Australian Google Earth Engine Burnt Area Map

A Rapid, National Approach to Fire Severity Mapping

Department of Agriculture, Water and the Environment

Cataloguing data

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Acknowledgements

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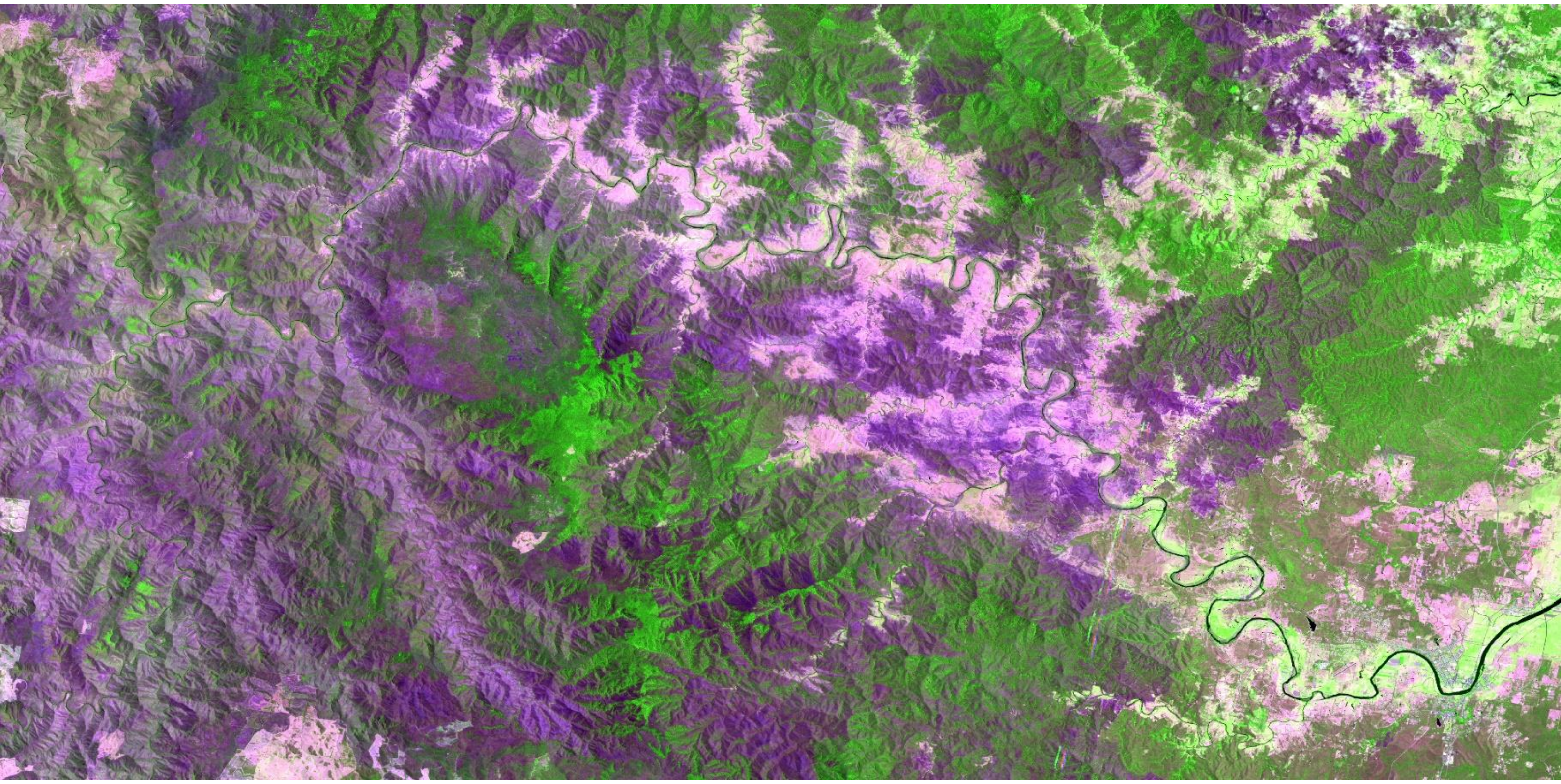

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Executive Summary

The Commonwealth Department of Agriculture, Water and the Environment (DAWE) collaborated with the NSW Department of Planning, Industry and Environment (DPIE) to develop a rapid, national approach to mapping fire severity.

The results will be used to quantify the potential impacts of the 2019/20 bushfires on wildlife, plants and ecological communities and to identify appropriate response and recovery actions.

The DPIE Remote Sensing and Landscape Science Branch has developed the Australian Google Earth Engine Burnt Area Map (AUS GEEBAM). The dataset uses Sentinel-2 satellite imagery from before and after the fires of the 2019/20 bushfire season. AUS GEEBAM presents four fire severity classes for the areas represented in the National Indicative Aggregated Fire Extent Dataset (NIAFED) from the 25th of February 2020.

By leveraging the processing power of cloud computing, AUS GEEBAM can be produced rapidly. This allows for fortnightly updates of fire severity during a fire season if required. This document details the methodology used and provides a brief comparison to existing fire severity maps from states and territories.

A set of random points were used to examine the relationship between AUS GEEBAM and fire severity mapping from Victoria, New South Wales and South Australia. The points were stratified by each state's maps. When comparing four classes (Unburnt, Low and Moderate, High, and Very High severity) the overall accuracy of AUS GEEBAM was between 48% and 82%. When comparing two simple classes (Moderate and High severity) the overall accuracy rose to between 72% and 92%. It is important to note that this is not a traditional validation as there is no point of truth. Each map used in the comparisons will contain errors.

AUS GEEBAM was calibrated using visual interpretation of remote sensing data and no field data was used. Currently, field data and detailed air photo analysis is collected independently in each state and territory. It would be a powerful resource if it were collated at a Commonwealth level and made available to researchers.

The intention of AUS GEEBAM is not to replace fire severity maps from each state and territory but to provide a nationally consistent fire severity map. It is likely that individual state and territory fire severity maps will more accurately represent variation in fire severity as they benefit from local expertise and local calibration data. However, the state and territory datasets do not fulfil the need for a national fire severity dataset built with a common methodology.

Background

In late 2019 and early 2020, Australia experienced concurrent mega-fires throughout New South Wales, Queensland, Victoria and South Australia and its most devastating fire season on record (Nolan et al. 2020).

Fire can impact natural ecosystems and ecological communities by releasing sequestered carbon (Abbott et al. 2016), altering nutrient cycles and water quality (Ice et al. 2004, Bladon et al. 2014), altering plant distribution (Barlow and Peres 2008), and causing wildlife injury and mortality (Esque et al. 2003).

When assessing the impact of a fire within an ecosystem it is of great importance to understand how and where the fire has burnt, as often fires burn with varied intensities, leaving a landscape burnt at a range of severity levels.

Here, the term fire intensity is used to describe fire behaviour and the energy that is released from the fire, while fire severity refers to the effects the fire had on the ecosystem, vegetation or loss in biodiversity.

The Australian Government's Threatened Species Recovery Hub set a goal to provide an immediate ecological response to Australia's 2019/2020 wildfire events. This calls for conservation practitioners to provide a "rapid assessment of biodiversity loss" and to "locate and protect key refuge areas" (Dickman et al. 2020).

To mitigate against bushfire events and assist with the species recovery effort it is important to understand the spatial extent of fires across species distributions and landscapes as well as to rapidly identify refugia habitat for targeted post-bushfire conservation actions.

Potential bushfire refuges often persist in fire affected landscapes. Keppel et al. (2012) suggest terrestrial biodiversity can potentially persist in this refugia habitat, which can remain intact in an otherwise largely fire affected landscape (Collins et al. 2019), often due to factors of topography, fuel loads, and fire intensity (Bradstock et al. 2010, Collins et al. 2012).

In order to meet these goals, a rapid spatial assessment tool is required to understand the scale and severity of bushfire.

Techniques for fire severity mapping have traditionally relied on the difference between vegetation indices from before and after fires (Keely, 2009). More recent advances, such as relativised vegetation indices, use imagery from before the fire to help calibrate between fires (Parks et al. 2014).

Victoria has developed a fire severity mapping method using machine learning classification (random forests) of vegetation indices from before and after fire using Sentinel-2 satellite imagery (Collins et al. 2018). The results highlight the benefit of using multiple vegetation indices in a classification. It is based on a large collection of point data from previous fires and visual interpretation of high spatial resolution remote sensing data. However, it has not been implemented more widely.

Gibson et al. (2020) demonstrated a similar approach to mapping fire extent and severity through a machine learning framework based on Sentinel-2 satellite imagery. It shared the advantage of being calibrated with fires from previous seasons and included vegetation cover as a component. However, while this is being implemented operationally with state agencies in NSW, to date it remains incomplete for all fires in NSW.

Severity classes derived from vegetation indices from before and after fires (Parks et al. 2014) are widely used to map the severity of large bushfires (Collins et al. 2018). Using a single vegetation index and setting thresholds has the advantage of being rapid and simple to implement widely. However, there are shortcomings that include poor delineation of low fire severity classes, and unsatisfactory performance when classification thresholds are applied to new landscapes.

Aim

The aim of this project was to create a consistent, rapid, national approach to fire severity mapping to inform bushfire response.

The requirements were to:

a) Create a national fire severity map with a consistent methodology and classification system,
b) Create an approach that can be reproduced rapidly during and after a fire season,
c) Establish a relationship between a national fire severity map and the products in use at state and territory agencies.

To meet these requirements, we introduce the Australian Google Earth Engine Burnt Area Map (AUS GEEBAM).

Methods

Overview of workflow
AUS GEEBAM relies on Sentinel-2 satellite imagery and vegetation indices from before and after fires. It differs to existing approaches in several ways. It harnesses the power of cloud computing (Google Earth Engine) to create national time series mosaics without clouds, shadows or artefacts.

The number of severity classes has been reduced by combining low and moderate severity fires.

AUS GEEBAM classes are calibrated systematically for each bioregion using visual interpretation of Sentinel 2 false colour composites. Allocating fire severity classes is carried out by a single interpreter. AUS GEEBAM is a scalable approach that can cover large areas rapidly, while still providing reasonable accuracy at higher severity classes.

This method does introduce bias. However, any product that relies on the visual interpretation of remote sensing for calibration is also subject to bias (Fisher et al. 2018; Collins et al. 2018; Gibson et al. 2020). To mitigate observer bias, bioregions and vegetation mapping were used to encourage a systematic approach to visual interpretation across the landscape (Figure 1). This allows the observer to focus on, for example, rainforest and alpine heathlands and calibrate them independently from tall forest.

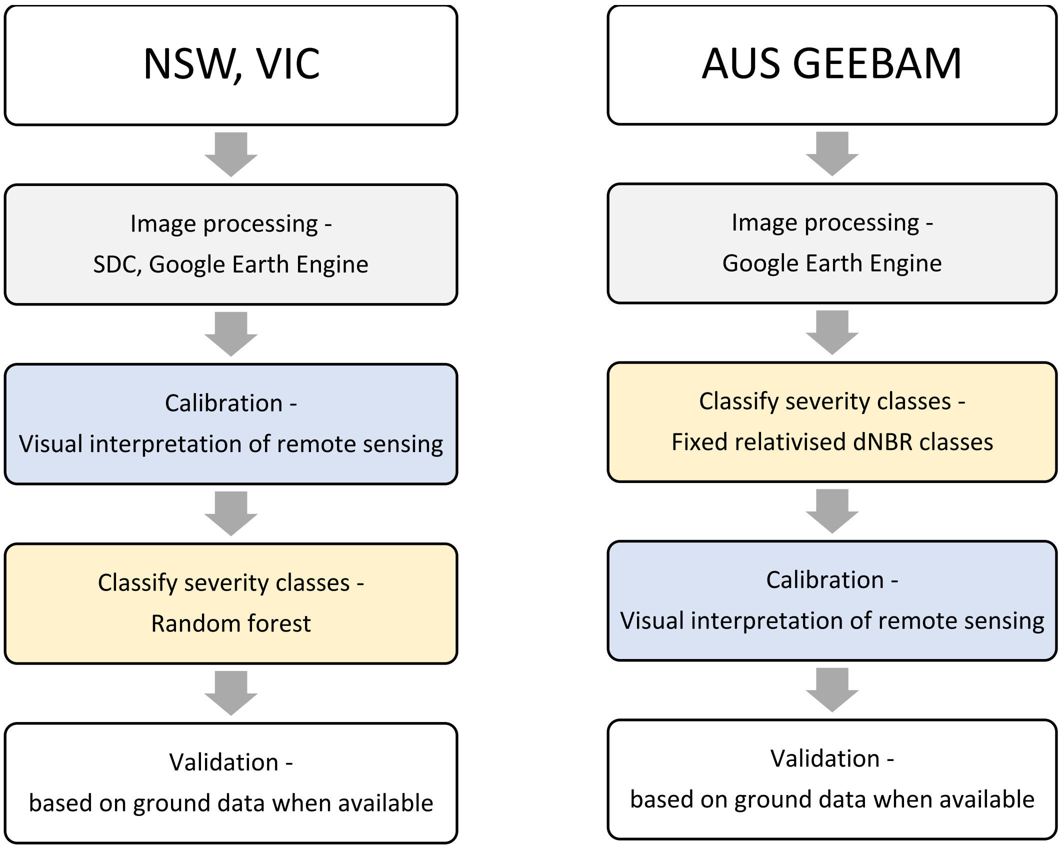

Figure 1. A comparison of workflows of fire severity maps from NSW/VIC and GEEBAM.

In the aftermath of the 2019/2020 fires there is a wide range of field data and very high-resolution aerial photography being acquired. These data will provide an opportunity to conduct a more rigorous evaluation of AUS GEEBAM. When enough data is available it will be possible to implement AUS GEEBAM classes based on multiple indices.

Data and Inputs

National Indicative Aggregated Fire Extent Dataset (NIAFED).

The extent of bushfires for AUS GEEBAM in 2019/2020 relies on the National Indicative Aggregated Fire Extent Dataset (NIAFED).

NIAFED takes the national Emergency Management Spatial Information Network Australia (EMSINA) data service, which is the official fire extent currently used by the Commonwealth and adds supplementary data from other sources to form a cumulative national view of fire extent.

The EMSINA data service shows current active fire incidents while NIAFED shows the total fire extent from 1st of July 2019 to the 24th of February 2020 (Figure 2). This dataset is released on behalf of the Commonwealth Government and endorsed by the National Burnt Area Dataset Working Group, convened by the National Bushfire Recovery Agency.

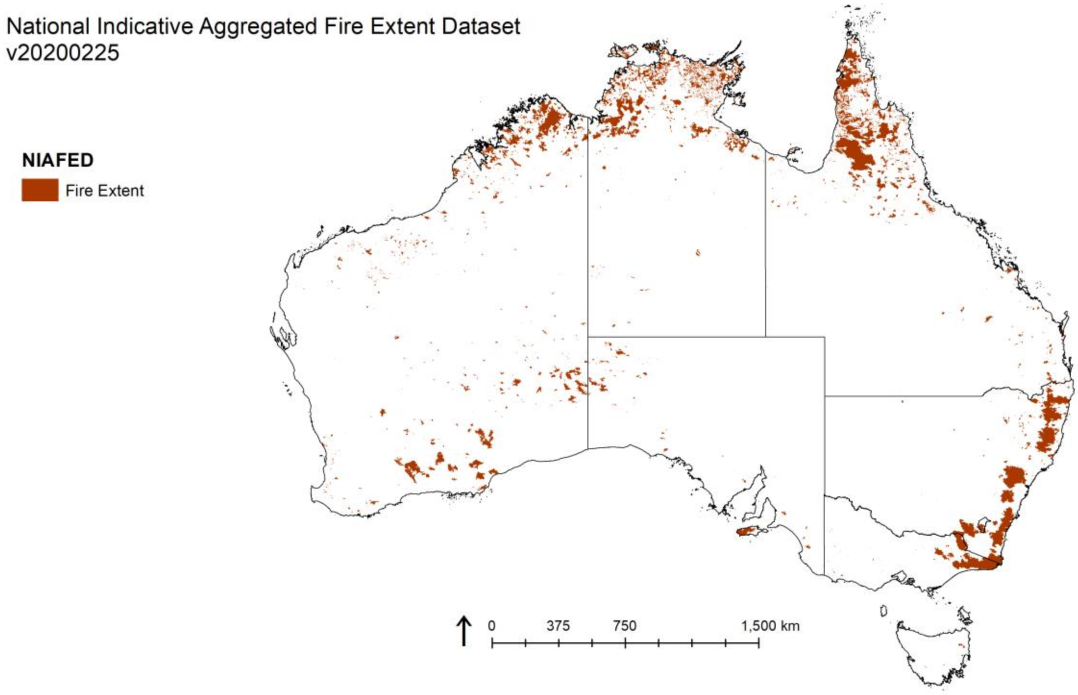

Figure 2. National Indicative Aggregated Fire Extent Dataset (NIAFED) for July 1st, 2019 to February 24th, 2020.

National Vegetation Information System (NVIS)

The National Vegetation Information System (NVIS) was developed to assist in managing a range of ecosystem services and practices such as biodiversity conservation, salinity control, improving water quality and fuel-load management.

The NVIS framework was developed to enable the compilation of a nationally consistent vegetation dataset from data collected by states and territories. NVIS describes the structural and floristic patterns of groups of plants in the landscape. Collectively, the different levels in the classification provide a description of vegetation that can be directly related to precise spatial areas as a vegetation map.

For AUS GEEBAM the latest available vegetation maps from each state were compiled, assigned NVIS vegetation types, and converted to a WGS84 40m raster (Figure 3).

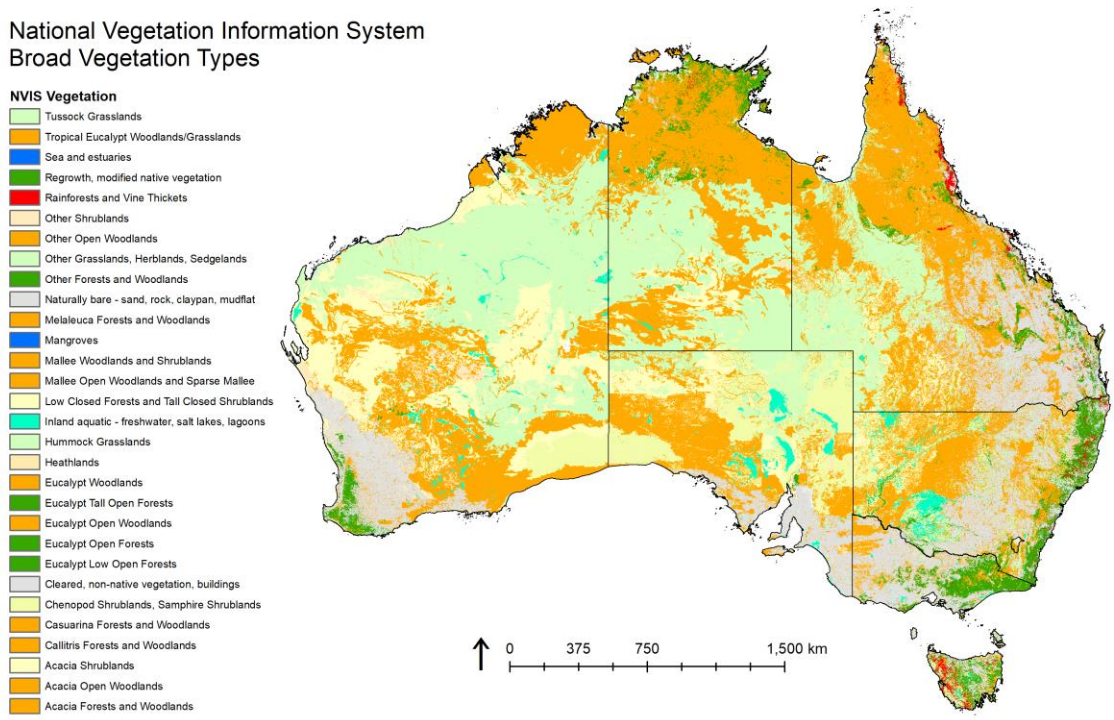

Figure 3. National Vegetation Information System (NVIS) symbolised by broad vegetation types.

Interim Biogeographic Regionalisation for Australia (IBRA)

The national and regional planning framework for the systematic development of a comprehensive, adequate and representative 'CAR' National Reserve System is provided by the Interim Biogeographic Regionalisation for Australia (IBRA).

The latest version, IBRA7, classifies Australia's landscapes into 89 large geographically distinct bioregions based on common climate, geology, landform, native vegetation and species information. For example, the Australian Alps, the Nullabor Plain and the Wet Tropics are distinct bioregions. The 89 bioregions are further refined to form 419 subregions which are more localised and homogenous geomorphological units in each bioregion. The bioregions and subregions are defined in the IBRA7 bioregional map. IBRA is a more detailed subset of the global ecoregions. For AUS GEEBAM the IBRA 7 bioregions were converted to a WGS84 40m raster (Figure 4).

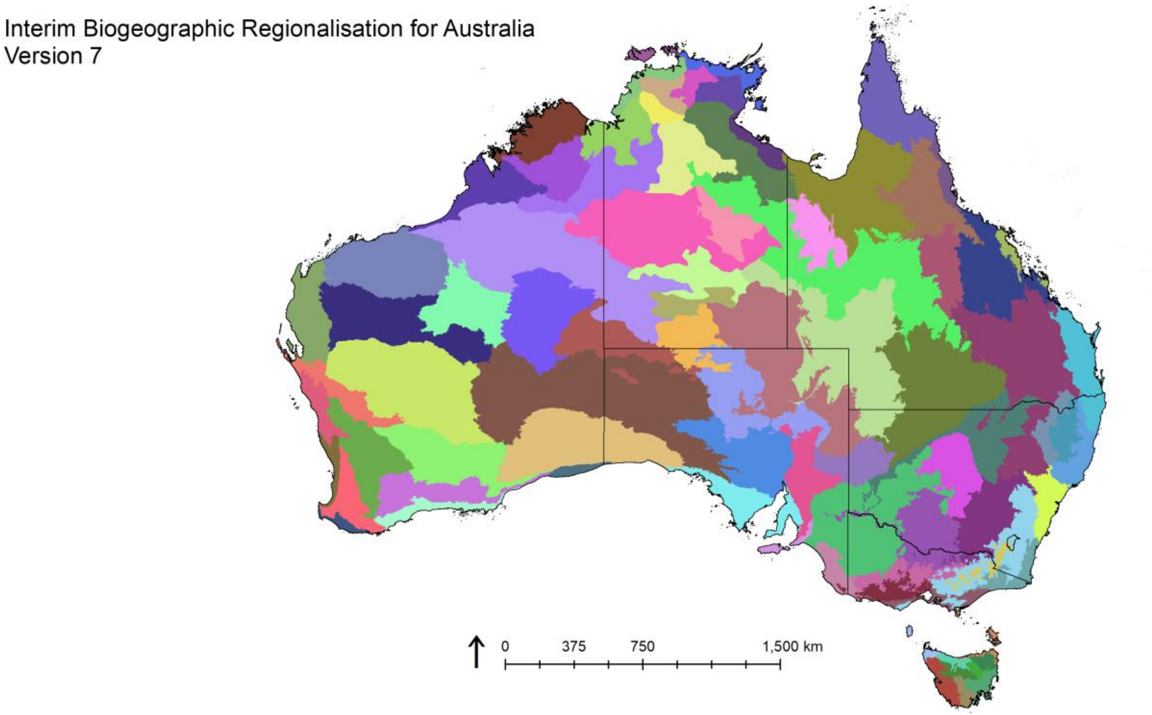

Figure 4. Interim Biogeographic Regionalisation for Australia (IBRA) converted to a WGS84 40m raster.

Sentinel-2 (S2) Surface Reflectance (L2)

Sentinel-2 is a wide-swath, high resolution, multispectral imaging mission with a global 5-day revisit frequency from the European Space Agency (ESA). The S2 Multispectral Instrument (MSI) samples 13 spectral bands: visible and Near Infra-Red (NIR) at 10 meters, red edge and Short Wave Infra-Red (SWIR) at 20 meters, and atmospheric bands at 60 meters spatial resolution. It provides data suitable for assessing state and change of vegetation, soil, and water cover.

For use in Google Earth Engine, the Sentinel-2 surface reflectance (L2) data are downloaded from the Copernicus Open Access Hub. Removal of clouds and atmospheric and topographic corrections are performed using sen2cor. See the Sentinel-2 User Handbook for details.

Creating time series mosaics of median surface reflectance

AUS GEEBAM relies on a mosaic of a series of Sentinel-2 images. The SWIR bands at 20 m mitigate smoke and haze in the atmosphere, and thus provides useful imagery for bushfire events.

AUS GEEBAM uses five national mosaics created as the basis for vegetation indices. The dates were chosen to represent the late fires in southern Australia up to May 15th, 2020. However, in this mosaic regrowth in northern NSW and QLD was clearly apparent as a “greening up” of the image. An early season image was used in tandem to capture fires earlier in the season up to the

15th of February 2020. To ensure the pre-fire mosaic was independent of these time series, and free of cloud and shadows, a time series from April 2018 to April 2019 was used.

The tropics have an entirely different fire season so two mosaics were created to capture fires in northern Australia up until the 15th of January 2020 (Table 1).

Table 1. Date ranges of time series mosaics calculated as the median pixel value.

Season	Version Name	Pre-fire Image Dates	Post-fire Image Dates	NIAFED Date
South Early	AUS GEEBAM	20180415 - 20190415	20191115 - 20200215	20200224
South Late	AUS GEEBAM	20180415 - 20190415	20200115 - 20200515	20200224
Tropics	AUS GEEBAM	20181015 - 20190115	20191015 - 20200115	20200224

Vegetation Indices

AUS GEEBAM uses the difference between the normalized burnt ratio (NBR) before and after fire. NBR is an index designed to highlight burnt areas in large fire zones. The formula is similar to the normalized difference vegetation index (NDVI), but it uses near-infra red (NIR) and short wave infra-red (SWIR2) wavelengths.

$$\mathrm{NBR} = \frac{\mathrm{NIR} - \mathrm{SWIR2}}{\mathrm{NIR} + \mathrm{SWIR2}}$$

The difference between the pre-fire and post-fire NBR is denoted as dNBR. A higher value of dNBR indicates increased likelihood that the area has burnt, while areas with negative dNBR values may indicate regrowth following a fire. The dNBR formula is demonstrated below:

$$\mathrm{dNBR} = \mathrm{Pre} - \mathrm{fire\ NBR} - \mathrm{Post} - \mathrm{fire\ NBR}$$

Relativised Normalized Burnt Ratio (RNBR)

Parks et al (2014) proposed a Landsat-based burn severity metric, the relativized burn ratio (RNBR). Simply put, RNBR is the dNBR divided by an adjustment to the pre-fire NBR. Adding 1.001 to the denominator ensures that the denominator will never be zero, thereby preventing the equation from reaching infinity and failing.

A relativized version of burn severity is advantageous where pre-fire vegetative cover is low. Low NBR will generally have low dNBR values regardless of the degree of fire-induced mortality of the vegetation. As an absolute measure of change, dNBR simply does not allow for the quantification of high severity in these cases, even if all pre-fire vegetation is consumed. As a result, dNBR values are often correlated to pre-fire NBR. The denominator in the equation for RNBR removes this correlation and allows the metric to be more sensitive than dNBR to changes where pre-fire vegetation cover is low. As such, a relative index like RNBR is theoretically more suited to detect changes to vegetation on a consistent scale:

$$\mathrm{RNBR} = \frac{\mathrm{dNBR}}{(\mathrm{NBRpre} - \mathrm{fire} + 1.001)}$$

To incorporate RNBR values for both the early and late fire season Sentinel 2 mosaics, the maximum RNBR value was selected for each pixel to create MaxRNBR used in creating severity classes.

Reclassifying continuous RNBR values as ordinal quantiles

AUS GEEBAM relies on Sentinel-2 satellite imagery and vegetation indices from before and after fires. RNBR classes are created by dividing the frequency distribution into equal groups, each containing the same fraction of the total population (~0.235 RNBR increments).

Calibrating RNBR quantiles using visual interpretation of remote sensing

To determine a reference unburnt condition, the NIAFED extent was buffered by 2km. For each NVIS broad vegetation type in each IBRA bioregion a reference unburnt RNBR class was determined. That value was available to calculate a standardised offset or a reference unburnt value.

Each IBRA bioregion was systematically assessed to correct for obvious errors. For example, the Very High severity class could be adjusted down by one RNBR Value for a fire where its extent extended into an area of lower severity. Conversely, there were areas of shrublands that had clearly burnt at Very High severity where all of the biomass is likely to have been consumed but low pre-fire biomass had given it a lower RNBR Value.

Rainforest was calibrated independently to detect subtle changes in RNBR. Despite the apparent low severity of fires in these systems, most rainforests are sensitive to fire and recovery can be slow (Hjerpe et al. 2001, Cochrane and Schulze 1999, Brando et al. 2014). Post-fire monitoring is warranted in these situations to ascertain the response of rainforest to low severity fires.

Each pixel of AUS GEEBAM contains the raw RNBR Value, the RNBR Class and the GEEBAM Value. This allows an end user to observe which values have been adjusted during the calibration away from the default global RNBR Value and allows for some transparency in the process.

The process, while complex to explain, is simple to implement. Calibration of RNBR for AUS GEEBAM was completed by a single operator in two days. Using a single operator helps reduce observer error, as does the systematic process and the reference unburnt values. Given that single index thresholds are known to feature poor delineation of low fire severity classes (Collins et al. 2018), the Low and Moderate severity classes were combined (Table 2).

Table 2. AUS GEEBAM classes with descriptions.

GEEBAM Value	GEEBAM Class	Description
1	No data	No data indicates areas outside NIAFED or NVIS categories that do not represent native vegetation (e.g. cleared land, water)
2	Unburnt	Little or no change observed between pre-fire and post-fire imagery
3	Low and Moderate	Some change or moderate change detected when compared to reference unburnt areas outside the NIAFED extent
4	High	Vegetation is mostly scorched
5	Very high	Vegetation is clearly consumed

Evaluating AUS GEEBAM

AUS GEEBAM was calibrated using visual interpretation of remote sensing data and no field data was used. Field data is still being collected and will be required to provide confidence intervals and a validation of map accuracy.

As an interim solution a multiple lines of evidence approach was taken to evaluate AUS GEEBAM. To explore the relationship between AUS GEEBAM and fire severity mapping from Victoria (VIC), New South Wales (NSW) and South Australia (SA), a set of points were randomly stratified as the basis of a comparison. This will help users understand the strengths and limitations of AUS GEEBAM and how it can be used to supplement the fire severity maps from local agencies (Table 3).

The points were used to calculate a measure of overall accuracy for AUS GEEBAM ("Classified") relative to local products ("Ground Truth"). The points were stratified by fire severity mapping from VIC, NSW and SA and intersected with those fire severity maps (resampled to 40m WGS84) and AUS GEEBAM (40m WGS84).

It is important to note that this is not a traditional validation as there is no point of truth. Both maps will contain errors.

Table 3. Fire severity mapping from Victoria (VIC), New South Wales (NSW) and South Australia (SA)

State or Territory	Dataset Name	Description	Custodian	Link
NSW	Fire Extent and Severity Map (FESM)	Fire severity is a metric of the loss of biomass caused by fire. In collaboration with the NSW Rural Fire Service, DPIE Remote Sensing & Regulatory Mapping team has developed a semi-automated approach to mapping fire extent and severity through a machine learning framework based on Sentinel-2 satellite imagery.	DPIE	NSW
VIC	Fire severity map	Fire severity classification of bushfires (wildfires) impacting ~1.5 million hectares of predominantly forested public land in eastern and north-eastern Victoria (and ~300,000 ha of southern NSW), between November 2019 and March 2020.	DELWP	VIC
SA	Fire severity map	Fire severity mapping based on Landsat 8 / Sentinel-2 imagery has been completed for: Cudlee Creek, Keilira & Bunbury Fires (SE), Kangaroo Island, and Miltalie. Fire severity = Pre-fire image NBR – Post-fire image NBR.	DEW	SA

Equivalence was determined for each severity map for all four AUS GEEBAM classes (Table 4) representing "Unburnt", "Low and Moderate severity", "High severity" and "Very High Severity".

Table 4. Fire severity map evaluation class equivalent for four classes

Test Class	AUS GEEBAM	AUS GEEBAM Value	NSW Fire Severity	NSW Value	VIC Fire Severity	VIC Value	SA Fire Severity	SA Value
Not used	Not Native	1	Non-FESM mapped burnt area, No data, grasslands	1	Non-woody, No data	1	No data	
C_2	Unburnt	2	Unburnt	0	Unburnt	2	Unburnt (< 0.25)	1
C_3	Low and Moderate	3	Low, Moderate	2, 3	Low , Medium canopy scorch	3, 4	Low (0.25-0.50)	2
C_4	High	4	High Severity	4	High canopy scorch	5	Medium (0.50-0.75)	3
C_5	Very High	5	Extreme Severity	5	Canopy burnt	6	High (> 0.75)	4

AUS GEEBAM is a rapid triage tool for decision makers where the question may simply be, “How much has burnt and where are the really severe fires?”. Therefore, map evaluation class equivalents were also created for two classes representing “Moderate” and “High”.

Classes that were not used in the severity equivalence classes include No Data, Not Native Vegetation and burnt areas not mapped in NSW. Points were only selected that fell within the NIAFED extent.

Table 5. Fire severity map evaluation class equivalent for two classes

Test Class	AUS GEEBAM	AUS GEEBAM Value	NSW Fire Severity	NSW Value	VIC Fire Severity	VIC Value	SA Fire Severity	SA Value
Not used	Not Native,	1	Non-FESM mapped burnt area, No data, grasslands	1	Non-woody, No data	1, 2	No data	
C_2	Unburnt, Low and Moderate	2, 3	Unburnt, Low, Moderate	2, 3	Unburnt, Low, Medium canopy scorch	3, 4	Unburnt (< 0.25), Low (0.25-0.50)	1, 2
C_5	High and Very High	4, 5	High Severity, Extreme Severity	4, 5	High canopy scorch/High burnt	5, 6	Medium (0.50-0.75), High (> 0.75)	3, 4

A confusion matrix was calculated on errors of omission and commission. It calculated the user's accuracy and producer's accuracy for each class as well as overall accuracy. These accuracy rates range from 0 –1, with 1 representing 100 percent accuracy.

User's accuracy shows false positives, where pixels are incorrectly classified as a known class when they should have been classified as something else. Producer's accuracy is a false negative, where pixels of a known class are classified as something other than that class. The overall accuracy is calculated as the total number of correctly classified pixels (diagonal elements) divided by the total number of test pixels.

Results

The most powerful tool used in AUS GEEBAM is the automated creation of times series Sentinel-2 mosaics. AUS GEEBAM uses the median from a time series of surface reflectance images to mitigate cloud, shadow, and haze. This allows for the creation of multiple national mosaics from a series of dates in two days. That includes date selection and visual assessment, downloading, mosaicking and the creation of vegetation indices (Figure 5).

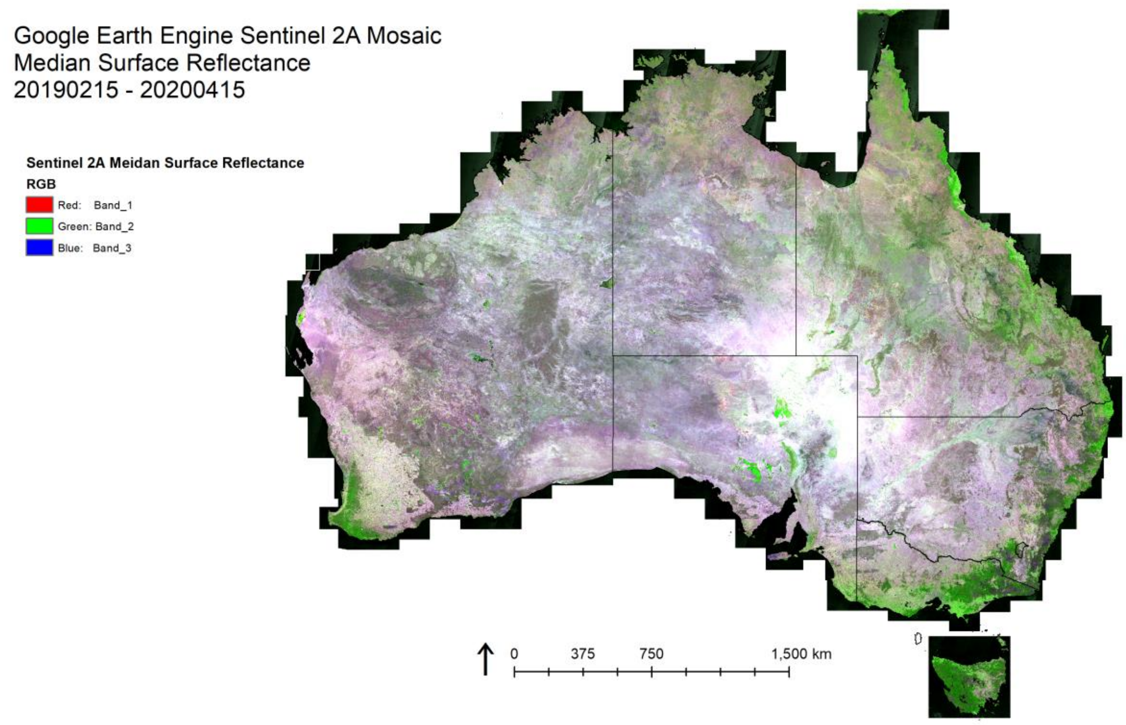

Figure 5. Sentinel-2 Surface Reflectance WGS84 40m mosaic.

The three mosaics that made up the southern MaxRNBR were pre-fire NBR, early season post-fire NBR and late season NBR (Table 1). The MaxRNBR was divided into quantiles that are listed in Table 6.

Table 6. Reclassifying continuous RNBR Values as ordinal quantiles.

RNBR Value	RNBR From	RNBR To	RNBR Class	Count	Hectares
-3	-4.999	-0.043	2	4347	701
-2	-0.043	-0.020	2	8911	1437
-1	-0.020	0.004	2	31028	5004
0	0.004	0.004	2	22584685	3642546
2	0.004	0.027	2	17902288	2887351
3	0.027	0.051	2	17575749	2834685
4	0.051	0.074	2	14700823	2371006
5	0.074	0.098	2	13379492	2157897
6	0.098	0.121	2	12742853	2055217
7	0.121	0.145	2	11989747	1933753
8	0.145	0.168	3	11029982	1778959
9	0.168	0.192	3	10100610	1629066
10	0.192	0.215	3	9249255	1491756
11	0.215	0.239	3	8410640	1356501
12	0.239	0.262	3	7601680	1226029
13	0.262	0.286	3	6845718	1104104
14	0.286	0.309	3	6138827	990094
15	0.309	0.333	3	5459173	880477
16	0.333	0.356	4	4819203	777260
17	0.356	0.380	4	4204033	678043
18	0.380	0.403	4	3636479	586506
19	0.403	0.427	4	3124301	503899
20	0.427	0.450	4	2674641	431377
21	0.450	0.497	4	4156869	670436
22	0.497	0.544	5	2925668	471863
23	0.544	0.591	5	1999976	322564
24	0.591	0.990	5	1972124	318072

Table 6 includes the RNBR Value with the corresponding range of raw RNBR values, the global default RNBR class, the number of pixels and the number hectares this count represents. RNBR classes are available in AUS GEEBAM and can be displayed as greyscale as a representation of raw RNBR values.

Each pixel of AUS GEEBAM (Figure 6) contains the raw RNBR Value, the RNBR Class and the GEEBAM Value. This allows an end user to observe which values have been adjusted during the calibration away from the default global RNBR Value and allows for some transparency in the results.

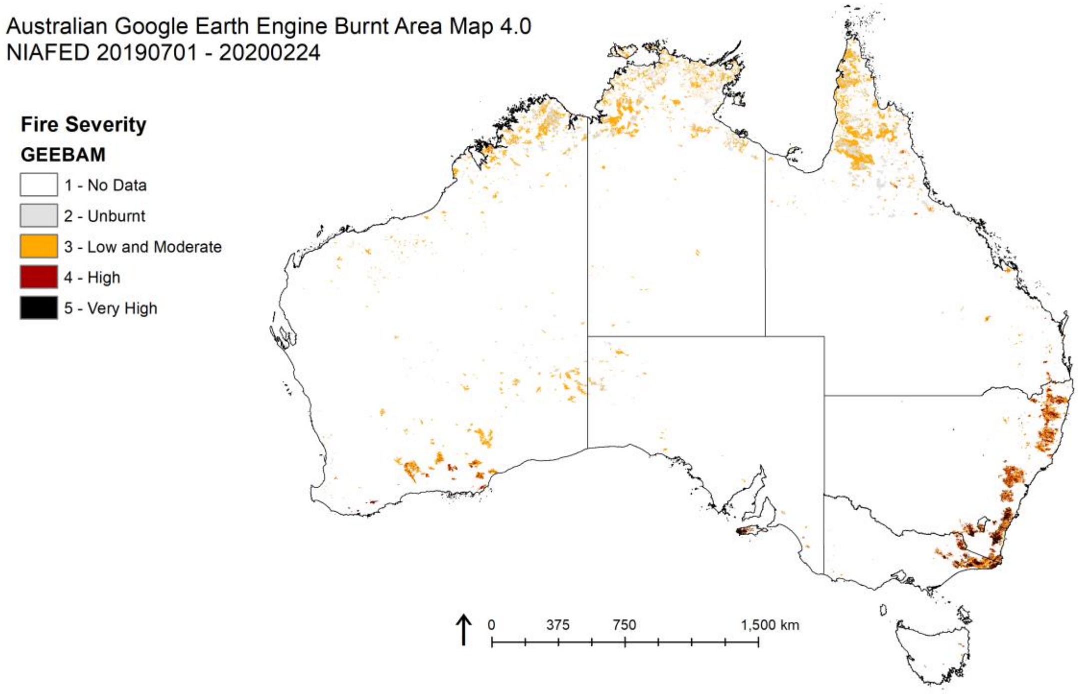

Figure 6. Australian Google Earth Engine Burnt Area Map 4.0

Randomly select points were stratified by the fire severity map products from NSW (n = 1975), VIC (n = 1841) and Kangaroo Island in SA (n = 252). The "ground truth" points from each State's map were then compared with the AUS GEEBAM classification results at the same locations.

The points were stratified by each state's maps. When using four classes (Unburnt, Low and Moderate, High, and Very High severity) the overall accuracy of AUS GEEBAM was between 48% and 82%. When using two simple classes (Moderate, High severity) the overall accuracy rose to between 72% and 92% (Appendix).

The figures below illustrate how the Sentinel 2 imagery (Figure 7), and AUS GEEBAM (Figure 9) compare to fire severity mapping from Victoria (Figure 8). There are also images of the fires impact on Kangaroo Island (Figure 10) in South Australia with the corresponding AUS GEEBAM Classes (Figure 11).

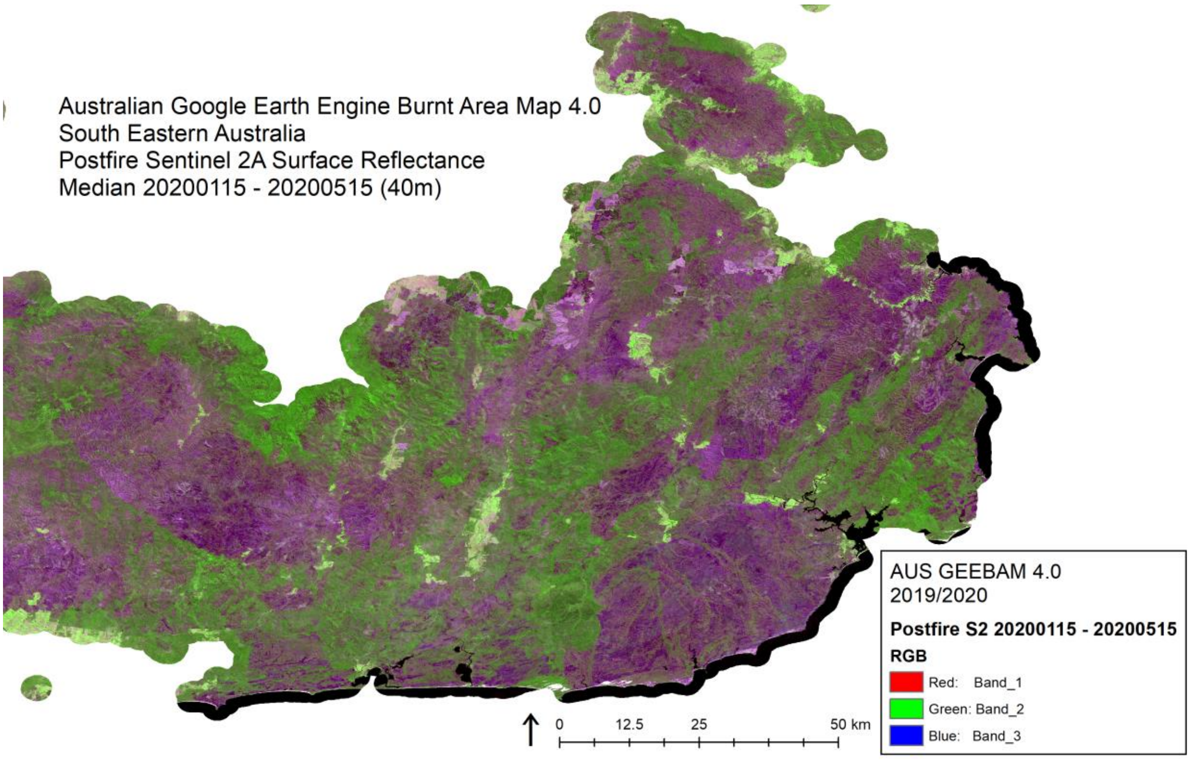

Figure 7. South Eastern Australia – False Colour Mosaic - GEEBAM

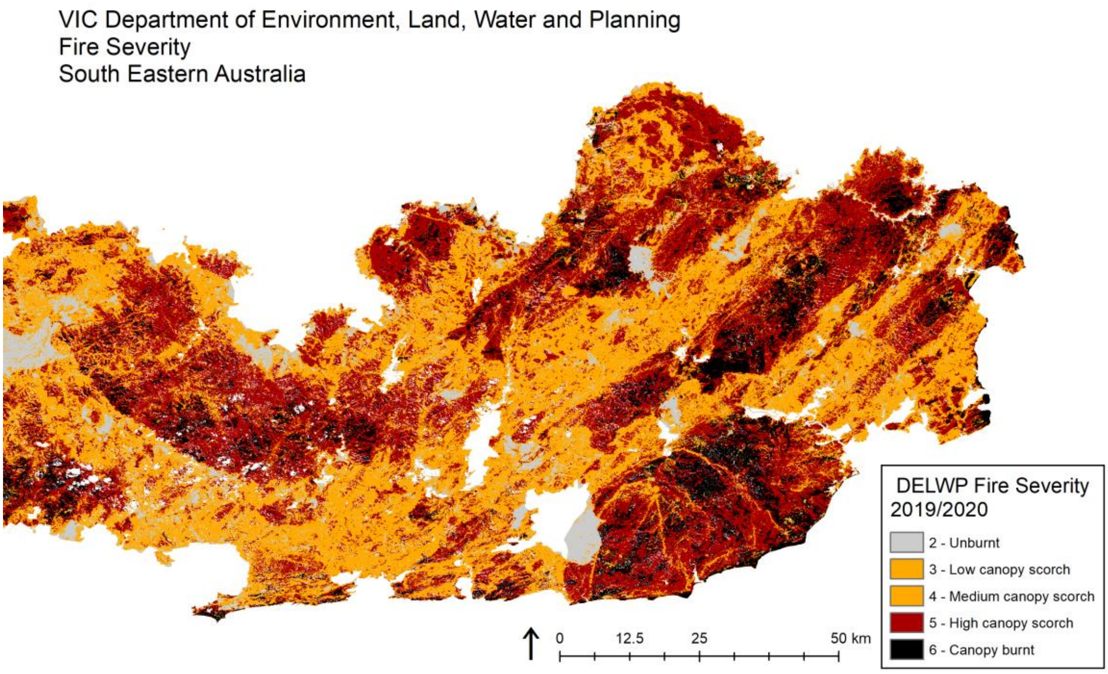

Figure 8. South Eastern Australia – Victorian fire severity map – DELWP

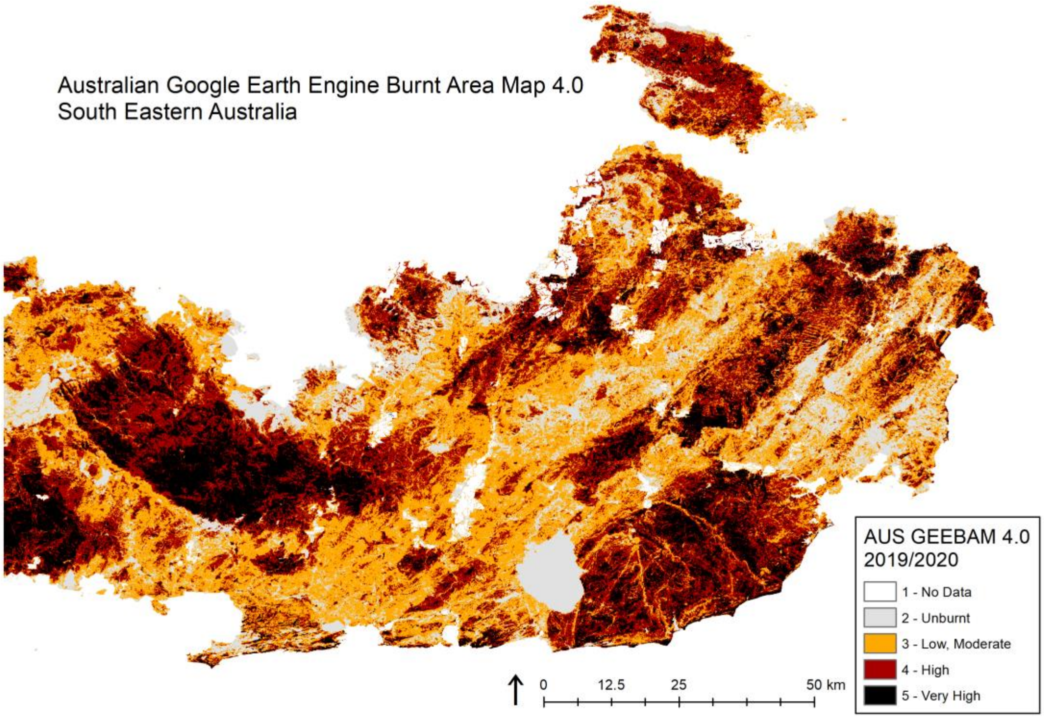

Figure 9. South Eastern Australia – AUS GEEBAM fire severity classes – AUS GEEBAM

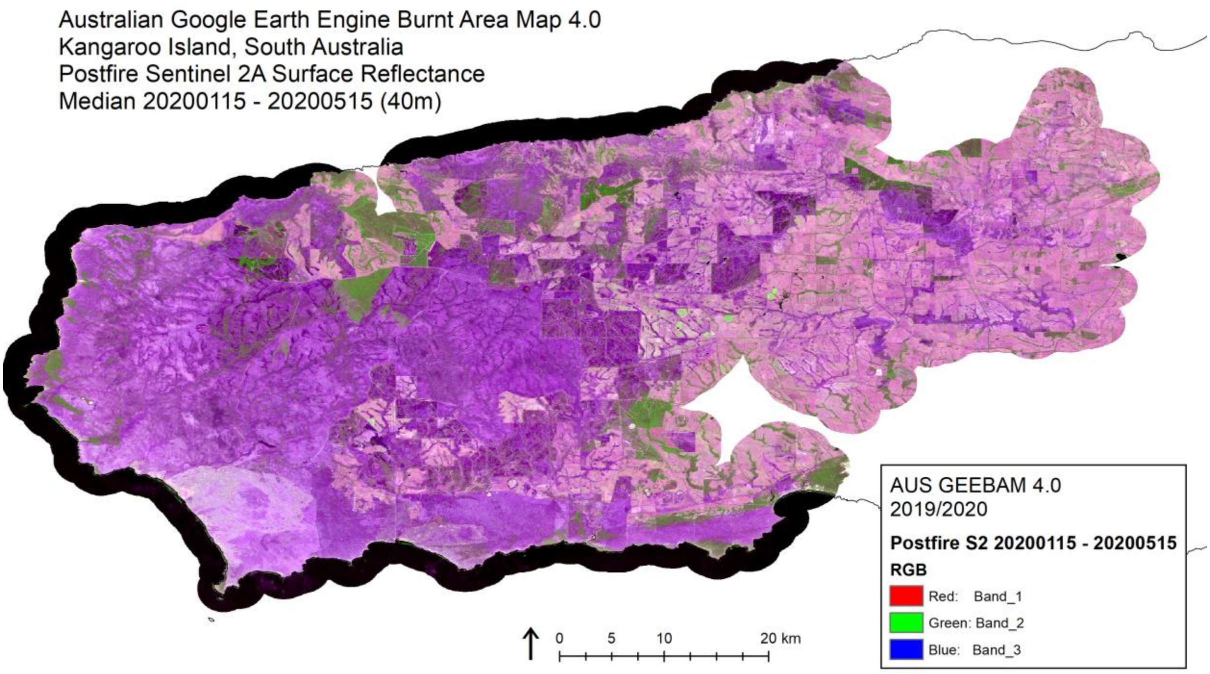

Figure 10. South Australia – Kangaroo Island - False Colour Mosaic – GEEBAM

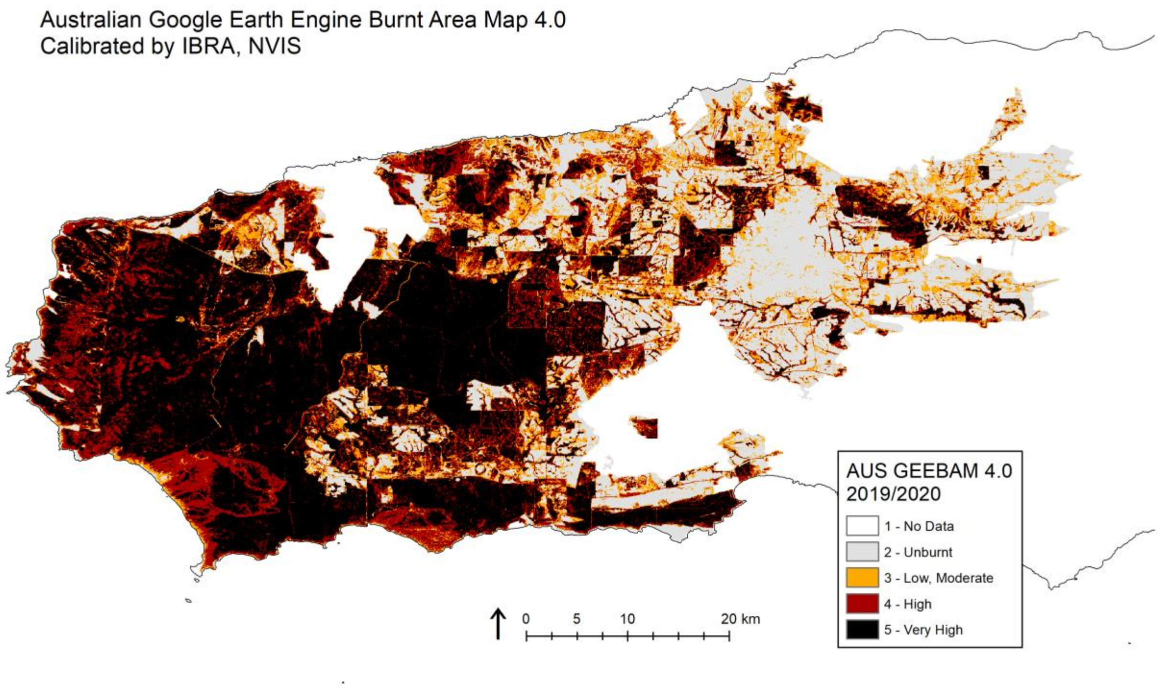

Figure 11. South Australia – Kangaroo Island - GEEBAM fire severity classes – AUS GEEBAM

Discussion

State and Territory fire severity maps are likely to be more accurate than AUS GEEBAM, particularly where they use ground truth data to train the interpretation of satellite imagery. However, all data based on interpretation of remotely sensed imagery is subject to some degree of error. This makes validation of AUS GEEBAM against state and territory datasets challenging. Where the datasets disagree, there is potential for error in both the state and territory data and AUS GEEBAM. Future work will focus on validating AUS GEEBAM based on field data and/or interpretation using very high-resolution remote sensing data. A nationally coordinated and openly accessible set of fire ground truth data would be a valuable asset for this work.

As the intention of AUS GEEBAM was solely to provide a nationally consistent fire severity map, AUS GEEBAM is likely to be less nuanced at low severities than state and territory products, and will not reflect what is found in the field as well as products created with local expertise and calibration data.

AUS GEEBAM is a rapid triage tool for decision makers where the question may simply be, "How much has burnt and where are the really severe fires?". It is designed to be as simple as possible and to be reproduced nation-wide as required.

With a set of training data points, AUS GEEBAM could implement a more sophisticated approach such as the use of multiple indices and deep learning classification without any compromise in scalability and speed. Tools like AUS GEEBAM will become increasingly important as impacts of climate change are realised. They build the capacity for rapid conservation responses, and allow further exploratory investigations into the magnitude and behaviour of bushfire events.

The rapid spatial data provided by the GEEBAM system will be a useful addition to inform public policy decision making for fire and landscape management. Consistent national coverage and classification are important when prioritising responses to widespread bushfire events, with AUS GEEBAM delivering on these requirements.

It is important that there is continuous development of rapid assessment tools to provide spatial data and identification of potential fire refuges and areas of very high severity.

Appendix

New South Wales Fire Extent and Severity Map
(cvmsre_NSWInterim_20200419_ag7l0)

https://data.gov.au/dataset/ds-nsw-c28a6aa8-a7ce-4181-8ed1-fd221dfcefc8/details?q=

Fire Extent and Severity Map (FESM) covers most of the 5.7 million hectares affected by bushfires in NSW between September 2019 and April 2020.

FESM defines fire severity as a metric of the loss of biomass caused by fire. The state-wide severity map has standardised classes to allow comparison of different fires across the landscape. The FESM severity classes include unburnt, low severity (burnt understory, unburnt canopy), moderate severity (partial canopy scorch), high severity (complete canopy scorch, partial canopy consumption), extreme (full canopy consumption).

Table 7. NSW fire severity map – 4 class confusion matrix

ClassValue	C_2	C_3	C_4	C_5	Total	U_Accuracy	Kappa
C_2	128	141	33	2	304	0.421053	0
C_3	167	366	178	6	717	0.51046	0
C_4	97	165	337	51	650	0.518462	0
C_5	60	11	107	126	304	0.414474	0
Total	452	683	655	185	1975	0	0
P_Accuracy	0.283186	0.535871	0.514504	0.681081	0	0.484557	0
Kappa	0	0	0	0	0	0	0.279764

Table 8. NSW fire severity map – 2 class confusion matrix

ClassValue	C_2	C_5	Total	U_Accuracy	Kappa
C_2	802	219	1021	0.785504	0
C_5	333	621	954	0.650943	0
Total	1135	840	1975	0	0
P_Accuracy	0.706608	0.739286	0	0.720506	0
Kappa	0	0	0	0	0.438166

Victorian Fire severity map

https://discover.data.vic.gov.au/dataset/fire-severity-map-of-the-major-fires-in-gippsland-and-north-east-victoria-in-2019-20-version-1-

The Victorian fire severity map covers ~1.5 million hectares of fire affected areas of predominantly forested public land in eastern and north-eastern Victoria (and ~300,000 ha of southern NSW), between November 2019 and March 2020.

Fire severity mapping was derived using machine learning classification (Random forests) of eight Spectral Indices (SI) from pre and post-fire Sentinel-2 satellite imagery. The fire severity classification has 6 classes, (6) High canopy consumption resolution - 20% canopy foliage consumed), (5) High canopy scorch - >80% of canopy foliage is scorched, (4) Medium canopy scorch - Canopy is a mosaic of both unburnt and scorched foliage, 20 - 80%, (3) Low canopy scorch - Canopy foliage is largely unaffected (90%) unburnt.

Table 9. VIC fire severity map – 4 class confusion matrix

ClassValue	C_2	C_3	C_4	C_5	Total	U_Accuracy	Kappa
C_2	103	263	3	0	369	0.279133	0
C_3	35	429	148	5	617	0.6953	0
C_4	1	72	401	73	547	0.73309	0
C_5	0	9	129	170	308	0.551948	0
Total	139	773	681	248	1841	0	0
P_Accuracy	0.741007	0.554981	0.58884	0.685484	0	0.599131	0
Kappa	0	0	0	0	0	0	0.436746

Table 10. VIC fire severity map – 2 class confusion matrix

ClassValue	C_2	C_5	Total	U_Accuracy	Kappa
C_2	830	156	986	0.841785	0
C_5	82	773	855	0.904094	0
Total	912	929	1841	0	0
P_Accuracy	0.910088	0.832078	0	0.870722	0
Kappa	0	0	0	0	0.741615

South Australian Fire severity map

The SA fire severity map was calculated using the following methodology:

1. Pre and post-fire imagery using either Landsat 8 / Sentinel-2 imagery level 2 (bottom of atmosphere surface reflectance) downloaded from USGS / Copernicus Open Access Hub/NCI.
2. Band stacking to datasets of same resolution.
3. Normalised Burn Ratio = (NIR – SWIR) / (NIR + SWIR) applied to pre and post images.
   Landsat 8: Band 4 (NIR), Band 7 (SWIR).
   Sentinel-2: Band 8A (NIR) / Band 12 (SWIR).
4. Fire severity = Pre fire image NBR – Post fire image NBR.

Classes are: Unburnt (< 0.25), Low (0.25-0.50), Medium (0.50-0.75), and High (> 0.75).

Table 11. SA fire severity map – 4 class confusion matrix

Class Value	C_2	C_3	C_4	C_5	Total	User Accuracy	Kappa
C_2	41	29	0	0	70	0.585714	0
C_3	3	19	6	0	28	0.678571	0
C_4	0	6	39	4	49	0.795918	0
C_5	0	0	14	91	105	0.866667	0
Total	44	54	59	95	252	0	0
P Accuracy	0.93181	0.351852	0.661017	0.957895	0	0.753968	0
Kappa	0	0	0	0	0	0	0.660687

Table 12. SA fire severity map – 2 class confusion matrix

Class Value	C_3	C_5	Total	User Accuracy	Kappa
C_3	92	6	98	0.938776	0
C_5	6	148	154	0.961039	0
Total	98	154	252	0	0
P Accuracy	0.938776	0.961039	0	0.952381	0
Kappa	0	0	0	0	0.899814

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