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Fire severity mapping and dense forest stands

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Contents

1 Summary

This project demonstrates the ability to apply the burn severity mapping process developed in Densmore et al., (2023) on a broad spatial and temporal scale. An archive of severity maps, that covers the Perth Hills district, has been created that can be used to produce a number of detailed, novel datasets, such as “severity of last burn”, “number of severe burns” and “maximum severity”. Additionally, datasets such as “years since last burn” and “fire frequency” can be created utilising mapped burnt areas, rather than treatment area, as has been available in the past.

The utility of this archive of severity maps was put to the test to examine the influence of silviculture, and more specifically, dense forest stands that are candidates for ecological thinning. No broad scale relationship was found between dense forest stands and fire severity. However, in one catchment for one fire, a relationship existed, but this is not systematic enough to be conclusive. A lack of precision was identified in the dense stands dataset. Attempts were made to correct this using satellite imagery as a reference, but even with the improved silviculture boundaries no relationship to severity was found.

There did seem to be a strong relationship between burn severity in one prescribed burn and severity in a prescribed burn seven years earlier. In this case unburnt areas from a 2014 burn, generally burnt to a very high level in 2021. It must be stressed that this is only one occurrence that has been tested, but it certainly is an interesting result that warrants further investigation.

The biggest challenge in the project relate to data management, data dissemination and efficient analysis workflows. These elements will be the focus of further code development. Further research which is required into the modelling component include:

- quantifying the positional accuracy of the burnt/unburnt boundary;
- testing the influence of the time between the fire date and first post fire image;
- assessing severity accuracy within specific ecosystem types;
- expansion and validation of heath mapping; and
- model development, including field data collection, in additional Ibra regions.

2 Introduction

The DBCA-060 dataset is a spatial compilation of fire events that have occurred mostly on, but not limited to, state-managed lands in Western Australia (WA). The data include both wildfires (WF) and prescribed burns (PB), with the earliest fire records dating back to 1937. While it is not complete, the dataset is a comprehensive and twice-yearly updated source of information for fire management across the State.

There are many potential applications of the dataset, such as for use in fire risk assessment, fire ecology research, fire management planning, and climate change research. However, while the DBCA-060 dataset is a great source of valuable information, it has also been collated over many years, using various methods and inputs, resulting in varying levels of accuracy. Furthermore, many PB records capture treatment boundaries, rather than actual area burnt, leading to overestimated burn areas (by ~28%; Dixon et al. 2022) and underestimated fire intervals. Despite this, DBCA's fire history has been used in several fire related publications since its public release in December 2018, demonstrating its necessity and highlighting the need to improve its level of accuracy.

In 2022, Zylstra et al. used the DBCA-060 dataset to explore forest flammability in relation to time since last fire and fuel load. They used 55 years of records to test the hypothesis of a forest flammability peak between 7 and 56 years since last fire and infer important management recommendations. The dataset was filtered down to 528 343 ha of burns between 1964 and 2018, located in forested areas of National Parks across four IBRA subregions (Perth, Northern, and Southern Jarrah Forest, and Warren). No further filter was applied to the dataset, leading to a broad array of burn polygons, significantly decreasing in size and frequency along the time since last fire gradient.

Campbell et al. (2022) replicated Boer et al.'s study from 2009, which also employed the DBCA fire history dataset, to examine the effect of conducting prescribed burns on the probability of experiencing a large wildfire (> 1 000 ha). Campbell et al. (2022) used DBCA-060, cropped to the extent of the DBCA's PB land management zone (DBCA-059), across four bioregions (Perth, Northern, and Southern Jarrah Forest, and Warren) from 1953 to 2020. By comparison, in their initial study, Boer et al. (2009) focused on the Southern Jarrah Forest and Warren bioregions, from 1953 to 2003. Campbell et al. (2022) findings, while contradicting those of Boer et al. (2009) as they did not find a significant negative relationship between PB and WF, suggested that a more complex mosaic of patches and fire ages in the landscape were key to reducing large wildfire probability.

Keith et al. (2022) also used the DBCA-060 dataset as part of their assessment of the 2019-2020 Australian megafire impact on ecosystems. Their findings identify high fire frequency as a key threat to many ecosystem types which emphasize the need for an accurate and up to date State fire record, and providing a baseline for conservation research.

Fire severity modelling

The increased availability of satellite imagery and development of analytical tools has advanced applications in landscape change analyses. In fire severity modelling approaches, satellite imagery is used to generate spectral indices that relate to vegetation, soil, or moisture reflectance attributes, which are then measured against severity scores independently assigned to burnt sites.

In this study, the changes in the spectral index Normalized Burn Ratio (NBR) were measured against Oz Composite Burn Index (OzCBI) values. The OzCBI is a ground measure of fire severity adjusted to the southwestern Australian flora and fauna habitat, from the fire severity score GeoCBI (De Santis & Chuvieco, 2009, Densmore et al., 2023). Other spectral indices exist that can be used individually in simple regression models, or combined, in machine classifier models like Random Forests (RF), as in Dixon et al. (2022).

In their study, Dixon et al. (2022) used the DBCA-060 dataset to identify the location of fires across the Northern Jarrah Forest IBRA subregion, then utilised a RF model and a range of 8 Landsat-derived spectral indices, including a differenced NBR (dNBR) to predict fire severity. They filtered the DBCA fire history down to 713 burns by age, type, bioregion, and surface area and masked out all non-forested areas. They additionally narrowed down burn dates using MODIS data. Their model was trained using 11 000+ Landsat pixels from 64 unique burns, manually labelled as one of five fire severity categories. Such a large training dataset typically meets the requirements of RF models, if evenly distributed among severity classes (Collins et al., 2020). Labelling was interpreted from high spatial resolution (3.5-7 cm) post-fire aerial imagery, however, below canopy changes can typically reduce the prediction accuracy of low and medium severity classes (Collins et al., 2020).

While fieldwork is generally resource-intensive, it can provide a more detailed assessment of burn sites in all strata. In this study, a total of 778 sites spread among 34 burns were visited and systematically sampled within 12 months post-fire and assigned an OzCBI value (Densmore et al., 2023). The training data was regressed using a quadratic model against dNBR values, calculated from a pre-burn NBR raster and a maximum difference post-burn composite raster. This allowed the capture of all changes due to fire, such as in multiple ignition PB, that can typically be conducted over several months. The lowest recorded post-fire NBR value at each pixel was subtracted from pre-fire values to produce a maximum dNBR composite raster (Densmore et al., 2023).

Finally, to compensate for non-fire induced change in vegetation, such as phenological or seasonal variations that can occur over months-long periods and decrease prediction accuracy, the use of an offset spectral index value is recommended and applied in this study (Collins et al., 2020; Miller et al., 2023).

3 Methodology

A semi-automated workflow was developed to systematically map fires in southwestern Western Australia. This process is divided into two main branches:

- a historical branch, using Landsat 5-8 satellites and using DBCA-060 fire history dataset as a baseline to work from,
- an operational branch, that uses Sentinel 2 satellite to map the fire severity of prescribed burns as they are being conducted each season.

The general common workflow for these two branches is explained in this report. The detailed model development and research underlying the mapping process can be found in the “OzCBI Burn Severity Mapping Technical Guide v1.2”. All automated parts of the process are conducted using a sequence of R scripts with RStudio Version 1.4.1103 (RStudio Team, 2020).

Study Area

The project initially targeted the Northern Jarrah Forest IBRA within the Perth Hills district and then progressed south to the Wellington district to answer the needs of several ongoing research projects (Figure 1). Time coverage is from 1988 to 2023 for the Perth Hills district and from 2018 to 2023 for the remainder of the Swan region and 2021 to 2023 for the South West and Warren Regions.

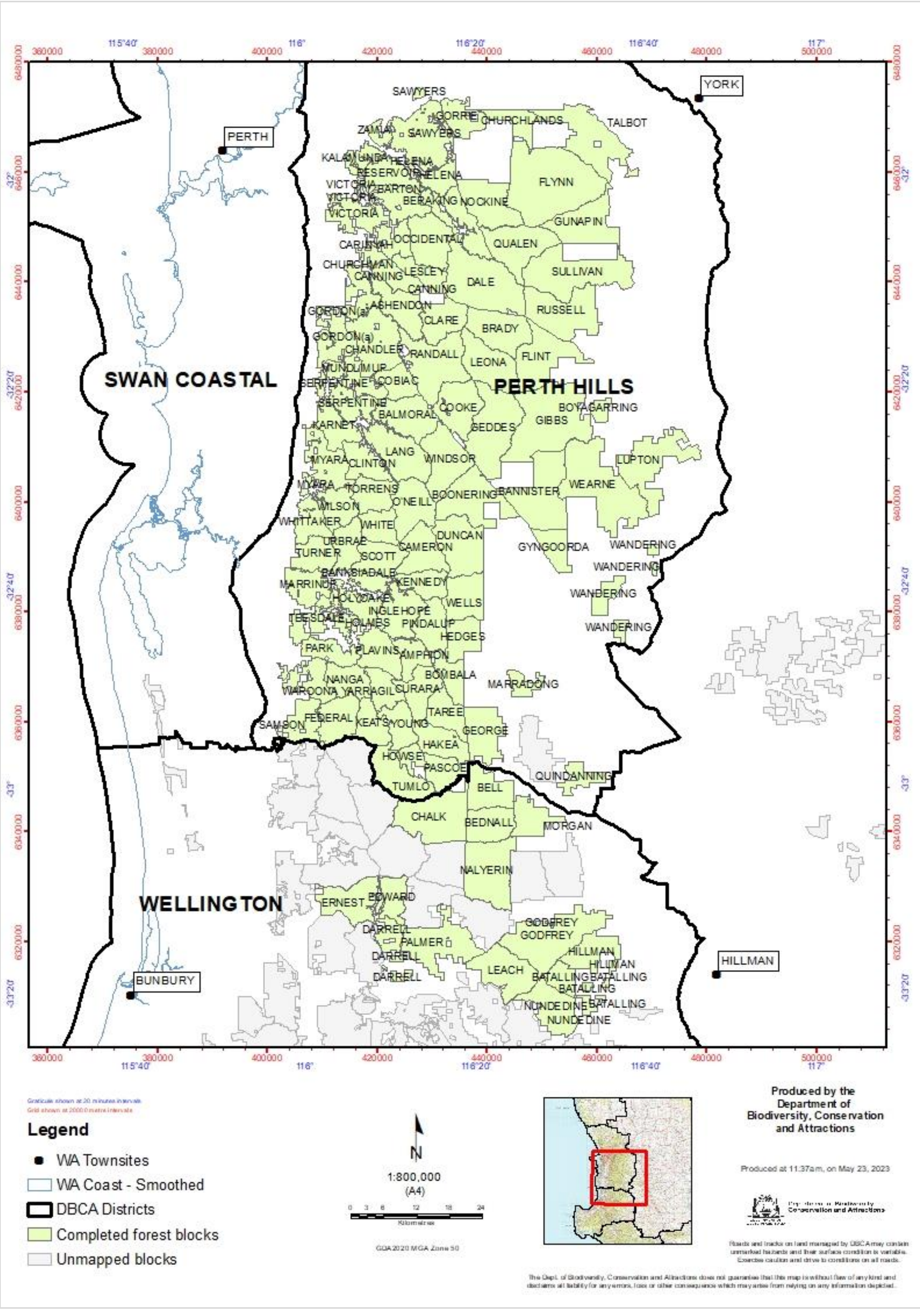


Figure 1: Focus area showing completed forest blocks (blocks for which fire severity has been mapped between 1988 and 2023) in green and unmapped blocks in grey. The mapping process took place between September 2022 to May 2023.

Obtaining satellite data

Satellite imagery was downloaded from the Geoscience Australia platform, Digital Earth Australia (DEA) (https://app.sandbox.dea.ga.gov.au/), using a multi-polygon shapefile of all fires for a selected area combined to a csv document listing each burn's unique ID, start and end date. A flowchart of the general process is shown in Figure 2.

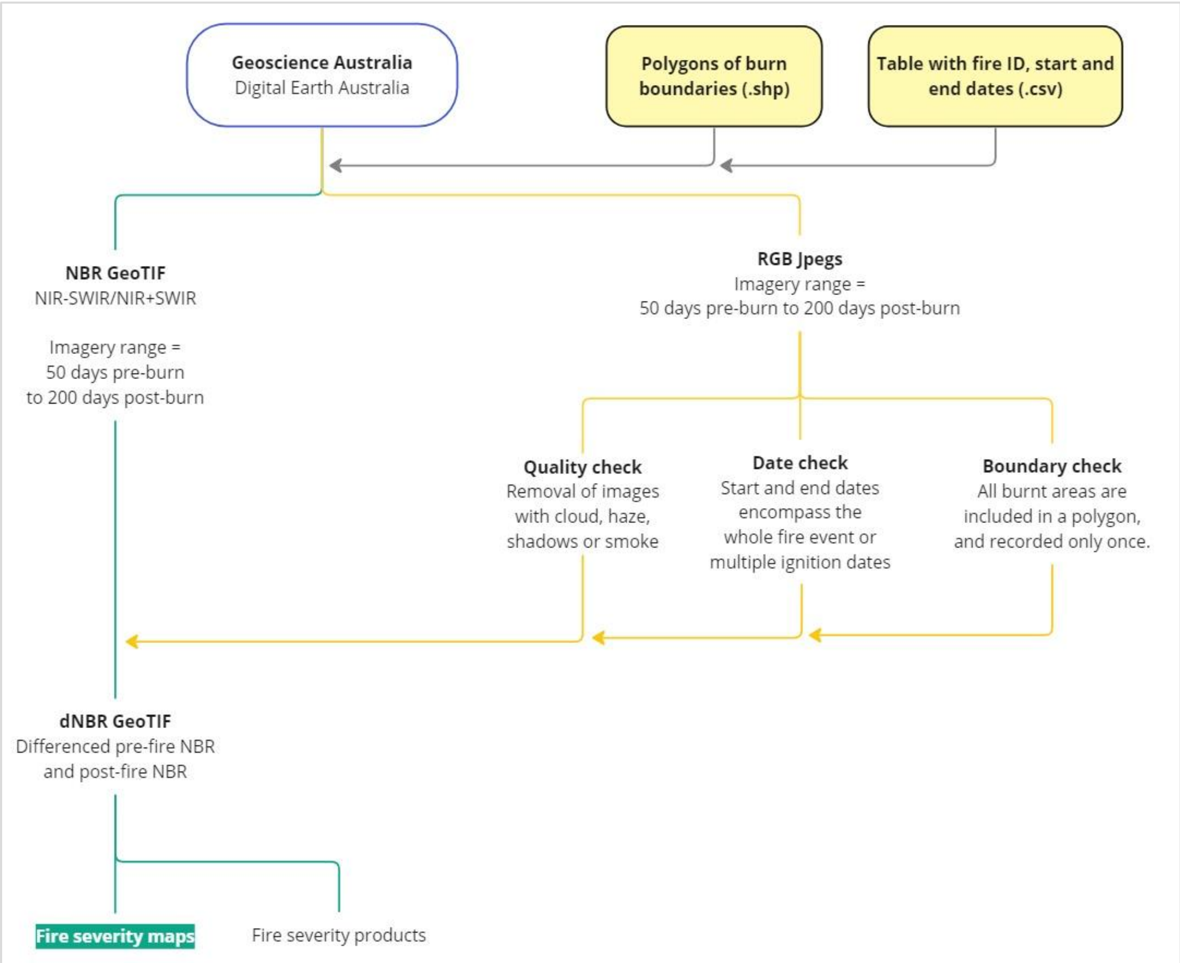


Figure 2: Flow chart of mapping fire severity for southwestern Western Australia using Sentinel 2 or Landsat 5-7 imagery.

The DBCA forest block dataset was used to systematically select fire records from the DBCA-060 fire history and progress through the Department districts. In the polygon (fire boundary) selection process, a unique ID was generated and assigned to each record of the fire history, using each polygon's district name, recorded year, and centroid coordinates. A unique ID check ensured that a polygon overlapping more than one forest block was only selected and mapped once.

From the selection of polygons for each block, a shape file was created and used to obtain all available imagery at each burn location for a buffer period of 50 days prior to start date and 200 days post-end date. Once downloaded, the imagery was extracted and organised per burn ID. For each burn ID, a sequence of georeferenced NBR Tifs and corresponding red, green and blue (RGB) GB picture in Jpeg format were available (Figure 3).

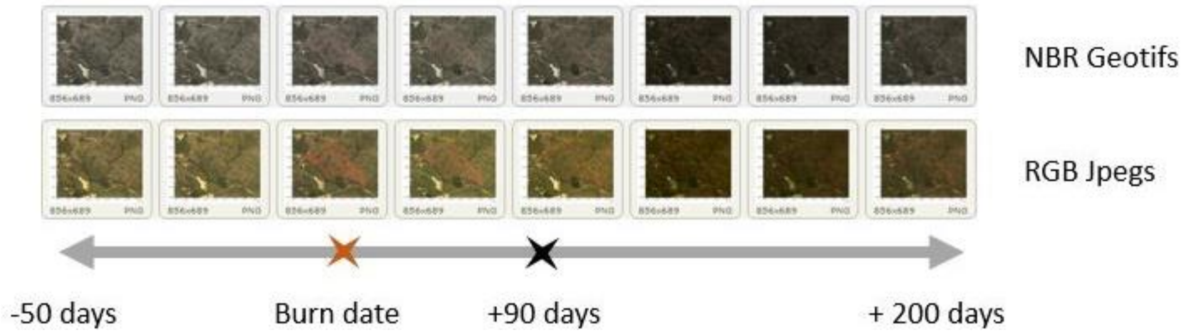


Figure 3: Time frame and format of downloaded content for each record of DBCA-060 fire history, from Digital Earth Australia.

Cleaning and preparing the data

Cloud removal

Red, green and blue pictures were used to browse the imagery and thoroughly remove any capture containing clouds, haze, shadows or smoke (Figure 4).

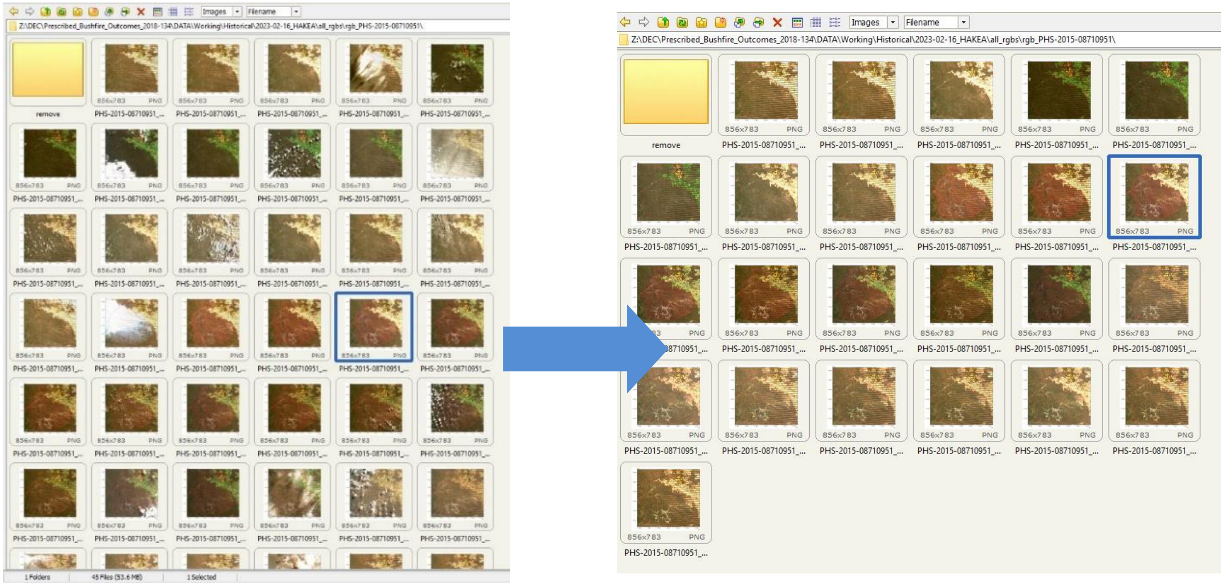


Figure 4: Cloud removal process, leaving a sequence of clean, exploitable imagery for each burn.

Date check and phenological adjustment

The date of burn event was checked against the recorded date found in the DBCA-060 fire history document. If inaccurate, it was updated in the associated csv document to match the date of the first image showing the burn. For multiple ignition burns conducted over several months, the end date (set by default to start date + 90 days) was manually overridden to include all partial burns for the fire event.

Pre-burn winter imagery was removed where needed, to minimize vegetation greenness difference between pre- and post-burn imagery. Post-fire summer images were matched to the February or March pre-burn images of the same year.

Boundary check

Polygon boundaries were systematically checked to identify and include any missing burnt patch, not already included in another burn (Figure 5).

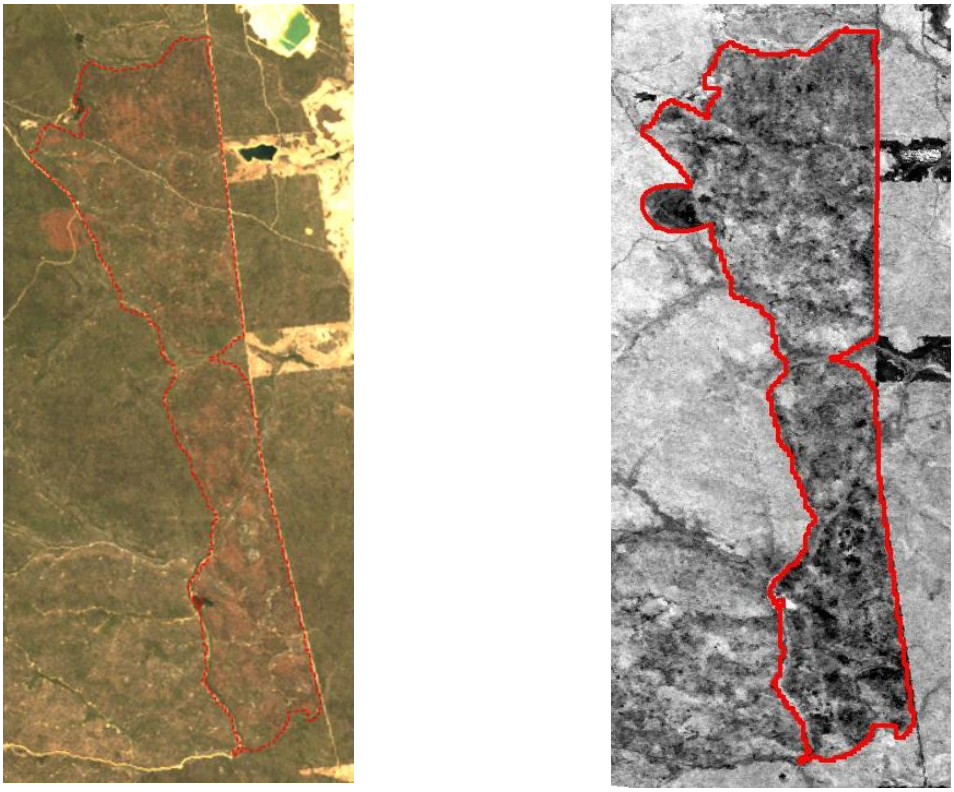


Figure 5: Left: pre boundary correction, and right: after boundary was updated to include the burnt patch in the northwest.

Producing a dNBR max image

A maximum dNBR composite image was created that used the GeoTif NBRs matching the selection applied to the RGB Jpegs, the updated csv table of burn dates as well as the updated boundaries. The composite image was created by subtracting the minimum pixel values of all the post-fire NBR images between the start and end dates from the pre-fire NBR pixel values (Figure 6).

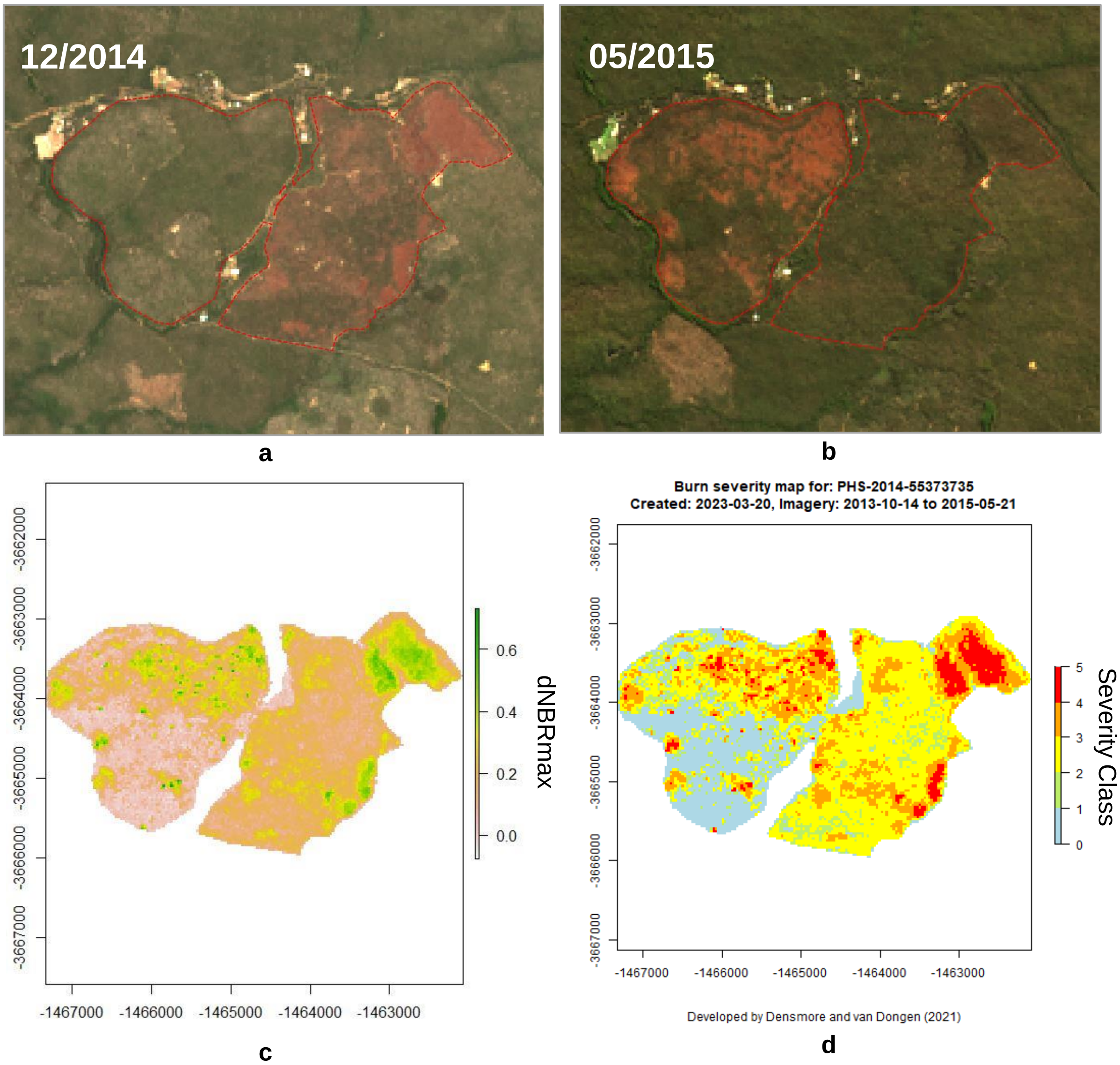


Figure 6: Multiple ignition prescribed burn, with a) first ignition in December 2014 and b) last ignition in May 2015. c) is the resulting maximum differenced NBR, and d) is the severity map calculated from it. Classes in the severity map range from unburnt (blue) to very high (red).

Seasonal correction

In southwestern Australia, prescribed burns are commonly conducted under moist conditions during spring and autumn, but cloud-free post-fire imagery for these events typically becomes available during dry periods.

To account for the change in greenness not due to fire, a 150 m buffer was delineated in the unburnt area around the fire polygon. The average NBR drop between the pre- and post-fire images in that buffer was then removed from the differenced NBR raster (Figure 7).

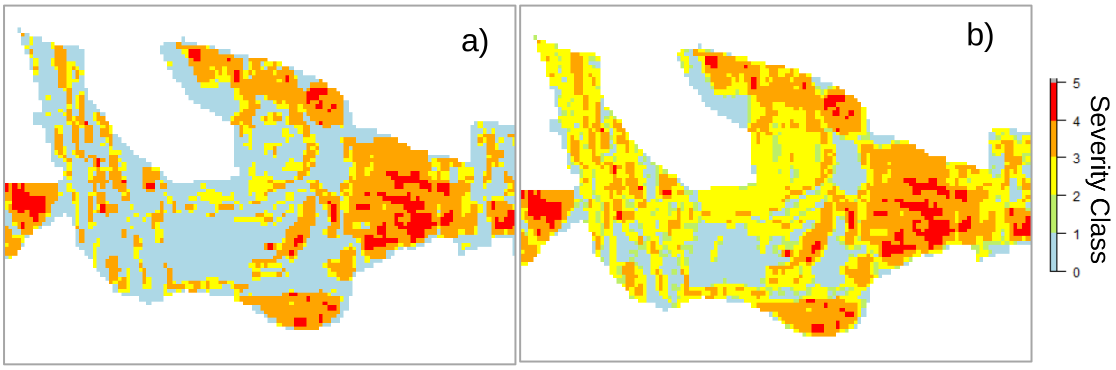


Figure 7: Severity maps with classes unburnt (blue) to very high (red). The versions shown are a) without the seasonal correction and b) after applying the correction. The corrected map has less unburnt and more low severity areas.

Silviculture

To examine the influence of dense forest stands on burn severity, a spatial dataset which delineated areas of dense regrowth was acquired. The delineated areas are an extract from the DBCA silvicultural Operations dataset. The dataset was created to help identify where ecological thinning could take place in the future. The dense regrowth dataset covers much of the Northern Jarrah Forest. An example within the Brady forest block is shown in Figure 8.

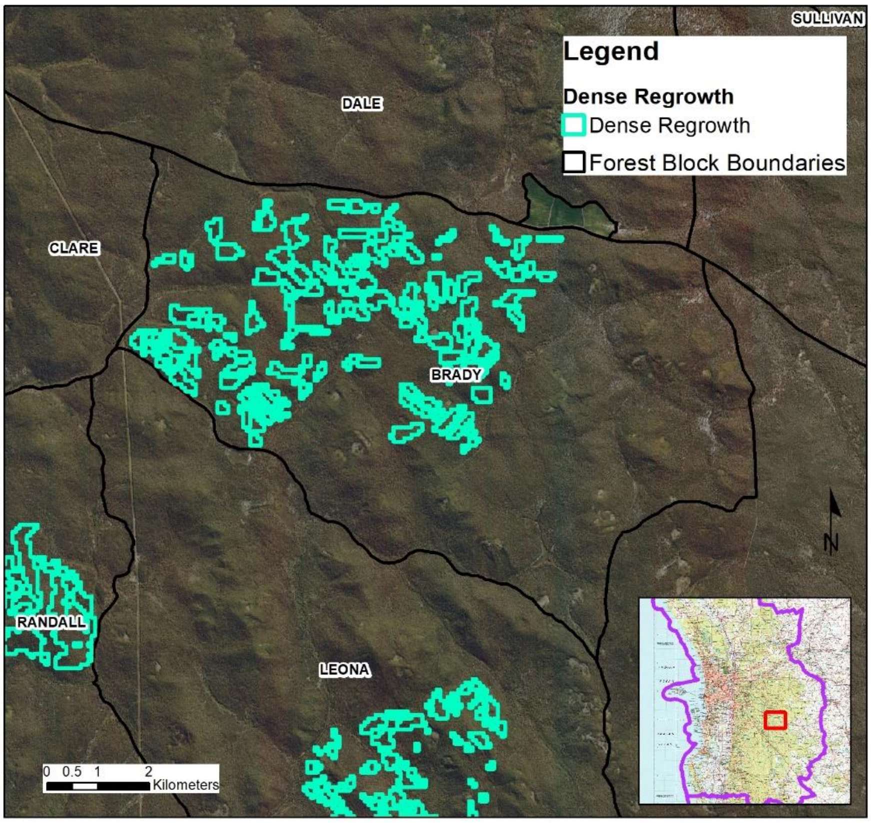


Figure 8: Dense regrowth stands in Brady forest block.

A buffer zone was created around the dense regrowth dataset. This was used as a reference area. The area of each burn severity class for all fires that have occurred within the areas of regrowth and the buffer zone was then calculated. These statistics were then split by year and by forest block.

The dense regrowth boundaries for Brady block were improved by examining historical silvicultural planning maps and Landsat imagery. This process is shown in Figure 9. The silviculture planning maps were georeferenced and compared to the dense regrowth layer and Landsat satellite imagery. The patterns evident in the Landsat imagery and the silviculture planning map were then used to manually delineate and classify treated, unharvested, and reserve areas within the forest block. Statistics relating to the area of each burn severity class within the silviculture classes were then calculated.

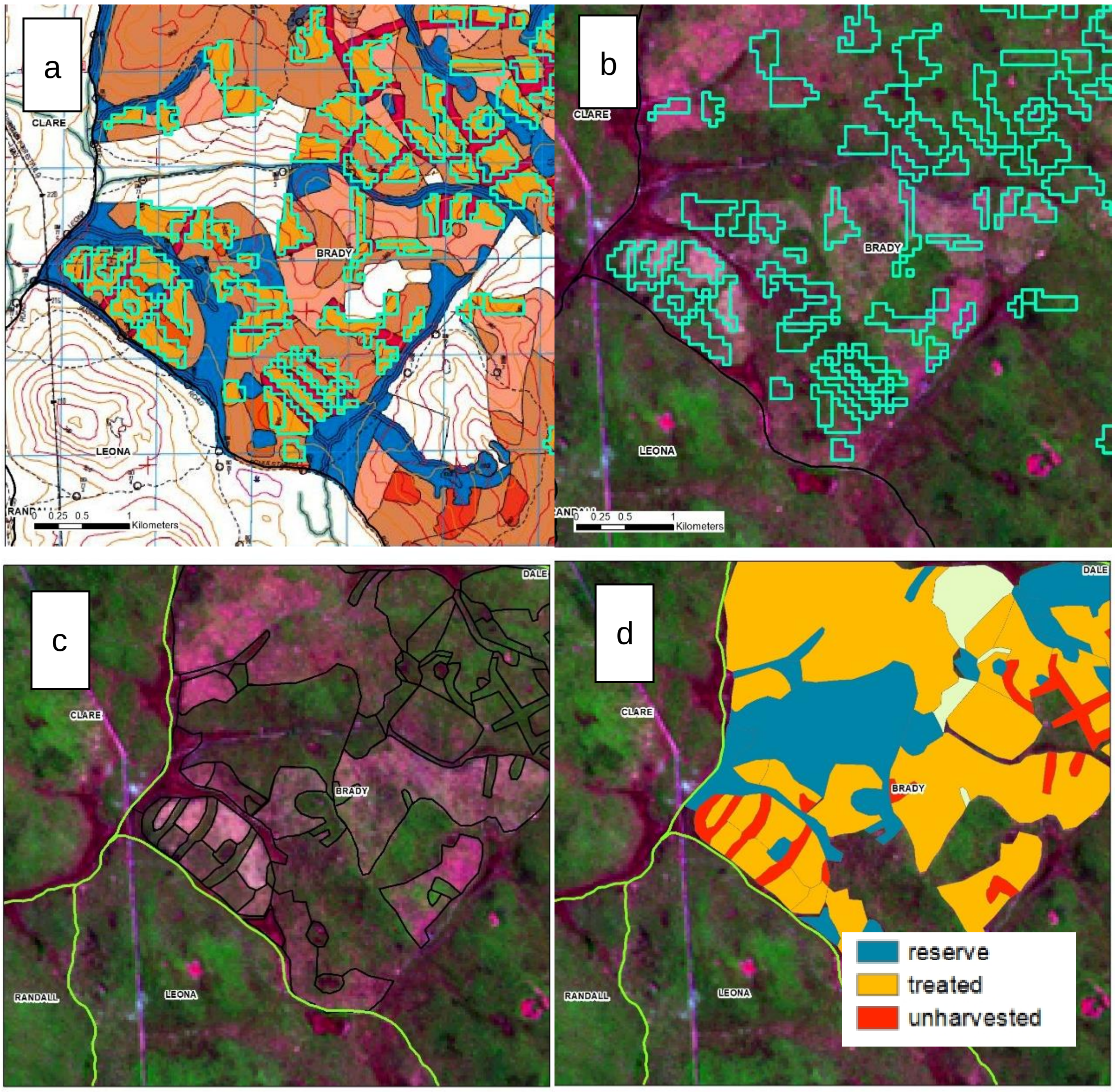


Figure 9: Improvement of silviculture boundaries. a) silviculture plan map with dense regrowth dataset in cyan, the dense regrowth areas correspond with the orange areas on the map., b) dense regrowth area with Landsat imagery, c) manual delineation of treatment boundaries with Landsat imagery and d) classified manually delineated treatments.

4 Results

Fire severity datasets

From the maps of fire severity, a series of datasets can be created. Here we present a selection of them, mapped for the Northern Jarrah Forest subregion, for data covering 1988 to 2022.

A “fire frequency” dataset is shown in Figure 10. This shows that a majority of the NJF has burnt less than 4 times in 36 years. It also shows a maximum frequency of 8 fires for the time frame, and some long unburnt (30+ years) pockets.

The “maximum severity” dataset is shown in Figure 11. This shows that large areas of the landscape in the subregion have been severely burnt at least once. In contrast, Figure 12, the “number of high severity burns”, shows that those high severity fires happened mostly once for the designated period (1988 to 2022).

A “severity of last burn” dataset is shown in Figure 13. This dataset could be used, in combination with a “years since last burn” dataset Figure 14 to perhaps model fuel accumulation.

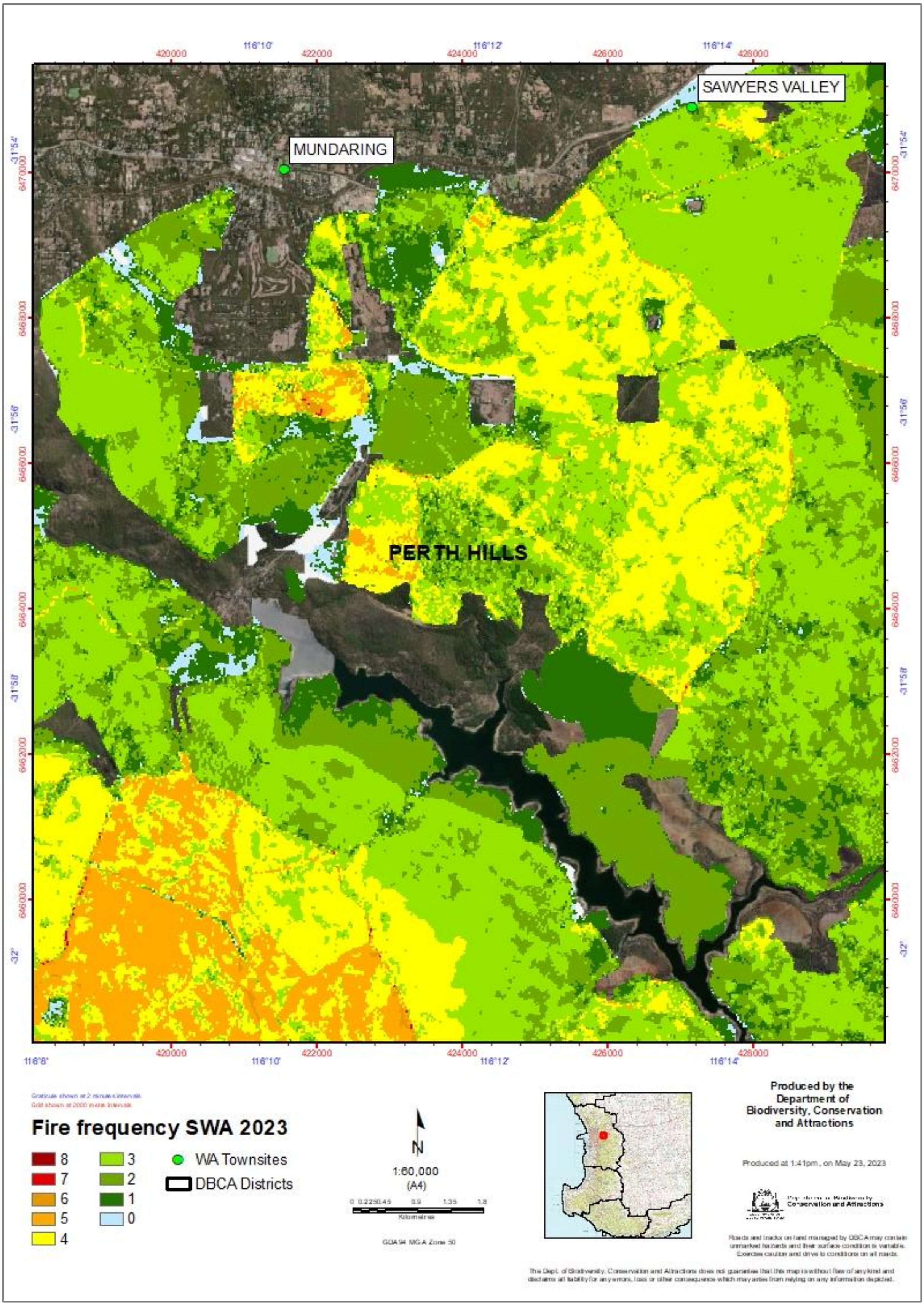


Figure 10: Prescribed burn and wildfire frequency for the Northern Jarrah Forest subregion, mapped for 1988-2023.

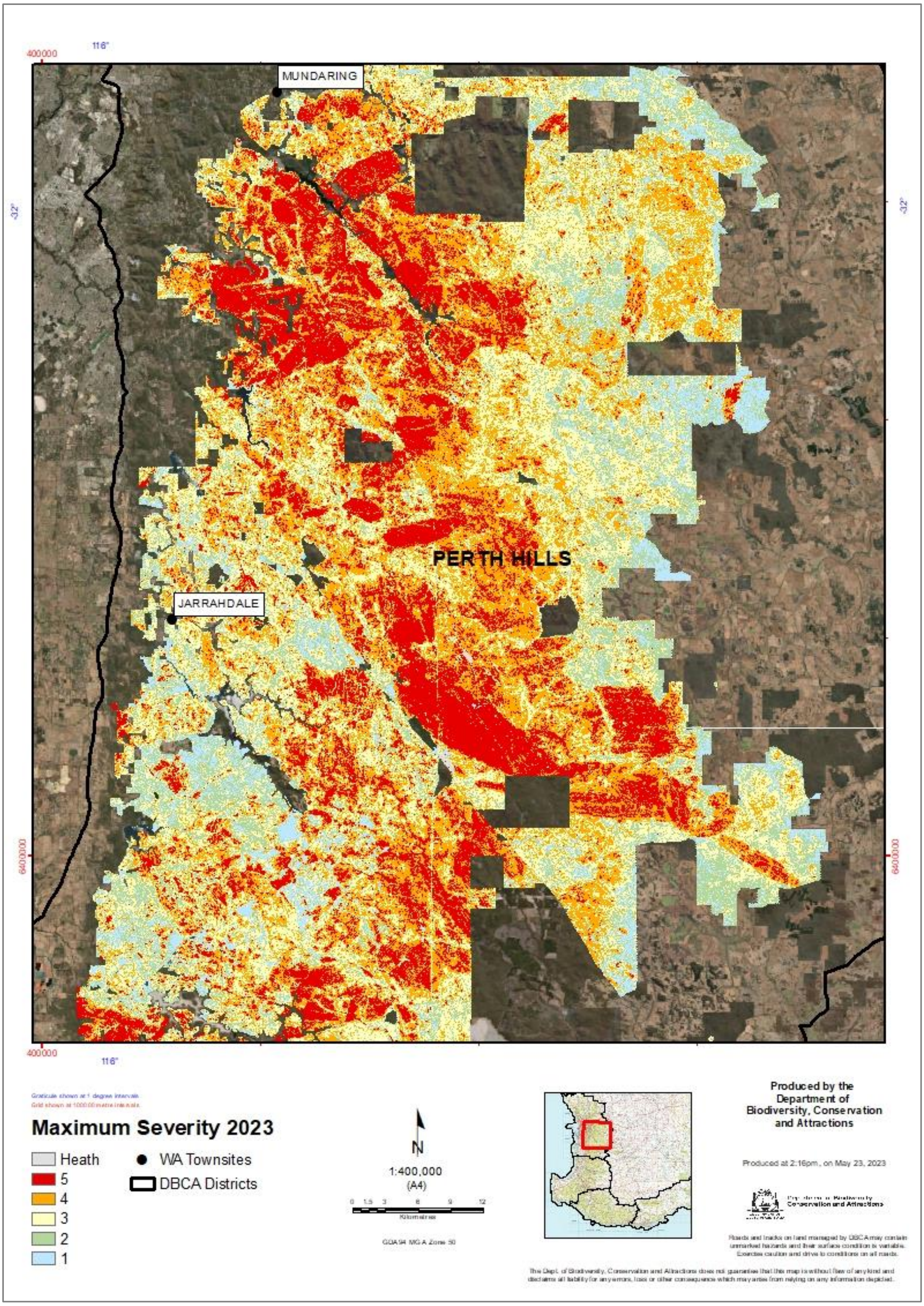


Figure 11: Maximum prescribed burn and wildfire severity mapped for the Northern Jarrah Forest subregion, between 1988-2023.

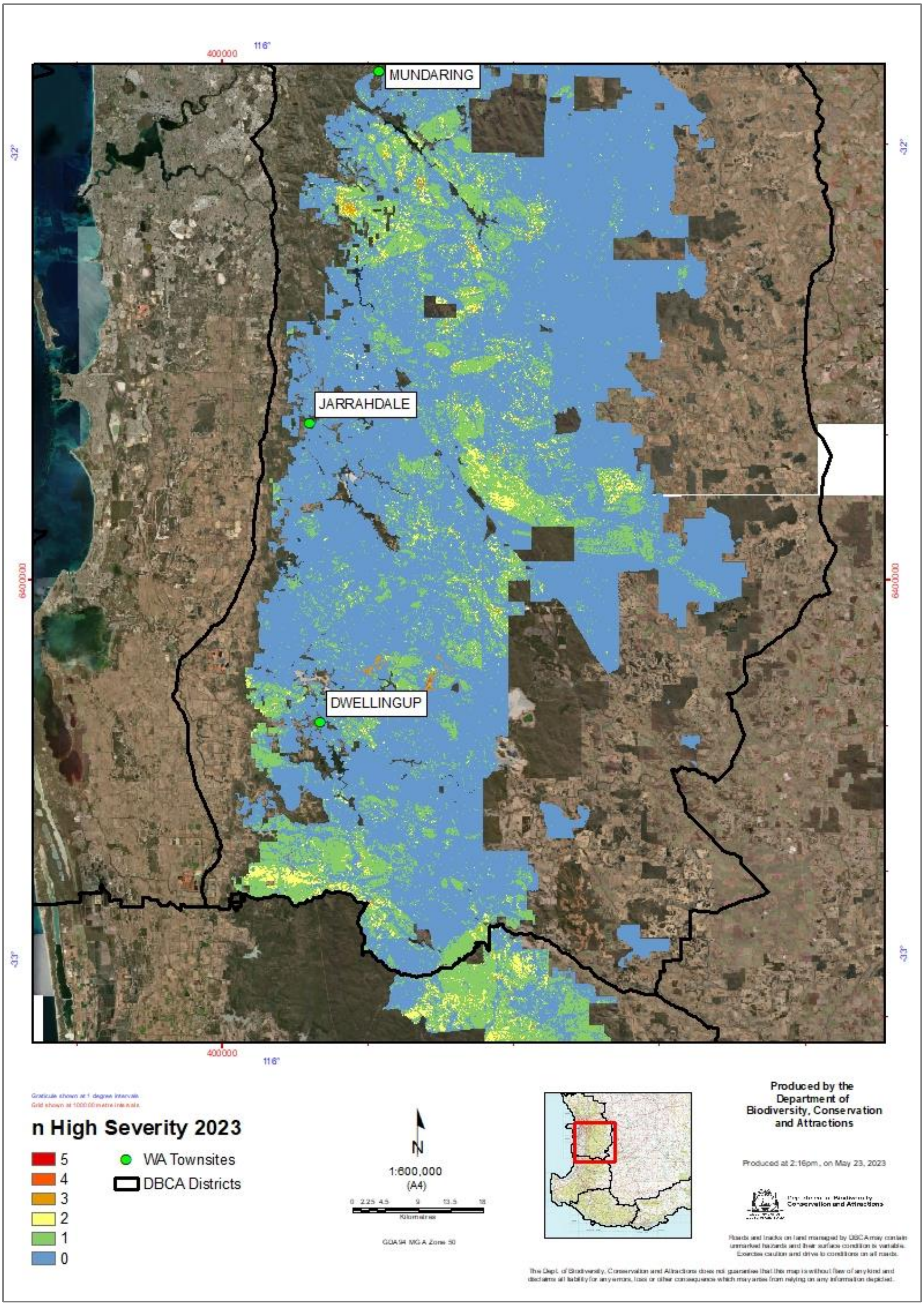


Figure 12: Number of high severity prescribed burns and wildfires for the Northern Jarrah Forest subregion, between 1988-2023.

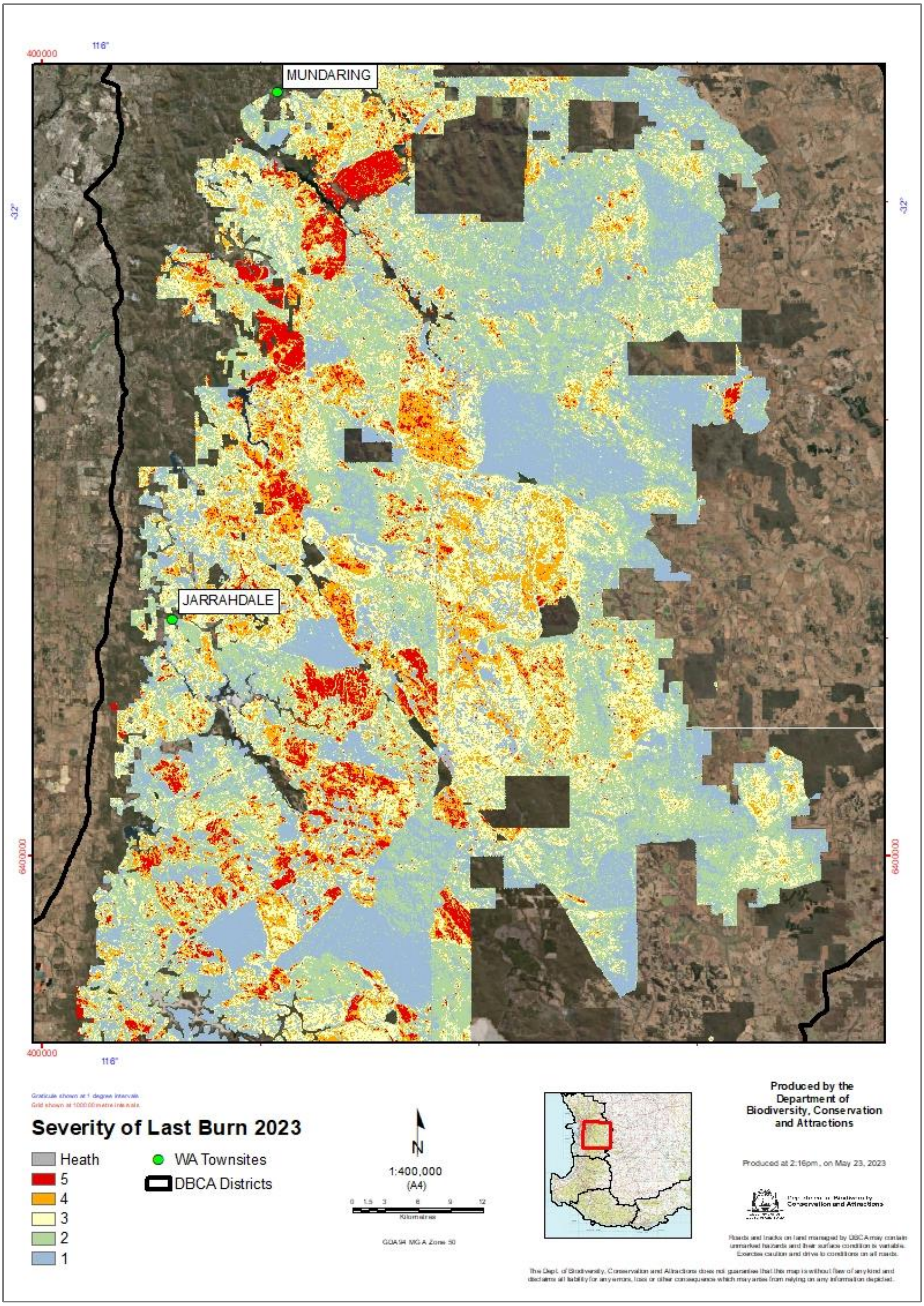


Figure 13: Severity of last fire (prescribed burn or wildfire) for the Northern Jarrah Forest, data available from 1988-2023.

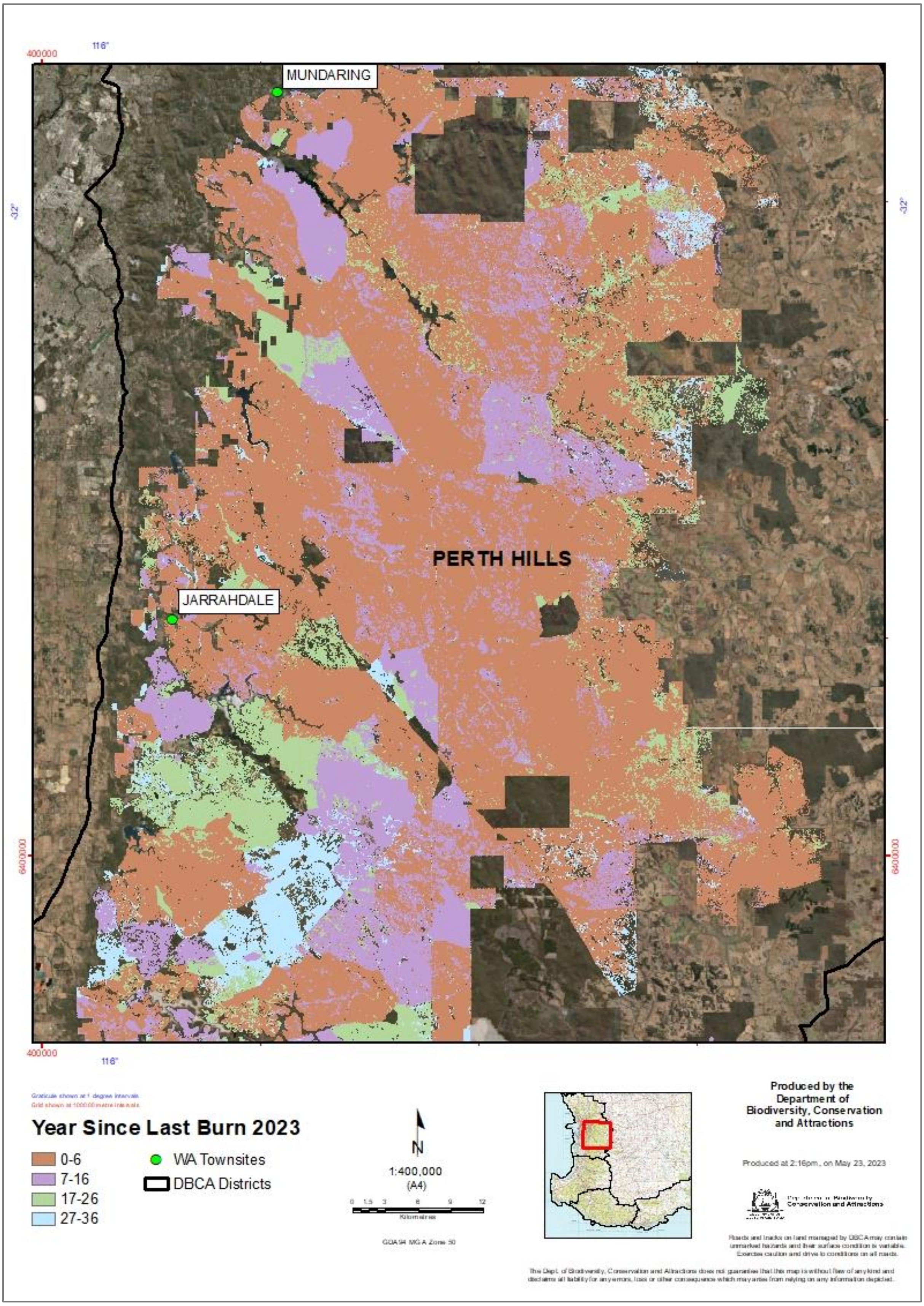


Figure 14: Years since last burn (prescribed burn or wildfire) mapped for the Northern Jarrah Forest subregion, between 1988-2023.

Accessibility of the data

Work is ongoing to create a convenient way to render the data accessible. Using QGIS, a spatial index can be accessed that contains all the burn polygons associated to a severity map (Figure 15). Each polygon is linked to either a “load” or “map” attribute (Figure 16).

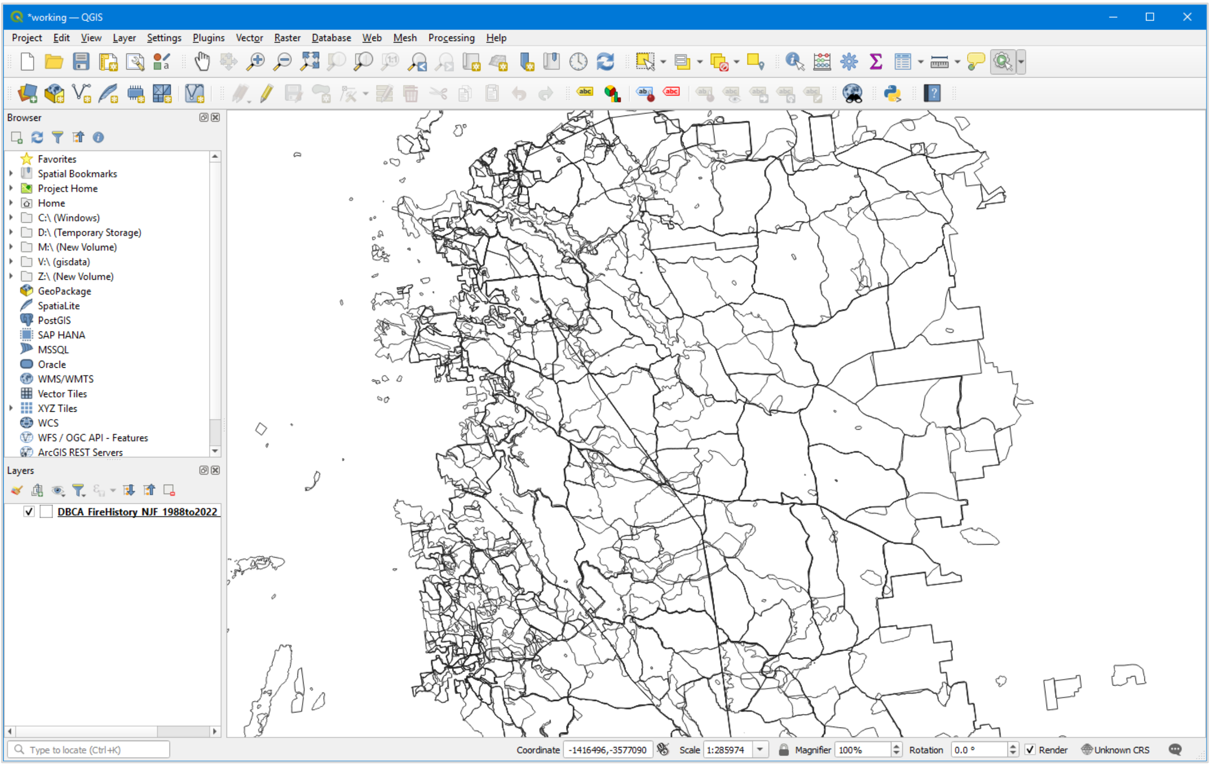


Figure 15: Spatial index of burn shapes associated with a severity map, here shown for a section of the Northern Jarrah Forest. The earliest maps available are from 1988.

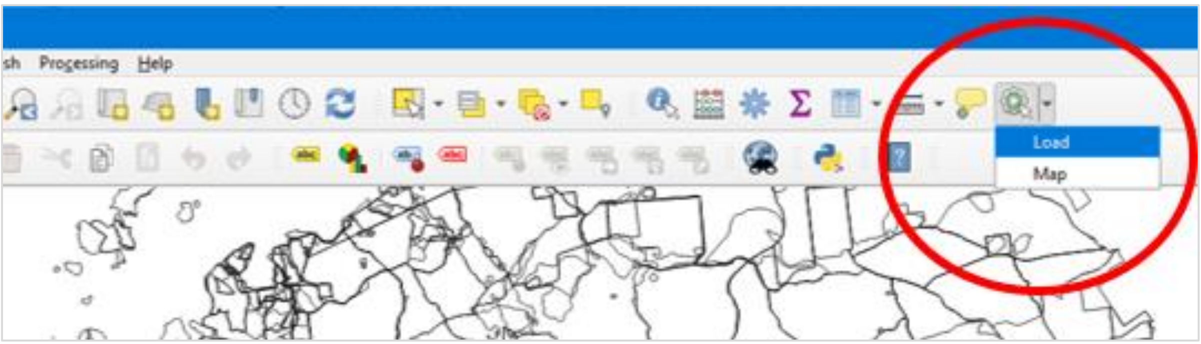
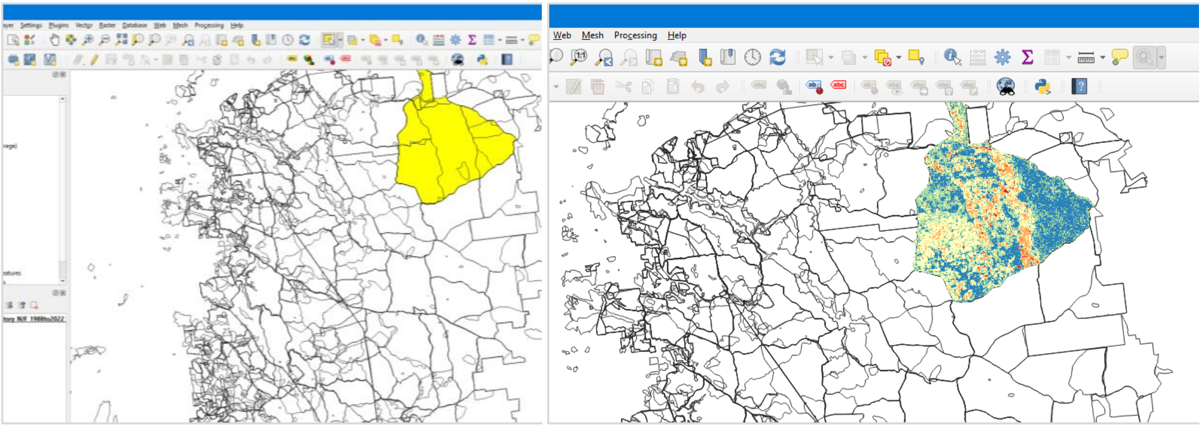


Figure 16: Action button to load GeoTifs or open visuals of severity maps for a location.

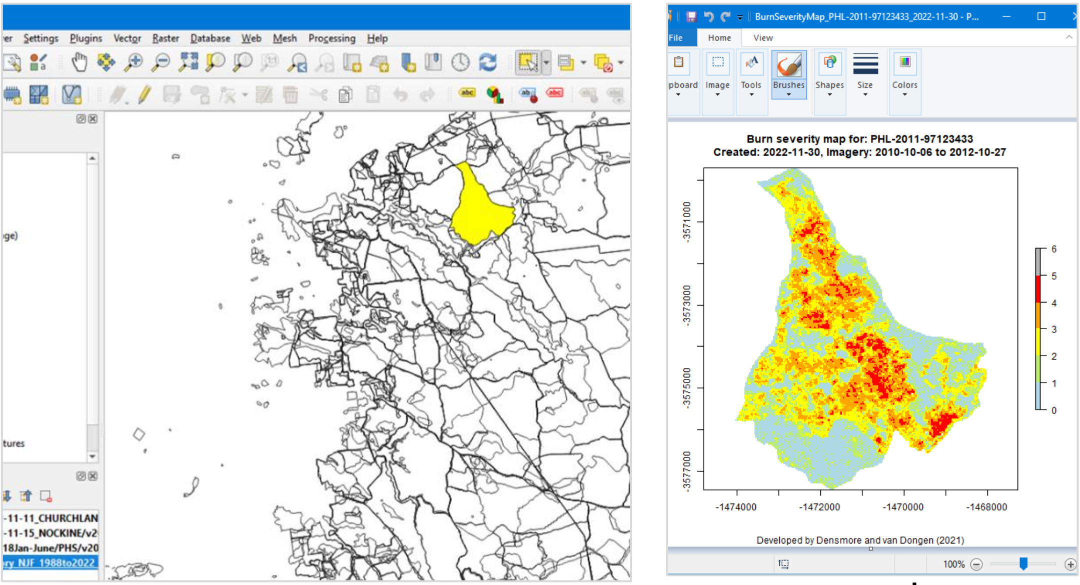
Using the load action will allow to click in the spatial index to open any existing severity map at that location, for 1988 to present burns. The maps open as a new GeoTif layer which can be used to create statistics or a comprehensive fire history for the area (Figure 17).



a b

Figure 17: a) Shows the area enquired by user (in yellow), and b) one of the potential severity maps for that area.

By using the second option, the map action, a click on the map will now link to the severity map visuals available for that location. Those visuals can then be used for various applications, such as in reports for studies conducted in the area (Figure 18).



a b

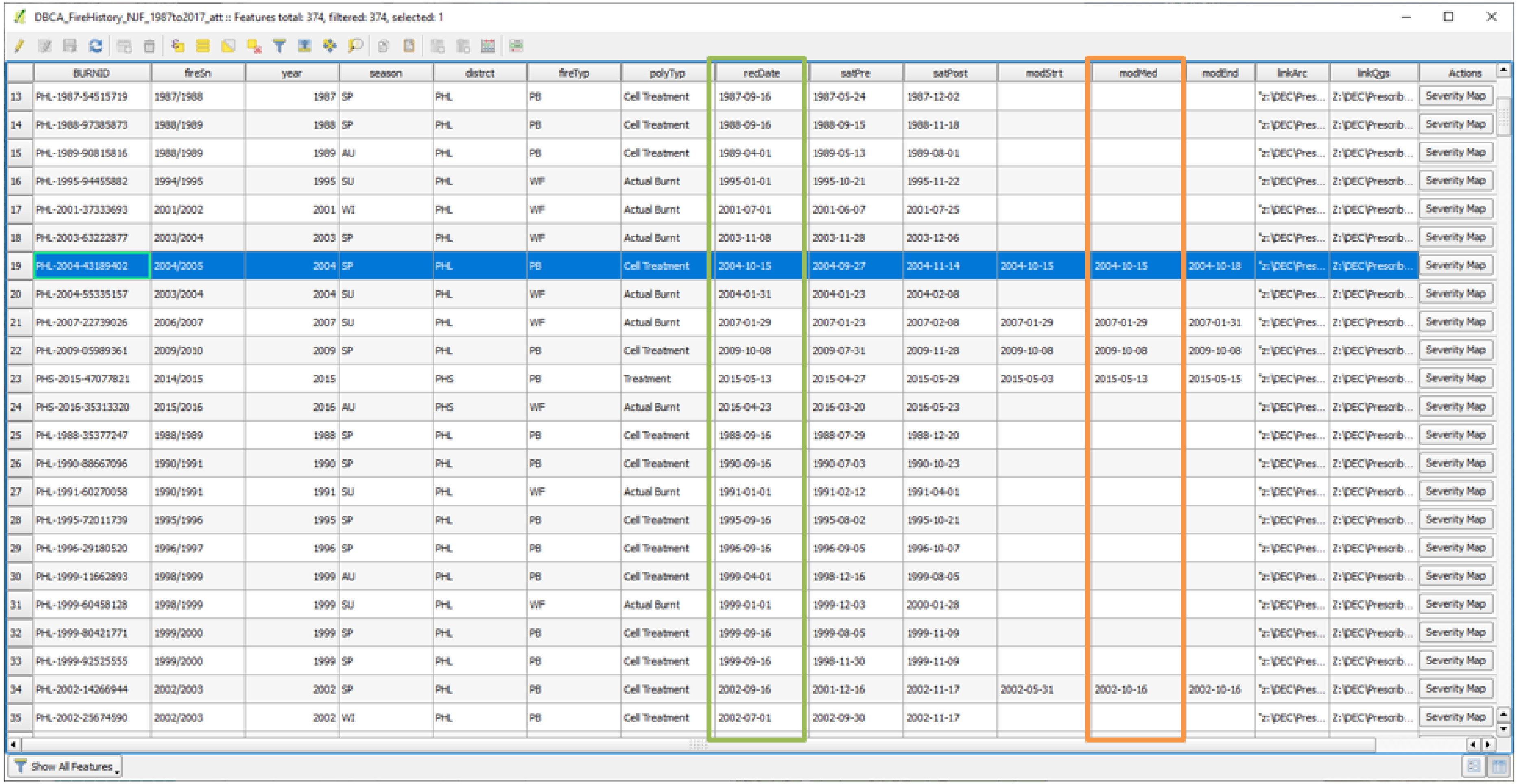
Figure 18: a) An area is inquired (in yellow), using the map action button in QGIS, which opens b) a visual of the available severity map(s) for the location.

Complete accessibility of the new database outside of the Department is still in the process of being evaluated, but hopefully this can be achieved in the near future, providing a more accurate and easily accessible fire severity database for fire researchers and managers around the State.

MODIS burn date

The Moderate Resolution Imaging Spectroradiometer (MODIS) instrument operates from two satellites and captures a range of data about the Earth’s lands, oceans, and atmosphere. Its capacity to detect and measure hotspots makes it a useful tool in mapping fire and fire related metrics.

Fire severity studies such as Dixon et al. (2022) have used MODIS products to correct or narrow fire start and end dates from DBCA-060 dataset records. In this study, MODIS products were intersected with burn shapes to generate start, median and end dates for burn events. This allows for further refinement of the burn date and also gives an indication of the period of time the burn took place. (Figure 19).



DBCA_FireHistory_NJF_1987to2017_att :: Features total: 374, filtered: 374, selected: 1

	BURNID	fireSn	year	season	distrct	fireTyp	polyTyp	recDate	satPre	satPost	modStrt	modMed	modEnd	linkArc	linkQgs	Actions
13	PHL-1987-54515719	1987/1988	1987	SP	PHL	PB	Cell Treatment	1987-09-16	1987-05-24	1987-12-02				"z:\DEC\Pres...	Z:\DEC\Prescrib...	Severity Map
14	PHL-1988-97385873	1988/1989	1988	SP	PHL	PB	Cell Treatment	1988-09-16	1988-09-15	1988-11-18				"z:\DEC\Pres...	Z:\DEC\Prescrib...	Severity Map
15	PHL-1989-90815816	1988/1989	1989	AU	PHL	PB	Cell Treatment	1989-04-01	1989-05-13	1989-08-01				"z:\DEC\Pres...	Z:\DEC\Prescrib...	Severity Map
16	PHL-1995-94455882	1994/1995	1995	SU	PHL	WF	Actual Burnt	1995-01-01	1995-10-21	1995-11-22				"z:\DEC\Pres...	Z:\DEC\Prescrib...	Severity Map
17	PHL-2001-37333693	2001/2002	2001	WI	PHL	WF	Actual Burnt	2001-07-01	2001-06-07	2001-07-25				"z:\DEC\Pres...	Z:\DEC\Prescrib...	Severity Map
18	PHL-2003-63222877	2003/2004	2003	SP	PHL	WF	Actual Burnt	2003-11-08	2003-11-28	2003-12-06				"z:\DEC\Pres...	Z:\DEC\Prescrib...	Severity Map
19	PHL-2004-43189402	2004/2005	2004	SP	PHL	PB	Cell Treatment	2004-10-15	2004-09-27	2004-11-14	2004-10-15	2004-10-15	2004-10-18	"z:\DEC\Pres...	Z:\DEC\Prescrib...	Severity Map
20	PHL-2004-55335157	2003/2004	2004	SU	PHL	WF	Actual Burnt	2004-01-31	2004-01-23	2004-02-08				"z:\DEC\Pres...	Z:\DEC\Prescrib...	Severity Map
21	PHL-2007-22739026	2006/2007	2007	SU	PHL	WF	Actual Burnt	2007-01-29	2007-01-23	2007-02-08	2007-01-29	2007-01-29	2007-01-31	"z:\DEC\Pres...	Z:\DEC\Prescrib...	Severity Map
22	PHL-2009-05989361	2009/2010	2009	SP	PHL	PB	Cell Treatment	2009-10-08	2009-07-31	2009-11-28	2009-10-08	2009-10-08	2009-10-08	"z:\DEC\Pres...	Z:\DEC\Prescrib...	Severity Map
23	PHS-2015-47077821	2014/2015	2015		PHS	PB	Treatment	2015-05-13	2015-04-27	2015-05-29	2015-05-03	2015-05-13	2015-05-15	"z:\DEC\Pres...	Z:\DEC\Prescrib...	Severity Map
24	PHS-2016-35313320	2015/2016	2016	AU	PHS	WF	Actual Burnt	2016-04-23	2016-03-20	2016-05-23				"z:\DEC\Pres...	Z:\DEC\Prescrib...	Severity Map
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27	PHL-1991-60270058	1990/1991	1991	SU	PHL	WF	Actual Burnt	1991-01-01	1991-02-12	1991-04-01				"z:\DEC\Pres...	Z:\DEC\Prescrib...	Severity Map
28	PHL-1995-72011739	1995/1996	1995	SP	PHL	PB	Cell Treatment	1995-09-16	1995-08-02	1995-10-21				"z:\DEC\Pres...	Z:\DEC\Prescrib...	Severity Map
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30	PHL-1999-11662893	1998/1999	1999	AU	PHL	PB	Cell Treatment	1999-04-01	1998-12-16	1999-08-05				"z:\DEC\Pres...	Z:\DEC\Prescrib...	Severity Map
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32	PHL-1999-80421771	1999/2000	1999	SP	PHL	PB	Cell Treatment	1999-09-16	1999-08-05	1999-11-09				"z:\DEC\Pres...	Z:\DEC\Prescrib...	Severity Map
33	PHL-1999-92525555	1999/2000	1999	SP	PHL	PB	Cell Treatment	1999-09-16	1998-11-30	1999-11-09				"z:\DEC\Pres...	Z:\DEC\Prescrib...	Severity Map
34	PHL-2002-14266944	2002/2003	2002	SP	PHL	PB	Cell Treatment	2002-09-16	2001-12-16	2002-11-17	2002-05-31	2002-10-16	2002-10-16	"z:\DEC\Pres...	Z:\DEC\Prescrib...	Severity Map
35	PHL-2002-25674590	2002/2003	2002	WI	PHL	PB	Cell Treatment	2002-07-01	2002-09-30	2002-11-17				"z:\DEC\Pres...	Z:\DEC\Prescrib...	Severity Map

Show All Features

Figure 19: Attribute table for burn events, organized by unique burn ID. The attribute highlighted in green is the DBCA recorded date, after manual correction, while the attribute highlighted in orange is the median event date recorded by MODIS.

There are significant limitations to the MODIS products. The coarse spatial resolution of MODIS thermal (1km) or Burn Area (500m) products limits their ability to capture small burns. The size of burns which were able to be attributed with MODIS dates is shown in Figure 20. This shows that most (95%) fires detected by MODIS are larger than 95 ha, while 95% of fires not detected by MODIS are smaller than 1921 ha. Additionally, there is no burn detection observed prior to the 31st of May 2002 (Figure 21), resulting in missing MODIS data for the majority of the analysis period.

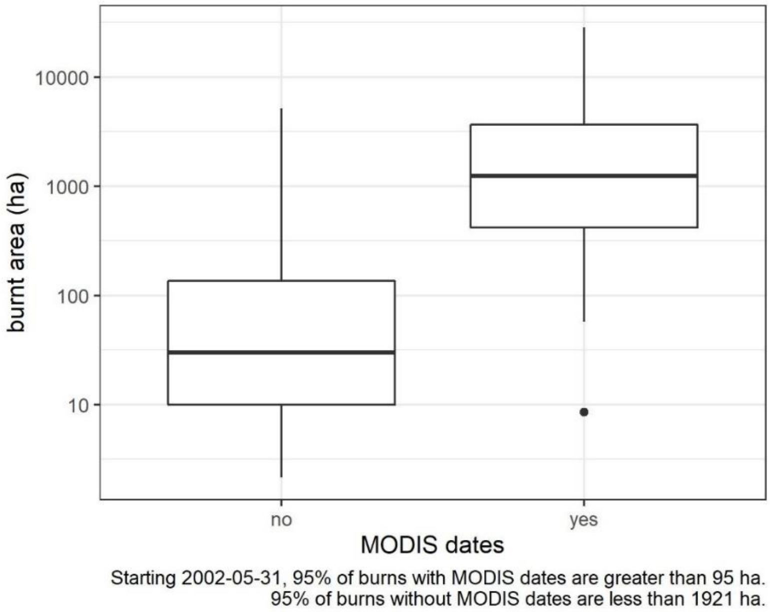

Figure 20: Boxplot of MODIS detection range by burnt area (ha), starting from May 2002.

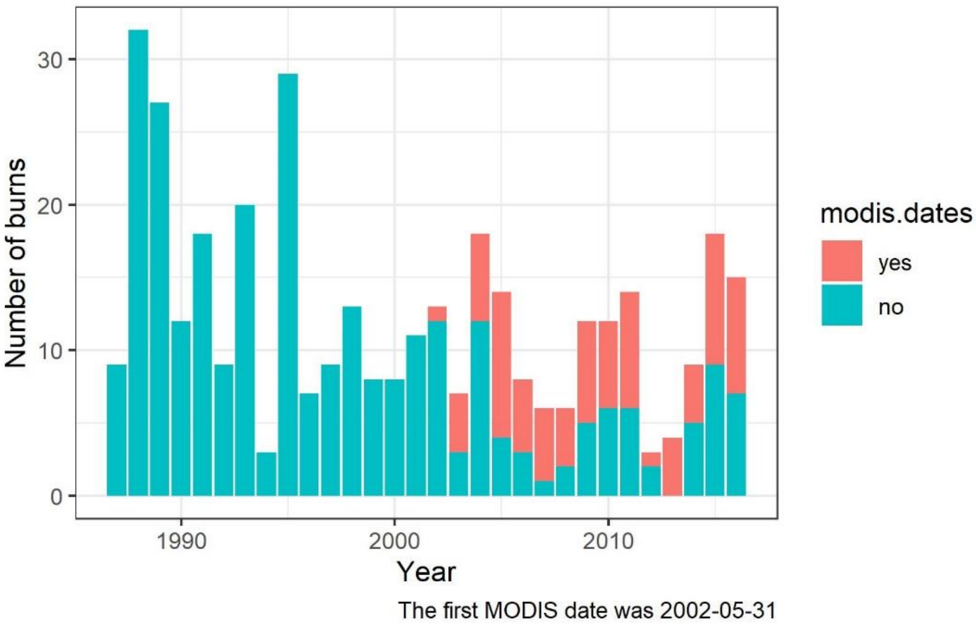

Figure 21: The number of MODIS detected burns per year.

Severity by Silviculture

Burn severity across dense regrowth areas and the buffer for years 1999 to 2022 is shown Figure 22. There is minimal difference in the distribution of burn severity classes between the two zones.

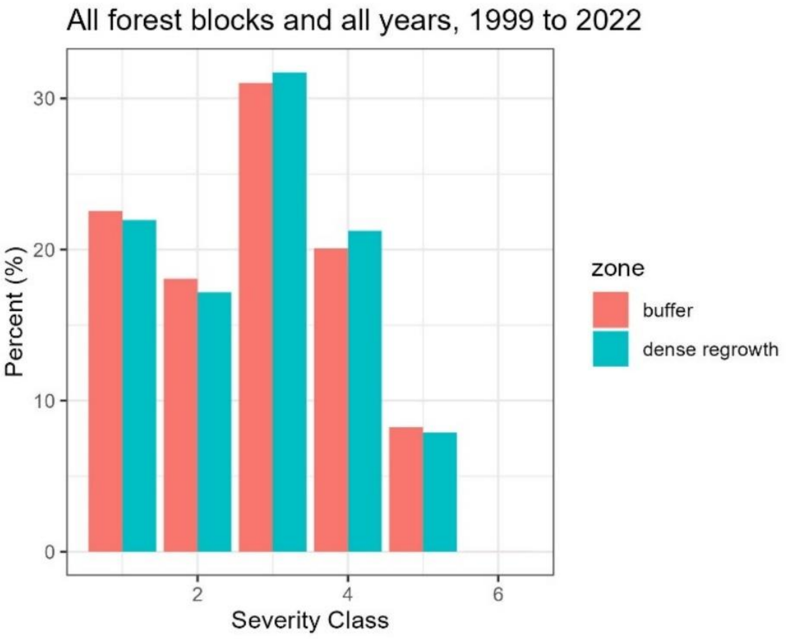

Figure 22: Burn severity class of dense regrowth areas in comparison to the reference buffer zone.

The comparison of burn severity between the dense regrowth and buffer zone can be examined and displayed by year. Areas in the regrowth dataset were last treated between 1986 and 1999 the effect of treatment on burn severity may not be evident for several years. However, plots show no systematic difference in severity between the two zones at any point (Figure 23).

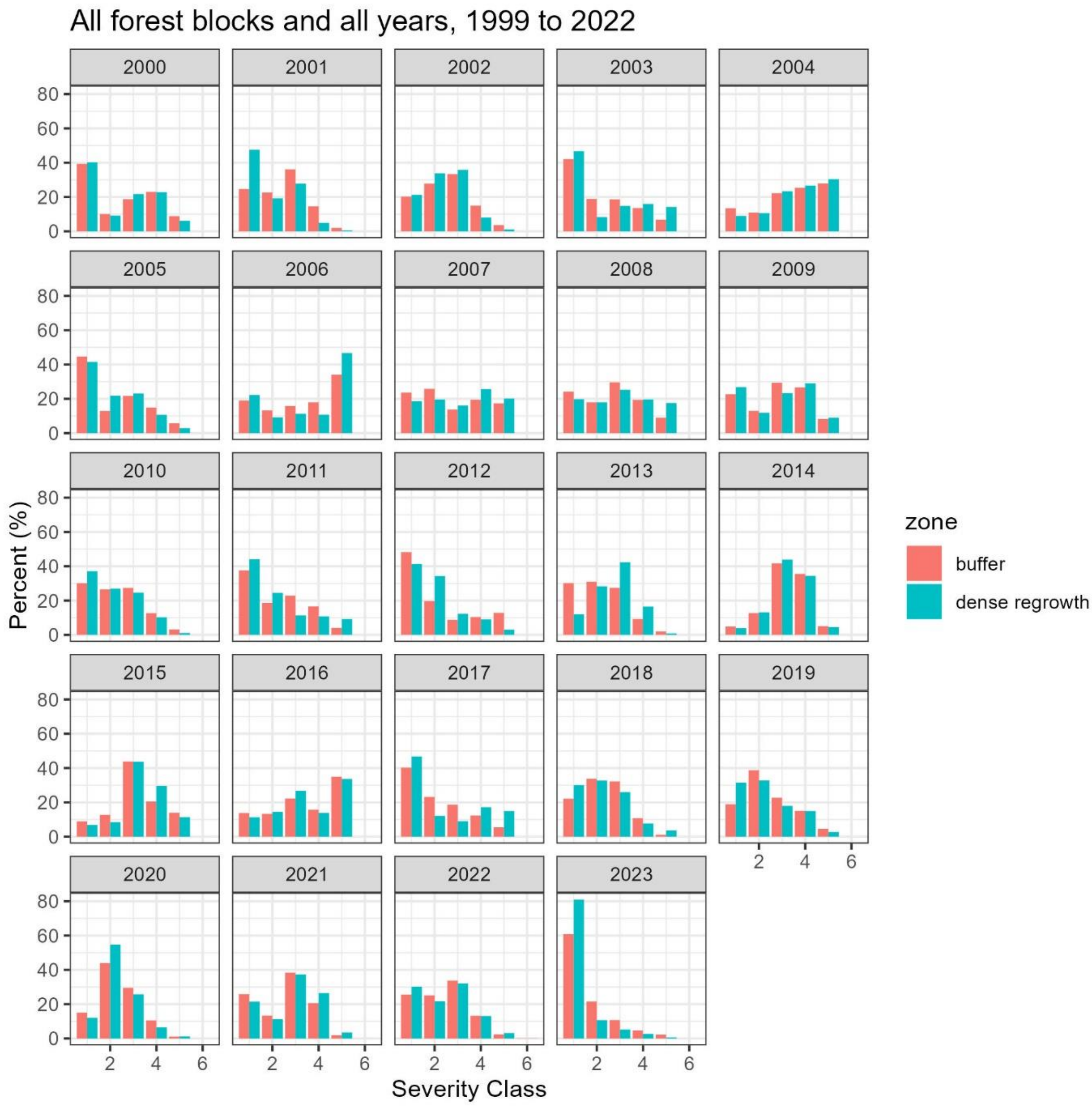

Figure 23: Burn severity class of dense regrowth areas in comparison to the reference buffer zone displayed by year.

The burn severity statistics can be examined by forest block (Figure 24). Of all the forest blocks, Batalling, Carinyah and Cobiac seemed to show some difference between regrowth and buffer areas. On closer inspection, the results from Batalling and Carinyah were due to very small (< 1ha), areas of regrowth producing skewed, unrepresentative results. However, the results from Cobiac for 2018 showed a stronger pattern (Figure 25).

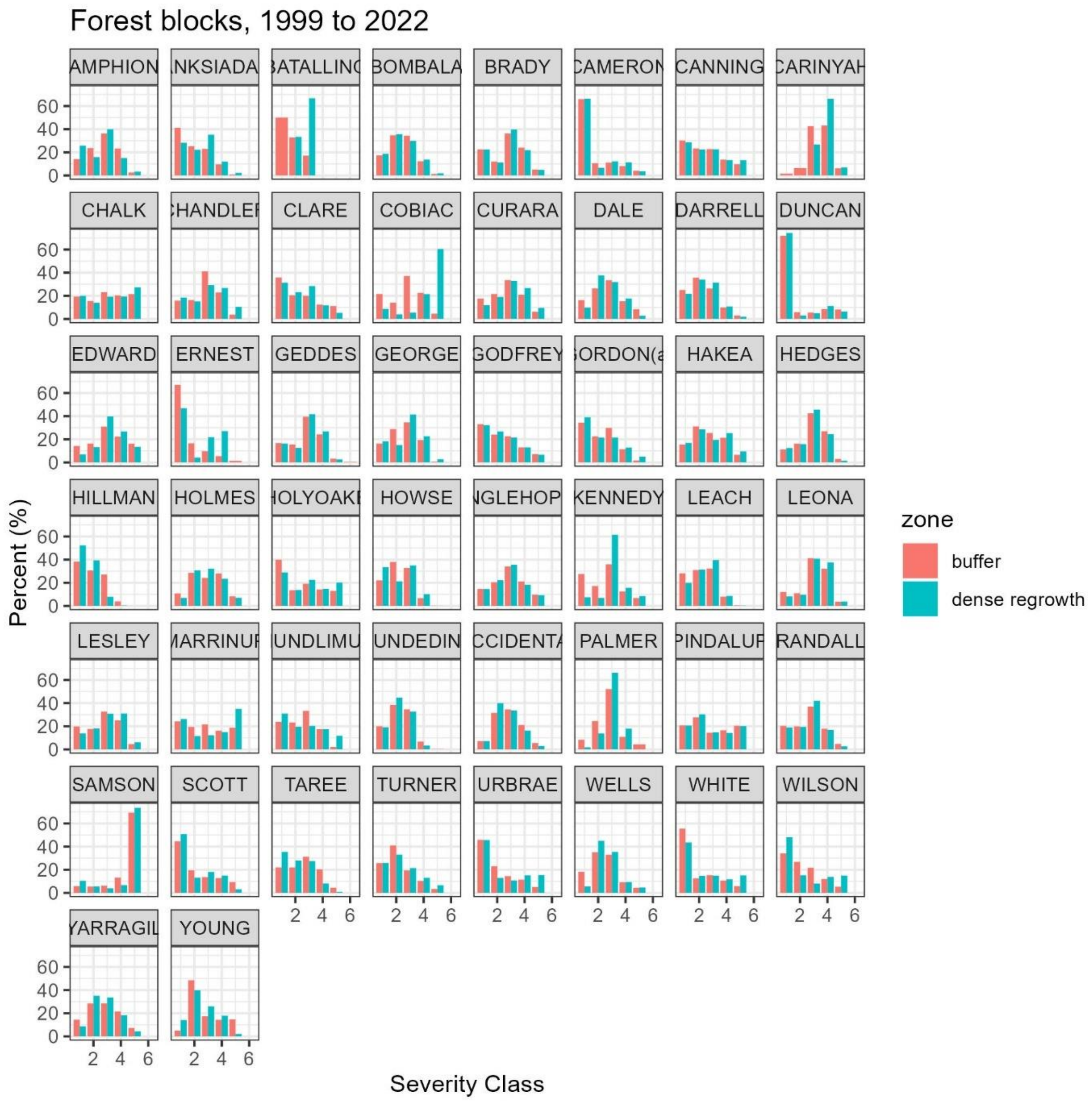

Figure 24: Burn severity class of dense regrowth areas in comparison to the reference buffer zone displayed by forest block.

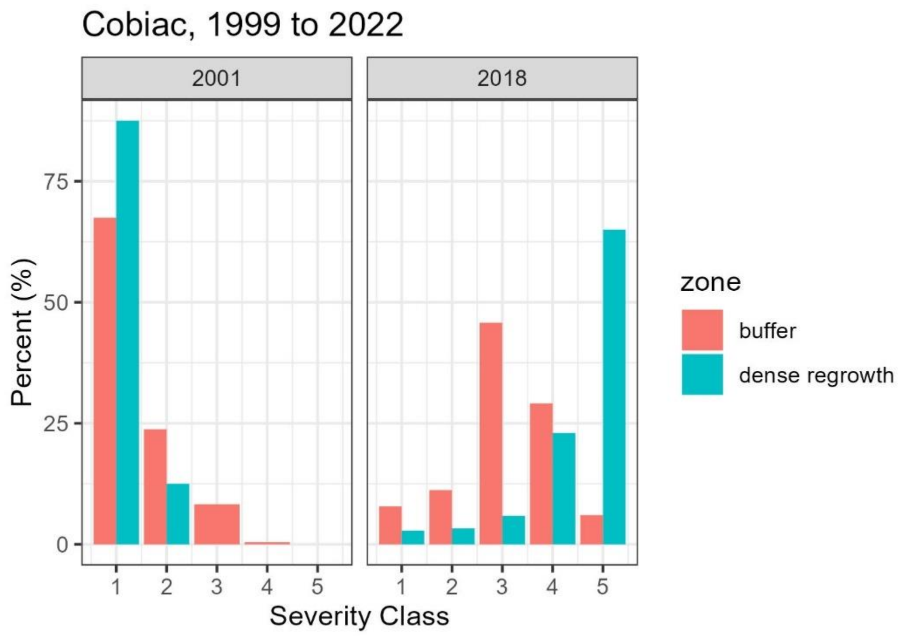

Figure 25: Burn severity of dense regrowth areas in Cobiac forest block displayed by year of fire event.

The burn severity map from Cobiac for 2018 is shown in Figure 26. In this case, an area of high severity burn aligns closely with the boundary of the regrowth layer.

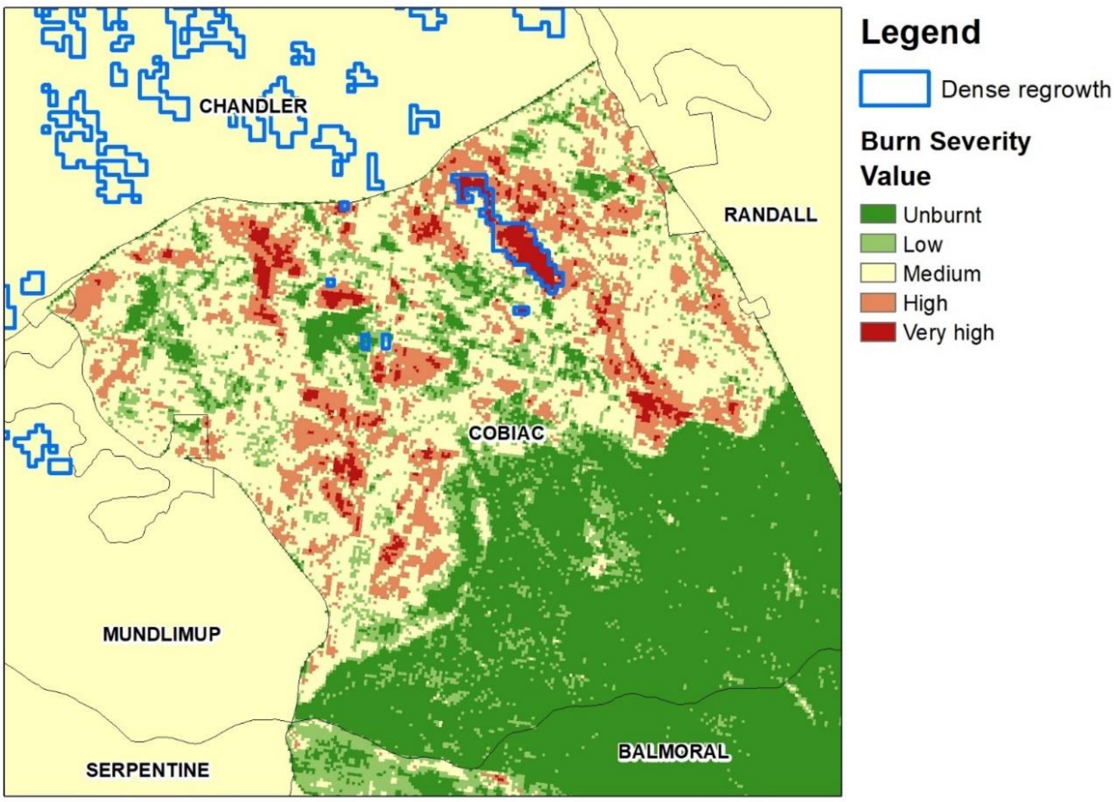

Figure 26: Burn severity of a 2018 prescribed burn at Cobiac forest block with dense regrowth areas contoured in blue.

Detailed silviculture and severity

The analysis of detailed silvicultural boundaries in relation to burns from 2014 and 2021 within Brady block is shown below. Burn severity maps from 2014 and 2021 are shown along with treatment boundaries (Figure 27).

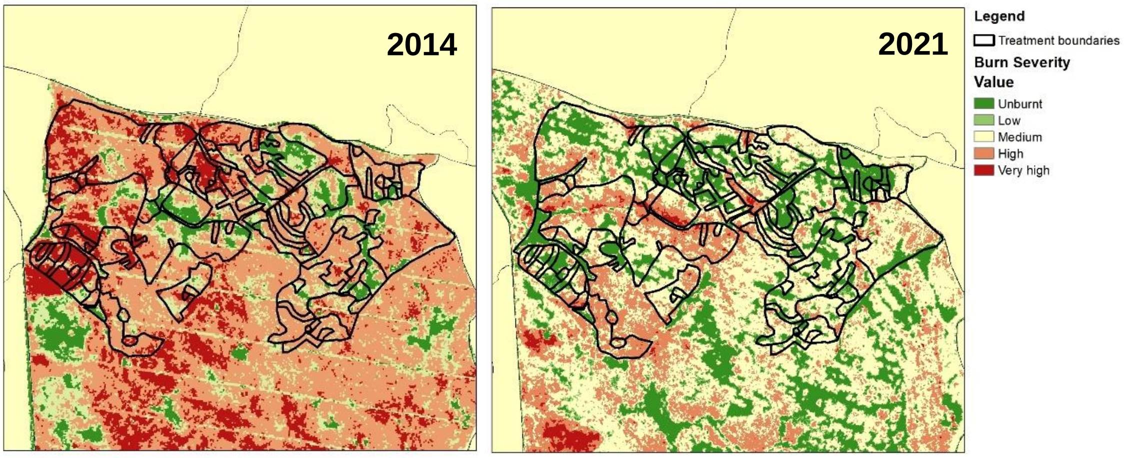

Figure 27: Burn severity maps for 2014 and 2021 for Brady block with silviculture boundaries overlayed.

The burn severity for the treatment areas at Brady can be shown via analysis of the OzCBI score, rather than severity classes. Note that the severity class maps are created by classifying a modelled raster containing the OzCBI score. No significant differences in burn severity, as expressed by the OzCBI score, were observed (Figure 28).

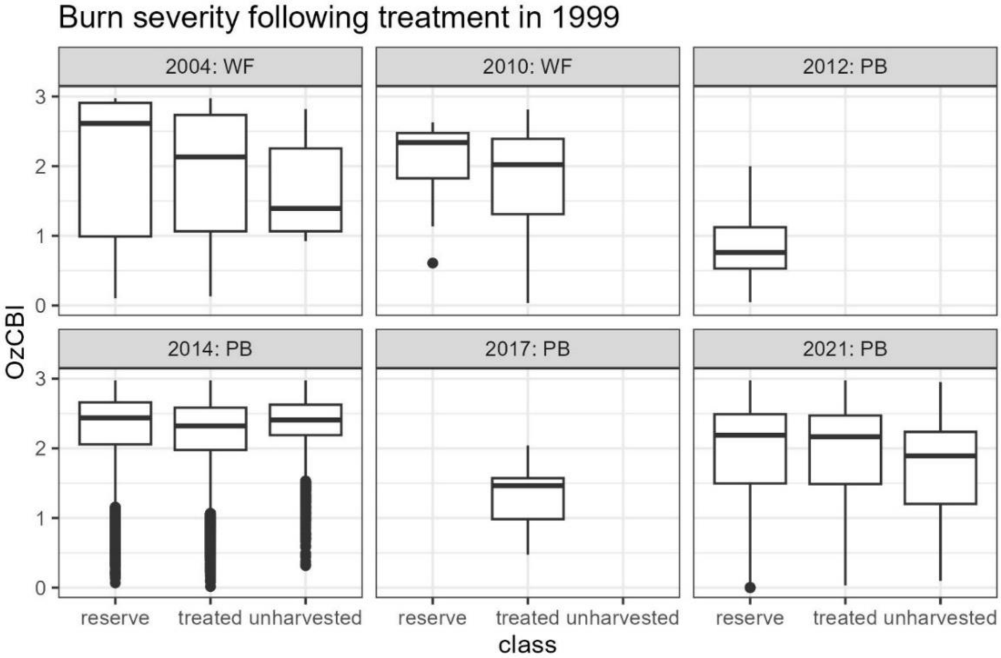

Figure 28: Burn severity (scored by OzCBI), for each treatment class, for all burns that occurred in Brady block from 1999 to 2023.

A pattern did emerge from examining the 2014 and 2021 prescribed burns intersecting with Brady block which showed that areas associated to low severity classes and low OzCBI score in 2014 recorded a high severity burn in 2021 (Figure 29).

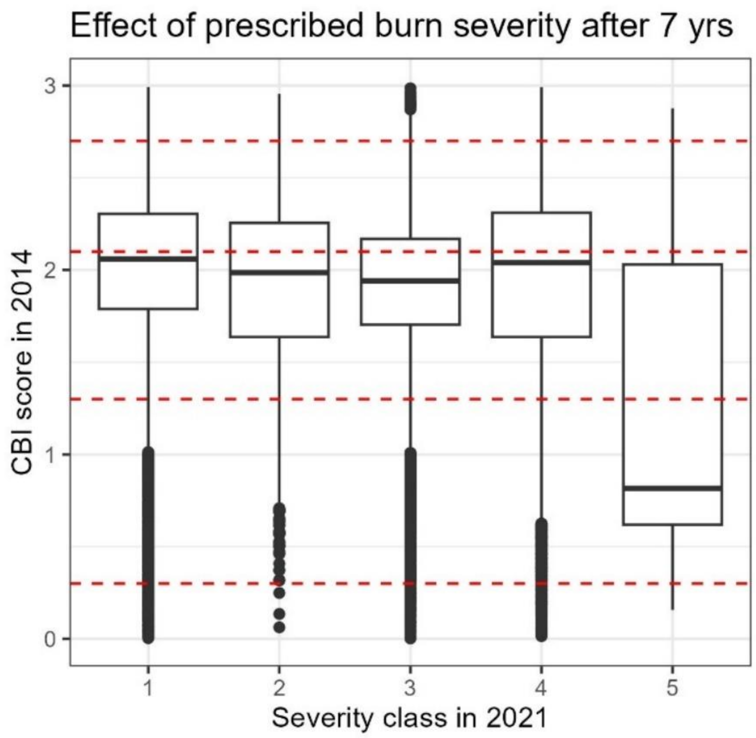

Figure 29: Burn severity within Brady block from 2021 compared to OzCBI severity scores from 2014.

5 Discussion and Conclusions

Progress

Between September 2022 and June 2023, over ~2000 burns across 106 forest blocks have been processed and mapped as part of the operational and historical branches of this project. The large number of records processed during the process presented an array of isolated and more common challenges, linked to the way fire polygons were recorded, the specific burn locations or even the interactions of burns with each other, among others. Each situation has given us the opportunity to refine the process, by developing solutions for each of them, while maintaining the versatility of the code for future burns to be mapped.

The continuous application of the code to multiple burns also revealed patterns and thresholds leading to more realistic and sensible results, which matched the RGB visuals more accurately. To maintain homogeneity in the process and improve the results, those progresses are now being applied retrospectively to the first mapped blocks.

The fire severity process has more recently targeted specific areas for projects requiring measures of fire severity. Those projects along with the operational mapping each provide opportunities for feedback on the usefulness and ease of sharing of the severity products. It is hoped to continue retrospectively mapping fire severity for southwestern Australia in the next two to three years, down to the Warren IBRA subregion to obtain a comprehensive, up to date and dynamic fire history of the area.

Impacts of image availability

Over the last 30+ years, several Landsat missions were launched, and Landsat 5 to 8 were used in the historical part of this project, acquiring, and delivering new imagery every 16 days. Landsat 5 was launched in 1984 while the fire history dataset records start in 1937. Many of the burns visible in Landsat imagery captured in 1986 and 1987 did not have the required, clear imagery to produce a valid severity map. For this reason, historical severity mapping can only reliably be conducted from 1988.

The revisit time of Landsat imagery and frequent cloud interference can sometimes create months-gap in the availability of qualitative imagery, lowering chances to capture the exact burn start dates and / or extending the time elapsed between pre- and post-fire images. This, no doubt, introduces some error to the analysis, as a significant gap from the fire date to the first post fire image will likely lower the resulting mapped severity. This error is difficult to account for as the recorded fire dates are known to be inaccurate, Additionally, a “Scan Line Corrector” failure in Landsat 7 sensor happened in June 2003, creating non-data stripes in acquired imagery. Attempts have been made to account for this error, but some burns still retain diagonal stripes.

With the launch of Sentinel 2a (2015) and 2b (2017), the temporal resolution of captures has more than doubled, with a revisit time of 5 days for both satellites. Operational mapping therefore uses Sentinel products, allowing for more rapid updates of severity maps and better chances of getting cloud-free images, especially in the southern areas of the project. Ongoing consultation with DBCA regional staff allows for continual feedback as to the robustness of the process and gives confidence to validity of the approach.

Severity by Silviculture

The analysis of burn severity in relation to the areas of dense regrowth found no broad scale, systematic influence on burn severity. Of the 50 analysed forest blocks, in only one, Cobiac, did there appear to be a close spatial relationship between severity and areas of dense regrowth. This spatial relationship was only associated to a single burn. Such an isolated case warrants further investigation but does not allow for any conclusive statements regarding the influence of regrowth areas to be made.

Improving the positional accuracy of silvicultural treatment boundaries still show no relationship between severity and treatment type, however this was only examined in one forest block.

The most interesting result seemed to be the inverse relationship between patches of high and low severity from the 2014 and 2021 prescribed burns from Brady block. A more comprehensive analysis of this effect is recommended as further research.

References

Boer, M. M., Sadler, R. J., Wittkuhn, R. S., McCaw, L., & Grierson, P. F. (2009). Long-term impacts of prescribed burning on regional extent and incidence of wildfires—Evidence from 50 years of active fire management in SW Australian forests. *Forest Ecology and Management*, *259*(1), 132–142. https://doi.org/10.1016/j.foreco.2009.10.005

Campbell, T., Bradshaw, D. S., Dixon, K. W., & Zylstra, P. (2022, September 5). *Full article: Wildfire risk management across diverse bioregions in a changing climate*. https://www.tandfonline.com/doi/full/10.1080/19475705.2022.2119891

Collins, L., McCarthy, G., Mellor, A., Newell, G., & Smith, L. (2020). Training data requirements for fire severity mapping using Landsat imagery and random forest. *Remote Sensing of Environment*, *245*, 111839. https://doi.org/10.1016/j.rse.2020.111839

De Santis, A., & Chuvieco, E. (2009). GeoCBI: A modified version of the Composite Burn Index for the initial assessment of the short-term burn severity from remotely sensed data. *Remote Sensing of Environment*, *113*(3), 554–562. https://doi.org/10.1016/j.rse.2008.10.011

Densmore, V. S., van Dongen, R. J., Ong, R., & Harris, B. G. (2023). OzCBI: The composite burn index adapted to assess fire severity and key fauna habitat features in Australian ecosystems. *Australian Forestry*, *0*(0), 1–21. https://doi.org/10.1080/00049158.2023.2168400

Dixon, D. J., Callow, J. N., Duncan, J. M. A., Setterfield, S. A., & Pauli, N. (2022). Regional-scale fire severity mapping of Eucalyptus forests with the Landsat archive. *Remote Sensing of Environment*, *270*, 112863. https://doi.org/10.1016/j.rse.2021.112863

Keith, D. A., Allen, S. P., Gallagher, R. V., Mackenzie, B. D. E., Auld, T. D., Barrett, S., Buchan, A., English, V., Gosper, C., Kelly, D., McIllwee, A., Melrose, R. T., Miller, B. P., Neldner, V. J., Simpson, C. C., Tolsma, A. D., Rogers, D., van Leeuwen, S., White, M. D., … Tozer, M. G. (2022). Fire-related threats and transformational change in Australian ecosystems. *Global Ecology and Biogeography*, *31*(10), 2070–2084. https://doi.org/10.1111/geb.13500

Miller, C. W., Harvey, B. J., Kane, V. R., Moskal, L. M., Alvarado, E., Miller, C. W., Harvey, B. J., Kane, V. R., Moskal, L. M., & Alvarado, E. (2023). Different approaches make comparing studies of burn severity challenging: A review of methods used to link remotely sensed data with the Composite Burn Index. *International Journal of Wildland Fire*, *32*(4), 449–475. https://doi.org/10.1071/WF22050

RStudio Team. (2020). *RStudio: Integrated Development for R. RStudio*. PBC. http://www.rstudio.com/

Zylstra, P. J., Bradshaw, S. D., & Lindenmayer, D. B. (2022). Self-thinning forest understoreys reduce wildfire risk, even in a warming climate. *Environmental Research Letters*, *17*(4), 044022. https://doi.org/10.1088/1748-9326/ac5c10