

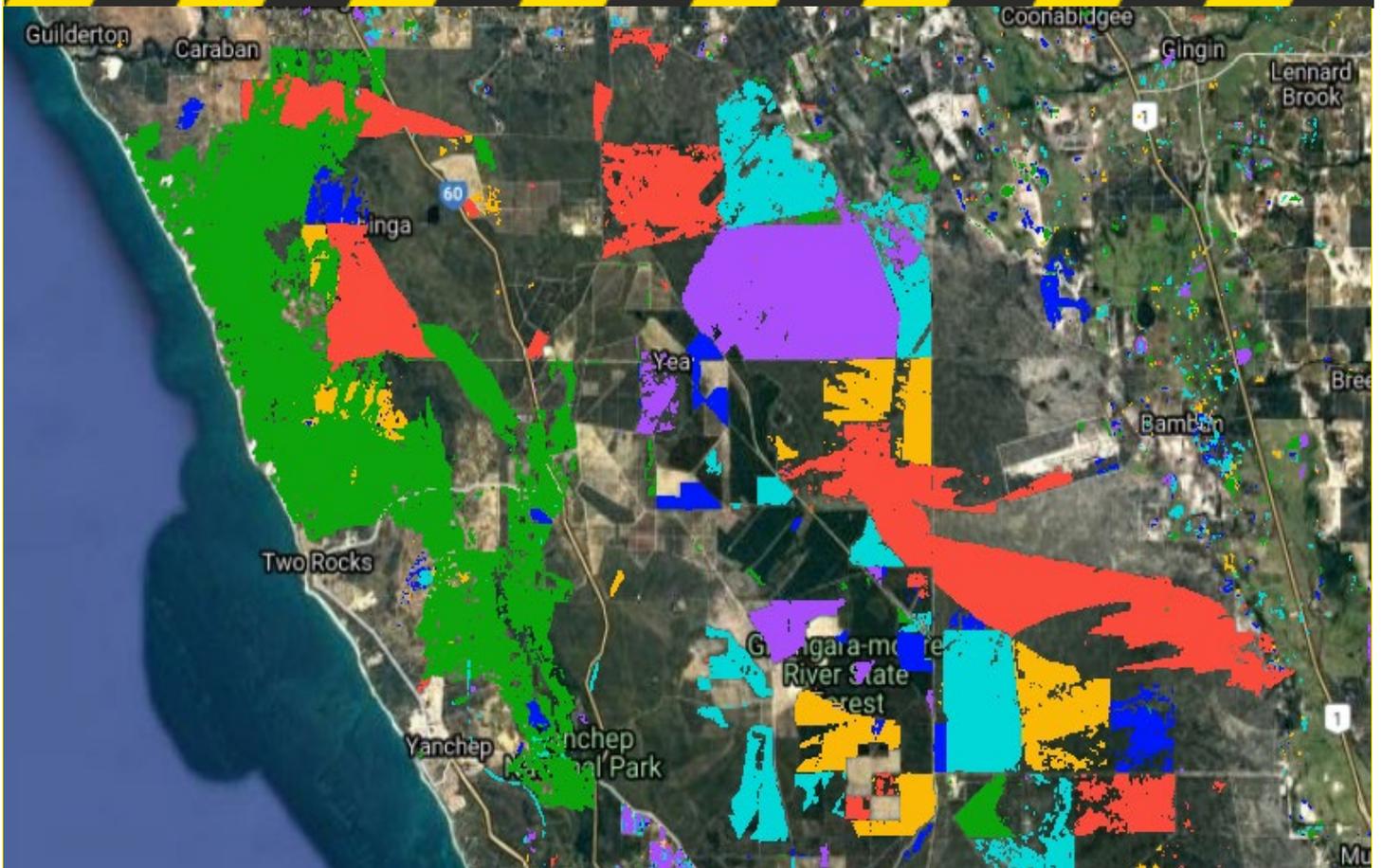
BLACK SUMMER 2019–20 RESEARCH

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ESTIMATING FUEL MOISTURE AND FIRE HISTORY FROM SENTINEL 2 SATELLITE IMAGERY

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Cover: Fire History developed from Sentinel 2 imagery from 2016 to early 2021, over the greater Yanchep region in WA. Base Map from Google Maps.



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- Department of Fire and Emergency Services WA (DFES)
- Department of Biodiversity, Conservation and Attractions WA (DBCA)
- Australian National University (ANU)
- Murdoch University

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EXECUTIVE SUMMARY

The Department of Fire and Emergency Services (DFES), the Department of Biodiversity, Conservation and Attractions (DBCA), the Australian National University (ANU) and Murdoch University have a project entitled "Quantifying seasonal variation in live fuel moisture content, fuel dynamics and the effects of the mosaic of prescribed burning on fire behaviour in near-urban coastal vegetation mosaic"

Fuel moisture is a key factor affecting the flammability, fire behaviour, damage potential and suppression difficulty of bushfires, and it is an input to fire danger rating and fire behaviour prediction systems.

While there are well-developed models that predict the moisture content of dead fuels such as cured grass and forest litter, no models or methods exist for predicting or effectively measuring the moisture content of predominately live fuels, such as the shrublands of SW-WA.

Within this larger project, Landgate, with the above partners have been working on a sub-project to provide DFES and DBCA with Sentinel 2 satellite imagery derived datasets, aiming to provide an improved capability to understand changes in fuel moisture within the coastal shrubland region, along with a detailed fire history spanning 2016 to June 2021.



INTRODUCTION

DFES, DBCA, ANU and Murdoch university are running a project for the BNHCRC entitled “Quantifying seasonal variation in live fuel moisture content, fuel dynamics and the effects of the mosaic of prescribed burning on fire behaviour in near-urban coastal vegetation mosaic”.

Fuel moisture is a key factor affecting the flammability, fire behaviour, damage potential and suppression difficulty of bushfires, and it is an input to fire danger rating and fire behaviour prediction systems.

This report summarised the outcomes of a sub-project of this larger project, providing DFES with the satellite imagery and value-added processing they require to meet the objectives of the main project.

Landgate, in partnership with DFES have been processing Sentinel 2 satellite imagery for a variety of bushfire related requirements such as fire scar mapping, and this project builds upon the processing streams developed for operational requirements.

The objectives of this sub-project are to develop a surrogate measure for fuel moisture, and fire history using Sentinel 2 satellite imagery, over the study area of the greater Yanchep region.

This project aims to provide DFES and DBCA with an improved capability to understand changes in fuel moisture within the coastal shrubland region in the greater Yanchep area and to create a comprehensive fire history from 2016.

Having an improved understanding of fuel moisture will provide fire managers with an understanding of the rate of change and better inform decisions around prescribed burning and bushfire risk as it changes with seasonality.



RESEARCH APPROACH

The intention of the Project is to undertake the Research:

- to deliver research activities to further our understanding of the events during the Black Summer Bushfire Crisis;
- with DFES, DBCA and ANU, develop a surrogate measure for fuel moisture using Sentinel 2 satellite imagery, over the study area of the coastal shrubland region in the greater Yanchep area;
- to provide an improved capability to understand changes in fuel moisture within the coastal shrubland region in the greater Yanchep area; and
- to provide fire history and burn severity from Sentinel 2 satellite imagery over the coastal shrubland region in the greater Yanchep area, using automatic methods developed previously by Landgate.

At the conclusion of the Research, the Contractor will provide / deliver:

- Processed time series of Sentinel 2 satellite imagery for the analysis of fuel moisture, fire history and burn severity, to inform fire reconstruction research into the Yanchep fires of 2019/2020 and the wider region.

METHODOLOGY AND DELIVERABLES

Please find following a table of key milestones as per the project service agreement, and comments regarding decisions made and project outcomes.

item	milestone	Target	status	comments
1.3.1	Project requirements discussion with DFES, DBCA and BNHCRC	31/3/21	complete	<p>Project meeting was held on 24th March 2021. The meeting consisted of Agnes Kristina (DFES), Adrian Allen (Landgate), Marta Yebra (ANU) and Shukhrat Shokirov (ANU).</p> <p>Decisions included:</p> <ul style="list-style-type: none"> - Use Sentinel 2A and 2B satellite imagery - Pre-processing level: use NBR-T processed imagery from GA - Utilise existing processes for fire scars processing (SLIC) - Apply cloud masked to nulls / or defined value (TBD) - Process time series applying VARI algorithms: (B03 (g) - B04 (r)) / (B03(g) + B04(r) - B02(b)) - Also, if possible, with VARI 700 algorithm: (B05-1.7*B04+0.7*B02) / (B05+2.3*B04-1.3*B02) - Tiles to be processed over the study area include: <ul style="list-style-type: none"> 50JLL (Lancelin), 50JLM (Cerventes), 50JLN (Mingenew)) - Time period = whole available archive of those files. <p>Items to be determined within the team prior to full processing include:</p> <ul style="list-style-type: none"> - Whether to apply a water mask? (status: TBD) - Whether to apply cloud mask? (status: yes) - Do we process scenes that meet a certain cloud % value? (status: we will append the cloud percentage within the filename, to allow for future analysis requirements).
1.3.2	Determine satellite scenes	31/3/21	complete	<p>The project stakeholders (DFES) decided that the area of interest for this research project was the 3 files as first identified, being:</p> <ul style="list-style-type: none"> - 50JLL(Lancelin), - 50JLM (Cerventes) - 50JLN (Mingenew)
1.3.3	Access satellite imagery from S2A and S2B archive	31/3/21	complete	<p>Access to S2 satellite imagery for fuel moisture / VARI algorithm processing:</p> <ul style="list-style-type: none"> - Determined to use NBAR-T processed S2 data. - Processed by GA - Available on the NCI THREDDS server Current Status - Ingest and processing code written, tested and sample data produced. Awaiting assessment of suitability.



				<p>Access to S2 satellite imagery for fire history processing:</p> <ul style="list-style-type: none"> - determined to use Level 1C processing from ESA. - Work process to fit in with existing fire scar mapping processes. <p>Current Status</p> <ul style="list-style-type: none"> - Ingest and processing code written, all files and archived have been downloaded. Processing investigation commencing soon.
1.3.4	Quarterly report	31/3/21		Payment \$12,100
1.4.1	Determine fuel moisture algorithm with DFES, DBCA and ANU (Marta)	31/5/21	complete	<p>Decision was that Landgate would process the time series of S2 data applying VARI algorithm:</p> <ul style="list-style-type: none"> - $(B03(g) - B04(r)) / (B03(g) + B04(r) - B02(b))$ <p>Also, if possible, with VARI 700 algorithm:</p> <ul style="list-style-type: none"> - $(B05 - 1.7*B04 + 0.7*B02) / (B05 + 2.3*B04 - 1.3*B02)$
1.4.2	Pre-process image archive	31/5/21	complete	<p>Fuel Moisture / VARI Processing</p> <ul style="list-style-type: none"> - Ingest and processing code written, - Code tested - sample data produced. - Awaiting assessment of suitability. <p>Fire History Processing</p> <ul style="list-style-type: none"> - Ingest and processing code written, - Code tested - Downloaded all files and time series required - Processing investigation commencing soon
1.4.3	Post-process imagery with fuel moisture, fire scar mapping, and burn severity algorithms	30/5/21	complete	<p>Fuel Moisture / VARI Processing</p> <ul style="list-style-type: none"> - Sample data provided to DFES - Awaiting assessment of suitability. <p>Fire History Processing</p> <ul style="list-style-type: none"> - Initial processing complete, - Investigation of suitability of thresholds - Re-processing commenced
1.4.4	Analysis by Landgate, DFES, DBCA and ANU	30/6/21	complete	DFES provided a recommendation to process the archive
1.4.5	Re-process if required, otherwise deliver / deploy processed data to DFES and DBCA	30/6/21	complete	<p>Fuel Moisture / VARI Processing</p> <ul style="list-style-type: none"> - Archive processed - Made available to DFES via AWS S3 bucket <p>Fire History Processing</p> <ul style="list-style-type: none"> - Archive processed - Made available to DFES via AWS S3 bucket

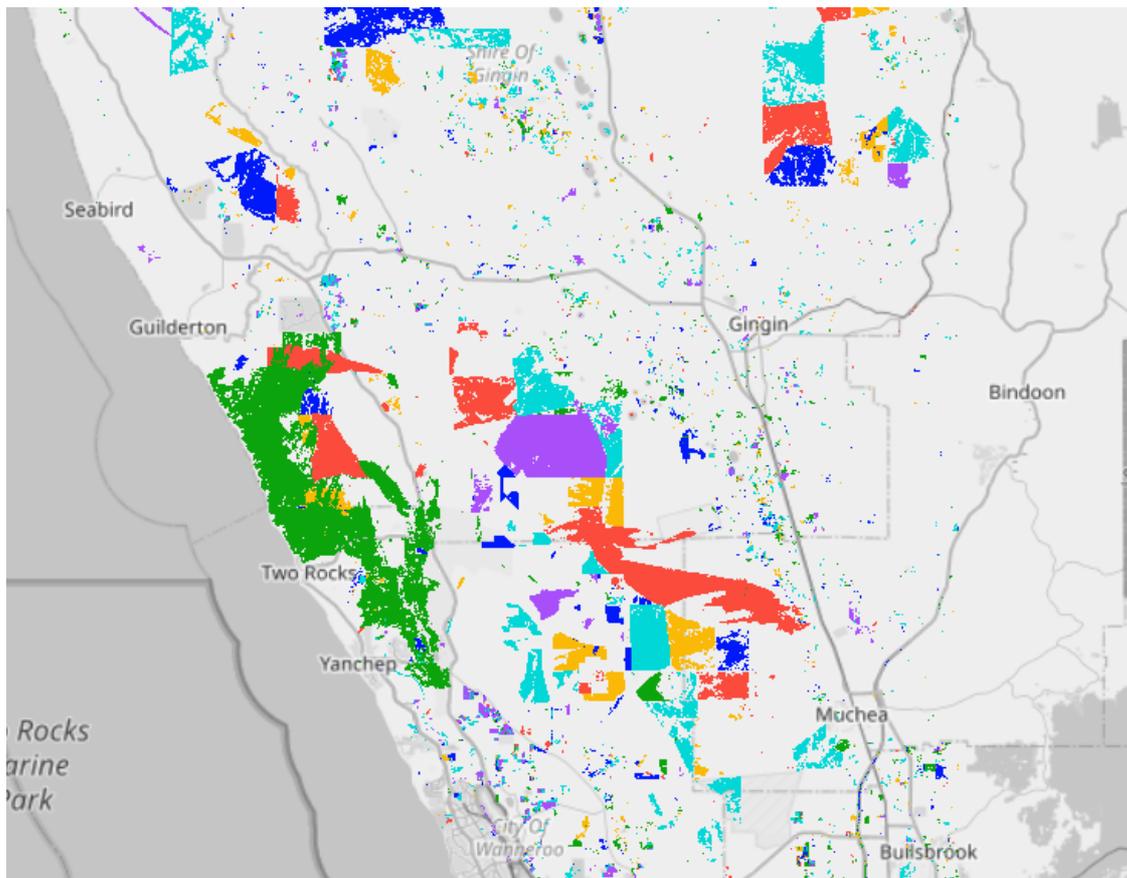
RESULTS

The results of the investigation and processing include a fire history and associated severity estimate from Sentinel 2 imagery spanning 2016 to June 2021, and a time series of fuel moisture surrogate data using two defined remote sensing algorithms. These deliverables are discussed further in the following sections.

FIRE HISTORY FROM SENTINEL 2 IMAGERY

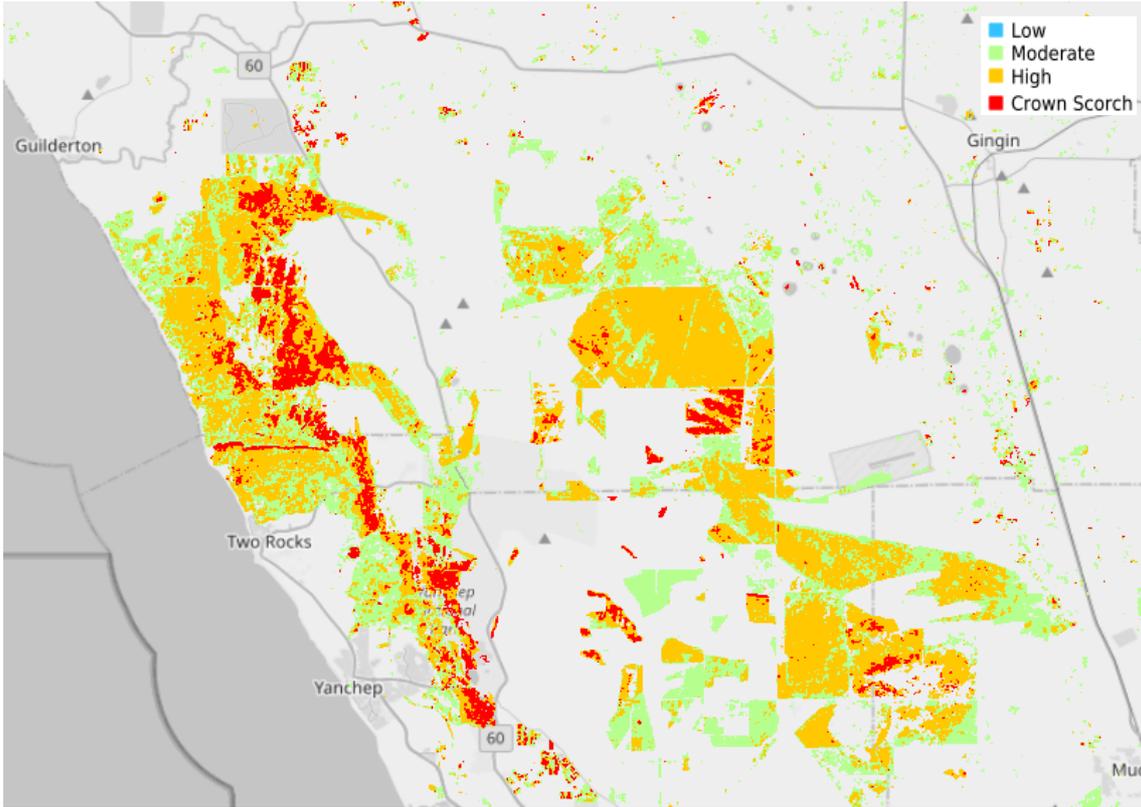
Landgate has been processing and providing Sentinel 2 imagery and creating value added products since the satellites launch. Within this project, we have applied our automatic fire scar mapping algorithm to the full time-series available of Sentinel 2 satellite imagery, spanning 2016 to 30 June 2021. The processing level within this project was L1C, from ESA.

The derived dataset consists of a TIF image file for each year. Each file contains the date of the mapped fire scar as the digital data value. For example, a fire scar mapped from a Sentinel 2 image from the 1st February 2018 would have data value of 201 in the 2018 file. A scar mapped on the 12th October would have a data value of 1021. The below image shows a subset of the fire history developed over the greater Yanchep area spanning 2016 to 30 June 2021.



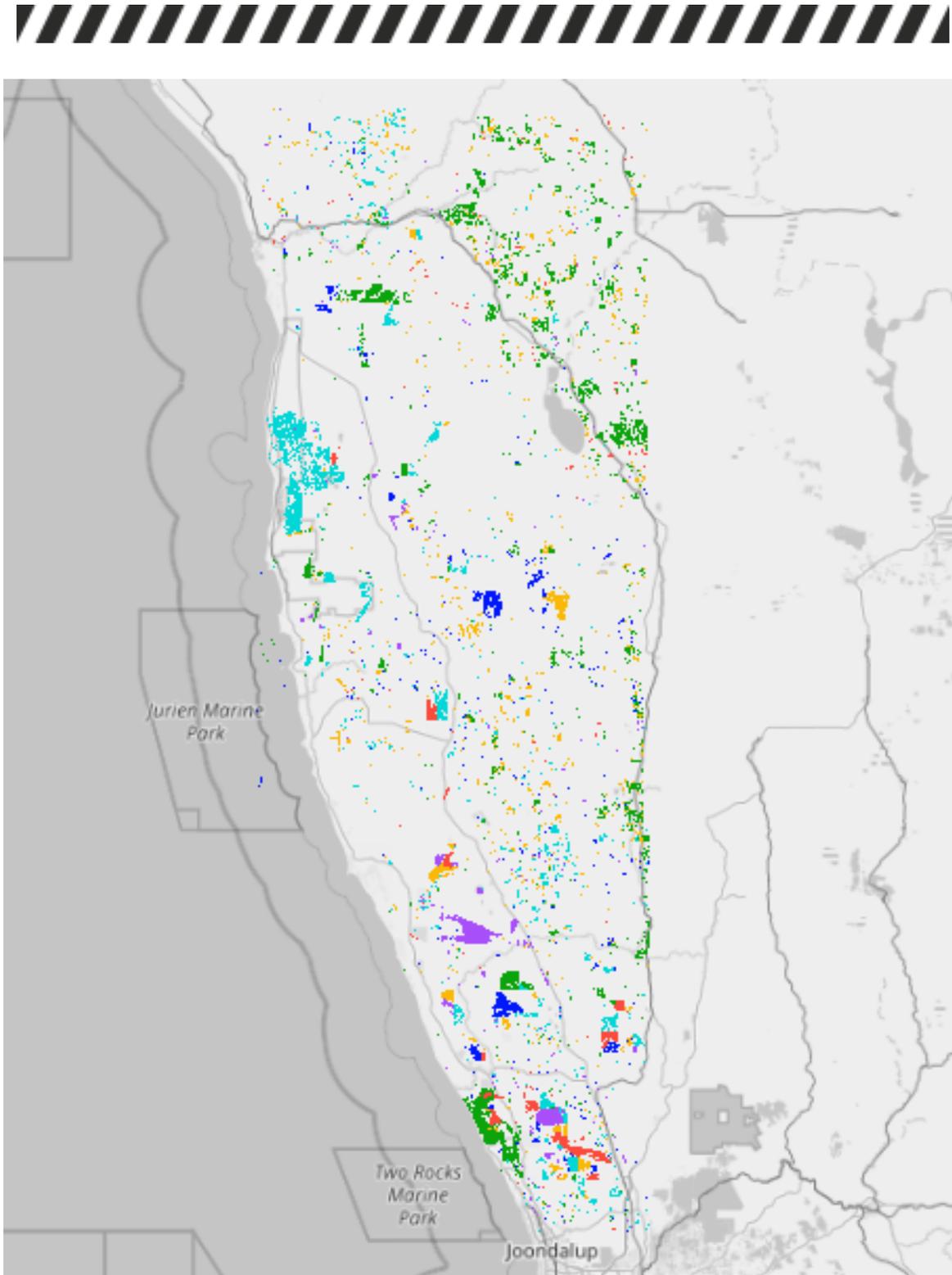
FIRE HISTORY DEVELOPED FROM 2016 TO 30 JUNE 2021 FROM SENTINEL 2 IMAGERY.

The below image shows a subset of the fire severity dataset that is also produced for each fire history area identified, over the greater Yanchep area spanning 2016 to 30 June 2021.



FIRE SEVERITY HISTORY DEVELOPED FROM 2016 TO 30 JUNE 2021 FROM SENTINEL 2 IMAGERY

The below image shows the total area processed for this project, being 3 Sentinel 2 tiles : 50JLL (Lancelin), 50JLM (Cerventes), and 50JLN (Mingenew).



FIRE HISTORY DEVELOPED FROM 2016 TO 30 JUNE 2021 FROM SENTINEL 2 IMAGERY OVER 3 TILES.

FUEL MOISTURE ESTIMATION ALGORITHMS

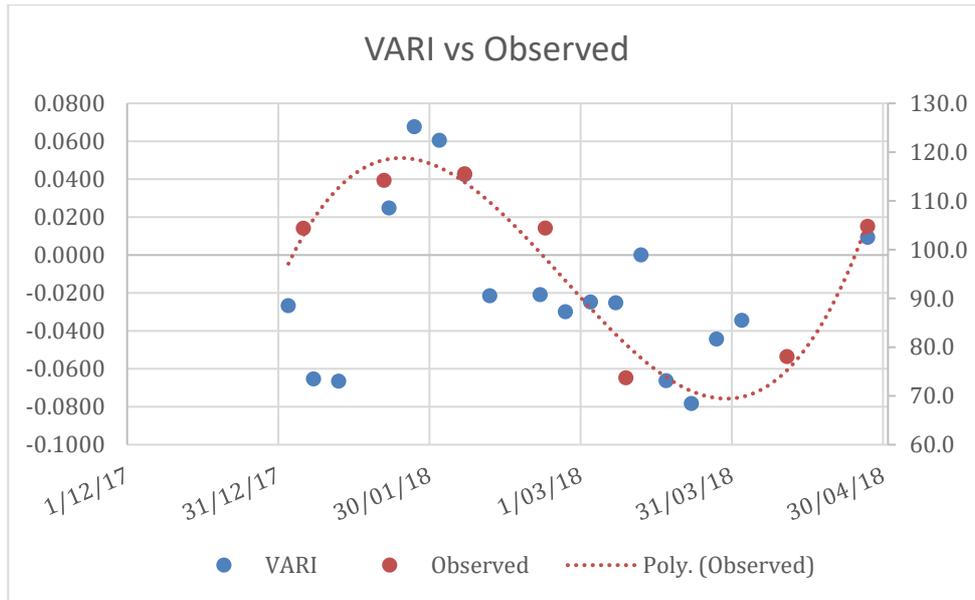
The project team was interested to investigate whether an existing remote sensing formula would have a high correlation with fuel moisture observations in the near coastal shrublands. DFES had briefly investigated using the Visible Atmospherically Resistant Index (VARI) algorithm and seen correlation with fuel moisture. Within this project, DFES were interested to have a time series of sentinel 2 data developed with the VARI algorithm, to enable further research. Therefore,

VARI imagery was produced over the 3 tiles of interest, for the archive spanning 2016 to June 2021. In addition to this deliverable, the project team also discussed merit in investigating the VARI 700 algorithm too. Therefore, in addition, an archive of VARI 700 imagery was also produced for further investigation.

DFES have 3 sites where field observations have been collected. The below table shows a sample of VARI imagery values developed vs observed fuel moisture values for further analysis.

Date	VARI	OBSERVED
2/01/2018	-0.02679831	
5/01/2018		104.362253
7/01/2018		
7/01/2018	-0.06540698	
10/01/2018		
12/01/2018	-0.06657420	
17/01/2018		
20/01/2018		
21/01/2018		114.1661945
22/01/2018	0.02470930	
25/01/2018		
27/01/2018		
27/01/2018	0.06761566	
30/01/2018		
1/02/2018	0.06042296	
6/02/2018	0.04235537	115.5254165
9/02/2018		
11/02/2018	-0.02150538	
14/02/2018		
16/02/2018		
19/02/2018		
21/02/2018	-0.02098951	
22/02/2018		104.3837904
		etc....

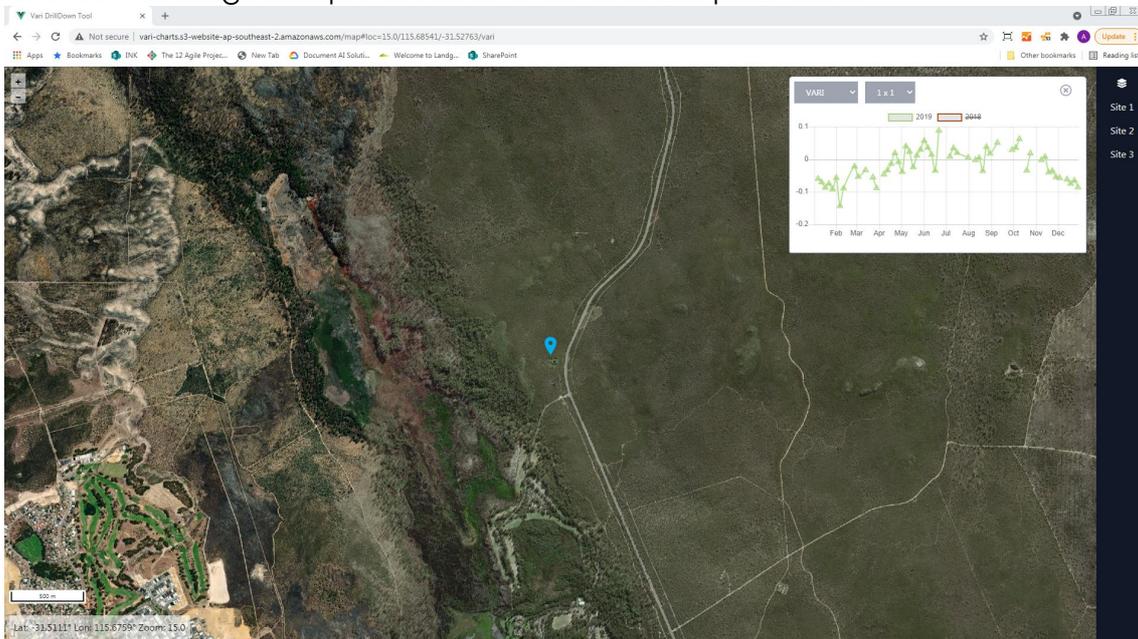
The chart below shows the VARI calculations vs observed values for DFES test site 3. The time series data will enable DFES to see if there is a relationship between VARI or VARI700 calculations and observed fuel moisture from their field observations.



VARI CALCULATIONS VS OBSERVED VALUES FOR 2018.

INTERACTIVE QUERY TOOL

To assist with the analysis, we loaded the VARI and VARI700 imagery produced for 2018 and 2019 into an online interactive mapping system where locations on an image map can be selected and the VARI and VARI700 values can be retrieved and visualised for 2018 and 2019. The Interactive Query Tool¹ enables rapid querying to support GIS analysis and visualisation of this time series data set and can average sample areas at a 1x1 and 3x3 pixel area.



INTERACTIVE QUERY TOOL TO VISUALISE TIME SERIES TRENDS FOR VARI AND VARI700 DATA.

¹ Access to the Interactive Query Tool (<http://vari-charts.s3-website-ap-southeast-2.amazonaws.com>) can be arranged by contacting Adrian Allen at Landgate via rsrs@landgate.wa.gov.au.



CONCLUSION

This project has developed a series of time series products from Sentinel 2 satellite imagery, to assist in furthering our understanding of the events during the Black Summer Bushfires, in particular, the Yanchep fire in WA.

The study area is the coastal shrubland region of the greater Yanchep area spanning the Sentinel 2 image tiles 50JLL (Lancelin), 50JLM (Cerventes), and 50JLN (Mingenew)

The project developed value added Sentinel 2 imagery datasets applying the VARI and VARI 700 algorithms, to the full Sentinel 2 imagery archive spanning 2015/21 to June 2021, to investigate their suitability as surrogate measures for fuel moisture.

The project also developed a fire history and associated burn severity estimate from Sentinel 2 satellite imagery over the coastal shrubland region in the greater Yanchep area spanning 2016 to June 2016, using automatic methods developed previously by Landgate.

The processed time series of Sentinel 2 satellite imagery will assist inform fire reconstruction research into the Yanchep fires of 2019/2020 and the wider region.



TEAM MEMBERS

The team involved in this sub project is listed below. The wider project is led by DFES, DBCA, ANU and Murdoch University.

RESEARCH TEAM

Adrian Allen (Landgate)

Norman Santich (Landgate)

Passang Dorji (Landgate)

Agnes Kristina (DFES)

Jackson Parker (DFES)

END-USERS

DFES

DBCA

Murdoch University