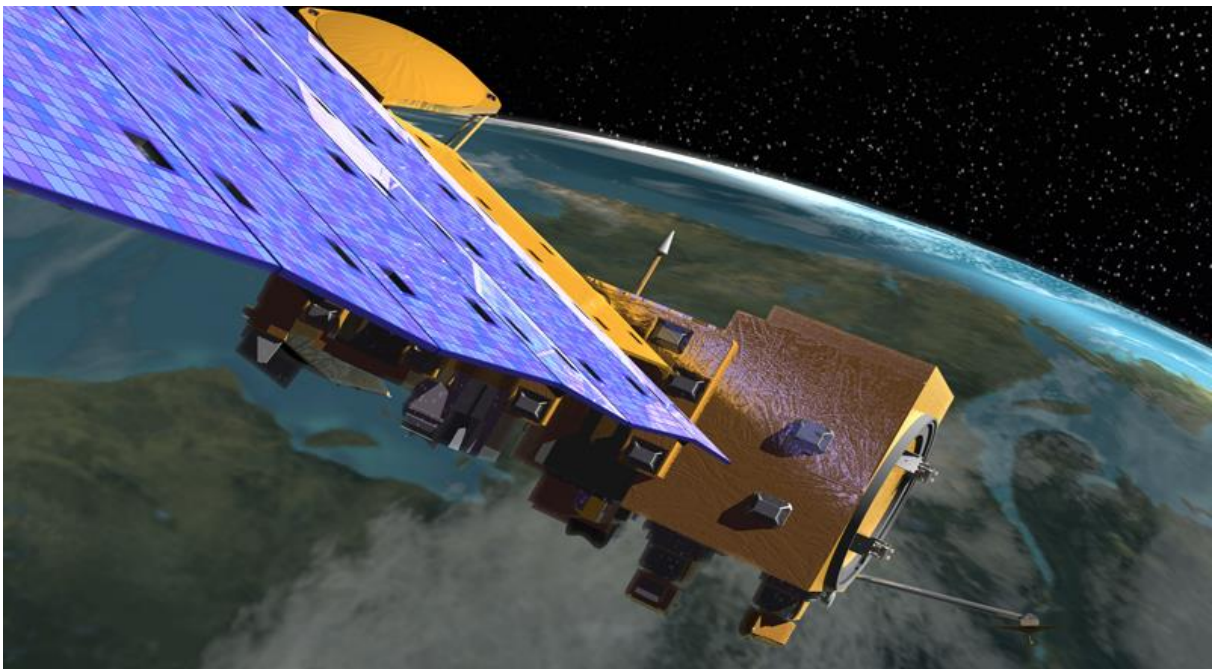


FINAL REPORT

Professional Services Contract

No. GVD-P-17-001



Extending NAFI Fire History Mapping

Peter Jacklyn
Darwin Centre for Bushfire Research,
Charles Darwin University
peter.jacklyn@cdu.edu.au

September 2017

Table of Contents

1. Background.....	2
2. Data Sources	3
3. Methods.....	4
3.1 Pre-processing	4
3.2 Object Based Image Analysis	5
3.3 Mapper analysis.....	6
4. Outputs produced	7
4.1 250m fire scar datasets for the years 2000, 2001 and 2002	8
4.1.1 Downloading 2000, 2001, 2002 fire scar data:	8
4.1.2 Viewing 2000, 2001, 2002 fire scar data on NAFI	8
4.1.3 Viewing 2000, 2001, 2002 fire scar data on Google Earth	9
4.2 250 fire histories for 2000-2016	11
4.2.1 Downloading fire history data.....	11
4.2.2 Viewing the 2000-2016 fire histories on NAFI.....	11
4.2.3 Viewing 2000-2016 fire history data on Google Earth	12
4.2.4 Viewing 2000-2016 fire history data as a Web Map Service (WMS)	13
4.3 250m fire histories for 2000 – 2009	14
5. Fire Report Menus and Fire History Interrogation	14
6. Help and Instruction	23
7. Issues and Lessons learned	23
8. Knowledge Gaps.....	24
9. Data Sensitivities	24
10. Recommendations for Future Work.....	24
11. References.....	25

1. Background

This work is part of a larger initiative to extend the 250m fire scar mapping available through the NAFI website (www.firenorth.org.au) from the Kimberley to the boundaries of the wheat belt in WA – shown in blue below:

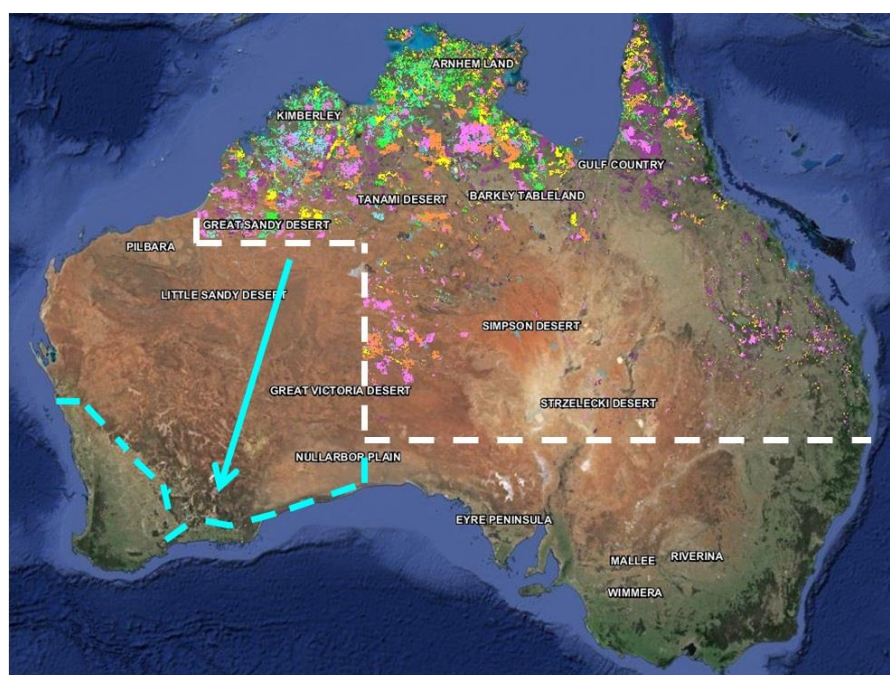
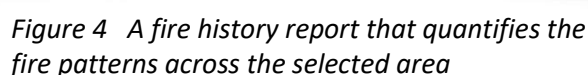


Figure 1. The existing NAFI fire scar extent (white dashed line) is being extended to the blue dashed line. Fire scars are shown as coloured patches.

The 250m fire scar mapping, sourced from the MODIS¹ sensors carried on NASA earth observing satellites (shown on the cover), allows for comprehensive fire mapping across the open rangelands landscapes of Australia at a reasonably low cost. The comprehensive nature of the mapping then allows fire histories to be created which can be used for fire planning and management. This moderate resolution mapping can also assist broad scale management of current fires.

An initial contract with Rangelands NRM has added 11 years of fire history (2006-2016) across this area. A further contract with Roy Hill added the years 2003 – 2005 across this region and this contract will add the final years 2000-2002 which utilises all satellite imagery available from the MODIS satellites. Fire histories for the years 2000-2016 will then be created and these fire data will be viewable on, and downloadable from, the NAFI website www.firenorth.org.au (Figure 2). Menu entries for selected areas will also be created on the NAFI fire reporting site www.infonet.org.au (Figures 3 and 4).

¹ Moderate Resolution Imaging Spectroradiometer



The burnt area or “fire scar” mapping used in this project is based on imagery from the MODIS sensor carried on board the NASA earth observing satellites *Terra* and *Aqua*. Daytime images from these sensors (below) are available twice a day from each satellite giving four possible updates a day.

Great Victoria Desert Biodiversity Trust
Issue Date: 29/09/2017

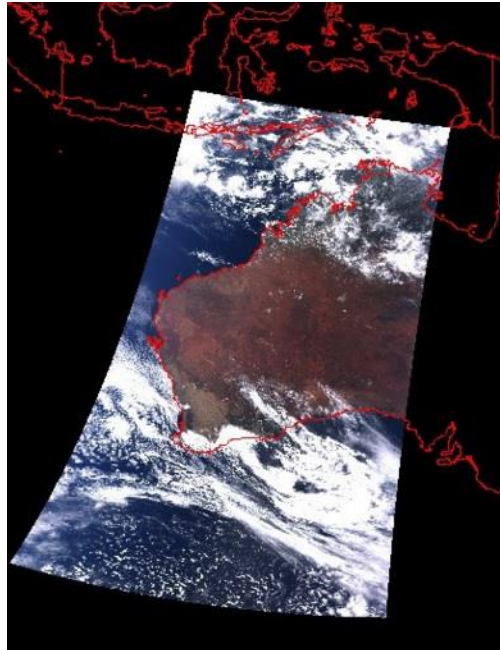


Figure 5. Raw MODIS image

The MODIS imagery however has some key advantages over the Landsat imagery for landscape-scale mapping of fire scars: (a) the four updates a day (compared to one update every 16 days for Landsat) mean that all significant fires are usually captured by the MODIS imagery; and (b) the lower resolution allows entire states to be mapped by a single human mapper once or twice a week. While fully automated fire scar mapping techniques are very useful, as things stand today reliable fire scar mapping across all rangelands landscapes at all times of year is not possible with human examination of each image. Frequently updated production of reliable and comprehensive fire scar mapping is useful for managing current landscape-scale fires and it also allows reliable fire histories to be assembled, which is the purpose of this project.

3. Methods

3.1 Pre-processing

Once a MODIS image is downloaded from the satellite, it is processed to make it useful for fire scar mapping. The image is corrected for the angle of the satellite and given geo-references, and the radiance is corrected so that only ground reflection is present (which makes fire scars easier to identify). Additional atmospheric correction is also conducted (Maier 2010). The imagery is then clipped to the south WA region and served as a tif file format via a website for use by the mappers (shown below). For this project, this “pre-processing” service is provided by Maitec.

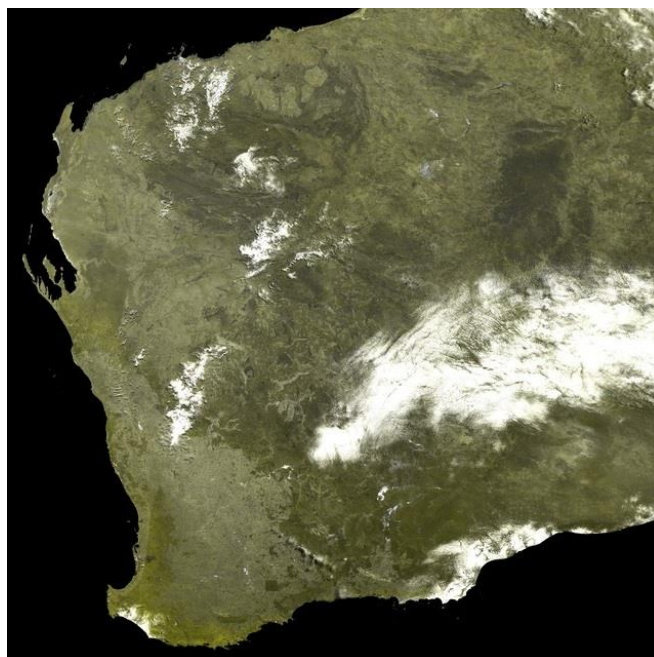


Figure 6. Pre-processed MODIS image - compare to raw image in fig 5 above

For the historical mapping in this project, a sufficient number of MODIS images are selected across the target year to ensure no fire events are missed: images with the least total cloud cover are selected or, where extensive cloud cover is persistent, with the least cloud over areas of active fire as identified through active fire (hot spot) data.

3.2 Object Based Image Analysis

The mapper then runs an automated process that compares a given MODIS image with a previous one to identify areas that were likely to have been burnt in the interval between the images. This process uses an Object Based Image Analysis (OBIA) approach to segment the image into regular regions of similar spectral statistical classes. Multiple adjacent pixels are grouped into 'Objects' based on similar colour, shape and contextual characteristics. Pixels are grouped into image objects based primarily on the spectral response of the MODIS 250 metre near infra-red (NIR) wavelength band. When burning occurs, the major reflectance change occurs in the NIR, particularly under dense tree cover, whilst the burning of dry grass causes an overall decrease in reflectance (the pixels go darker). A difference-image that highlights these changes between the two satellite images produces an initial image of vector polygon objects that represent potential new fire scars (Pereira, 2003). These objects are then further classified into a set of fire classes based on threshold values of the mean reflectance change (Figure 7).

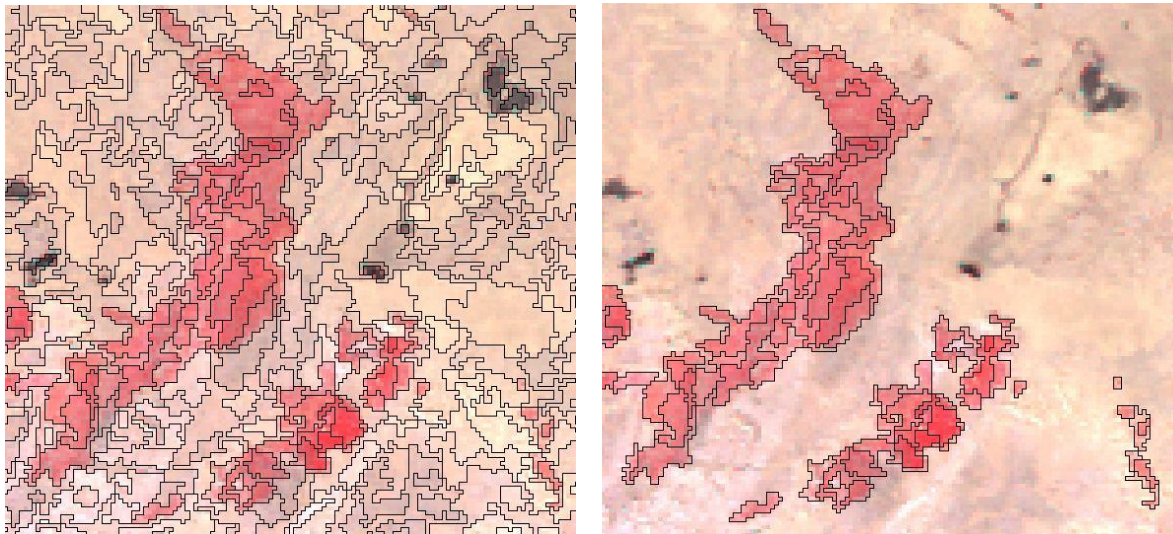


Figure 7. (a) initial segmentation into image objects and (b) with threshold classification identifying burnt areas.

This OBIA approach generally produces a cleaner map product, more meaningful to human users than the pixel by pixel classification used in other burnt area classification processes. Ecognition image analysis software is used for the segmentation and initial classification.

3.3 Mapper analysis

The next step is for the human mapper to examine the difference image and identify any of these burnt area objects that are not actually fire scars (e.g. water bodies or dark soil are sometimes picked up) and to identify fire scars that may have been missed (particularly cooler, patchy fires). A particular issue in mapping arid landscapes occurs when sparse vegetation on highly reflective sandy landscapes are burnt – the fire initially produces a darkening and reduced reflectance due to the burnt vegetation, but then the vegetation can be blown away and the now exposed bare sand produces an increase in reflectance.

To further assist the identification of burnt areas a range of ancillary data are overlaid on the imagery during the mapping process including:

- Active-fire “hotspot” data, derived from both AVHRR and MODIS imagery are used to help identify small fires and assist the mapping in cloud affected areas.
- Landsat fire scar mapping can be obtained from other agencies (e.g. from DPaW) for some areas.
- Hydrographic data. As rivers, floodplains and other bodies of water dry out through the course of the dry season, the change can appear similar to the effect of fire in the NIR.

Another important component of the fire mapping process is user input. Land managers are encouraged to provide feedback on the mapping and identify areas that are incorrectly mapped. Responding to community input during the mapping not only increases the overall accuracy of the mapping it also increases ownership of and confidence in the mapping product. The fact that the NAFI mapping is conducted in collaboration with land managers, not as an automated predefined process,

is one reason for the widespread community engagement with this product (for more details see Fisher and Edwards, 2015).

Production and distribution of mapping products

Once the fire scar mapping has been completed for a given year, an annual fire scar dataset is created as (a) a geo-referenced image in tif format with each pixel in the image attributed by the month it was detected as being burnt or by a 0 if unburnt and (b) as a vector shapefile with each polygon (corresponding to the image objects above) attributed (GRIDCODE) by the month in which it was detected as burnt or by 0 if unburnt. These products are created using ArcGIS tools.

The three image datasets for 2000, 2001 and 2002 are then combined with the existing 14 image datasets for the years 2003 – 2016 to produce three fire history image datasets: the fire frequency for 2000 – 2016, the late fire frequency for 2000-2016 (i.e. the frequency of fires that occurred after July 31) and the time since last burnt for 2000 – 2016 (i.e. the time in years since a particular location was last burnt). These products are created using pixel analysis ArcGIS tools. ArcGIS tools are then used to create the corresponding shapefiles. More details on these datasets are described below in the outputs section.

This process is then repeated to produce the equivalent fire frequency, late fire frequency and time since last burnt datasets for 2000-2009.

Once they are checked the image datasets for each individual year and for the fire histories are loaded into the NAFI online databases – Oracle spatial databases. This allows the fire scar data to be distributed in the following ways:

- As images on a dynamic map viewer which is linked to a number of online tools that help people monitor and manage rangelands fire;
- As kml files, which can be displayed on *Google Earth* which is an easy map viewer to use and allows users' to display their own map data;
- As a Web Map Service that can be displayed on other websites or on ArcMap etc.

The annual and fire history fire scar data are also placed in folders on the NAFI server so they can be downloaded by users.

Infonet fire report methods

The fire report tool is located on its own website www.infonet.org.au and can also be accessed via the NAFI website through the Create Report tab. This online tool takes the fire scar data stored on the NAFI database and carries out a pixel-based analysis that determines the area of the fire scars and presents this in graphical and tabular form. The correction of area for latitude is carried out by tools associated with the database. More details on the reports are described below.

4. Outputs produced

The outputs produced by the project are listed below. They are all accessed via the NAFI website www.firenorth.org.au with access details provided for each output. (Previously there has been

evidence suggesting that Anglogold has firewall/network settings that make accessing the NAFI and Infonet sites difficult. If this is the case these sites should be accessed from another network.)

4.1 250m fire scar datasets for the years 2000, 2001 and 2002

4.1.1 Downloading 2000, 2001, 2002 fire scar data:

These are provided as geo-tif images and as shapefiles which are zipped together with a read-me file summarising the data and an ANZLIC metadata description. They can be downloaded from the NAFI site and then queried in mapping software for the month burnt. Go to www.firenorth.org.au and, as shown in Fig. 8, select the “Download Data” tab > “Data as image or shapefile” menu on the left > “Fire scar by year” (red arrow). Then select the years and file type you want to download – the years produced by this project are highlighted by the red boxes below.

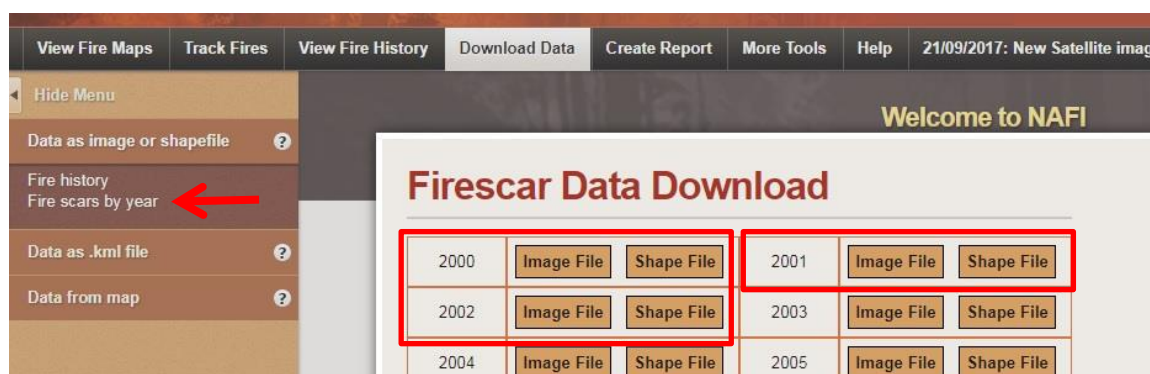


Figure 8. Downloading fire scar data

4.1.2 Viewing 2000, 2001, 2002 fire scar data on NAFI

To view the fire scar data produced by the project on the NAFI map viewer, go to www.firenorth.org.au and in the left hand side of the home page you will see the “View Fire Map” menu. Click on the small arrow to left of “WA Deserts” in this menu and then “South” as shown below:



Figure 9. NAFI map menu

This will bring up a map of the GVD area on NAFI.

The default display shows current active fires and fire scars, if you select the “View Fire History” tab above the map you will see a new menu on the left as shown in Fig. 10 – click on the “Past fire scars by month” sub menu and you should see all available fire scar years with 2000-2002 at the top (red

box). Tick the left hand box next to the layer to display it. You can change the background maps by clicking the background maps options at top right (blue arrow). You can zoom in and zoom out using the slider bar (red arrow).

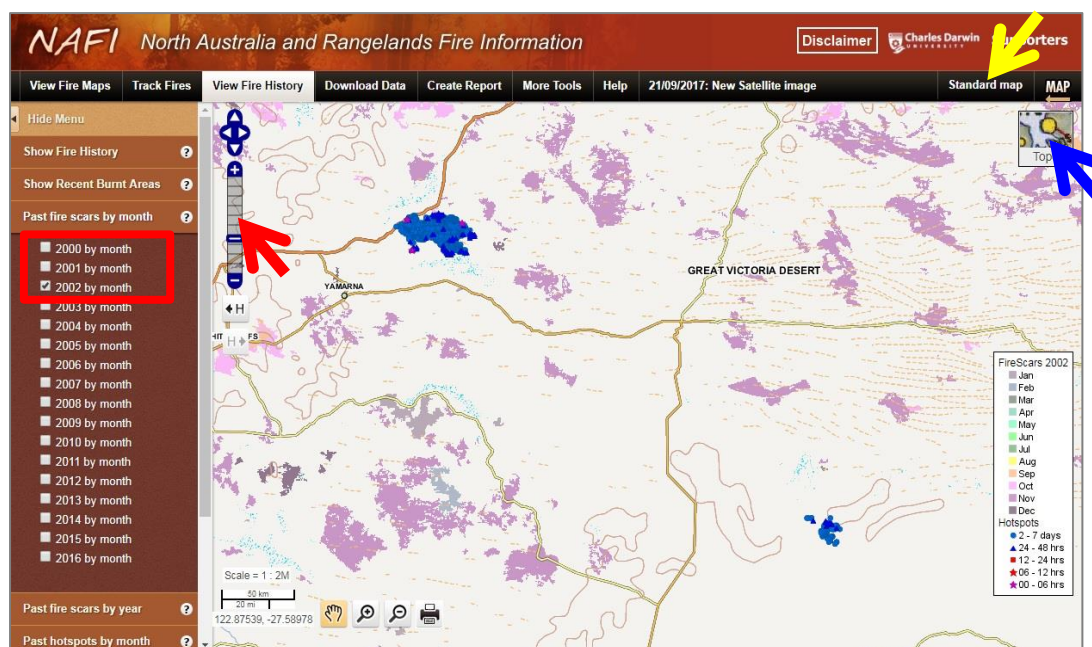


Figure 10. Viewing fire scars on NAFI

To remove the display of historical fire scars, un-tick the layer and then select the “Standard Map” link (yellow arrow) which will return to the display of current fire scars and hotspots. Note that the current fire scars on the default NAFI display can be queried for mapping interval – which shows the latest date that the fire scars were updated. All the controls of the map viewer are explained under the “Help” tab above the map.

4.1.3 Viewing 2000, 2001, 2002 fire scar data on Google Earth

To view these fire scars on *Google Earth* (which is easy to use and allows the display of the users’ own data) go to the “Download Data” tab above the map and from the menu that appears on the left, select “Data as .kml file” (Fig. 11). From the menu option below, select “Past years’ fire scars” (red arrow) and from the box that appears, select “Fire scars by month 2000-16” (red box). This will download the appropriate kml file.



Figure 11. Downloading fire scar data as a kml file

If you have installed *Google Earth* or *Google Earth Pro* (both free to download) you will be able to view this .kml file by double-clicking on it. It will probably open zoomed-out over Australia and you should see the “burnt by month...” layers in the left hand menu in the

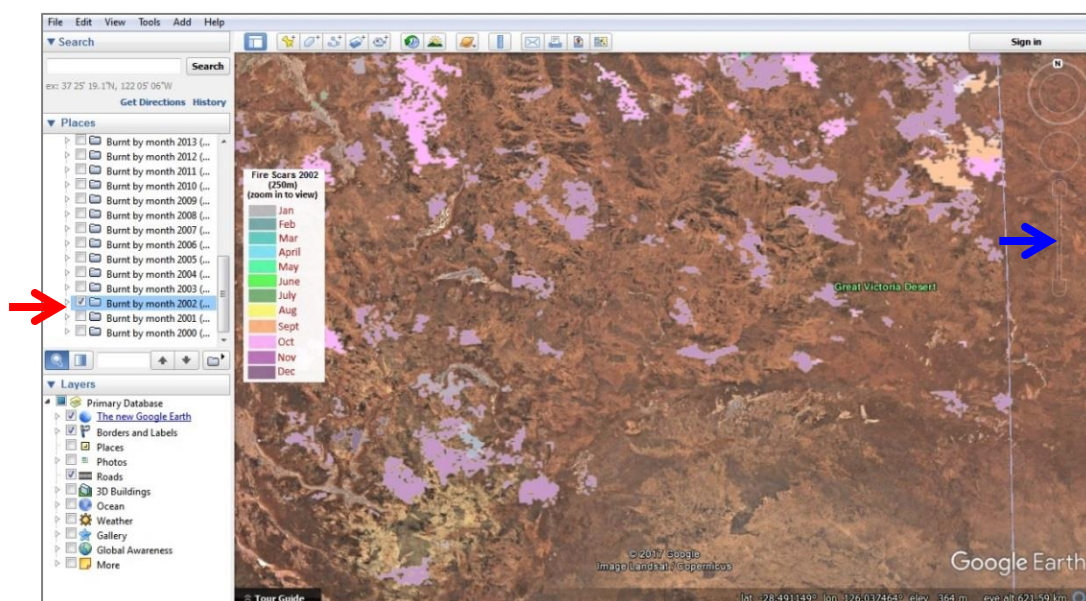


Figure 12. Viewing fire scar data on Google Earth

“Temporary Places” folder (Fig. 12). You will firstly need to zoom in using the slider bar (blue arrow) as the fire scars do not display until you are zoomed in a bit (to make navigation quicker). Then select the year you want to display from the left hand menu (red arrow) and the fire scars should appear.

4.2 250 fire histories for 2000-2016

These data are available in three formats. (a) The fire frequency for 2000-2016 which is useful for seeing what country has potentially suffered the most impact from frequent fire and what country has been spared frequent fire. (b) The late fire frequency for 2000-2016 which shows the frequency of fires that burnt after July 31. In seasonal northern Australia these fires are usually more intense than fires that burnt earlier in the year due to higher temperatures and greater grassy fuel loads later in the year – so the frequency of late fires can be a guide to the impact of more intense fires. In the arid areas this may not hold to the same extent as January - March fires, for example, may be intense, so this layer may be less useful. (c) The time since an area was last burnt 2000-2016 which displays the number of years since a given area was last burnt. This data is useful for estimating impact on fire sensitive vegetation that requires a number of years to recover from fire. This layer can also be useful in estimating fuel loads.

4.2.1 Downloading fire history data

As with the data for individual fire scar years, these data are available for download as geo-tifs or shapefiles. Go to www.firenorth.org.au and select the “Download Data” tab > “Data as image or shapefile” menu on the left > “Fire history” as shown in Fig. 13. Then select the fire history and file type you want to download from the box that pops up. The Nth Australia and WA fire histories produced by this project are highlighted by the red box.

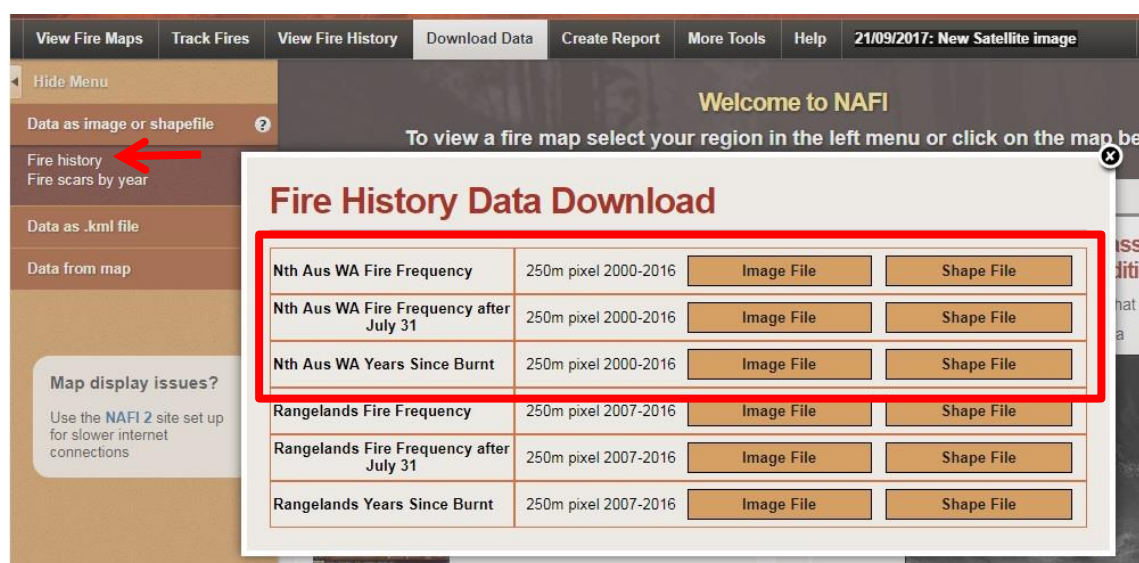


Figure 13. Downloading fire history data

4.2.2 Viewing the 2000-2016 fire histories on NAFI

Follow the same steps as for viewing the fire scar years above, but under the “View Fire History” tab, leave left hand menu open at “Show Fire History”. As shown in Fig. 14, the top section of this menu lets you display 2000-2016 fire histories: Years burnt (fire frequency); Late burnt (late fire frequency) and Last Burnt (times Since Last Burnt).

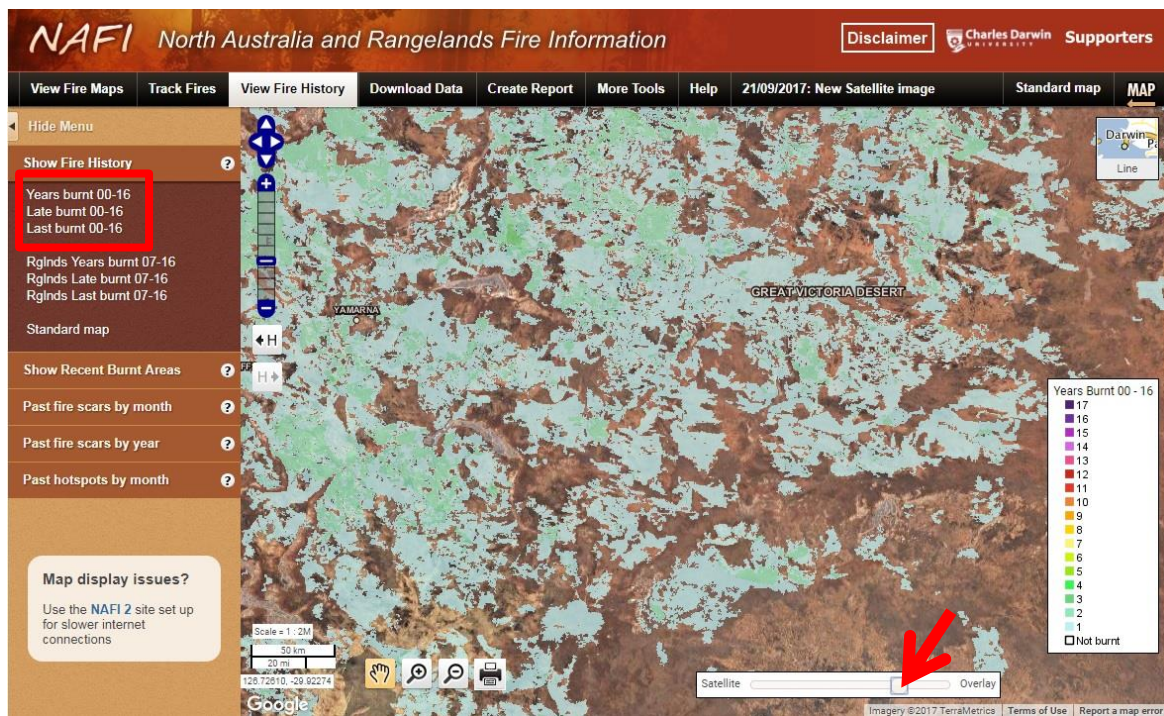


Figure 14. Viewing fire history data on NAFI

If you have the Google satellite image as a background, you can use the slider bar to alter the transparency of the displayed fire scars (red arrow).

4.2.3 Viewing 2000-2016 fire history data on Google Earth

As for the fire scar data, go to the “Download Data” tab above the map and from the menu that appears on the left, select “Data as .kml file” (Fig. 15). From the menu option below, select “Fire history patterns” (red arrow) and from the box that appears, select “Nth Aus Fire history 2000-16” (red box). This will download the appropriate kml file.

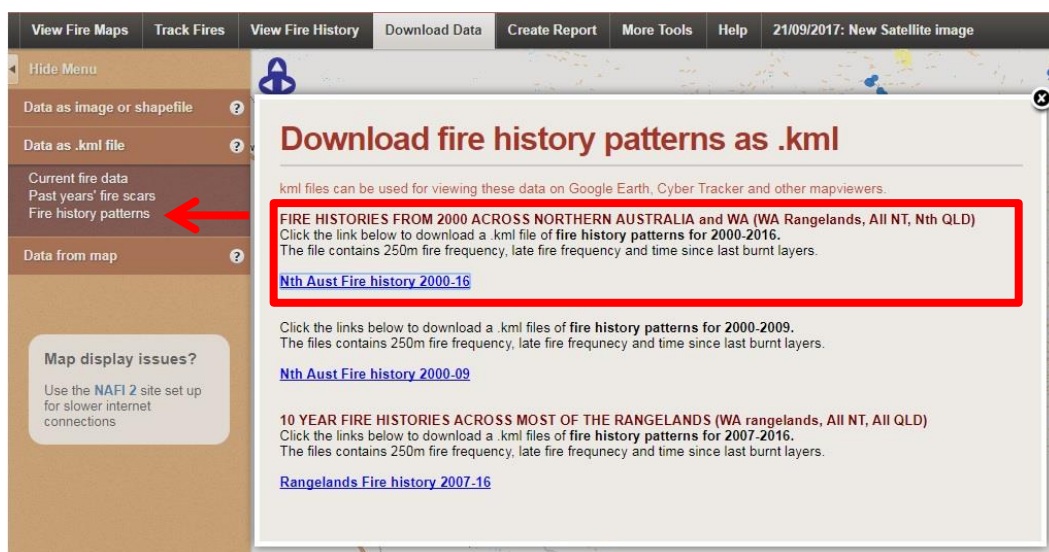


Figure 15. Downloading history data as a kml file

As for fire scars, if you have installed *Google Earth* you will be able to view this .kml file by double-clicking on it – and you should zoom in to your area of interest. Select the appropriate fire history from the list that appears in the *Google Earth* left hand menu in the Temporary Places folder.

4.2.4 Viewing 2000-2016 fire history data as a Web Map Service (WMS)

You can view image data as a Web Map Service (WMS) – maps linked to the NAFI database and displayed on your own map viewer whether it be ArcMap, or a corporate intranet or website. To do this, select the “More Tools” tab above the map and in the left hand menu, select “Google Earth, WMS” and select “View as WMS service” (Fig. 16) This is menu is also an alternative way to select the Google Earth kml downloads.

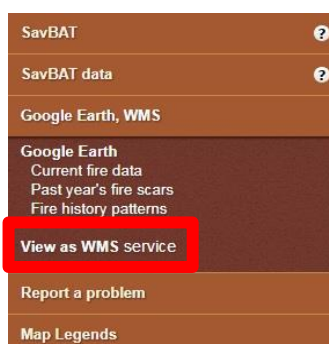


Figure 16. WMS link on More Tools

You will then be taken to a page (Fig. 17) that lists all the NAFI Map layers available as a Web Map Service and the link to use on your map viewer.

WMS - WEB MAP SERVICES

This Web Map Service (WMS) provides access to some of the data displayed on the NAFI website directly over the Internet so you can display it as a layer in your own map viewer such as a desktop GIS software application. Every time your map viewer requests new data from this WMS it will get the latest version.

These WMS layers are only available as images - you cannot control the symbology or query the attributes of the data.

Using WMS
To access the WMS data enter the following URL link in your GIS software application:

<http://www.firenorth.org.au/public?request=GetCapabilities>

and a list of the following data layers should be displayed.

- RANGELANDS_250M_FIRE_FREQUENCY (250m fire frequency since 2007 for most of Rangelands)
- RANGELANDS_250M_LATE_FIRE_FREQUENCY (250m late (after July 31) fire frequency since 2007 for most of Rangelands)
- RANGELANDS_250M_TIME_SINCE_LAST_BURNT (250m Time since last burnt since 2007 for most of Rangelands)
- Hotspots 48 hours to 7 days
- Hotspots 24 to 48 hours
- Hotspots 12 to 24 hours
- Hotspots 6 to 12 hours
- Hotspots 0 to 6 hours
- Fire Scars by Month 2010 (250m fire scars coloured by month for 2010)
- Fire Scars by Month 2011 (250m fire scars coloured by month for 2011)
- Fire Scars by Month 2012 (250m fire scars coloured by month for 2012)
- Fire Scars by Month 2013 (250m fire scars coloured by month for 2013)
- Fire Scars by Month 2014 (250m fire scars coloured by month for 2014)
- Fire Scars by Month 2015 (250m fire scars coloured by month for 2015)
- Fire Scars by Month 2016 (250m fire scars coloured by month for 2016)
- Fire Scars by Month Current (250m fire scars coloured by month to date for 2017)
- Fire Scars 2010 (250m single-colour fire scars for 2010)
- Fire Scars 2011 (250m single-colour fire scars for 2011)
- Fire Scars 2012 (250m single-colour fire scars for 2012)
- Fire Scars 2013 (250m single-colour fire scars for 2013)
- Fire Scars 2014 (250m single-colour fire scars for 2014)
- Fire Scars 2015 (250m single-colour fire scars for 2015)
- Fire Scars 2016 (250m single-colour fire scars for 2016)
- FIRFREQ250M_G (250m fire frequency since 2000 for Nth Aust and WA Rangelands)
- FIREFREQ250M_L_G (250m late (after July 31) fire frequency since 2000 for Nth Aust and WA Rangelands)
- FIRETSLB250M_G (250m Time since last burnt since 2000 for Nth Aust and WA Rangelands)

These layers are restricted to northern Australia and remote Australia: northern WA, the NT and Qld. The fire scars for 2013 also extend into northern SA. They are available in two projections: geographic (GDA 94) and Web Mercator

Figure 17. WMS entry page

Enter the WMS link (red box) in the WMS link area on your map viewer (this will vary with the application you are using) to set up the WMS for these NAFI layers. The 2000-2016 fire history layers from this project are included in the WMS feed (blue box).

4.3 250m fire histories for 2000 – 2009

These data are produced in the same fire history formats as the 2000-2016 fire histories (fire frequency, late fire frequency, time since last burnt). These layers are primarily used as an internal dataset for the fire reports service so that changes in fire regimes over time can be quantified by comparing these fire histories (which represent the baseline or oldest 250m 10 year history available) with the most recent 10 year fire history. Their use is illustrated in the reports section below.

These fire histories are available as kml files – follow the same steps as for the 2000-2016 fire histories except select the 2000-2009 option on the download box as shown in Fig. 18.

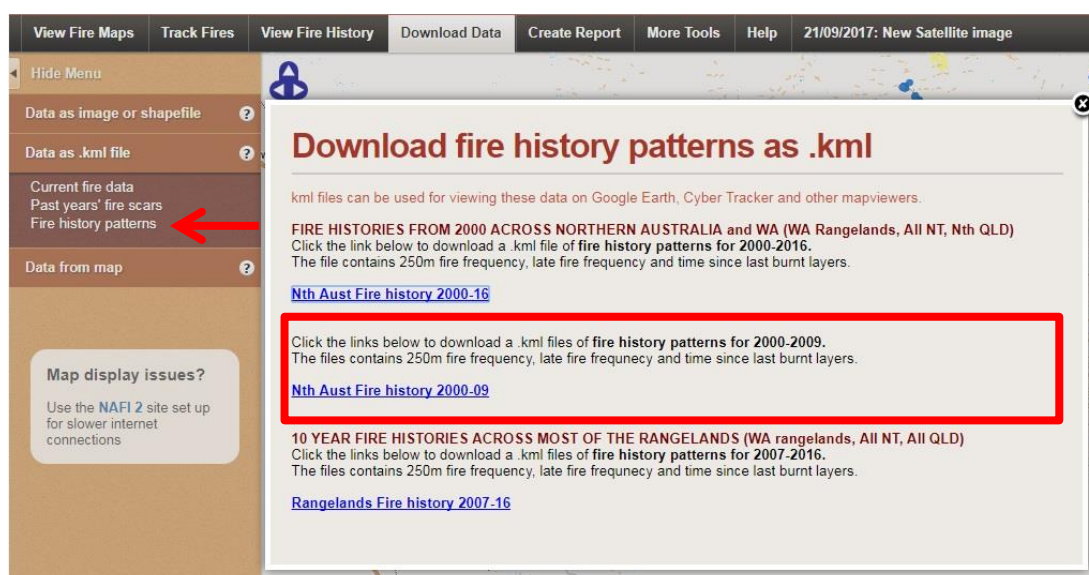


Figure 18. Downloading baseline fire history as a kml file

5. Fire Report Menus and Fire History Interrogation

The NRM Infonet reporting tool that allows users to quantify fire patterns in an area of interest is found under the “Create Report” tab above the map on the NAFI site, or it can be accessed via the address www.infonet.org.au. This tool was developed separately from NAFI and has now been merged with it.

The Infonet site is based on a dynamic map viewer like NAFI, with a set of drop-down menus in the upper left of the map that allows you to select different areas to report on, and various types of report. When you access the Infonet site from NAFI under the “Create Report” tab an area equivalent to the map extent you were viewing in NAFI will be automatically created on the Infonet site and will appear as a pink rectangle on the Infonet site map. Once you use the drop-down menu to select a pre-set area, this default area will no longer be selected.

The following pre-set areas have been created for Western Australia:

Table 1: Infonet menus and area names produced by this project

Menu name: Native Title Determination
Spinifex people NTDA
Pilki people NTDA
Yilka people NTDA
Ngaanyatjarra NTDA
Menu name: Parks and Reserves
Great Victoria Desert Nature Reserve
Neale Junction Nature Reserve
Yeo Lake Nature Reserve
Plumridge Lakes Nature Reserve
Queen Victoria Spring Nature Reserve
De La Poer Range Nature Reserve
Menu name: Bioregions
Great Victoria Desert
Shield GVD sub region
Central GVD sub region

To select these areas use the drop down menus as shown below

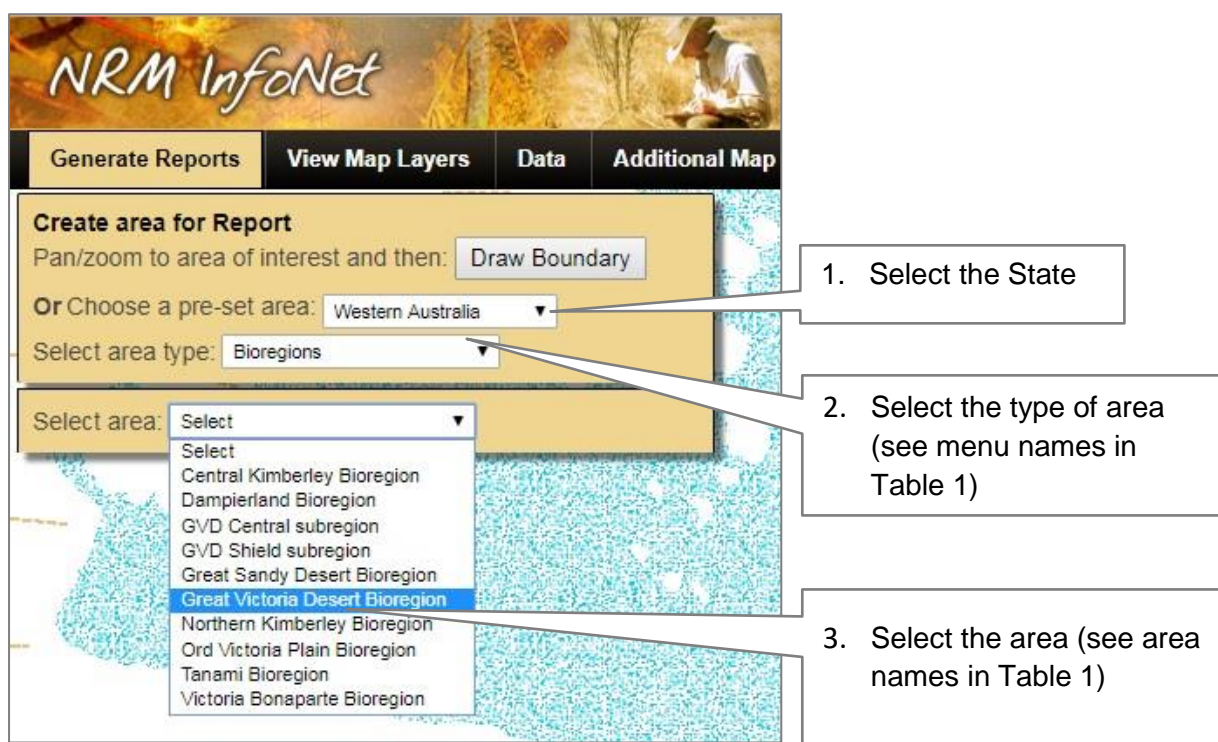


Figure 19. Selecting a pre-set area

Once you have made the final area selection the area should appear on the Infonet map in pink along with the report type options in the menu (Fig. 20). Select the "Fire History" report option on the left

(red arrow) and the Fire History Report options will appear below. (You can drag the map to better position the selected area.)

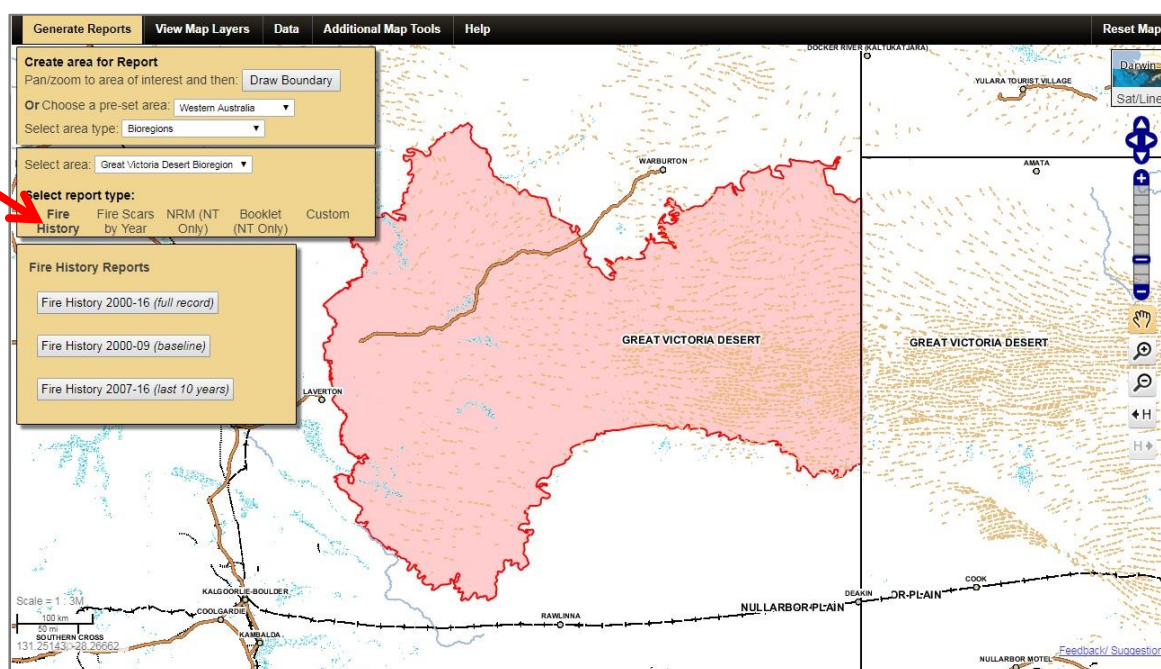


Figure 20. Producing a fire history report

The three fire history report options are for 2000-2016 (full record), 2000-2009 (baseline) and 2007-2016 (last 10 years). The first two options feature fire scar data created by this project.

Selecting one of the options should immediately trigger the download of a pdf report on that fire history. The pdf reports for each option have been pre-generated and are stored on the server. The report will have the following pages:

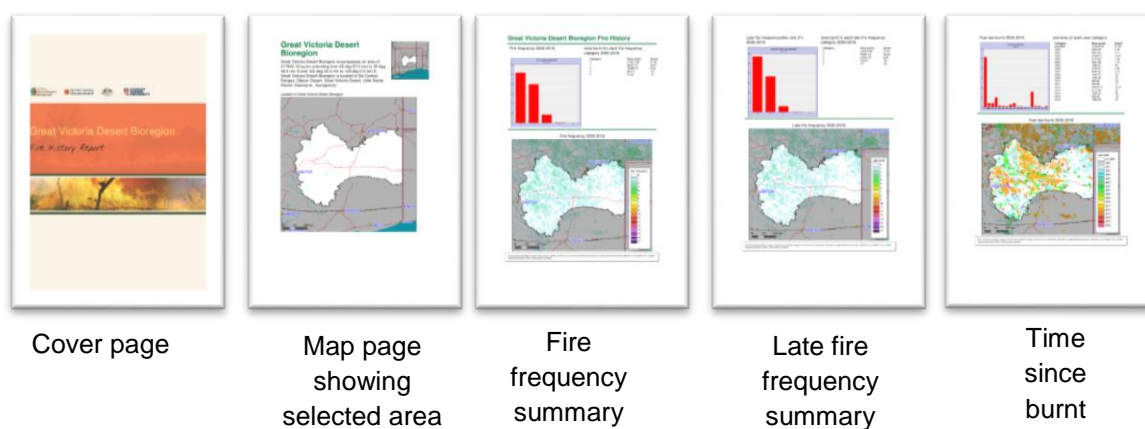
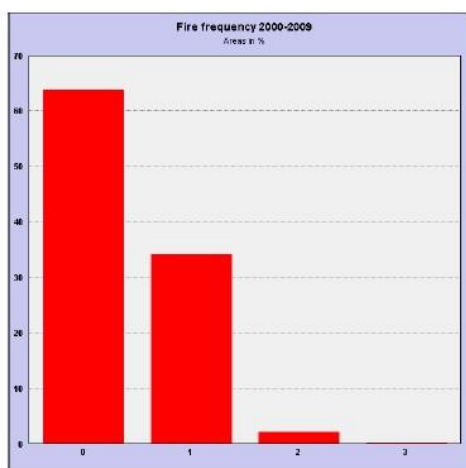


Figure 21. Pages of a fire history report

(There is also a final page outlining the limitations of the data.) Each fire summary page has a map of the fire history, and a bar graph and table showing the areas in square km subject to different fire frequencies or the areas last burnt in different years.

The three report types can be used to characterise how fire regimes are changing and to identify fire management issues. For example, for the Great Victoria Desert Bioregion we can compare the baseline fire frequency from 2000-09 with the most recent fire history from 2007-16 (Figs 22, 23). These periods overlap by a couple of years but do give an idea of how regimes are changing.

Fire frequency 2000-2009

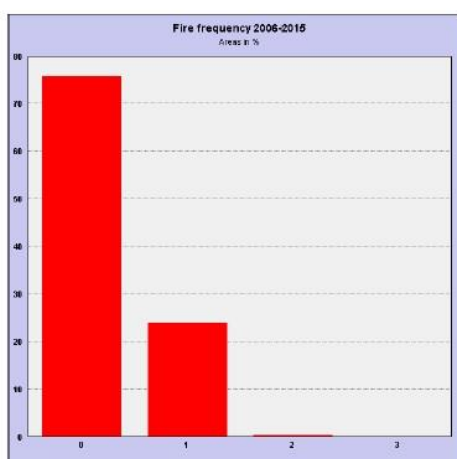


area burnt for each fire frequency category 2000-2009

Category	Area sq km	Area%
0	138792.27	63.68
1	74308.91	34.10
2	4648.87	2.13
3	192.13	.09

Figure 22. Areas burnt in the GVD Bioregion with different fire frequencies 2000-2009

Fire frequency 2007-2016



area burnt in each fire frequency category 2007-2016

Category	Area sq km	Area%
0	165227.95	75.81
1	51939.07	23.83
2	774.27	.36
3	.89	.00

Figure 23. Areas burnt the GVD Bioregion with different fire frequencies 2007-2016

These analyses show some broad patterns:

- In both 10 year periods most areas (63% and 75% of the total GVD Bioregion area) were unburnt with a smaller area being burnt once (25% and 34%). Much smaller areas were burnt two or three times in both periods.
- More areas in the bioregion were burnt in the baseline period (36%) than the most recent decade (24%)

We can also use the “Fire Scar” report to look at how much area in the bioregion was burnt in each year (Fig 23).

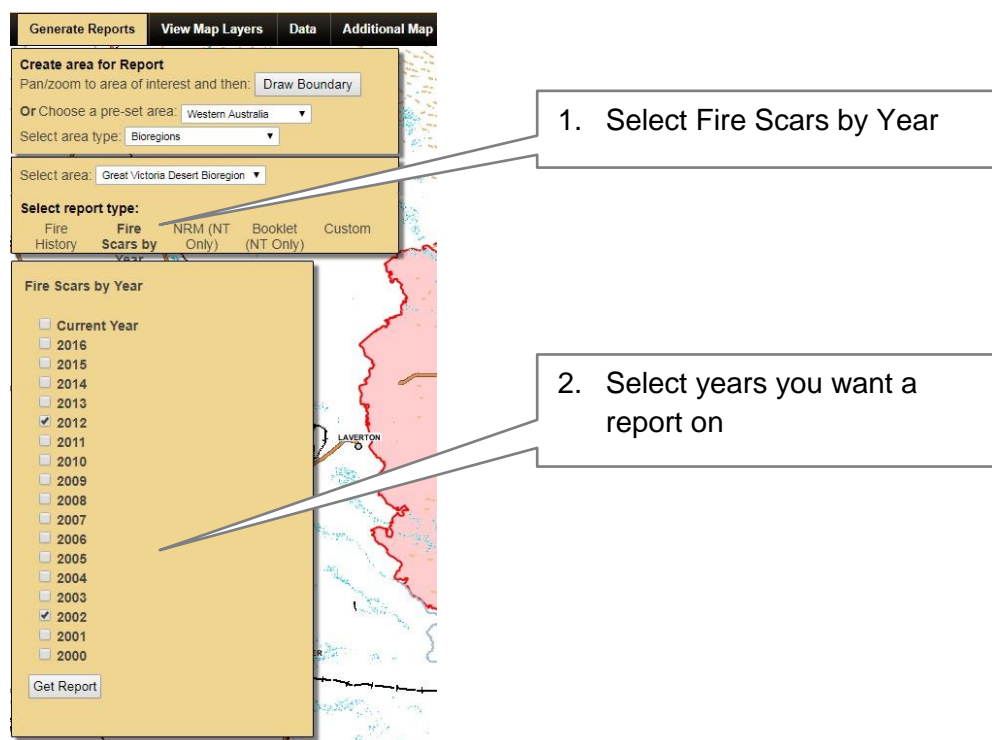


Figure 24. Producing a Fire Scars by Year Report

You can produce a Fire Scars by Year report for more than one year and it will have the following pages:

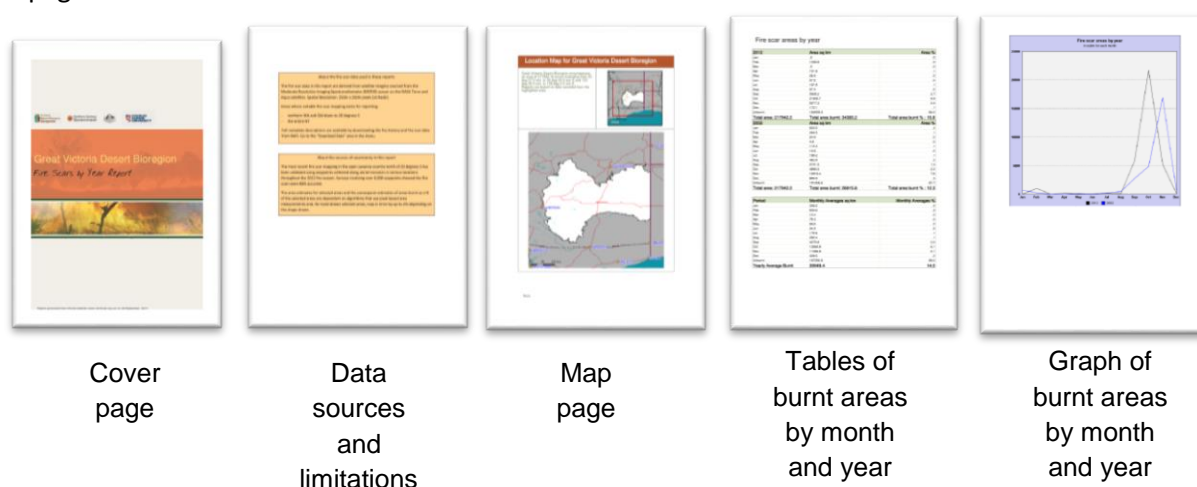


Figure 25. Pages of a fire scar by year report

From the graph page we can extract the area burnt in each year across the GVD Bioregion, and if we do this for each year from 2000 we get the following figures.

Table 2: Areas burnt each year in GVD Bioregion

Year	Area Burnt (km ²)
2000	17,758.0
2001	12,908.2
2002	26,915.6
2003	3,524.0
2004	2,650.2
2005	2,014.8
2006	6,667.7
2007	9,288.4
2008	1,184.0
2009	1,321.8
2010	593.3
2011	384.8
2012	34,383.2
2013	2,113.4
2014	1,995.0
2015	336.4
2016	1,888.9

2010-11 La Nina

- The greater areas burnt in the baseline period in the bioregion reflect the three years of extensive fires in 2000, 2001 and 2002. By contrast, the most recent decade has seen some years with very low fire extents: 2010, 2011 and 2015. This pattern was probably affected by the strong La Nina conditions that produced higher rainfalls in this region in 2010 and 2011.
- The very extensive 2012 fires may in turn have been influenced by the high rainfall in 2010 and 2011 in this region which may have produced more vegetation growth.

An issue of interest here is the potential impact of unusual weather events that may occur infrequently. The intense 2010-11 La Nina may have helped produce the extensive 2012 fires in this region. How long before another such event is expected? Will the frequency of such events and of the resulting extensive fires be affected by climate change?

Concerning the location of these fires in the GVD Bioregion we can look at the map of fire frequency (Fig. 26) and time since last burnt (Fig. 27) for 2000-16:

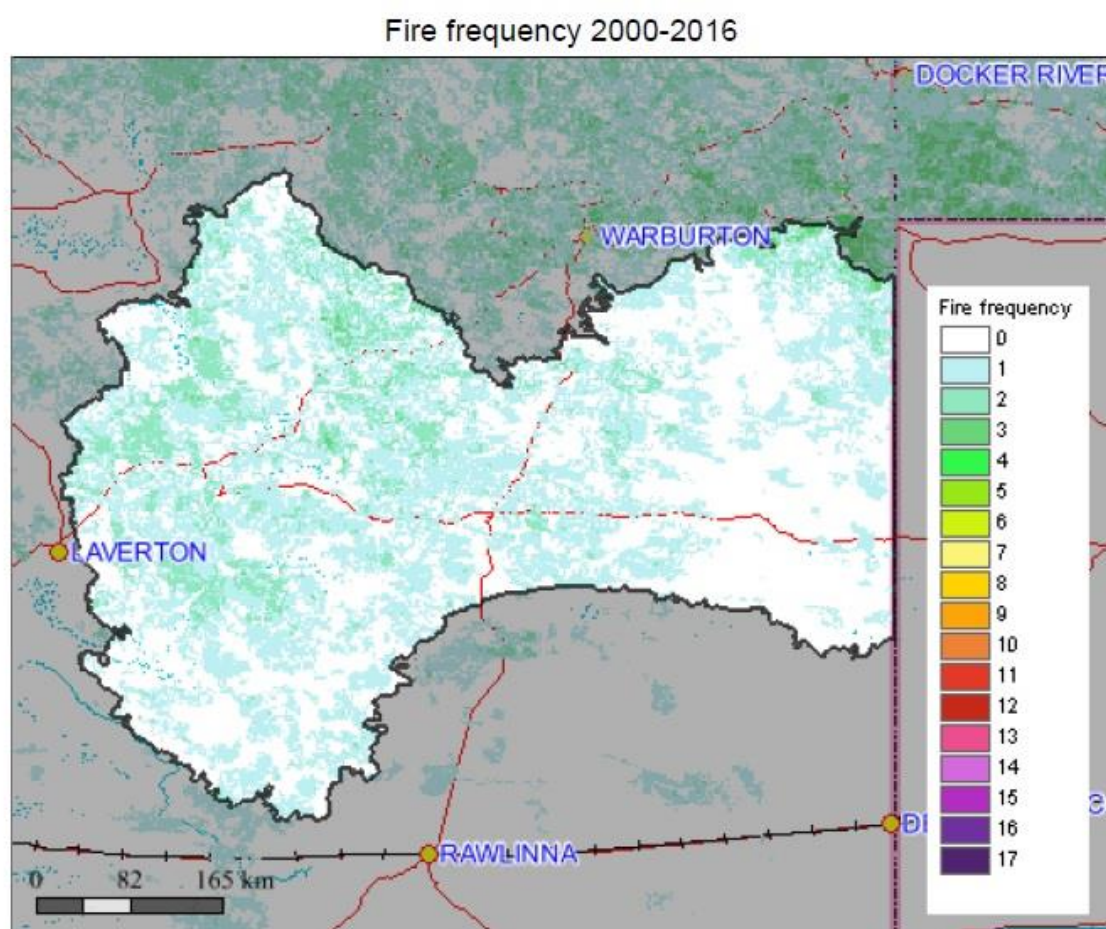
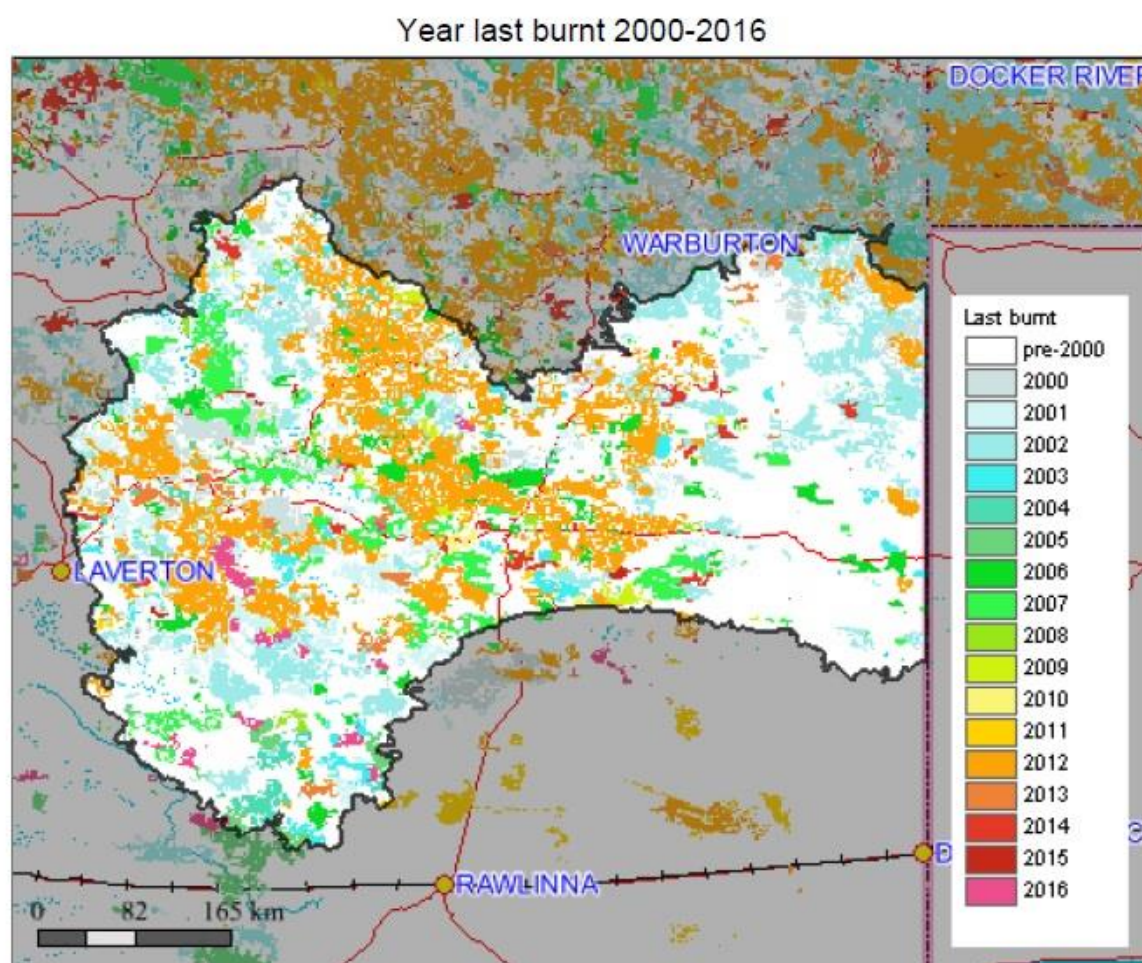


Fig. 26 shows the most fire-prone areas are in the western part of the bioregion. This pattern is seen in both the 2000-09 and 2007-16 periods and may be related to long standing settlement, vegetation and weather patterns.

Over this longer period we see a greater percentage of areas being burnt once (40%) and twice (8%) than for the 10 year periods above, but these frequencies can be difficult to interpret – might many of these areas burnt twice have a 10 year gap between fires? (i.e. between the large 2002 and 2012 fires?). It can often be best to focus on smaller areas and look at fire scar patterns from individual years.

The time since last burnt map (Fig. 27) for the bioregion shows a significant area of the region was last burnt in 2012. Weather records also indicate above average rainfall across much of the region since 2012, so an extensive fire in the near future may be possible which could increase the fire frequencies across the region significantly.



If we look at the months that were burnt in the years with the four greatest fire extents in the GVD (2000, 2001, 2002 and 2012 – see Table 2) shown below in Fig. 28, we see that the most fires burn in the months September – January: in the spring and early summer. So it is worth carefully monitoring fires in these months. Currently, for example, the NAFI site shows a fire spreading north of Lake Yeo (Fig. 29) which may be a sign of things to come given the extensive fires occurring across the arid zone this year.

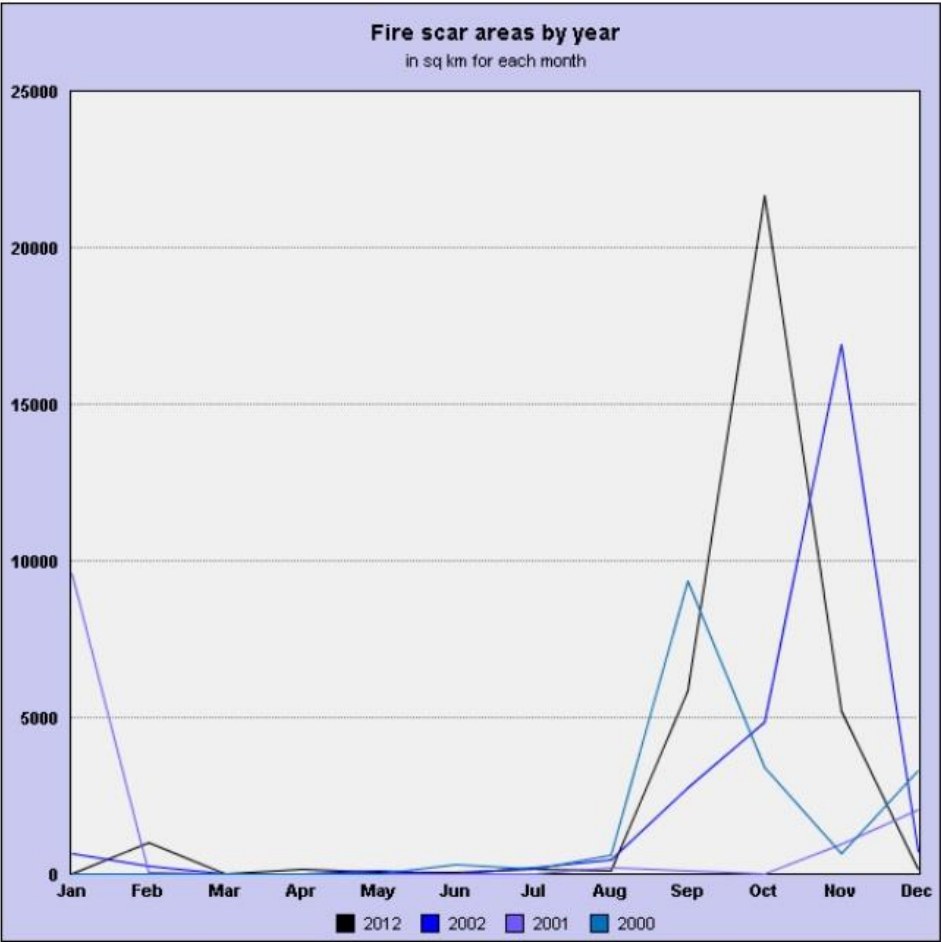


Figure 28. Months burnt for the four most extensive fire years in the GVD Bioregion

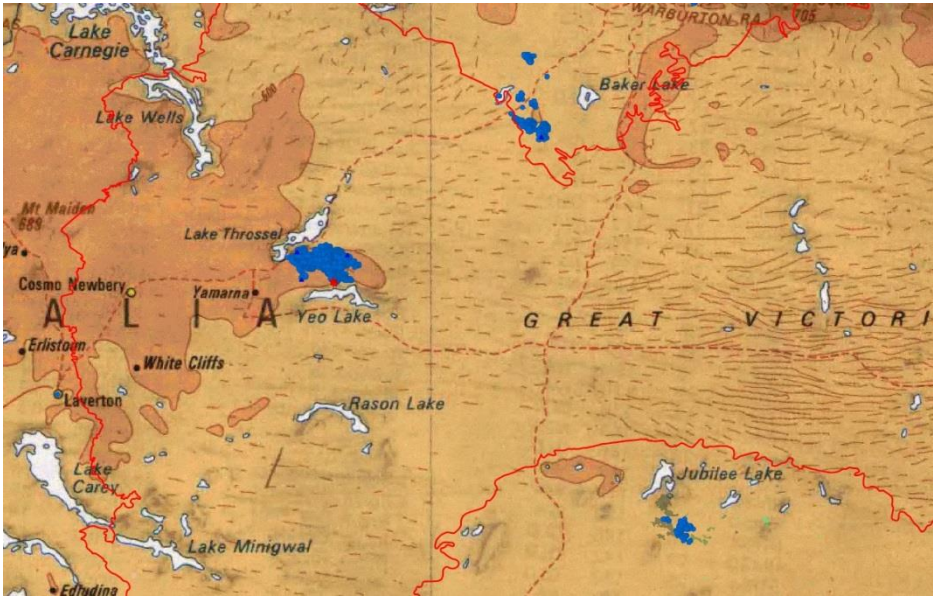


Figure 29. Current Fires (Sept 28th 2017) in the GVD Bioregion

Regarding the other areas in Table 1, broadly similar fire patterns are seen and the following points can be made:

- The northwest areas such the large Ngaanyatjarra NTD have somewhat higher fire frequencies.
- The southwest areas such as the GVD Nature Reserve and the Spinifex NTDA have reduced fire frequencies
- Fire frequency declines significantly once you move west away from the Great Victoria Desert into the pastoral zone

A more detailed analysis of the fire patterns in these areas is best left to people who have a good understanding of the country and fire ecology and who can use these data and the NAFI site and other tools to good effect.

6. Help and Instruction

The instructions above allow Anglogold to access and verify the outputs produced by the project and to see how they can be used. Most users of these data, however, will want to use them in combination with the other data and tools available in the NAFI and Infonet websites. Comprehensive pdf help guides are available for both sites.

The NAFI site pdf help is at:

http://www.firenorth.org.au/nafi3/views/help/Help_pdf.html

The Infonet report site pdf help is at:

http://www.ntinfonet.org.au/infonet2/views/help/Using_site.pdf

7. Issues and Lessons learned

The issues and lessons learned concern the complexity of arid zone fire scar mapping. For example, as mentioned in the methods section, when sparse vegetation on highly reflective sandy landscapes are burnt the fire initially produces a darkening and reduced reflectance due to the burnt vegetation, but then the vegetation can be blown away and the now exposed bare sand produces an increase in reflectance. In tropical northern Australia, where the majority of fires occur and where most mapping is carried out, fires generally produce a reduction in reflectance so a new system has to be implemented for much arid zone mapping to take account of this behaviour.

The accuracy of the mapping is also improved by feedback from fire managers on the ground and in the case of the areas in this report, there is a sparse population of fire managers and most are not networked in with NAFI yet. So we have had little feedback on the mapping. This situation should

improve as more people start to use the maps. This underlines the point that the mapping is open to continual improvement in the years after the initial mapping of a new area.

8. Knowledge Gaps

The knowledge gaps in this project mostly concern the limitations of the fire scar data outlined above:

- There may be some missed or anomalous fire scars which can be corrected
- The 250m resolution of the fire scar data will not show finer scale patchiness which can be useful to gauge the impacts of fire on vegetation. So while the 250m fire scar mapping can be useful in managing and planning for current fires, and in identifying areas of concern, if you want to gauge impact on vegetation it is useful to carry out finer-scale mapping (e.g. from Landsat/Sentinel 2 imagery) or carry out on-ground inspections.
- One point that is brought home to us time and again is that most of the knowledge needed to manage fire in these landscapes is not in these data but in the local knowledge of the country and how it responds to fire in different conditions. So the additional fire data needed should be driven by this local knowledge.

9. Data Sensitivities

These data will produce most benefit if they are shared broadly among all fire managers, so we do not usually apply any restrictions. In many cases the data used will be a combination of fire scar data that involves a number of IP stakeholders including, for example Rangelands NRM and The Federal Government. Formal data sharing agreements that include that data produced in this project may be useful in the future to enable sharing of a range of fire related spatial datasets.

10. Recommendations for Future Work

As mentioned above future work in this area should be driven by feedback from local fire managers. Some possible options include:

- Continued feedback from local fire managers to improve the fire scar data and digital tools
- Higher resolution (Landsat/Sentinel 2) fire scar mapping to assist gauging the impact of fire on vegetation in selected areas
- Provision of higher resolution fire scar imagery to assist operational management of fire. An example of a prototype system is shown here: http://www.firenorth.org.au/nafi3/views/about/Landsat_download.htm but future systems would involve direct transmission of imagery to portable devices.
- Use of open-source software tools to help arid zone fire managers access and customise fire mapping data

- Information sharing on useful tools for arid zone fire management e.g. see <http://www.firemanager.org.au/>
- Training for arid zone fire managers in the use of fire spatial data and digital tools.

11. References

- FISHER, R. and EDWARDS, A.C., 2015. Fire extent and mapping: procedures, validation and website application. *Carbon Accounting and Savanna Fire Management*, edited by: Murphy, BP, Edwards, AC, Meyer, CP, and Russell-Smith, J., CSIRO Publishing, Melbourne, Australia, pp.57-72.
- MAIER, S. W. 2010. Changes in surface reflectance from wildfires on the Australian continent measured by MODIS. *International Journal of Remote Sensing*, 31, 3161-3176.
- PEREIRA, J. M. C. 2003. Remote sensing of burned areas in tropical savannas. *International Journal of Wildland Fire*, 12, 259-270.