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NSW Post-fire Biomass Recovery Monitoring by Remote Sensing

Report for 3 years following 2019–20

Department of Planning and Environment

Acknowledgement of Country

The Department of Planning and Environment acknowledges the Traditional Custodians of the lands where we work and live.

We pay our respects to Elders past, present and emerging.

This resource may contain images or names of deceased persons in photographs or historical content.

Cover photo: Bald Rock regrowth since February 2019 fires. Leah Pippos/DPE

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Introduction

Observational monitoring of post-fire biomass recovery at the landscape scale is important to help us understand drivers of recovery processes, identify vulnerable ecosystems and prioritise management interventions to support ecological resilience. Remote sensing scientists from the Department of Planning and Environment's (hereafter the department's) Science, Economics and Insights Division have developed the NSW Post-fire Biomass Recovery Monitoring system. By mapping post-fire change in a satellite-based spectral reflectance index, the method can be used to monitor the change in the amount and greenness of vegetation cover following fires that have been previously mapped through the NSW fire extent and severity mapping (FESM) system (DPIE 2021).

Although bushfires are part of a natural cycle in our environment, they are increasing in frequency, severity and extent and continue to encroach on the wildland–urban interface. As the magnitude of disturbance and compounding stressors increase, post-fire recovery processes may be altered, making ecosystems vulnerable to significant change in structure and function, or ecological collapse. Following the extreme bushfire season of 2019–20, there is considerable concern from land managers and researchers regarding the pressure these fires have imparted on ecological resilience at a landscape scale, particularly due to short inter-fire intervals.

Our novel approach provides a relatively simple and practical estimate for broad-scale, early monitoring of post-fire biomass recovery. It follows recent advances in systematic, standardised remote sensing approaches to mapping fire severity (FESM; Gibson et al. 2020). Together, the fire severity and post-fire biomass recovery products provide consistent methods for mapping and monitoring fires in New South Wales, extensive opportunities for fire and landscape ecology research, and targeting management actions.

It is important to note that the remote sensing estimates reported here cannot discern between a stable state that has recovered to the pre-disturbance structure and function, and an alternative stable state. Furthermore, the mapping must not be interpreted as a surrogate estimate for all levels of post-fire ecological recovery. The intended use of the data is for early monitoring of post-fire recovery of vegetation cover at the landscape scale and as a decision support tool for identifying potentially vulnerable ecosystems with limited or delayed recovery. There may be additional areas of concern that are not highlighted by this method.

This report summarises the 2019–20 post-fire recovery monitoring analysis for 1, 2 and 3 years following the black summer of 2019–20. The summary report is accompanied by spatial data on the Sharing and Enabling Environmental Data (SEED) portal.

NSW Post-fire Biomass Recovery Monitoring method

The NSW Post-fire Biomass Recovery Monitoring system is based on the concept that a disturbed system state will be reflected by high rates of system change, while undisturbed or recovered system states are characterised by near-zero rates of change. This reflects the typical pattern of diminishing rates of spectral change in post-fire recovery trajectories. The burnt area initially shows large post-fire changes in vegetation cover until it eventually returns to a stable state, synchronising with surrounding unburnt area (Figure 1).

Figure 1 **Typical pattern of spectral change in post-fire time series**

Commonly, remote sensing methods of post-fire biomass recovery compare the post-fire environment to a pre-fire baseline. However, these approaches are strongly influenced by the method used to define the pre-fire baseline and are very likely to be confounded by climatic fluctuations over various timeframes. Our novel approach uses a spectral index, which compares the difference in the Normalised Burn Ratio-2 (NBR2, a short-wave infrared spectral index; Storey et al. 2016; Hislop et al. 2018) between the target recovery year relative to 1 year previous, for any time since fire. This provides an estimate of the relative increase (i.e. post-fire biomass recovery class values greater than 7) or decrease (i.e. post-fire biomass recovery class values less than 7) in vegetative cover (Table 1). This method does not attempt to assess vegetation cover relative to a pre-fire baseline.

The NSW Post-fire Biomass Recovery Monitoring system is integrated with the well-established FESM operational system, using the same technology. FESM is a remote sensing assessment of fire extent and severity that estimates the loss or change in vegetation caused by fire (Table 2). By comparing the post-fire biomass recovery classes across fire severity classes, patterns of post-fire recovery can be robustly compared between fires across the landscape and through time.

Further information on the FESM method is available on our *Fire extent and severity maps* webpage (see 'More information' below).

Table 1 **Post-fire recovery classification**

Pixel value	Post-fire recovery class	Index values
1	extreme decrease	<–500
2	very large decrease	–400 to –500
3	large decrease	–300 to –400
4	moderate decrease	–200 to –300
5	small decrease	–100 to –200
6	very small decrease	–50 to –100
7	little to no change	–50 to 50
8	very small increase	50 to 100
9	small increase	100 to 200
10	moderate increase	200 to 300
11	large increase	300 to 400
12	very large increase	400 to 500
13	extreme increase	>500

Table 2 **FESM fire severity classification**

Severity class	Description	Percentage foliage fire-affected
Unburnt	Unburnt surface with green canopy	0% canopy and understory burnt
Extent only	Burnt surface (grass fires)	100% burnt area
Low	Burnt understory with unburnt canopy	>10% burnt understory >90% green canopy
Moderate	Partial canopy scorch	20–90% canopy scorched
High	Full canopy scorch (+/– partial canopy consumption)	>90% canopy scorched <50% canopy biomass consumed
Extreme	Full canopy consumption	>50% canopy biomass consumed

Interpretation of a time series of maps and calculating the post-fire recovery class areas across fire severity classes are useful tools to indicate when the burnt area may have reached a stable state. A stable state may be indicated when post-fire recovery values represent little to no change in cover, and where all fire severity classes are synchronised with surrounding unburnt areas, over multiple consecutive years. This may indicate either recovery to the pre-fire state, or an alternative stable state, but this distinction cannot be determined from this remote sensing method.

Accuracy and future improvements

In developing the NSW Post-fire Biomass Recovery Monitoring system, various spectral indices and approaches were tested against field measures of post-fire recovery. The modified NBR index (NBR2) performed best in monitoring post-fire change (Gibson et al. 2022). Our results align with other recent research that has found NBR2 to be particularly useful in post-fire recovery monitoring of forested ecosystems (Storey et al. 2016; Hislop et al. 2018).

The method was found to strongly differentiate between severity classes and correlate well with field-based measures of recovery dynamics taken at 1 year post-fire (Gibson et al. 2022). Remote sensing using spectral indices does not provide direct observation of changes in vertical structure of vegetation. However, our field data showed that the method captured recovery trends that were associated with forest structure. For example, in high and extreme severity classes, greater values of the index (i.e. relatively greater increases in cover) were associated with a higher percentage of trees with canopy resprouting, while sites with a higher percentage of trees with topkill were associated with lower index values (i.e. relatively lower increases in cover).

The method is expected to have similar limitations as other remotely sensed estimates of change in vegetation cover based on spectral indices. There is likely to be reduced accuracy with topographic complexity, high canopy density, and in wetter areas that change significantly in optical reflectance signals over short time periods, especially through summer (Gibson et al. 2020). There is ongoing development and testing of the Post-fire Biomass Recovery Monitoring system, including further field validation across a wider range of ecosystems and time since fire to assess performance of the index more comprehensively across the landscape. Research is also underway to examine the potential for radar satellite sensors to contribute to the NSW Post-fire Biomass Recovery Monitoring system, addressing the difficult problem of assessing post-fire structural change at the statewide scale.

NSW statewide assessment of 2019–20 post-fire biomass recovery

The 2019–20 fire year was widely recognised as unprecedented in the extent of wildfires that occurred along the eastern part of New South Wales. In the 3 years following these fires, there has been drought-breaking high rainfall and relatively mild temperatures due to extended La Niña conditions. The high rainfall conditions would have largely been favourable to post-fire vegetative recovery, although flooding and erosion from extreme rainfall events may have been detrimental to post-fire biomass recovery in some areas.

In the first year following the 2019–20 fires, over 75% of the areas that were burnt at higher severity had large to extreme increases in vegetative cover (Table 3, Figure 2, Figure 6a). This is likely due to the typical post-fire flush of epicormic resprouting and new seedling establishment. Only 1% of areas burnt at high or extreme severity had little to no change in cover, and 2% of total burnt area had small decreases in vegetation cover compared to the previous year. Notably, the Sydney Basin had a much larger proportion of area with small to moderate increase in vegetative cover compared to other areas of the state (Figure 2).

In the second year following the 2019–20 fires, approximately 15% of the areas burnt at high or extreme severity had moderate to very large increases in vegetative cover across the state (Table 4, Figure 3, Figure 6b). Around 30% of areas burnt at high or extreme severity had little to no change in cover, and 6% of total burnt area had small decreases in vegetation cover compared to the previous year. In the third year following the 2019–20 fires overall, there were much smaller levels of change in cover (Table 5, Figure 4, Figure 6c). This is likely to have been in part due to the change in rainfall conditions that occurred in 2022–23 across the 2019–20 fireground (Figure 5).

It is important to note that the mapping has been generated on a fire-by-fire basis. Some adjacent fires occurred at different times throughout the fire season, particularly in the north of the state, with both early and later season fires occurring within a local area. This may explain incongruous landscape patterns where some adjacent fires appear to have starkly contrasting changes in post-fire vegetation cover.

Table 3 **Statewide assessment of severity class by post-fire biomass recovery class for year 1 post-2019–20**

Severity class	Definition	Post-fire biomass recovery class areas (hectares)													
		no data*	1. extreme decrease	2. very large decrease	3. large decrease	4. moderate decrease	5. small decrease	6. very small decrease	7. little to no change	8. very small increase	9. small increase	10. moderate increase	11. large increase	12. very large increase	13. extreme increase
extreme	full canopy consumption	5,409	10	2	12	56	267	376	4240	8,645	40,252	67,206	84,872	90,562	747,960
high	full canopy scorch, partial consumption	9,993	19	16	261	1,108	3,534	4,354	22,174	28,019	126,379	195,854	202,907	176,617	444,980
moderate	partial canopy scorch	43,670	289	70	280	1,090	3,353	5,774	62,354	103,686	358,663	366,277	265,410	157,452	170,561
low	burnt understory, unburnt canopy	80,052	519	66	253	915	2,676	5,829	124,677	162,286	351,579	243,006	120,542	50,169	72,326

*no data is the area within the 2019–20 FESM extent that could not be assessed with the post-fire stability index due to factors such as cloud contamination or subsequent fire

Table 4 Statewide assessment of severity class by post-fire biomass recovery class for year 2 post-2019–20

Severity class	Definition	Post-fire biomass recovery class areas (hectares)													
		no data*	1. extreme decrease	2. very large decrease	3. large decrease	4. moderate decrease	5. small decrease	6. very small decrease	7. little to no change	8. very small increase	9. small increase	10. moderate increase	11. large increase	12. very large increase	13. extreme increase
extreme	full canopy consumption	11,849	98	72	526	1,682	5,949	18,597	274,069	212,178	314,874	128,042	47,024	18,612	16,297
high	full canopy scorch, partial consumption	16,947	250	124	450	1,568	7,080	29,484	391,135	297,983	344,634	95,063	22,883	5,333	3,282
moderate	partial canopy scorch	92,532	1,401	614	934	2,977	21,109	76,652	713,853	345,573	230,470	39,487	8,438	2,784	2,105
low	burnt understory, unburnt canopy	134,698	1,027	279	698	2,503	22,671	97,759	603,590	203,698	120,498	19,946	4,479	1,522	1,527

*no data is the area within the 2019–20 FESM extent that could not be assessed with the post-fire stability index due to factors such as cloud contamination or subsequent fire

Table 5 **Statewide assessment of severity class by post-fire biomass recovery class for year 3 post-2019–20**

Severity class	Definition	Post-fire biomass recovery class areas (hectares)													
		no data*	1. extreme decrease	2. very large decrease	3. large decrease	4. moderate decrease	5. small decrease	6. very small decrease	7. little to no change	8. very small increase	9. small increase	10. moderate increase	11. large increase	12. very large increase	13. extreme increase
extreme	full canopy consumption	44,655	246	208	1,083	4,705	41,997	106,514	635,226	143,571	56,812	9,370	2,874	1,116	1,491
high	full canopy scorch, partial consumption	70,306	466	350	1,225	4,860	44,074	125,700	750,950	149,322	58,134	7,937	1,588	634	669
moderate	partial canopy scorch	142,046	1,016	602	1,432	6,723	77,644	205,038	930,554	128,072	39,528	3,873	1,081	487	834
low	burnt understory, unburnt canopy	159,166	1,033	529	1,530	7,708	78,430	172,116	664,525	85,247	40,250	2,378	767	397	818

*no data is the area within the 2019–20 FESM extent that could not be assessed with the post-fire stability index due to factors such as cloud contamination or subsequent fire

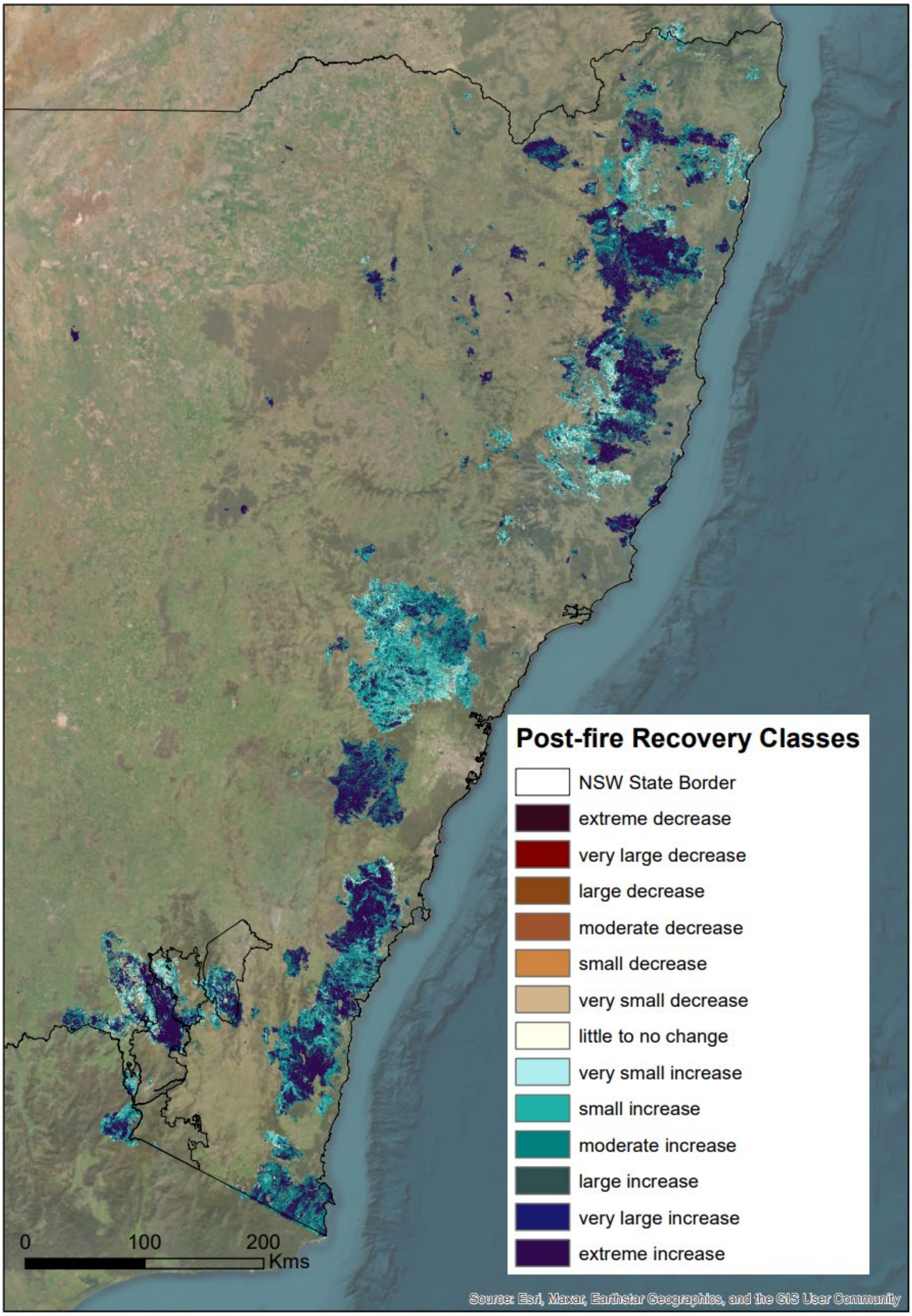

Figure 2 **Map of the eastern part of New South Wales showing the post-fire recovery classes at 1 year after the 2019–20 fire season**

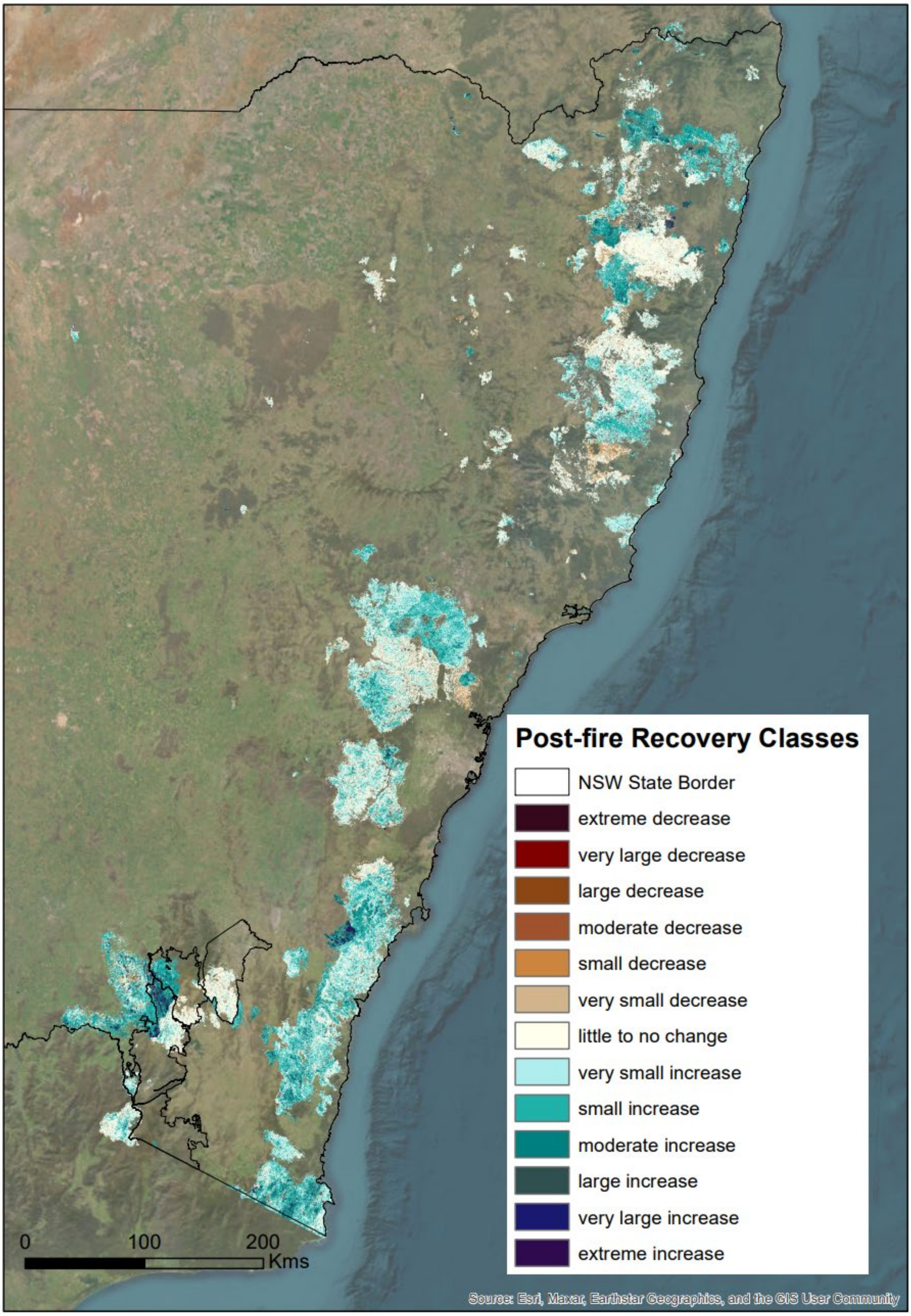

Figure 3 **Map of the eastern part of New South Wales showing the post-fire recovery classes at 2 years after the 2019–20 fire season**

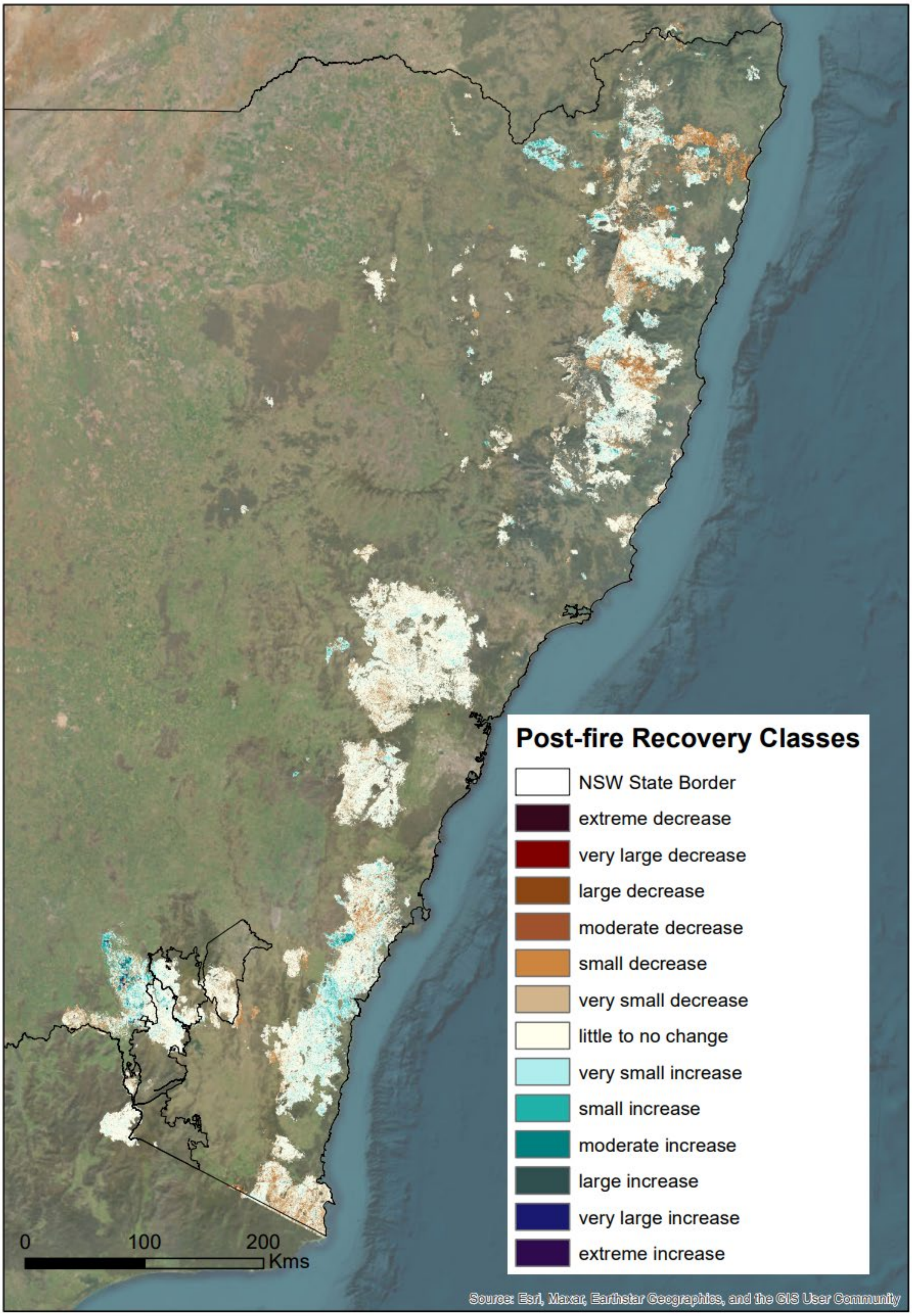

Figure 4 **Map of the eastern part of New South Wales showing the post-fire recovery classes at 3 years after the 2019–20 fire season**

Post-fire rainfall conditions in New South Wales

Many factors are known to influence post-fire recovery of vegetation, with variation in responses depending on community composition, landscape and environmental variables as well as characteristics of the fire itself. Moisture availability is one of the predominant influences on post-fire recovery, which may interact with other factors (Nolan et al. 2021). At the broad landscape scale, the rainfall across the 2019–20 fire ground in New South Wales for 1 and 2 years after the fires was well above average, due to the extreme La Niña conditions (Figure 5a and Figure 5b). In the third year after 2019–20, the rainfall was much lower over the 2019–20 fire ground compared to the previous year (Figure 5c; BOM 2023). Across all 3 years following 2019–20, the fire ground in New South Wales had from 500–1,500 mm more rainfall than the long-term trend (1961–90). These post-fire rainfall conditions are likely to have strongly influenced the nature of post-fire recovery following the 2019–20 fires. Post-fire recovery dynamics following other fires with different post-fire rainfall conditions are likely to exhibit different patterns. This highlights the importance of observational monitoring, in contrast to generalised predictions, in understanding post-fire recovery dynamics.

Interpretation against severity mapping

Interpretation of the post-fire recovery class areas across fire severity classes over sequential years is a useful tool for assessing post-fire recovery dynamics. Stability in vegetation cover (not necessarily vegetation structure) may be indicated when post-fire recovery values represent little to no change in cover (i.e. values near 7), are uniform across all fire severity classes (i.e. show synchronous distributions), over multiple consecutive years (i.e. 2 or 3+ years; Figure 6). Class values of 7 represent little to no change, while values above 7 indicate increasing cover, and values below 7 indicate decreasing cover, relative to 1 year previous. Here we report the post-fire recovery class areas across fire severity classes for 1, 2 and 3 years following 2019–20 at the statewide level.

At the statewide scale, the post-fire recovery trends show the typical post-fire flush of extreme vegetation cover increase in the high and extreme severity classes in years 1 and 2. In year 3, there was largely minimal change in cover compared to the previous year (Figure 6). This is likely to have been influenced by the change in rainfall conditions across the fire ground, which was much lower in year 3 compared to year 2 (Figure 5). Further increases in vegetation cover are expected in subsequent years, especially in the higher severity classes.

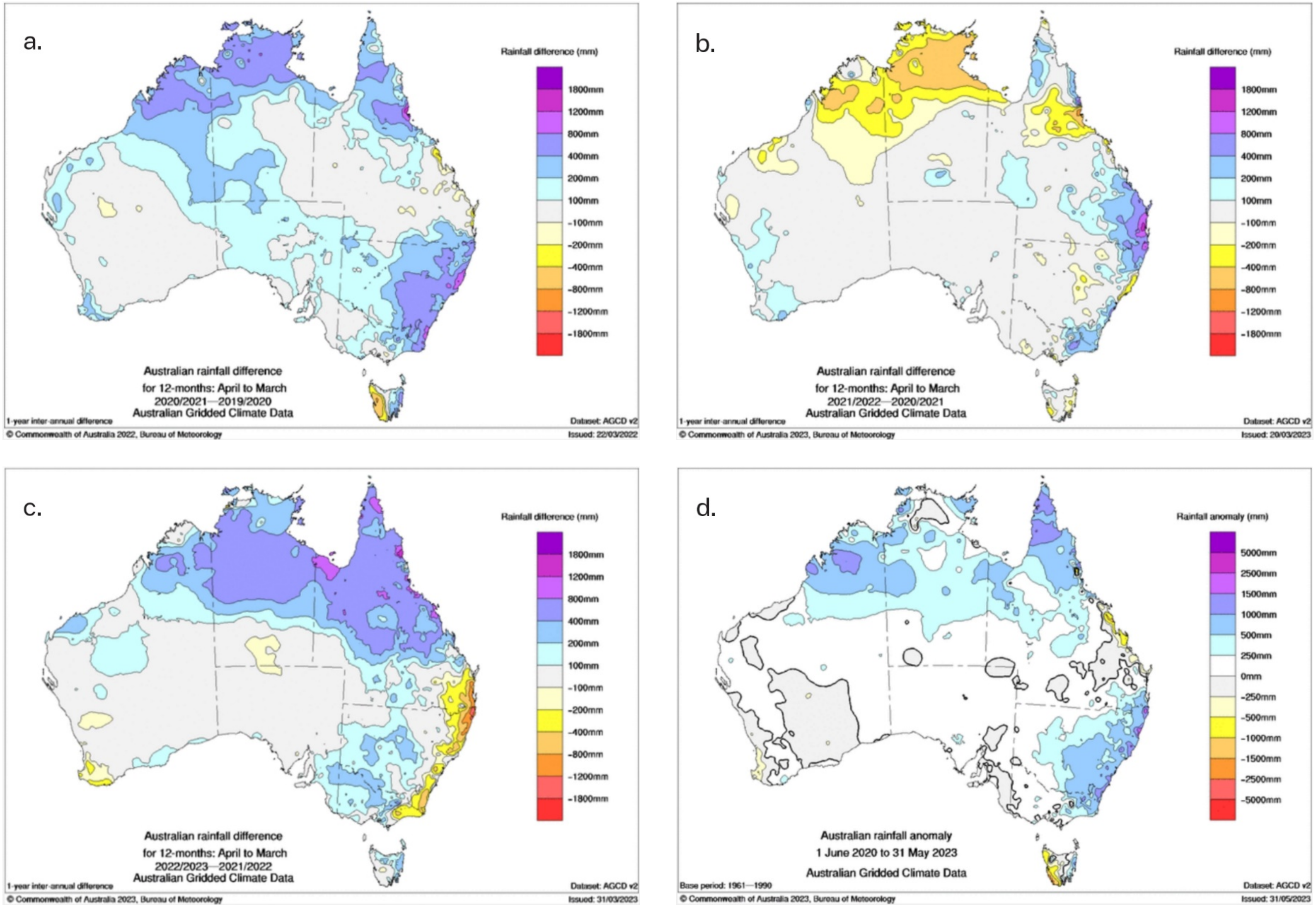

Figure 5 **Australian rainfall differences: (a) year 1 post-2019–20 compared to 2019–20, (b) year 2 post-2019–20 compared to year 1 post-2019–20, (c) year 3 post-2019–20 compared to year 2 post-2019–20, and (d) 36-month rainfall anomaly (departure from the long-term (1961–1990) average) from the end of the 2019–20 fire year to May 2023 (BOM 2023)**

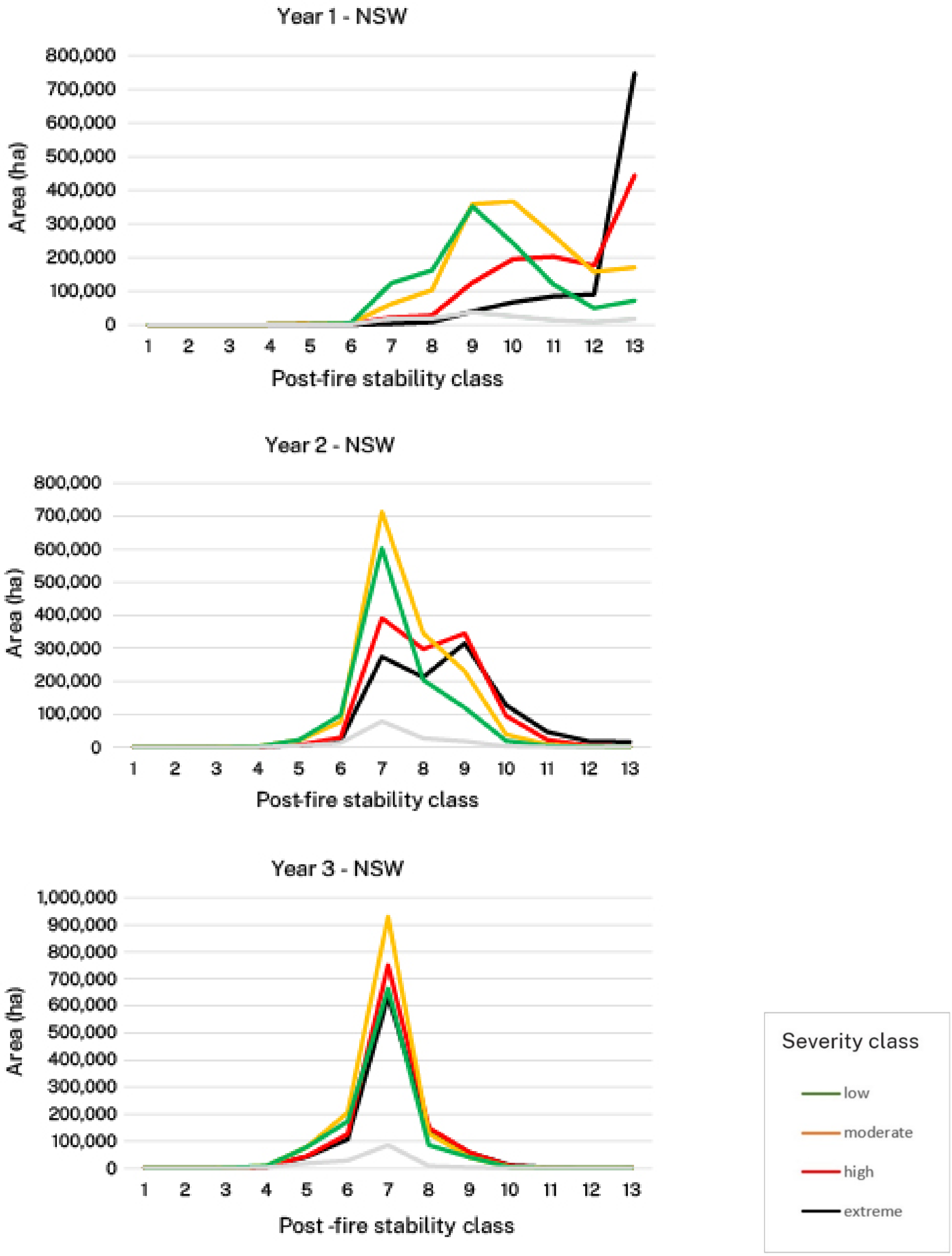

Figure 6 **Statewide assessment of post-fire recovery class areas against fire severity classes for: (a) year 1 post-2019–20, (b) year 2 post-2019–20, and (c) year 3 post-2019–20**

Post-fire recovery class 7 represents little to no change, while greater than 7 represents increases in vegetation cover, and less than 7 represents decreases in vegetation cover.

Areas of limited or delayed post-fire recovery

An assessment of post-fire recovery of vegetation cover across 60 field sites in dry sclerophyll forests in the Blue Mountains and South Coast of New South Wales showed a significant influence of preceding fire intervals and fire severity on post-fire recovery of vegetation (the department's unpublished data). There was significantly lower post-fire recovery at high severity sites with short fire intervals, defined as 2 sequential fire intervals of <10 years, compared to long fire intervals, defined as 1 previous fire interval >10 years, for years 1 and 2 (Figure 7). This aligns with preliminary field investigations of post-fire fuel dynamics, where elevated fuel cover, fuel connectivity and mean maximum height were significantly lower in short compared to long fire interval sites. This is likely due to short interval fires reducing the vigour of shrub regeneration by exhausting soil seed and underground bud banks, particularly for obligate seeding species (Chris Gordon pers comm.).

One of the important applications of the NSW Post-fire Biomass Recovery Monitoring system is to identify areas of potential vulnerability through assessment of recovery dynamics at the broad statewide scale. Based on the field results of post-fire recovery at high severity, short fire interval sites, the following thresholds were used to delineate areas of limited or delayed post-fire recovery at the statewide scale:

- less than 12 (very large increase) in the year 1 post-fire recovery product
- less than 9 (small increase) in the year 2 post-fire recovery product
- burnt at high or extreme severity in the 2019–20 FESM product.

A total of 425,496 ha has been mapped as areas of limited or delayed post-fire recovery at the statewide scale. This represents 19% of the total area that was burnt at high or extreme severity in the 2019–20 fires. Dry sclerophyll forests had the highest proportion of total high or extreme severity with limited or delayed post-fire recovery of vegetation cover (23.8%), while alpine complex had the lowest proportion (6.4%, Table 6, Figure 8). However, there were large bioregional differences because the NSW North Coast had a much smaller proportion with limited or delayed post-fire recovery (5.9%), while the Australian Alps and the Sydney Basin had 26.4% and 30% of total high or extreme severity with limited or delayed post-fire recovery of vegetation cover, respectively (Table 7).

This broad-scale assessment is intended to highlight areas across New South Wales with limited or delayed post-fire recovery that may warrant closer investigation. These atypical recovery dynamics may indicate potential threats to ecosystem resilience. However, in some locations, these patterns may be related to the dominant post-fire response traits of the community or the natural productivity of the local environment. A comprehensive, scientifically robust analysis to quantify the drivers of post-fire recovery following the 2019–20 fires, and the influence of compounding stressors, is highly recommended.

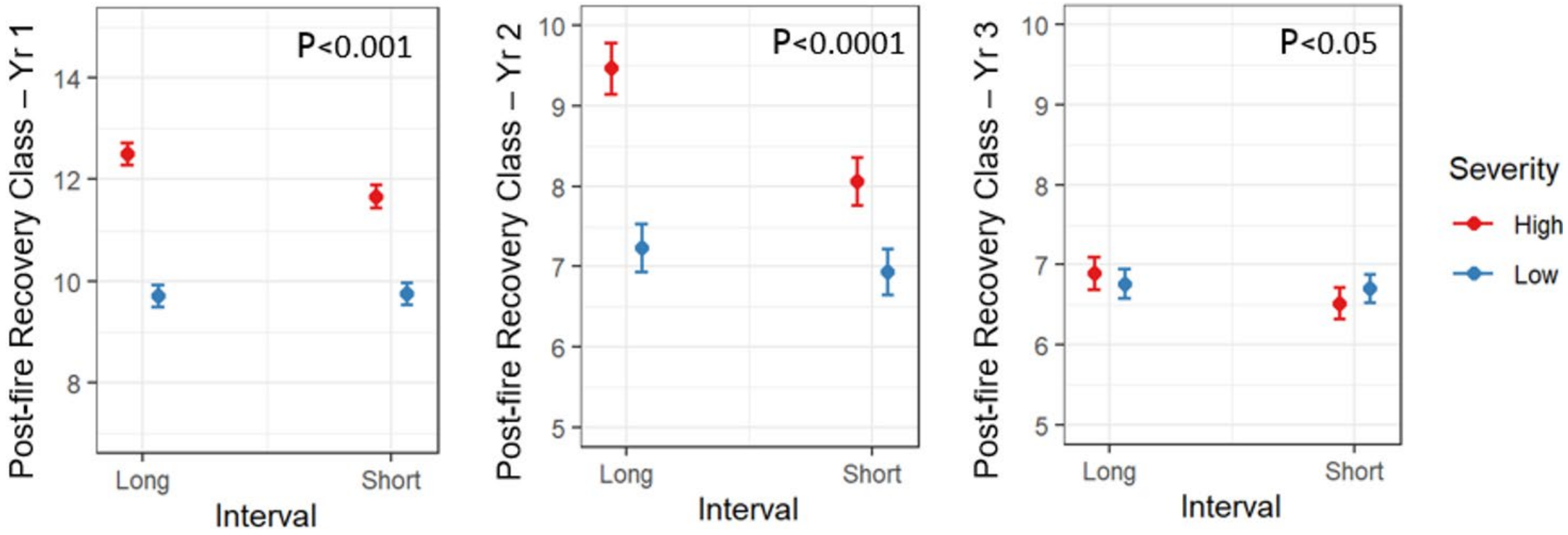

Figure 7 Effect of preceding fire intervals and fire severity on post-fire recovery

Table 6 **Area of limited or delayed post-fire recovery for a selection of vegetation formations, along with the proportion of total high and extreme severity area**

See the 2019–20 FESM report (DPIE 2020) for more detailed figures of total burnt area.

Vegetation formation	Area (ha) of limited or delayed post-fire recovery*	% of total high and extreme severity
Alpine complex	2,133	6.4
Dry sclerophyll forests (shrubby)	185,744	23.8
Heathlands	14,091	19.1
Rainforests	5,478	20.5
Wet sclerophyll forests (shrubby)	47,238	19.1

*Defined as less than class 12 in the year 1 post-fire recovery product, and less than class 9 in the year 2 post-fire recovery product, that were burnt at high or extreme severity in the 2019–20 FESM product.

Table 7 **Area of limited or delayed post-fire recovery for a selection of IBRA bioregions with the most burnt area, along with the proportion of total high and extreme severity area**

See the 2019–20 FESM report (DPIE 2020) for more detailed figures of total burnt area.

IBRA	Area (ha) of limited or delayed post-fire recovery	% of total high and extreme severity
Australian Alps	28,728	26.4
New England Tablelands	38,973	21.6
NSW North Coast	23,436	5.9
South East Corner	61,112	15.7
Sydney Basin	151,713	30

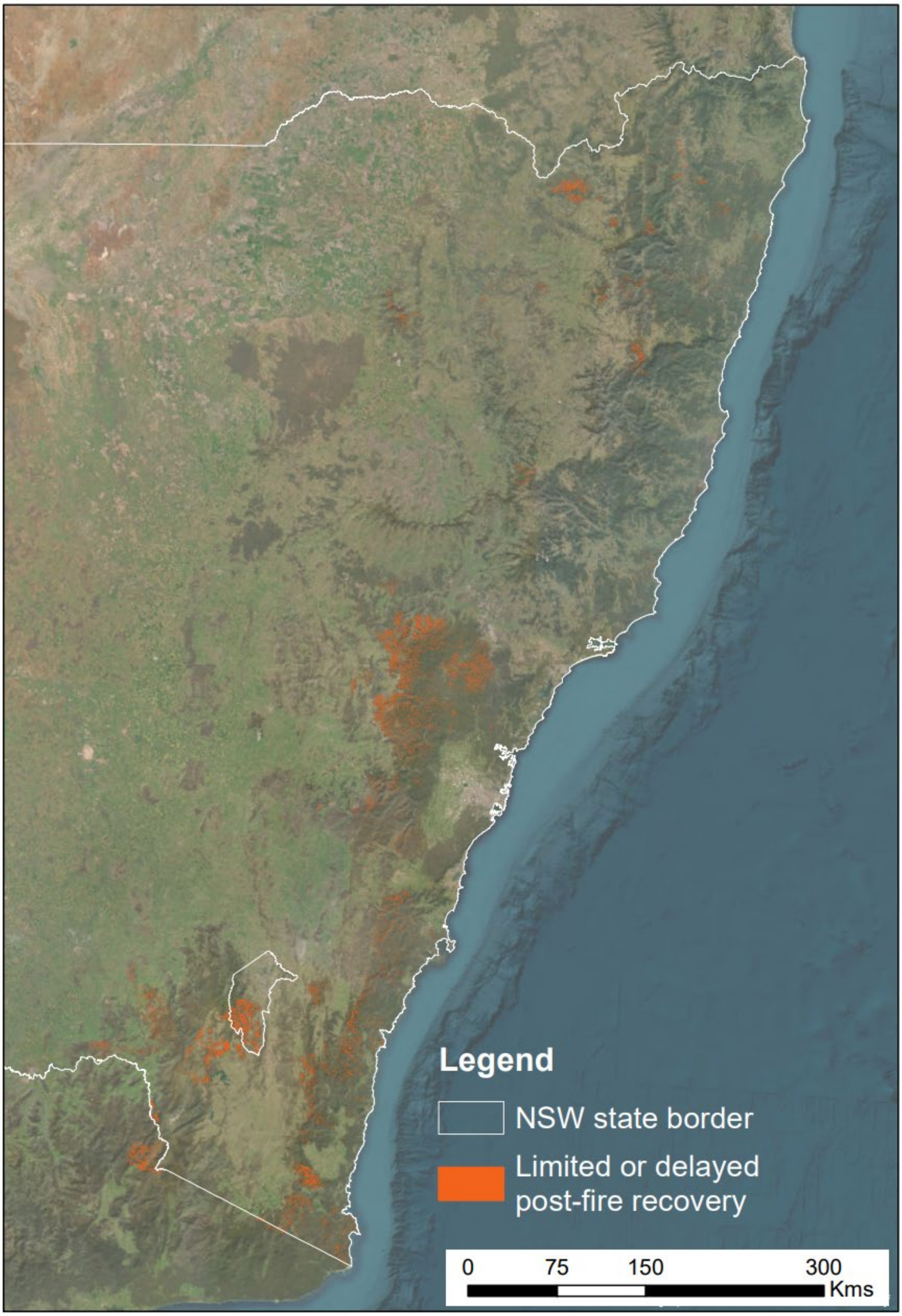

Figure 8 Areas of limited or delayed post-fire recovery in New South Wales, defined as less than class 12 in the year 1 post-fire recovery product, and less than class 9 in the year 2 post-fire recovery product, that were burnt at high or extreme severity in the 2019–20 FESM product

More information

Webpages

- Landcover science, NSW Department of Planning and Environment
- Fire extent and severity maps, NSW Department of Planning and Environment

Data availability

- Post-fire Biomass Recovery Monitoring datasets are available on the SEED portal

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