Belt South and on the New England Tableland. In the latter two bioregions there were areas with clusters of hotspots with no matching fire scars.

* In South East Queensland, there were many fire scar and hotspot matches, but also many hotspot clusters with no matching fire scar.

* There were very few hotspots in the Channel Country and no fire scars. Likewise there were very few hotspots on the Mitchell Grass Downs.

Northern hotspots appear to be more consistently associated with a mapped fire scar, with the southern bioregions more likely to have large clusters of hotspots without matching fire scars. However, there can be reasons for hotspot occurrence other than fire, such as large mining pits or areas of bare rock. Such geographic features are usually checked during the mapping process, so results here are only indicative and highlight the need to ensure that strict quality assurance processes are followed.

The early onset of the wet season reduced the usefulness of this process because there was significantly less fire activity in 2010 than has occurred in other years.

4.2.2 Hotspot occurrence, fire scar mapping vs. roadside survey

The data from the 2008 road survey where actual fire scars were recorded on the ground using a GPS gave the following results when compared with the NAFI site:

* Gulf Plains - The majority of the surveyed road lies within the Gulf Plains bioregion; 30 points were recorded as having some evidence of fire. Of these, only four matched with corresponding hotspot data, and only one area had an associated fire scar.

* Mount Isa Inlier -13 burnt areas were noted, with one hotspot and matching fire scar.

* Mitchell Grass Downs - There were 13 points where fire activity was evident, with only one hotspot match and no fire scar.

* Desert Uplands - Only one burnt area was noted within Desert Uplands but this was not recorded in either hotspot or fire scar data.

* Einasleigh Uplands - Of the 11 waypoints with evidence of fire, only four had associated hotspot data, with no fire scars recorded in 2008 to account for them.

The inconsistencies can mostly be accounted for by the small sizes of road side fires, often lit to expand the potential of the road corridor to act as a fire break, and to reduce the chances of roadside fires spreading into adjoining pastures/paddocks.

4.2.3 Hotspot occurrence, fire scar mapping vs. Landsat imagery

A Landsat scene (9079, with coordinates: 151 0'22.576"E 26 32'12.47"S; 152 50'3.4"E 26 48'27.464"S; 152 27' 59.022"E 28 19'39.506"S; 150 36'25.267"E 28 3'3.656"S) was analysed for fire activity, indicated by burnt areas, for the years 2006 - September 2010 (58 images) and this fire activity was compared to records of fire activity as indicated by NAFI hotspots and MODIS fire scar mapping. The results can be summarised as follows:

* For 2007, 2008, 2009 and 2010 the NAFI hotspot mapping picked up more fire activity than the Landsat imagery. In 2006 the Landsat Imagery picked up more fire activity than the NAFI hotspots in the early dry season (May - July). The greater level of activity detected by the hotspots is likely to be due to the more frequent imagery available for MODIS hotspots (several images a day) vs. Landsat (an image every 16 days).

* For 2007 - 2010 the NAFI fire scar mapping registered most but not all of the fire activity registered by the Landsat imagery. In 2006, the first year that southern Queensland was mapped, only a few fires were captured by the MODIS fire scars.

* For all years, NAFI hotspots picked up more fires than the NAFI fire scars - although the extent of the fire was usually not as well defined by the hotspot clusters.

These results indicate that comparing Landsat imagery with MODIS Fire Scar mapping may provide a way of providing a State-wide quantitative assessment of the mapping - however care should be taken here as the Landsat imagery itself has not been ground-truthed and the 16 day gap between images probably produces omission errors for the Landsat Imagery.

The results also indicate there is an opportunity to improve the fire scar mapping in these closely settled southern landscapes by using the hotspot clusters as part of the mapping process.

4.3 Accuracy by Bioregion from Regional Contacts

Given the limitations of the surveys and data above, one of the main methods of gauging the accuracy of fire scar mapping across Queensland was to survey known users of the site. A selection of people with land management responsibilities, including national park rangers, were identified and contacted by telephone and email, with fire scar maps provided electronically to guide discussions. This survey could not provide the comprehensiveness or standardisation needed to produce quantitative estimates of omission and commission errors but could provide qualitative estimates of the errors for each bioregion (objective 1) as well as the issues that affected the data quality in each bioregion (objective 2). A map of Queensland's bioregions is shown in Figure 7.

4.3.1 Results by Bioregion

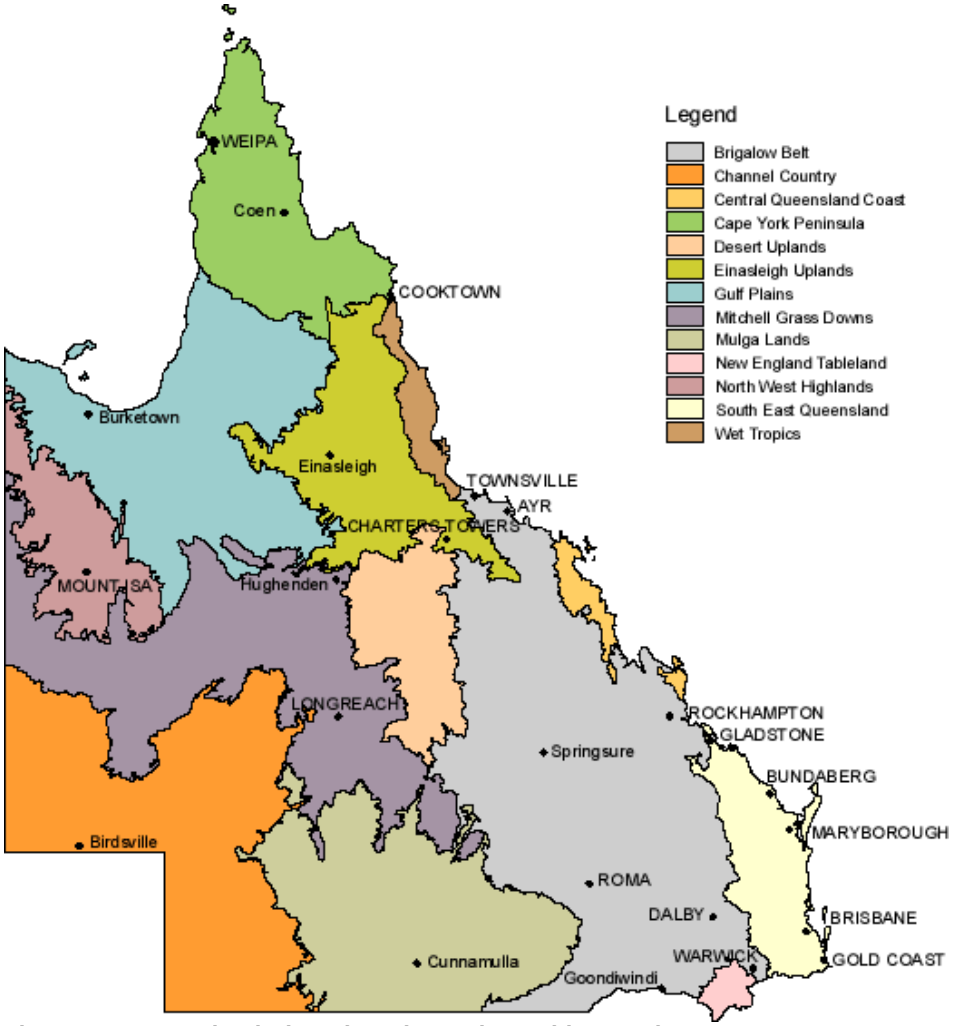


Figure 7 Queensland Bioregions (www.derm.qld.gov.au)

Note that the arid bioregions of Mulga Lands and Channel Country were not surveyed due to the very intermittent fire occurrence in these regions.

Cape York Peninsula Bioregion

Cape York Peninsula was the first bioregion in Queensland to benefit from satellite-derived fire scar mapping. As such, extensive ground-truthing has been undertaken since 2003. Key issues are: persistent cloud cover in some areas obscuring fire scars; low intensity fires in heavily forested areas not being detected; early season fires being overlooked due to a combination of small fire size, low fire intensity, and re-greening of the vegetation before the next cloud-free image becomes available. Mapping on the western side of Cape York Peninsula was more reliable than for the east (due to differences in cloud cover).

Wet Tropics Bioregion

The NAFI site provides good overall accuracy but a few fires are missed. The reliability of the NAFI fire scar & hot spot maps are affected by thicker canopied vegetation, steep valleys, cloud cover, and dense smoke. Accuracy improves from east to west -the further west the more accurate the scars.

North-west Highlands Bioregion

Some low intensity fires and fires that are small in size are not picked up by NAFI. Fire scars are more discernible where fire carried well, such as in spinifex grasslands and acacia woodlands; where there was barely enough fuel to carry a fire, fire scars are not distinct. Mapping these fires would be difficult because of the extensive areas of bare ground common in the semi-arid landscape. "Before" and "after" satellite images can look similar.

Large fires in the North-west Highlands were mapped reasonably accurately; the fire edges can be questionable, possibly related to lower fire intensities as the fire is going out. On the ground the fire edges have a highly variable pattern, which may be missed due to the scale of the mapping (satellite resolution), where fires continue as 'narrow fingers', as opposed to a fire front. This occurs in areas of discontinuous fuel, as is common in spinifex dominated landscapes.

There are many small ignition points across the North-west Highlands, with associated small burnt areas. Many of these do not 'take'; there are no corresponding fire scars due to the small size of the areas burnt. Similar comments apply to aerial incendiary runs, where there were many incendiaries dropped in locations that may have burnt 5 or 10 metres but not spread any further.

The lower intensity fires associated with early burns are sometimes too cool and do not run for long enough to be detected (ie the burn is out before the satellite passes over to record a hotspot, and fire size is too small to visually record a fire scar).

Gulf Plains Bioregion

In the Gulf Plains Bioregion, the mapping was generally effective in the later parts of the dry season. There is sometimes confusion between fire scars and wetland areas as the country dries out with the onset of the dry season. Similar to other areas, small fires and fires lit early in the dry season were also overlooked.

The automated mapping is prone to erroneously map fire across significant areas of riverine and floodplain country in this region.

Einasleigh Uplands Bioregion

The fire scars mapped over Blackbraes National Park represent true fires and are fairly accurate. Three burns that occurred and were mapped and reported upon within QPWS in 2007 were not shown on the NAFI fire history map. Although NAFI is not 100% accurate and sometimes fails to record low intensity burns, it has become an essential part of the long distance management of Blackbraes National Park. Unplanned burns can be monitored from home base. In recent times NAFI fire scars have been the sole basis for the National Parks Burn Report.

The automated 2009 fire scar map for Blackbraes was accurate for several fires but over-estimated the extent of the western 2009 fire. The 2008 automated map was accurate. The automated maps do not cover the 2007 year, when the manual NAFI fire scar missed a few fires.

Desert Uplands Bioregion

The NAFI map of fire scars is fairly accurate for this region and picks up most fires. The automated NAFI map accurately mapped a 2008 fire, but was inconsistent. It also missed a 2008 fire that was also missed by manual NAFI fire scar mapping. The automated NAFI map incorrectly mapped a few small fires that did not occur and, on occasion, also overestimated the extent of some actual fires.

Mitchell Grass Downs
Fire is not characteristically used in this landscape to maintain pasture productivity. It can be used to control woody and pest species, and to reduce fuel loads to reduce the risk of wildfire, but only infrequently and in small patches/mosaics. Many of the fires are too small to be detected with the NAFI mapping process.

Central QLD Coast Bioregion
The normal NAFI maps picked up a number of larger fires but missed some smaller ones. The automated NAFI map missed many fires in the Mackay region, including a large 2008 fire at Seaforth (which was picked up by the normal NAFI fire scar mapping).

Mapping was generally considered quite comprehensive and reasonably accurate in this bioregion with some tweaking needed for the edges. Once again, 'cool' patchy burns are less likely to appear on the NAFI site. Some comments were:

"The NAFI mapping picked up 2005, 2008 and 2009 fires, although the 2008 NAFI map was not as extensive to the east as actually occurred. NAFI did not pick up on some areas known to have burnt, such as areas burnt in 2007 ".

"a couple of burns in (2006) did not appear".

"None of the Whitsunday Island burns were picked up although they were relatively small - 25ha, 62ha and 7ha".

Brigalow Belt Bioregion
In some areas the fire scars appear to be more extensive than the area actually burnt on the ground, in other areas the full extent of the burn is not shown. Intra-fire patchiness is greater on the ground than shown by the maps; canopy cover is an issue in some areas.

SEQ bioregion
For the area just north of Brisbane, from south of Caboolture to north of Caloundra and including Bribie Island, the NAFI fire scars (from 2007 onwards) fairly accurately represent actual fires. But 40 or so small to large sized fires over those 3 years were not mapped by NAFI.

New England Tableland Bioregion
The normal NAFI fire scars accurately map some fires, but missed others. The new automated maps incorrectly located some fires and missed several other fires. The automated NAFI maps seem to put small fire scar specks across the landscape that were not fires.

4.3.2 Applicability to pastoral practice

We consider that the findings of this bioregional survey should be broadly applicable to both pastoralists and park managers. Both are engaged in similar fire management tasks when they use the fire scar maps. In the late fire season (September - December) both grazing land managers and park managers use the NAFI site and the fire scar maps as a wildfire response tool, whereas park managers tend to also use the maps for fire planning on an annual basis and to check the effectiveness of early fuel reduction burning. Effective planning for wildfire response late in the season requires good information on the location of early season fires as well. Pastoralists who participate in more formal fire planning exercises also use the site to gauge effectiveness of early burning and in assessing the overall regional fire patterns operating in their area.

4.4 Pastoralist Feedback

Of the seventeen questionnaires completed in the initial November 2010 survey, thirteen respondents were aware of and used the NAFI site. The four respondents who were not using the site were all keen to receive a link to the NAFI site and to start using it.

Of the 27 responses in phase two of the survey, where graziers were "cold called", twelve used the NAFI site and fifteen were either unaware of the site or, having heard of the site, had not commenced using it. Only two respondents had no interest in using the site.

4.4.1 Observations

* 73% of graziers surveyed use fire on a regular basis as a management tool for one or more of the following reasons: to create fire-breaks, control weeds, control regrowth and for pasture improvement.
* 12% use fire as a management tool on an irregular basis, mainly for weed control and pasture improvement.
* 15% do not use fire as a management tool.
* The majority of respondents who were not using the NAFI site were aware of the site. Many expressed having tried to locate the site unsuccessfully on the net. A link to the NAFI site was sent to all respondents who wished to access the site.
* The wives of the graziers appear to do most of the computer and internet business in rural areas.
* Those who were using the site rated it quite highly. The comment was often made that the NAFI site was as important to their operations as the Bureau of Meteorology (BOM) site.
* Respondents reported 49% of wildfires were from lightning strikes, 21% of wildfires came through from a neighbouring property, 17% of wildfires came from off a major road or railway, 13% of wildfires were from other human activity, i.e. miners, pig hunters, campers.

4.4.2 Limitations of the pastoralist survey

There were two significant limitations of this survey. Firstly, the discussion-based nature of data gathering meant that it was difficult to quantify the accuracy of hotspots and fire scars: respondents who used the site generally said it was very effective and it was difficult to draw them out on qualifying or quantifying the performance of the fire scar mapping. Secondly, it was very time-consuming to collect these data, limited as they were. Future projects should consider participating at rural shows and events (e.g. Beef Expo), where people could visit an information booth to check fires in their area, confirm mapping accuracy, improve their understanding of the site and, if interested, commit to further involvement.

4.5 The Accuracy of NAFI fire scar mapping

One aim of the project was to estimate the accuracy of remotely-sensed MODIS fire scar mapping. The various methods used to make this estimate had limitations: the Government databases either did not have an extensive geographical coverage or had inconsistent data entry and could not be easily queried; the other remotely-sensed data on fire occurrence were limited in their geographical scope, or in the dates analysed or both; the interviews with key bioregional contacts were by their nature difficult to standardise or to arrive at a quantitative assessment of accuracy; and the pastoralist survey only dealt with the performance of the site in broad terms. What these data allowed us to do was to broadly characterise the operational accuracy of the fire scar mapping by bioregion as shown in Table 3 below.

Table 3 Major issues affecting data quality and error sources.

Bioregion Group	Issues
Western Cape York Peninsula *Gulf Plains* *Northwest Highlands* *most of the Einasleigh Uplands* *Desert Uplands* *Mitchell Grass Downs* Operational Accuracy Generally reliable in the fire season. In general, maps produced for further north in these regions are more accurate. This may be because there is greater interaction between the people providing the mapping and their contacts in the local area for providing field verification.	Generally more open country, large property sizes, more northerly location with marked dry seasons. Usually limited cloud cover for much of the fire season. Omission errors Evidence suggests that in relatively clear conditions omission errors account for < 10% of the total area burnt in these regions. This estimate is based on feedback from fire managers, the observation that such errors mostly involve smaller patchy fires, the known extent of patchy fires in similar landscapes in the NT and the transect-based estimates of omission error in the NT (see above). Cloud cover can still cause omission errors as can humid conditions. This is a bigger problem in wet years such as 2010. Small fire size can be a problem in the Mitchell Grass Downs. Fire scar mapping also regularly misses smaller, cooler early dry season fires. Commission errors In open savanna country evidence suggests commission errors account for <2% of the area burnt. This estimate is based on feedback from fire managers and the transect-based estimates of commission error in the NT (see above). Landscape variation can cause commission errors. For example, wetland areas in the coastal areas of Cape York Peninsula and the Gulf Plains can occasionally be misidentified as fire scars.
Eastern Cape York Peninsula *Wet Tropics* *parts of Einasleigh Uplands* *Central Queensland Coast* *Brigalow Belt* *South East Queensland* *New England Tableland* Operational Accuracy Generally less reliable but still useful in good conditions and when complemented by hotspot data.	Generally more heavily wooded country, and Cape York Peninsula apart, more closely settled with smaller property sizes. Southern bioregions prone to more cloud cover during their fire seasons. Omission errors Based on feedback from fire managers, evidence suggests omission errors can account for > 10% of the area burnt in a fire season. Landscapes in these regions tend to be burnt less frequently and in some cases a single missed fire can be significant. Cloud cover in the fire season can be a significant cause of missed fires, particularly in the more southern and more coastal areas. Small fire size throughout year is also a major cause of omission error and canopy cover can often mask or disguise fire scars. Commission errors Less obvious than for the more open northern bioregions and more difficult to quantify, but smaller patchy commission errors can occur in wetlands and after rainfall.

Mulga Lands *Channel Country*	Open, arid landscapes with irregular rainfall and fire occurrence. Relatively low fire activity. Difficult to assess accuracy of fire scar mapping with the limited data available.

This broad assessment can be used as a basis for improving the mapping as it allows identification of the main issues that limit operational accuracy and their causes. The qualitative nature of the data makes it difficult to use this assessment as a baseline for future monitoring, but it has provided insight for establishing and instigating a method for measuring gradual improvement in the fire scar mapping over time.

4.6 Improving reliability of fire scar mapping for Qld grazing regions

Following the technical workshop in November 2010, three areas of improvement were identified that would enhance the reliability and effectiveness of the fire scar mapping in Queensland grazing regions:

1) Improving the fire scar accuracy

2) Improving the effective use of fire scar maps

3) Improving the awareness of how to access the fire scar maps

4.6.1 Improving accuracy of fire scar mapping in Queensland grazing regions

In the short term, this can be done in the following ways:

1. Increase the time available for MODIS fire scar mapping in Queensland. Currently around one to two days a week is spent mapping fire scars during the fire season. If the feedback below is to be incorporated this will need to increase to at least two and a half or three days a week. This will occur after June 30 2011.

2. Fire scar mapping in the far north tended to be more accurate partly because mappers received feedback before and after mapping from users. This is not the case in many Queensland grazing regions and in these areas MODIS fire scar mappers need to be regularly assisted with their mapping on a week-to-week basis by end-users. This will enable accuracy to be improved by making appropriate adjustments to the fire scar maps. This can be achieved by end-users sending in aerial prescribed burn (APB) lines or other ignition points prior to mapping, or by end-users pointing out missed scars etc. after the initial mapping. Improving communication between the fire mappers and end-users is necessary for this to be achieved, for example by having better emailing tools on the NAFI website and by establishing good working relationships with key people who act as conduits to other fire managers across the state. QFRS could play a role here as well as NRM groups as many of these have GIS capability as well as existing communication networks in their local areas.

3. Given the intrinsic limitations of any remotely sensed data, the MODIS fire scar manual mapping process needs to incorporate other methods of fire scar detection such as end-user reports, automated MODIS fire scar mapping and hotspot mapping. Although each of these methods may not be highly accurate in its own right, they serve as a useful check on the manual mapping. In particular, hotspot data needs to be closely checked for corresponding

fire scars as this may assist with identifying small fires, particularly in the more closely settled areas or in areas where fires are characteristically small. A final check should occur immediately prior to data being displayed on the NAFI website. An 'indicative burn area' could be mapped as a generic polygon if clusters of hotspots are present but there is genuinely no fire scar. This could be shown as a 'B' class fire scar on NAFI.

4. The sourcing of hotspot data from more northerly and easterly satellite downlink stations, such as Bureau of Meteorology's Fogg Dam site near Darwin and the Australian Institute of Marine Science (AIMS) site in Townsville, should be pursued. Such data should (1) give better coverage of Queensland fires than the current downlink stations used (Perth, Alice Springs and Hobart) and (2) give the ability to apply Queensland-specific fire detection algorithms to the MODIS image processing to improve hotspot detection further. Having better hotspot mapping provides better information for the MODIS fire scar mapping process and provides end-users with a better back-up to the fire scar mapping. The hotspot feed from the AIMS station in Townsville has now been secured by Landgate WA - and an improvement should be seen in the 2011 fire season.

In the longer term, the fundamental problem of limited resourcing for MODIS fire scar mapping and validation needs to be overcome; this is connected with the lack of published validation and the purely operational focus of the mapping. Current discussions with the Federal Government are looking to secure funding for MODIS fire scar mapping that has national applications under the Carbon Farming Initiative and employs a full-time mapping and validation specialist. This should see a significant improvement in the consistency and accuracy of the mapping. One potential issue is that the Federal Government is interested in applications such as measuring the degree of fire abatement achieved in Greenhouse Gas abatement projects and consistency may be valued over user-derived improvements to mapping accuracy. The interaction between effective and usable mapping for land management, and therefore better land management practices and greenhouse gas abatement, will need to be spelt out.

4.6.2 Improving effective use of fire scar mapping in Queensland grazing regions

When users are faced with problematic fire scar mapping, there are a range of ways they can better interpret the mapping themselves by using data available on the NAFI site. The end-user interviews revealed that many pastoralist users do not realise the range of tools and data available on the site. The following actions are recommended.

1. Investigating site modifications that would provide an easier way for pastoralists to access combined hotspot and fire scar maps for past fires would be advantageous, as hotspot clusters can often be a reliable guide to fire scars in the event that the fire scar was not mapped.

2. NAFI representatives should develop a "cheat sheet" to help new or unfamiliar grazing lands users navigate their way around the site.

3. Potential and existing NAFI grazing lands users require training to receive the full benefit of NAFI services, including from basic how-to and computer skills, to using layers and fire histories.

4.6.3 Improving awareness of the NAFI website in Queensland grazing regions

Most of the interviewed pastoralists are keen supporters of the NAFI database, and hope to see continued improvement of its accuracy. However, there were significant numbers who had heard

of NAFI but had lost the site address - and also significant numbers of pastoralists who had not heard of the NAFI site.

Regular involvement and feedback is required to maintain their interest, clarify data limitations and to capitalise on their local expertise. This volunteer resource is immensely valuable, but costly (in terms of time) to maintain. There is a need for extension personnel to provide site-support for grazing lands users and continue dialog, with increased site use and user feedback anticipated to provide the greatest gains to improving map accuracy, presentation, understanding and map use. This on-going dialog is beyond the scope of the project.

1. Meat and Livestock Australia should include a link to the NAFI site in all publications including web pages and CDs.

NAFI representatives should attend rural field days to carry out practical demonstrations of the site's capabilities.

2. Assistance in the use of the site should target rural women who tend to carry out office and computer duties.

3. The site needs to be further publicised to pastoralists, and the site address disseminated for easy reference (e.g. advertising, magnets etc). This could be incorporated into the training recommended in the above point.

4. Strategies should be tested to allow the site to be picked up more easily on search engines when generic terms such as "fire", "Queensland" etc are entered.

4.7 Mechanisms for ongoing improvement of NAFI fire scar maps for Queensland

The following mechanisms are suggested to ensure that fire scar mapping in Queensland continues to improve.

1. Networks between end-users and the fire mappers need to be expanded beyond the current networks in the far north. The fire scar feedback role that end-users have needs to be built into the tasks of groups like Landcare groups, QFRS, QPWS and the NRM groups.

2. The national and international networks of remote-sensing specialists should be used to track improvements in remote sensing technologies. The current networks used by the northern remote-sensing community could be expanded to more regularly include specialists from southern Queensland. Potential improvements should be canvassed with fire managers so practical applications can be identified. This has been carried out previously in venues like the North Australian Fire Managers Forum - and this should continue.

3. Regular workshops involving remote-sensing specialists, fire mappers, fire managers and the NAFI website managers should be held regularly to see that potential improvements are implemented in the most effective way.

4. MODIS fire scar mapping should be more closely linked to national priorities so that it is better placed to attract Federal funding and support.

5. Transect-based assessments should be carried out in key locations across Queensland.

6. Fire occurrence databases held by QFRS and QPWS should be cleaned up so they can be queried and used to help verify the fire scar mapping.

7. A practical, quantitative Queensland-wide assessment of fire scar mapping accuracy, which could be based on fire occurrence data, should be developed and implemented at regular intervals to keep track of changes in accuracy.

The first three mechanisms are already being implemented.

5 Success in achieving objectives

5.1 Success in achieving objectives

1. Reviewed the accuracy of fire scar mapping in each of Queensland's 13 bioregions through on-the-ground consultation with key stakeholders and produced a table for each bioregion showing estimates of the commission/omission error

It was not possible to produce a detailed quantitative assessment of omission and commission errors for each bioregion with the resources and time available. However a broader assessment of these errors was produced based on a range of data including feedback from end-users that can be used as a basis for improving the mapping accuracy. The project also outlined a practical approach to assessing fire scar accuracy and clarified the work needed to put this in place.

2. Identified both the major issues affecting data quality in each bioregion and the options for accommodating or overcoming these issues during the processing of satellite images

The major issues affecting data quality in each bioregion were identified (Table 3). Options for overcoming these issues during the processing of satellite images have been identified (Section 4.6.1). The building of greater feedback between end-users and fire scar mappers in particular should have a number of benefits for fire scar accuracy across all regions.

3. Improved the reliability of the NAFI website fire scar maps for Queensland grazing areas

The coming fire season should see an improved reliability of the NAFI website maps through:
1. increased time allocated to Queensland MODIS fire scar mapping
2. increased feedback between end users and fire mappers - the mechanisms for this are already being implemented;
3. an improved fire mapping procedure that better incorporates hotspot and other data;
4. drawing on an additional local downlink site for hotspots in Townsville;
5. additional tools on the NAFI website to help users employ the fire scar data more effectively in fire management.

4. Provided a mechanism for ongoing improvement of NAFI fire scar maps for Queensland.

The following mechanisms are being implemented:
1. increased feedback between end users and fire mappers
2. Using national and international networks to track improvements in remote sensing technologies
3. regular meetings of mapping technicians and remote sensing specialists

If Federal funding for MODIS fire scar mapping is secured this will be a major spur for ensuring continued improvement and validation of the mapping.

6 Impact on Meat and Livestock Industry – now & in five years time

6.1 Immediate impact on Meat and Livestock Industry

As outlined in section 5 above, the coming fire season should see improved reliability of the NAFI website maps due to the measures described being implemented. The NAFI site managers will also be raising awareness of the site this year in various ways. All other things being equal this should see grazing land managers in fire prone areas of Queensland in a position to better manage and plan for wildfires - and should see subsequent losses to wildfire reduced. However, fire and weather conditions can vary greatly from one year to the next and the impact of improved fire scar mapping procedures are best measured over a number of years. If we have a dry winter and northern dry season, 2011 is likely to see significant wildfires given the previous rainfall and the debris from Cyclone Yasi - and good fire management will play a greater than usual role in grazing land management.

6.2 Five-year impact on Meat and Livestock Industry

If the recommendations in this report are adopted then the five-year impact on the northern beef industry should be significant for following reasons.

1. The feedback networks between fire scar mappers and end-users will have produced significant improvements in the reliability and accuracy of the mapping.

2. More resources should be available for MODIS fire scar mapping through Federal funding and the mapping should be more uniformly accurate and validated.

3. A range of new technologies, such as new satellite sources, will have been built into the mapping process, improving its accuracy.

4. A range of new tools and the training to use them should be available on the NAFI website enabling grazing land managers to more effectively use fire data to plan for, and manage, fire.

5. The percentage of grazing land managers who use the NAFI website and who are better able to manage fire as a result should have increased due to the efforts to increase awareness of the site.

6. It should be easier to assess the accuracy of fire scar mapping through the use of Government databases.

7. Grazing land managers in the northern fire prone savannas will be in a better position to capitalise on opportunities to earn income from better fire management such as through wildfire and Greenhouse Gas abatement. This should help the economic performance of these properties.

In 2006, the Centre for International Economics estimated that use of the NAFI website by fire managers across north Australia, most of whom were pastoralists, saved them between $1M - $2M a year just in reduced monitoring costs. This did not include the benefits arising from reduced damage to infrastructure or fodder, or from better use of fire to maintain pasture

productivity. Since then the overall usage of the site has more than doubled, with particularly high uptake in central Queensland. If most of the measures above are implemented we can conservatively estimate savings and income opportunities amounting to many millions of dollars per year. The current cost for site operation and mapping is around $350K a year.

7 Conclusions and recommendations

7.1 Conclusions

MODIS fire scar and hotspot mapping delivered via the NAFI website are important tools that allow Queensland graziers to better monitor and manage fires, particularly in northern regions. The value of this mapping is likely to increase if (i) recent trends in usage continue; (ii) intense fire seasons, as seen in recent years, continue to occur; (iii) new opportunities for income through fire management arise, as is likely to occur in far northern Australia through Greenhouse Gas abatement projects; and (iv) if property planning and quantitative assessment of land management become more important. Assessing and improving the accuracy and reliability of these fire mapping tools are therefore important to the Queensland grazing industry.

This study has clarified the issues and limitations of this mapping across Queensland. In the more northerly and north western regions with open landscapes, largely cloud-free fire seasons, and with more established networks between end users and fire mappers, the fire scar mapping is generally accurate but with significant omission errors due mostly to cloud cover and cooler, smaller fires and commission errors often due to the variability of wetter landscapes near the coast. In the more eastern and southern regions, the fire scar mapping is less reliable. These areas tend to have more cloud cover in the fire season, many areas are more heavily vegetated, and these regions tend to be more closely settled with smaller fire sizes. These areas have more omission errors due to cloud cover, vegetation cover and small fire size.

In grazing areas improvement in fire scar accuracy can be significantly enhanced by increasing user feedback to the fire scar mapper, increasing the hours available for mapping, accessing improved hotpot data, and using hotspot and other data in the mapping process. The effective use of the fire scar data can also be improved by adding extra tools and clearer instructions on the NAFI website, and by raising awareness of the site among grazing land managers.

This study has also shown that producing a more rigorous quantitative assessment of the fire scar mapping has significant challenges. Carrying out transect-based validation across Queensland is expensive and does not capture all the aspects of fire-scar accuracy valued by fire managers. Yet such surveys are needed as an internationally acceptable standard of verification. Without this verification the mapping will struggle to attract many national and state level applications of the data and consequently it will struggle to attract the funding needed to improve accuracy and pay for verification. Discussions are taking place with the Federal Government that may resolve this issue and see the MODIS fire scar mapping used in the Carbon Farming Initiative with more rigorous validation.

If end-user databases of fire occurrence were better organised and more comprehensive, it should be possible to readily assess the fire scar mapping against both historical and new data, thereby providing the basis for gauging the on-going operational effectiveness of the mapping. This would complement any transect-based validation.

If the MODIS-based fire scar mapping does move to national applications, care needs to be taken that the benefits of its current local and operational focus are not lost. Links between the

mapping process and end-users are important both to ensure that the mapping remains relevant to users' needs and so that user information can continue to improve the mapping.

7.2 Recommendations

7.2.1 Improving accuracy of fire scar mapping in Queensland grazing regions

1. Increase the time available for MODIS fire scar mapping in Queensland from two days a week during the fire season to at least two and a half or three days a week (this will occur from June 30 2011).

2. Increase the feedback between end-users and the fire scar mappers, particularly in the more southerly grazing areas (this involves end-users sending in aerial prescribed burn (APB) lines or other ignition points prior to mapping, or by end-users pointing out missed scars etc. after the initial mapping). This can be done by having better emailing tools on the NAFI website and by establishing good working relationships with key people who act as conduits to other fire managers across the state. QFRS should play a role here as well as NRM groups as many of these have GIS capability as well as existing communication networks in their local areas.

3. The MODIS fire scar manual mapping process needs to incorporate other methods of fire scar detection such as end-user reports, automated MODIS fire scar mapping and hotspot mapping, which serve as a useful check on the manual mapping. Hotspot data promises to be particularly useful in assisting the identification of small fires. An 'indicative burn area' could be mapped as a generic polygon if clusters of hotspots are present but there is genuinely no fire scar. This could be shown as a 'B' class fire scar on NAFI.

4. Hotspot data from more northerly and easterly satellite downlink stations, such as Bureau of Meteorology's Fogg Dam site near Darwin and the Australian Institute Marine Science (AIMS) site in Townsville, should be pursued. Such data should (1) give better coverage of Queensland fires than the current downlink stations used (Perth, Alice Springs and Hobart) and (2) give the ability to apply Queensland-specific fire detection algorithms to the MODIS image processing to improve hotspot detection further. Having better hotspot mapping provides better information for the MODIS fire scar mapping process and provides end-users with a better back-up to the fire scar mapping. (The hotspot feed from the AIMS station in Townsville has now been secured by Landgate WA - and an improvement should be seen during the 2011 fire season.)

5. Opportunities to access new satellite data sources should be pursued. At present the fire scar and hotspot mapping rely on two NASA satellites, Terra and Aqua, that carry the MODIS sensor and while these satellites could operate for many years to come, they are already beyond their planned operational life as experimental satellites. Budget cuts have seen the launch of their replacements delayed until at least 2014. There are other satellites with broadly equivalent sensors and orbits due for launch over the next few years, and access to these satellites should be pursued. .

7.2.2 Improving effectiveness of NAFI website for grazing land managers

1. Modify the NAFI site so that pastoralists can more easily access combined hotspot and fire scar maps for past fires, as hotspot clusters can often be a reliable guide to fire scars in the event that the fire scar was not mapped.

2. “Cheat sheets” on the NAFI site should be developed to help new or unfamiliar grazing lands users navigate their way around the site.

3. Pastoralist users of the NAFI site would benefit from training to enjoy the full benefit of NAFI services. Such training could cover basic how-to and computer skills, as well as instruction on using map layers and fire histories.

7.2.3 Improving awareness of NAFI website among grazing land managers

1. Meat and Livestock Australia should include a link to the NAFI site in all publications including web pages and CDs.

2. NAFI representatives should attend rural field days to carry out practical demonstrations of the site’s capabilities.

3. Other aspects of awareness-raising could include advertising in trade publications and NAFI 'magnets' handed out at training events and field days. Rural women, who tend to carry out most office and computer duties, should be targeted in any strategy.

4. Strategies should be tested to allow the site to be picked up more easily on search engines when generic terms such as "fire", "Queensland" etc are entered.

7.2.4 Ensuring the fire scar mapping continues to improve

1. Once the feedback networks between end-users and the fire scar mappers have been expanded and established, such networks need to be institutionalised and built into the tasks of groups like Landcare groups, QFRS, QPWS and the NRM groups.

2. National and international networks of remote-sensing specialists should be used to keep track of improvements in remote sensing technologies. After expansion of these networks to more regularly include specialists from southern Queensland, reporting back should be formalised at venues like the North Australian Fire Managers Forum and should involve practitioners as well as remote sensing specialists.

3. Regular workshops involving remote-sensing specialists, fire mappers, fire managers and the NAFI website managers should be held regularly to see that potential improvements are implemented in the most effective way.

4. MODIS fire scar mapping should be more closely linked to national priorities so that it can more readily receive Federal funding and support.

5. Transect-based assessments should be carried out in key locations across Queensland

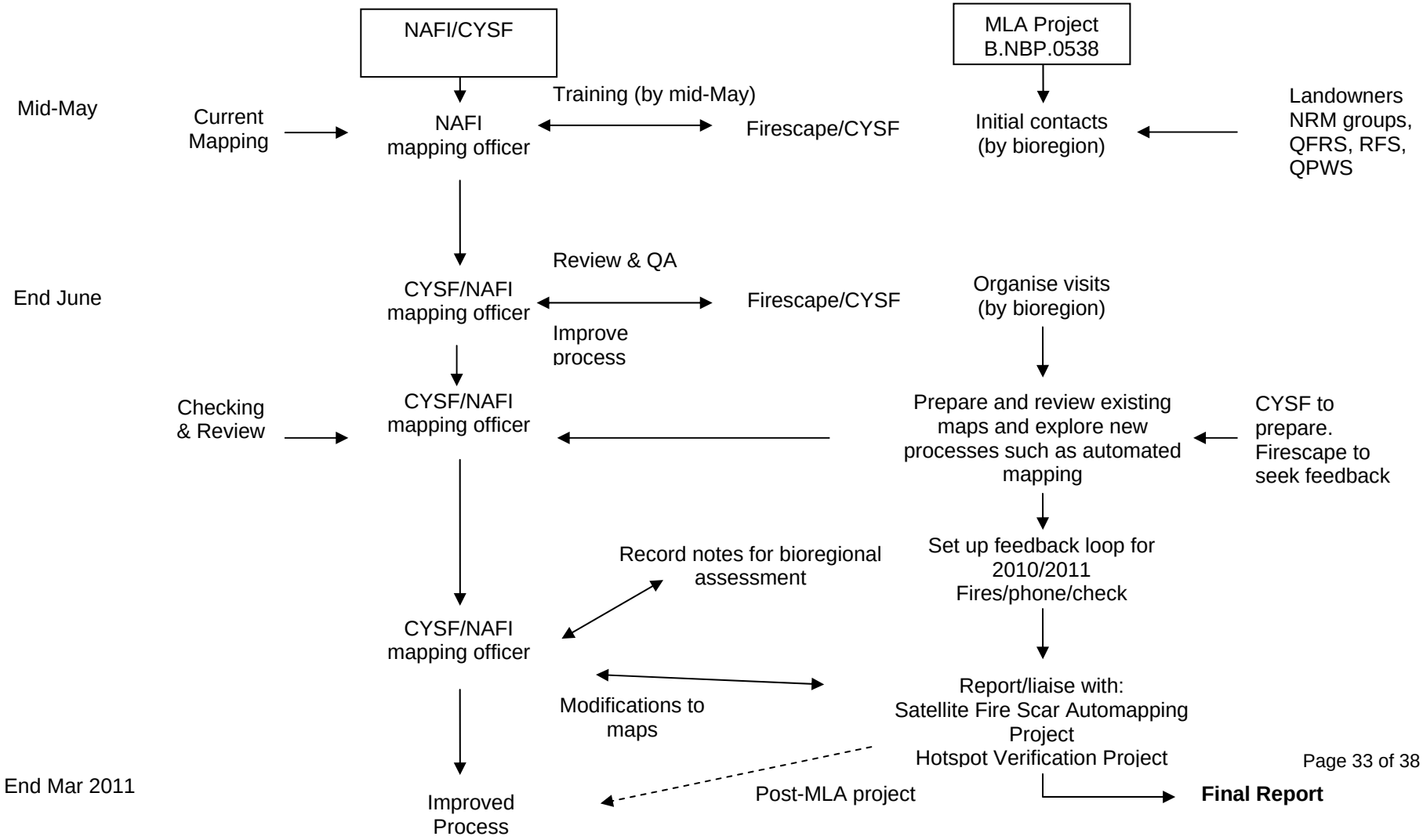
6. Fire occurrence databases held by QFRS and QPWS should be cleaned up so they can be queried and used to help verify the fire scar mapping.

7. A practical, quantitative Queensland-wide assessment of fire scar mapping accuracy, which could be based on fire occurrence data, should be developed and implemented at regular intervals to keep track of changes in accuracy.

8 Appendices

8.1 Appendix 1

Procedural flow diagram showing the process involved to deliver the project outcomes and an indication of the proposed time frame



8.2 Appendix 2

NAFI Questionnaire

Name……..…….....

Bioregion/s……...

Contact Details…….....……..

Do you use the NAFI service? Yes/No
Is this site useful to you/your organisation? Yes/No
How often do you use this site? _____

Fire information needs for this bioregion....…….....……
……
……

Is the NAFI information for your bioregion reliable? (Consider issues such as landscape and time of year, eg seasonal effects)
.....
.....……
……
……

Gaps/issues identified in the existing NAFI site……
……
……

Suggestions for improving NAFI services……
……
.....

Please return completed form to admin@firescape.com.au

8.3 Appendix 3

Record of pastoral survey effort

General Property Location	No of calls	No Contact	Call not returned	Call taken	Participated in questionnaire
Property A, Winton, Qld	2			X	
Property B, Winton, Qld	4			X	X
X Station, Mackay, Qld	3			X	X
Eton, Qld	1		X		
Illbibie, Qld	2	X			
Sarina Range, Qld	2	X			
X Station, Proserpine, Qld	2			X	X
X Station, Glenden, Qld	2	X			
Property X, Moranbah, Qld	2	X			
X Station, Middlemount, Qld	2			X	X
Area Director, Barcaldine, Qld	1			X	
Fire Warden, West Charleville, Qld	1		X		
X Station, Normanton, Qld	1			X	X
X Station, Barcaldine, Qld	1		X		
X Station, Tambo, Qld	2			X	X
X Station, Aramac, Qld	1			X	X
X Station, Barcaldine, Qld	1		X		
X Station, Alpha, Qld	1		X		
X Station, Forsayth, Qld	2			X	X
X Station, Springsure, Qld	2	X			
X Station, Duchess, Qld	2			X	X
A Station, Augathella, Qld	2			X	
B Station, Augathella, Qld	3			X	X
X Station, Mount Isa, Qld	2			X	
Lawn Hill area, north west Qld	1			X	
X Station, Einasleigh, Qld	1		X		
X Station, Charters Towers, Qld	1			X	X
Fire Warden, Cunnamulla, Qld	2	X			
X Station, Mount Isa, Qld	2			X	X
Coban Fire Warden, Cunnamulla	2	X			
Coongoola Fire Warden, Cunnamulla	2			X	
Baroona Fire Warden, Cunnamulla	1		X		
X Station, Chillagoe, Qld	2			X	X
X Station, Mt Carbine, Qld	2			X	X
Fire Warden, Croydon, Qld	1			X	
1st Fire officer, Croydon, Qld	1			X	
X Station, Croydon, Qld	1			X	X
X Station, Middlemount, Qld	2			X	X
X Station, Cunnamulla, Qld	1			X	X
X Station, Mary Kathleen, Qld	2			X	X
X Station, Mount Isa, Qld	3	X			
X Station, Mount Isa, Qld	2	X			

General Property Location	No of calls	No Contact	Call not returned	Call taken	Participated in questionnaire
X Station, Mount Isa, Qld	2			X	X
A Station., Normanton, Qld	1			X	
B Station, Normanton, Qld	1			X	
C Station, Normanton, Qld	2			X	X
D Station, Normanton, Qld	1			X	X
E Station, Normanton, Qld	1			X	X
X Station, McKinlay, Qld	2			X	
F Station, Normanton, Qld	2		X		
G Station, Normanton, Qld	2			X	X
H Station, Normanton, Qld	3	X			
A Station, Longreach, Qld	2			X	X
B Station, Longreach, Qld	2			X	X
C Station, Longreach, Qld	2			X	
A Station, Winton, Qld	1			X	X
X Station, Opalton, Qld	3			X	X
B Station, Winton, Qld	1			X	
A Station, Greenvale, Qld	2			X	X
B Station, Greenvale, Qld	1		X		
A Station, Jericho, Qld	2			X	X
X Station, Barcaldine, Qld	1	X			
B Station, Jericho, Qld	1	X			
C Station, Jericho, Qld	1	X			
X Station, Torrens Creek, Qld	2			X	X
A Station, Charters Towers, Qld	2			X	
B Station, Charters Towers, Qld	2			X	X
A Station, Pentland, Qld	4			X	X
B Station, Pentland, Qld	2		X		
A Station, Cloncurry, Qld	2	X			
B Station, Cloncurry, Qld	3			X	
C Station, Cloncurry, Qld	1		X		
D Station, Cloncurry, Qld	1	X			
A Station, Boulia, Qld	2			X	X
B Station, Boulia, Qld	2			X	X
C Station, Boulia, Qld	1	X			
X Station, Kynuna, Qld	1		X		
A Station, Julia Creek, Qld	2			X	X
B Station, Julia Creek, Qld	3	X			
C Station, Julia Creek, Qld	1		X		
D Station, Julia Creek, Qld	1			X	X
A Station, Richmond, Qld	1			X	
B Station, Richmond, Qld	3			X	X
X Station, Coen, Qld	1			X	
X Station, Kowanyama, Qld	1			X	X
A Station, Marlborough, Qld	1	X			
B Station, Marlborough, Qld	1			X	
A Station, Mt Coolon, Qld	1		X		
B Station, Mt Coolon, Qld	1	X			

General Property Location	No of calls	No Contact	Call not returned	Call taken	Participated in questionnaire
A Station, Clermont, Qld	1	X			
B Station, Clermont, Qld	1		X		
X Station, Belyando, Qld	1		X		
C Station, Clermont, Qld	1			X	
D Station, Clermont, Qld	2			X	X
E Station, Clermont, Qld	2			X	X
F Station, Clermont, Qld	1	X			
X Property, Weipa, Qld	3	X			
X Station, Pormpurraw, Qld	3			X	X
X Station, Coen, Qld	3			X	
A Station, Georgetown, Qld	1	X			
B Station, Georgetown, Qld	1			X	X
X Station, Kidston, Qld	1	X			
X Station, The Lynd, Qld	1	X			
X Station, Mt Surprise, Qld	1			X	X
C Station, Georgetown, Qld	1			X	X

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