2019–20 Wildfires

NSW Coastal Hardwood Forests Sustainable Yield Review

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Executive summary

During 2019-20, widespread bushfires impacted many areas available for timber harvesting under the NSW Regional Forest Agreements (RFAs). Due to the scale and severity of the fires, a review of the impact of the fires on wood supply and long-term sustainable yield is warranted.

The modelling presented in this report provides a preliminary insight into the impact of the 2019-20 fires. A comprehensive review incorporating full remeasurement of inventory plots in fire affected forests will be undertaken once it is safe and logistically possible to do so. However, in order to provide a timely update, the report draws on the best available data including fire severity modelling and a range of field studies and assessments, which provide a robust set of assumptions to reflect the fire impact in wood supply models.

The effects of the fire in relation to sustainable timber modelling include degradation and loss of existing wood products in situ, as well as loss of young regenerating and smaller regrowth trees. This report sets out the modelling approach and supporting evidence used to underpin the updated sustainability estimates reported for each RFA region. An overview of revised high-quality log wood flows for the first three modelling periods is shown in Table 1.

The modeling assumptions used in this work were developed during the first half of 2020. These assumptions will be monitored and updated as the impacts become apparent, including levels of tree mortality and degrade. A range of sensitivity testing on these assumptions has also been undertaken to ensure that alternative fire damage scenarios can be considered. Where appropriate the underlying models can be updated to reflect the different observed damage levels that become apparent over time.

Table 1: Overview of fire impact on short-term wood supply for NSW RFA regions

Annualised sustained yield for first three reporting periods			
RFA region	Year range	High-quality logs (m^3)	Modelled Reduction due to fire Impacts %
North East	2020 - 2031	230,000	4%
Eden	2020 - 2034	22,700	13%
South Coast	2020 - 2034	35,000	30%
Tumut	2020 - 2034	25,800	27%

Spotted Gum forest post-fire, December 2019.

Recovering Blackbutt forest, Kangaroo River State Forest, Mid North Coast Region, June 2020.

Modelling and analysis presented in this report demonstrate that both current growing stock and sustainable yields have been impacted to some degree across all RFA regions. The biggest impacts are seen in the southern regions, with lowered sawlog availability on the South Coast and Tumut in particular. The modelling presented for the Eden region focuses on recovery of timber from intensively burned areas for the first 10 years of the model and the volumes generated from this are similar to those required under the existing WSA. There is a slight reduction in forecast yields after this initial period.

In Tumut, the level of tree mortality was unclear at the time of modelling. Depending on this outcome the resulting sustainable wood supply may change significantly. The model presented in this review assumes significant recovery of dead standing trees in the initial period after the fires, then aims to produce timber volumes similar to those in the current wood supply agreements from the broader region. However, the potential supply from Tumut region then declines in the medium term.

For the north coast the main fire impacts were in slower growing or less commercially important areas. As large areas of faster growing species on more productive sites were not impacted, the reduction in sustainable yield is lower. In the long term, models indicate that fire-regenerated forests are likely to increase potential productive capacity after several decades of regeneration, recovery and growth.

Sustainable Wood Supply Summary

To satisfy ESFM principles and requirements under the NSW RFAs, harvest volumes and wood supply from NSW public native forests must follow a long-term sustainable yield strategy. As such the wood supply from each of the regions should be revised to align with the results of this post-fire sustainable yield modelling.

A summary of the revised post-fire sustainable yield of high quality logs for the period 2020 to 2024 in the three NSW RFA regions is provided in Table 2, along with yields of non-high quality products.

Table 2: Sustainable yield of high quality logs and other wood products in NSW RFA regions for the five year period 2020-2024.

Sustainable Yields for 2020 - 2024		
RFA region[1]	High quality logs (m^3)	Non-high quality logs (tonnes)
North East	230,000	569,000
Eden	25,000	160,000
Southern South Coast sub-region	35,000	231,000
Southern Tumut Coast sub-region[2]	20,400	48,000
Southern Tumut Coast sub-region Fire Salvage[3]	125,000	

1 The North East and Eden RFA regions are each modelled as single resource areas within FRAMES, as the forests within these regions share geographic or regional groupings, including common forest types and customers. The Southern RFA region is treated differently within FRAMES because it has two discrete resource areas being the coastal and tablelands forests in the South Coast sub-region, and alpine forest types with a separate customer base in the Tumut sub-region.

2 This volume assumes harvesting of unburnt timber from for 3 years (2022-24).

3 Fire Salvage program will only produce suitable high quality logs until fire killed Alpine Ash timber degrades which is likely to be within 18-36 months of the fire.

Objectives of this review

This review has been conducted by Forestry Corporation of New South Wales (Forestry Corporation) in response to the wildfire events that occurred in New South Wales from August 2019 through to February 2020. The fires were widespread across many areas of forest that are managed by Forestry Corporation and produce timber products under the Regional Forest Agreements (RFA) made between the New South Wales and Commonwealth Governments.

As well as being widespread, the fires were also characterised by substantial areas of high severity fire. As such, these fires warrant an assessment to determine if there are any impacts that should be considered with regards to long-term sustainable yields of hardwood timber from State forests. Sustainable yield is the volume of timber that can be harvested from State forests each year without diminishing the volume these same forests can produce into the future.

The RFAs for NSW were reviewed and extended in 2018. In relation to sustainable yields, the RFAs require that:

» NSW will ensure Sustainable Yield is calculated and managed consistent with the [Ecologically Sustainable Forest Management] ESFM principles.

Further, the RFAs state:

> *New South Wales will review and update Sustainable Yield calculations from State forests at least once every five-year review period, or more frequently on an as-needs basis. Sustainable Yield calculations will be based on modelling with the goal of yielding the maximum non-declining yield of high-quality logs over a minimum period of 100 years.*
>
> *… Document and review systems, processes, models and databases used in the calculation of Sustainable Yield specifically:*
>
> - *growth models and growth model inputs;*
> - *inventory plot currency and measurement;*
> - *spatial inputs that determine the modelled net harvest area;*
> - *silviculture, product recovery, yield tables and modelling assumptions to ensure that the modelled outputs reflect current practices and actual yields;*
> - *resource risk management aspects and mitigations (e.g. changes to the model due to resource loss through fire, changes to legislation or Regulatory Instruments that alter access to the resource and invalidate current modelling assumptions, or other impacts associated with climate change); and*
> - *monitor and publish a reconciliation of predicted versus actual Forest Products yields in the third and fifth years of every five-year period.*

Forestry Corporation updated the sustainable yield modelling for each region in 2018 to contribute to the review of the RFAs published by the Department of Primary Industries[4]. A further update was undertaken for the North Coast in 2019 to incorporate updated plantation yields and finalised regulatory settings in the Coastal Integrated Forestry Operations Approval (CIFOA). The CIFOA are assumed to be the relevant regulatory settings for the modeling environment for the full 100 year model time frame in each region. The current review fulfils the RFA requirement to update modelling of sustainable yield on an as-needs basis, in this case due to changes in the resource that have resulted from the significant fire events of the 2019-20 season. This review is being undertaken in a timely fashion with the best available data to inform immediate decision making. Further to this review, Forestry Corporation intends to provide updated analysis when field inventory updates are finalised. Field inventory is currently suspended for safety reasons in fire-affected forests, however it is expected to resume around 12 months from the date of the fires subject to risk assessment at the time. As this work will take a significant period of time to complete, this current review is an important interim step.

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4 Available from the NSW Department of Primary Industries website at: https://www.dpi.nsw.gov.au/forestry/regional-framework

Background

The 2019-20 fire season was the worst in living memory and a substantial area of the NSW State forest estate was impacted by bushfire. While Australian forests are generally very resilient to the impact of wildfires and have effective survival and regeneration strategies (Bradstock 2008), the scale and severity of these fires requires an assessment of the potential impacts on sustainable yield.

Over 5.4 million hectares of NSW was burnt during the fire season, which spanned from August 2019 until February 2020. Approximately 830,000 hectares of native State forest (44 per cent of the total area of native State forest in NSW) and around 62,000 hectares of timber plantations (24 per cent of the total State forest plantation area) were impacted by fire, with some RFA regions and sub-regions more affected than others. Within the North Coast RFA region, 49 per cent of the native forest area available for harvesting (referred to as net harvestable area or NHA) was impacted by fire. In the South Coast and Eden RFA areas, just over 80 per cent of native forest NHA was subject to fire. Importantly, the fires were not uniform in their severity and impacts. Table 3 below shows a full overview of the native forest harvestable area (NHA) mapped as having been impacted by fire in the 2019-20 fire season.

Table 3: Mapped fire extent on native forest areas available for timber production by RFA region and sub-region

RFA Region/Sub-region	Total Net Harvest Area (hectares)	NHA mapped as fire-affected (hectares)	Proportion of NHA impacted by fire (per cent)
North Coast Region	408,500	200,000	49%
Eden Region	109,400	87,300	80%
South Coast Sub-Region (South Coast Region)	128,800	109,800	85%
Tumut Sub-Region (South Coast Region)	44,800	31,100	69%

Not only were the fires of the 2019-2020 season widespread, but they were often intense, with crown fires not uncommon. As a result, a number of forests have suffered significant damage or degrade in terms of their timber values. The mosaic of fire severity and damage means calculating the effects on long-term sustainable yields is not a simple process. The resilience of individual forest types and species add to the complexity of the assessment and modelling task. Whilst most eucalypts and allied genera can withstand fire, some (Alpine Ash, *Eucalyptus delegatensis*, for example) are susceptible to even moderate fire and are often killed outright, but also regenerate profusely in the right conditions. More tolerant species will generally survive the fire but will often exhibit reduced volume growth as they concentrate available energy and growth resources into recovering crowns lost in the fire. Even the most fire tolerant eucalypt species can be killed if the fires are intense enough, particularly if trees are small and/or young. All of these effects have the potential to impact on future forest productivity.

This report examines the effects of the fires on sustainable yields in each of the regions covered by the 2018 NSW Government report on Sustainable Yield in NSW

RFA Regions[5]. Implications for timber supply in the short term (10 year) and long term (100 year) timeframes are outlined, along with consideration of timber quality and species availability outcomes. As some types of forests are more resilient to fire, and fire behaviour varied significantly over the season, the impacts of the fires are not uniform between or within regions.

State forests are managed to be continually harvested and regrown in perpetuity. Sustainable yield is the volume of timber that can be harvested from these forests each year without diminishing the volume these same forests will produce into the future.

Forestry Corporation models sustainable yield from State forests over a 100-year period using the Forest Resource and Management Evaluation System (FRAMES) modelling system, which is described in detail in the report on the development and implementation of the Forest Resource and Management Evaluation System (FRAMES)[6]. The key components of the FRAMES modelling system include:

- a Geographic Information System (GIS) recording harvest areas, forest types and management activities
- inventory data
- growth and yield simulator models
- a yield scheduler.

A headroom or safety margin is also applied to forecast wood supplies within FRAMES. Safety margins refer to the reduction applied for unanticipated constraints on wood supply. This reduction was introduced in 2013 and is to account for factors including catastrophic bushfire and other future, unanticipated changes, and also for tactical and operational constraints that may be known but are not fully captured in specific area or volume calculations. The safety margin for modelling hardwood sustainability in NSW State forests was specifically designed by an independent expert panel. Noting that FRAMES already includes a number of factors that address operational and regulatory constraints, the panel recommended a 10 per cent safety margin. This margin is applied as a write-down to all projected yields used in the modelling process.

The effects of fire in relation to sustainable timber modelling include degradation and loss of existing forest products standing in the forest as well as loss of young regenerating and small regrowth trees. Such impacts influence the productive capacity of the forests well beyond the immediate aftermath of the fire season.

Inventory assessments are traditionally carried out by physically measuring trees in randomly located inventory plots that have been established throughout State forests and are continually re-measured at regular intervals. An assessment of safety in the post-fire environment led to an interim policy of reducing fieldwork wherever possible to manage the risk for staff traversing burnt forests. Risk in the post fire environment was significantly heightened, particularly due to overhead hazards as burnt trees and damaged limbs often fall in the immediate aftermath of a fire. Consequently, inventory plots have not been re-measured in forests impacted by fire due to the significant safety risks during the period since the fires. As a result, new inventory data from fire-damaged stands is not available.

5 Available from the NSW Department of Primary Industries website at: https://www.dpi.nsw.gov.au/forestry/regional-framework

6 Forestry Corporation of NSW 2016, available at https://www.forestrycorporation.com.au/__data/assets/pdf_file/0016/702007/frames-development-and-implementation.pdf

This restriction on inventory measurement required that this preliminary resource modelling update to be based on the use of pre-fire inventory and the incorporation of modelled fire impacts. The modelling utilises data from qualitative assessments carried out using on ground and remote sensing techniques to develop a robust framework and assumption for modelling fire impact at a plot level. A new remote sensing technology has been used to assess and categorise fire severity. A range of visual field assessments and workshops have been completed to develop key assumptions to be applied to plots mapped in these severity categories. Further to this, a project involving historical fire modelling and assessment of internal tree quality changes in a previously fire-affected area in Eden was undertaken to allow for robust assumptions on product degrade and tree survival in that region. The results of this modelling, and the projects underpinning the assumptions that support it, are presented below.

The fires have also impacted forest ecology, flora and fauna, biodiversity and soil and water. Again, these impacts will also be highly variable across the NSW forest estate. The impact of the fires on these ecological forest values are the subject of a separate report that is available on Forestry Corporation's website[7].

7 Available at https://www.forestrycorporation.com.au/__data/assets/pdf_file/0004/1258780/wildfires-environmental-impacts.pdf

Methodology

Fire extent and severity mapping

In order to determine and model the impacts of the 2019-20 bushfires on the timber yields from NSW State forests, it was necessary to generate a spatially accurate representation of the fire extent and severity across all State forests in a timely manner. While other government agencies have produced fire severity mapping products in recent months, none were available within the timeframe that Forestry Corporation required to begin timber supply analysis. So, a custom model developed by Forestry Corporation in 2019 was used.

To represent the effects of the fires across the landscape, Forestry Corporation undertook a remote sensing project beginning in November 2019 to assess and test a satellite-based analysis tool for delineating fire extent and severity. The project has delivered a toolkit known as RAFIT, Rapid Assessment of Fire Impact on Timber, which produces an imagery-based classification of the severity of fire impact on forested landscapes. It is generated using a custom-built application within the Google Earth Engine (GEE) environment. The map produced was widely field tested for classification accuracy by Forestry Corporation field staff.

Remote sensing data

Data supporting the RAFIT project was sourced from the GEE data catalogue. Sentinel-2 Multi Spectral Instrument, Level-2A is the utilised data set. This imagery is a Bottom-of-Atmosphere (BOA) corrected reflectance product derived from processing Level-1C products (Top-of-Atmosphere (TOA), orthoimage) with sen2cor and sourced from scihub.

Computation and classification of RAFIT

RAFIT uses the well-recognised Normalised Burn Ratio[8] index (NBR) to estimate fire severity. This ratio draws on relationships between satellite-captured near-infrared and shortwave-infrared wavelength data. Healthy vegetation typically has very high near-infrared reflectance and correspondingly low reflectance in the shortwave infrared portion of the spectrum. Recently burned areas typically have relatively low reflectance in the near-infrared and high in the shortwave infrared band. The NBR ratio takes the form:

$$\text{NBR} = \frac{\text{NIR} - \text{SWIR}}{\text{NIR} + \text{SWIR}} * 1000$$

where NIR is Sentinel Band 8 and SWIR is Sentinel Band 12. A high NBR value generally indicates healthy vegetation and low values indicate bare ground and recently burned areas.

A generally accepted approach for computing fire severity is to use dNBR (delta NBR). This is calculated by subtracting NBR values of a pre-fire image from a post-fire image. A delta computation of pre and post impact is a change-analysis. To increase robustness in the analysis the pre-fire image of RAFIT is a median of images collected from the four-month period prior to the fires ('2019-05-01' to '2019-08-31').

8 Stambaugh, Michael C., Lyndia D. Hammer, and Ralph Godfrey. "Performance of burn-severity metrics and classification in oak woodlands and grasslands." Remote Sensing 7.8 (2015): 10501-10522.

This pre-fire image is automatically created for every computation request. The RAFIT application provides a date slider which allows the user to view and select the post-fire image. This permits an iterative analysis. The post-fire image is adjusted to a favourable time where environmental factors are suitable, and cloud or smoke interference is minimised (see "Selection of post-fire imagery" below). Typically, imagery captured soon after the burn but after fire activity ceased was used to generate the most reliable model for fire severity.

When a post-fire image is selected, the application calculates the difference between the NBR values in the pre- and post-fire images. This NBR difference or delta value (dNBR) takes the form:

$$dNBR = Imagery.median(Period) - Imagery\ (User's\ Choice)$$

where Period is from '2019-05-01' to '2019-08-31'. The latest imagery depends on the ending date as chosen by the user.

The dNBR value forms the basis of the fire severity classification. The classes one to five (Table 3) were developed from this analysis following ground-truthing observations of burn sites in the field, visual assessment of imagery and user feedback from staff testing RAFIT mapping in the field. A project to systematically capture geo-referenced ground truthing pictures was also instigated, with staff from all fire-impacted regions uploading photography reference points. Over 700 images have been uploaded to the library to assist in validation of classification values. Forestry Corporation has deemed RAFIT to be efficient and effective at modelling a spatially accurate map for fire severity.

Table 4: RAFIT dNBR ranges grouped into fire severity classes

Class	Description	dNBR Value
1	No indication of vegetation loss	dNBR < 200
2	Potentially burned, seasonal change or unhealthy. Understorey present	200 < dNBR < 350
3	Moderate burn, below canopy only, understorey heavily impacted	350 < dNBR < 500
4	Leaves browned but mostly uncrowned. Understorey completely burned	500 < dNBR < 680
5	Crowned/ mostly crowned	680 < dNBR

Selection of pre-fire imagery

The process of selecting appropriate pre-fire imagery capture times in relation to background environmental factors is very important in achieving burn severity mapping with consistent outcomes. Normalised burn ratios tend to vary across seasons and years due to localised environmental factors. Two geographically close State forests in Northern NSW were chosen to highlight this variation over the four-year window between 2016 and 2020 (Chaelundi and Marara State Forests, Figure 1 and Figure 2).

The seasonal influence on NBR is broadly similar in both localities, with values typically higher in winter and lower in summer when the forest is under more heat stress. Lower values in the winter and early part of spring of 2019 represent the effect of drought stress on the forests. The sudden drop in late October 2019 signals the dramatic change associated with fires in the locality.

Using a median as a pre-impact image for the change analysis introduces robustness as these seasonal variations are then accounted for. Further, the impact of individual image quality is reduced so less artefacts are introduced into the final product.

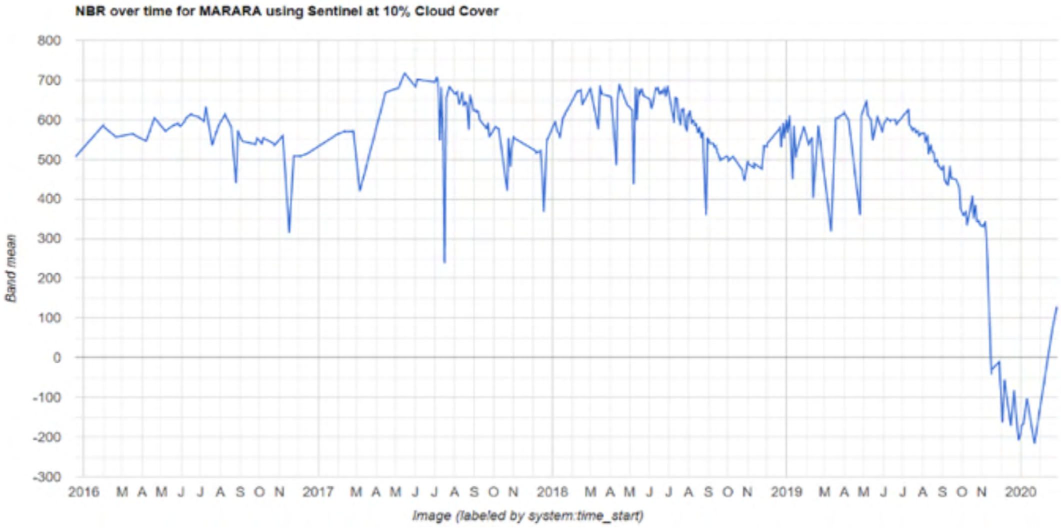


Figure 1: Normalised Burn Ratio mean of Marara State Forest from 2016 to 2020, showing seasonal patterns of vegetation change in the context of the fire.

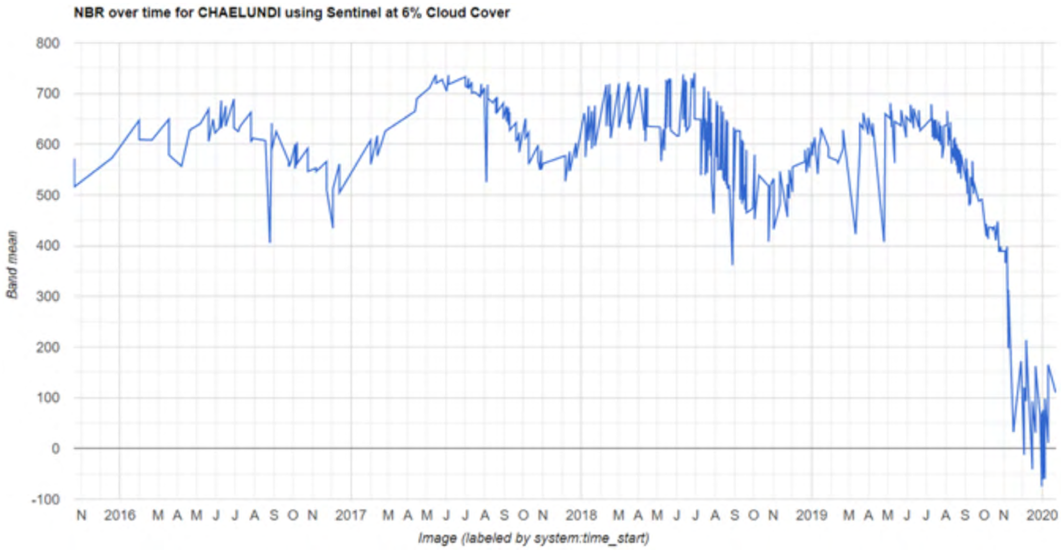


Figure 2: Normalised Burn Ratio mean of Chaelundi State Forest from 2016 to 2020, showing seasonal patterns of vegetation change in the context of the fire.

Selection of post-fire imagery

The date selection for the post-fire imagery in the RAFIT application is user-defined. However, the timing has been found to be critical due to on-ground processes within burnt eucalypt forests. It is crucial to select the image post-burn and prior to regeneration. In the field – and this is reflected in the imagery – epicormic growth and emergence of annuals was observed within days after initial rainfall. Further, forest patches that had burnt heavily but did not experience crown fire were observed to drop leaves within the first few weeks post burn. This impacted the values of dNBR and subsequently the image classification. This affected particularly the North and Mid North Coast of NSW as the period between the fire impact and onset of rainfalls ranged from several weeks to several months. In the south of NSW, rainfall set in with the completion of fires, or prior. With increased atmospheric disturbance, selection of post-burn and pre-recovery imagery is particularly challenging.

The drought stress mentioned in the previous section can be seen to cause the downward trend in NBR between July and early November 2019 (Figure 3). The wildfire corresponds with a near immediate drop in NBR in the second week of November. The values stabilise briefly then slowly continue to decline for the next eight weeks due to leaf drop. After mid-January

2020, the NBR values start to increase. In this locality, the increasing NBR trend coincides with good rainfalls and forest re-greening, both from epicormic growth on surviving trees and regeneration on the forest floor including grasses, ground cover species and emerging seedlings (Figure 4). On the Marara site, image selection between early December and mid-January was recommended. As the fire impacted different regions and sub-regions at different times, the imagery data used by Forestry Corporation in its RAFIT analysis was spliced together from locally-optimised dates for atmospheric clarity and time since fire. Forestry Corporation then created a combined, or mosaic, RAFIT layer of fire severity across all the native State forests in the coastal regions of NSW.

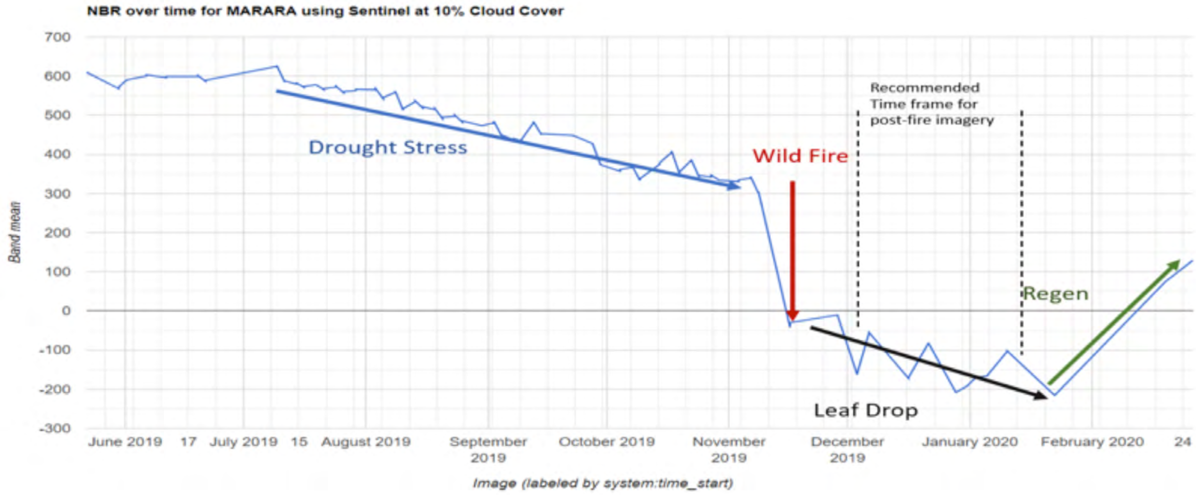
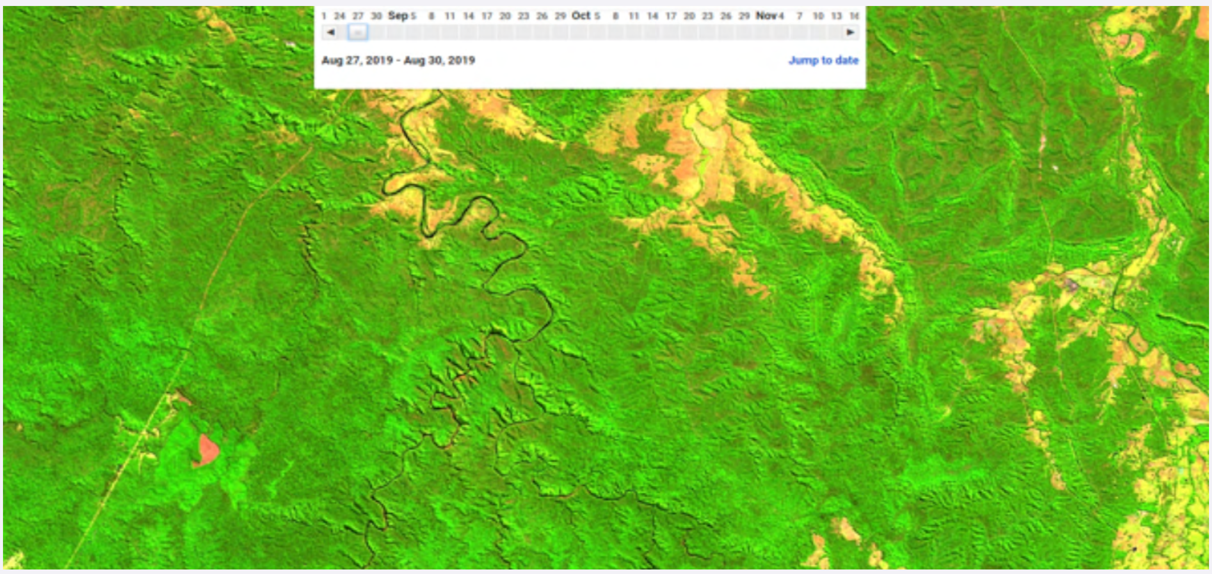
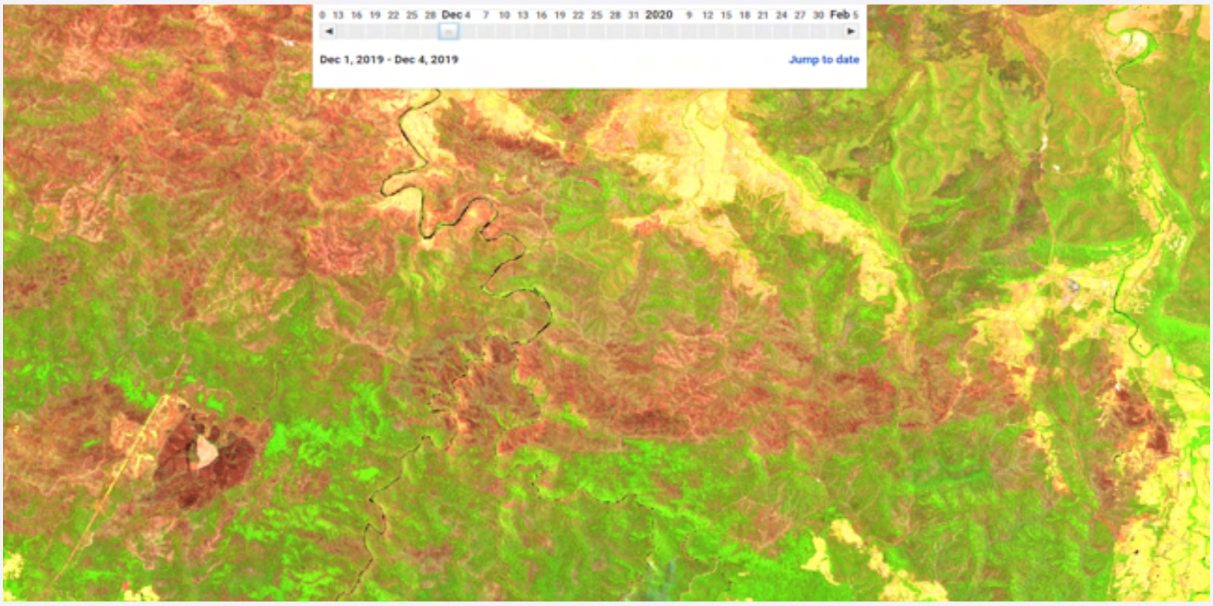


Figure 3: Changes through time in Marara State Forest reflected in mean NBR values and corresponding recommendation for timing of post-fire imagery.

It should be noted however, that in some localities it was difficult to fully exclude the changing drought influence on the dNBR value. The rapid drought-based deterioration of dNBR values on some sites has resulted in their classification as RAFIT 2: low severity reflecting drought stresses rather than fire influence. Importantly however, follow-up field inspections on some of these sites have not identified any factors that reduce the relevance of this classification for resource modelling. The environmental impacts of both drought and low-severity fire are incorporated in the base FRAMES growth models. The dynamics of the higher fire severity RAFIT classes form the focus of this study.

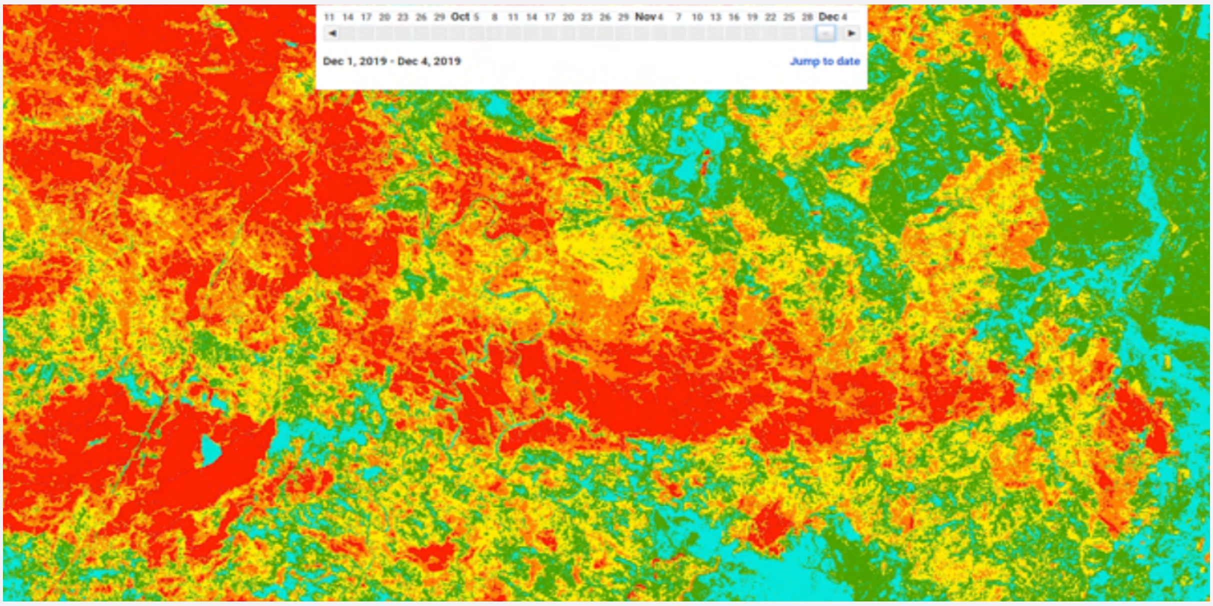


Pre-fire imagery over the Liberation Trail fire ground in Chaelundi and Marara State Forests in northern NSW. This is a standardised composite image calculated using median NBR values from the four months between 1 May and 31 August 2019, prior to the fire impact.



Post-fire imagery over the Liberation Trail fire ground. Vegetation impact on the fire ground is clear from the colour change in the satellite image. The dark patch at the South Western corner of the image is a burnt softwood plantation area.

The image date is between 1 and 4 December 2019, which is approximately one month after the main fire impacted the area. The fire spread rapidly and intensively eastward (left to right) covering over 70 kilometres from the Liberation Trail in the Guy Fawkes National Park through to the township of Glenreagh in just one afternoon. Less intense fire associated with backburning to contain the main fire then continued for some weeks.



RAFIT-classified image showing the five fire severity classes used in this sustainable yield review. This layer is generated through a delta or change-analysis of the two above images.

Figure 4: Pre- and post-fire imagery used to derive RAFIT fire severity classifications across the Chaelundi-Marama State forest areas.

RAFIT field validation and fire impact assessments

Forestry Corporation staff carried out months of field assessments and inspections of fire grounds in order to begin planning processes for timber supply, restore safe forest access and carry out general land management and planning activities. This involved taking georeferenced photos and unmanned aerial vehicle (UAV) imagery in the various RAFIT severity classes as mapped (Figure 5 and Figure 6). These images were compiled in a database and used to validate the mapping product. A series of workshops was held to elicit the base rule set for each region based on the cumulative understanding of Forestry Corporation staff to calibrate observations of damage levels in the different severity classes of RAFIT.

Figure 5: Aerial image taken by UAV of Dampier State Forest in June 2020. This area was mapped as RAFIT Class 5 in January 2020.

Figure 6: Aerial image taken by UAV of Kiwarrak State Forest June 2020. This area was mapped as RAFIT Class 4 and 5 in January 2020.

These rule sets were then re-checked in follow-up field inspections to iteratively confirm the assumptions used in this report (Figure 7).

Class 5: Complete burn including crowns

Class 4: Understorey completely burned. Upper-storey leaves browned but mostly not burned.

Class 3: Crown mostly intact, with green and brown leaves. Understorey burned.

Class 2: Fire, drought or other plant health impacts. Understorey present. Crown mostly green or slight browning.

Figure 7: Immediate post-fire field photographs and rule descriptions developed for each RAFIT class. Class 1 is unaffected forest.

Recovery re-assessments six to nine months after fires

Field assessments in the months following fires evaluated the initial fire severity and looked at recovery of the canopy across the estate to determine future wood supply impacts to be applied in modelling.

Initial field assessment enabled consideration of some immediate impacts, however, follow-up inspections in the months after the fires were more informative regarding the long-term survival and degradation of the affected stands.

These inspections enabled broad assessments of tree damage and mortality in different size classes.

The outcomes of these assessments for each region are documented in the regional modelling section of this report.

Figure 8a: Photo pair showing recovery in RAFIT Class 5 areas in Myrtle State Forest.

Figure 8b: Photo pair showing recovery in RAFIT Class 5 areas in Kangaroo River State Forest.

Long-term field validation project

In order to systematically track the recovery of forests across the estate, Forestry Corporation has established a series of long-term monitoring stations within State forests and initiated a program of plot-based time-series photography of the recovery process. Early photography from these monitoring stations supported the calibration of modelling assumptions used in this analysis. Future photography will help refine updates to the sustainable yield analysis as well as long-term environmental impact and recovery assessments.

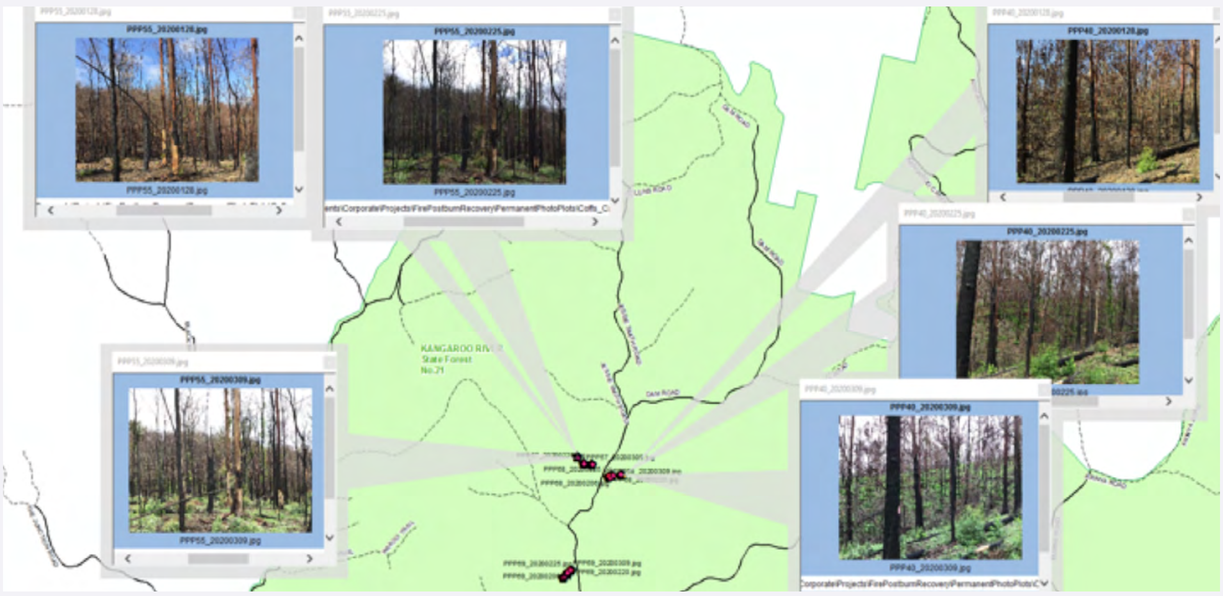


Figure 9: Location of long-term post-fire field validation points in Kangaroo State Forest

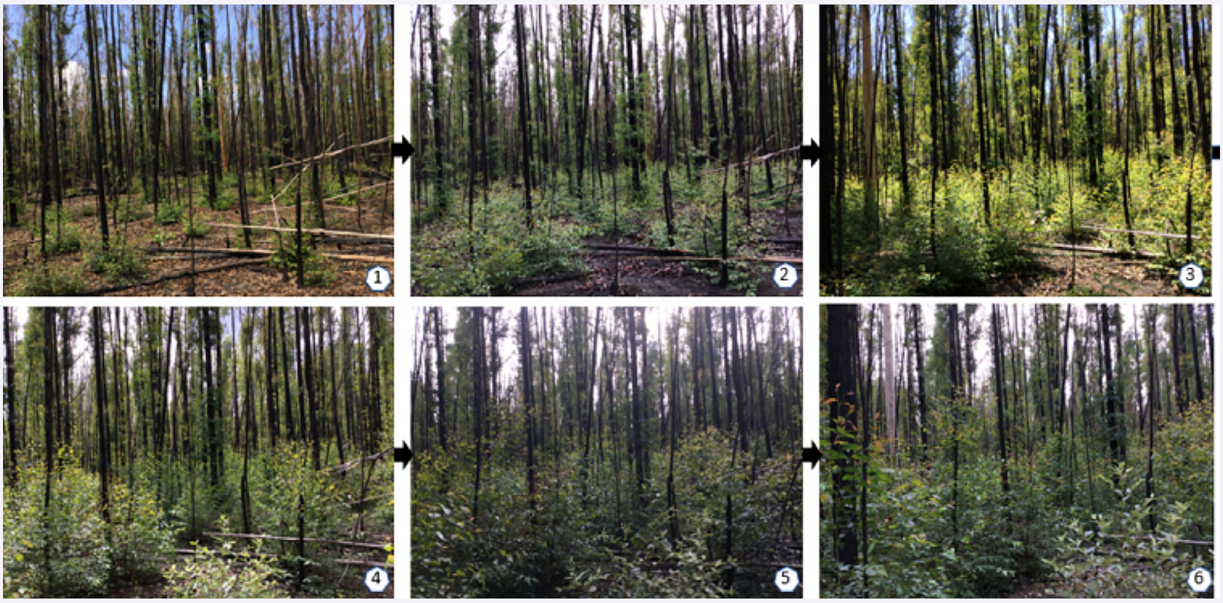


Figure 10: Example of six sequential images taken at long-term monitoring stations established within Tabbimoble State Forest.

The long-term field validation study will help to identify which aspects of recovery can be mapped using drone and satellite imagery. The challenge for both of these sources of aerial imagery is in separating green up signatures of plant matter into their sources, for example, epicormic growth along tree stems or understorey.

In many of the plots captured in RAFIT Class 5, the current trend identified is a greening up dominated by understorey (Figure 10). The analysis carried out is a machine-learning based classification of the captured photographs. From this a time-series trend is derived (Figure 11). Note that bare soil sharply declines as signatures for greenness increase.

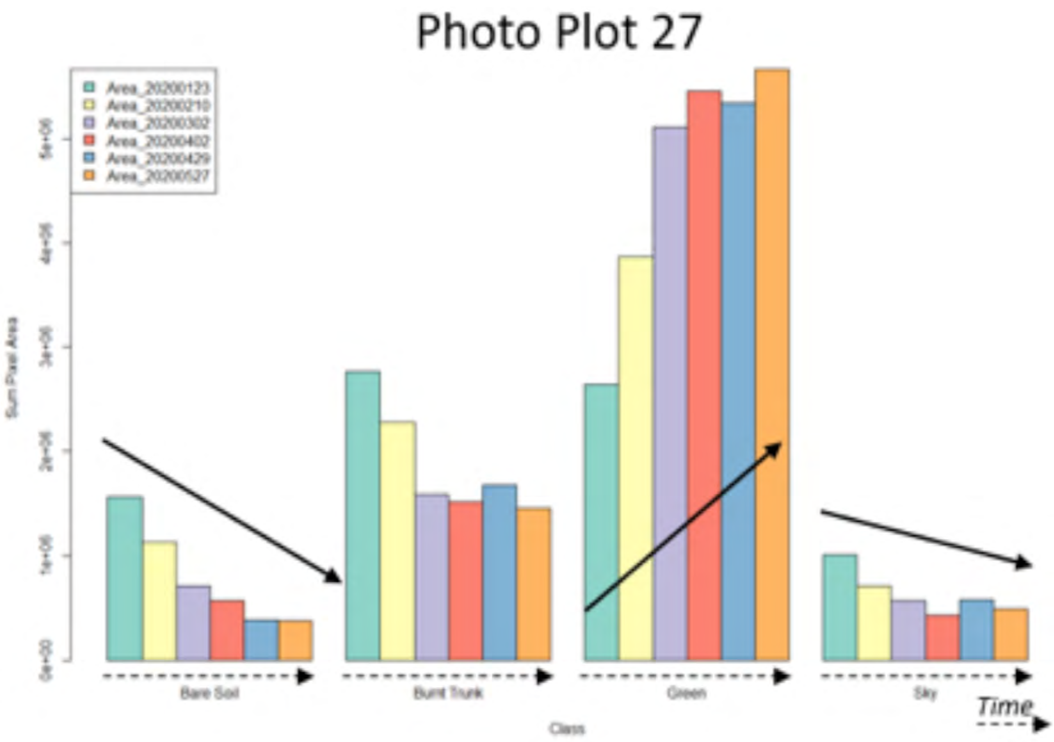


Figure 11: Example of how images captured across time are classified using machine-learning approaches and the resulting recovery trends.

All research carried out to assess recovery will need to incorporate the various spatial aspects of regeneration. There is a qualitative difference between a forest with recovering crowns and a forest with recovering understorey only. Using this multi-data sourced approach will help to determine the relationships between satellite imagery, drone footage and ground-based photo plots to determine the quality of recovery. The analysis may validate the recovery assumptions over time and may also complement strategic inventory as an input data for future yield modelling.

Goldmine Fire – recovery study

To build on the RAFIT work outlined above and underpin longer-term tree mortality and timber degradation model predictions, a study was carried out to assess later-stage post-fire forest recovery in areas with a known history of high severity fire events prior to the 2019-20 fire season. The 2016 Goldmine Fire area in Eden was one area chosen for further investigation. The 2016 Goldmine Fire was considered a good candidate for study, as the forest types impacted by this fire are broadly representative of a significant proportion of the Eden Region and South Coast foothill forests.

The methods and results of the Goldmine Fire recovery study are summarised below.

Methods

Prior to commencement of field assessment work, a RAFIT assessment was produced for the area of the Goldmine Fire for both the 2016 fire event and the 2019-20 fire season (Figure 12).

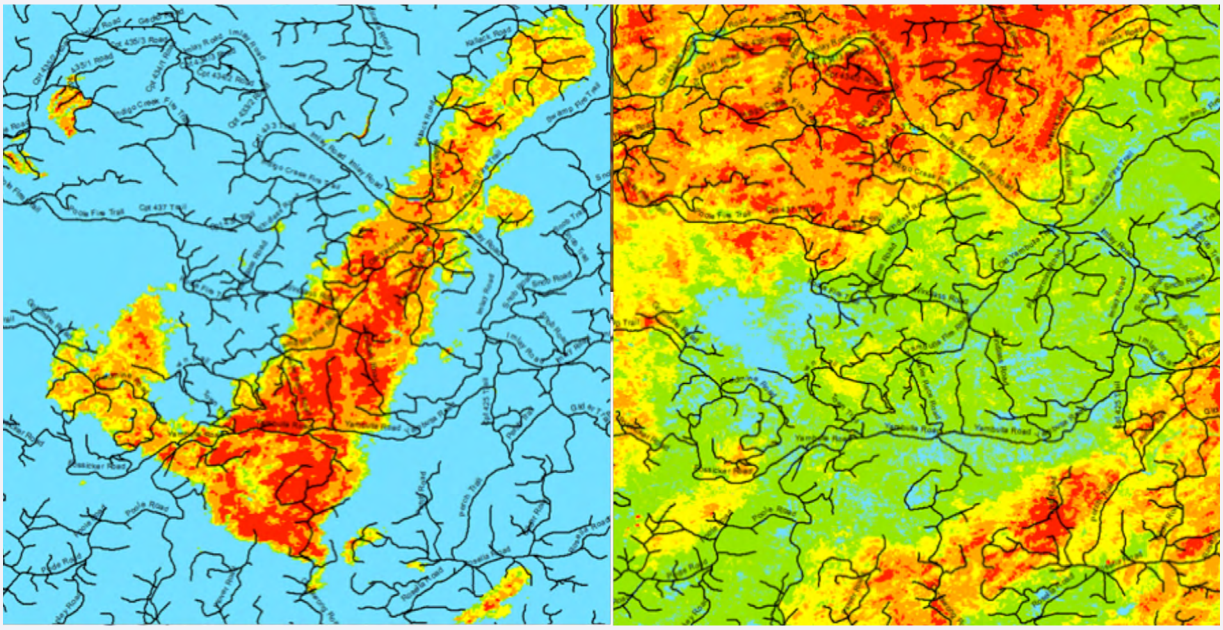


Figure 12: Left image shows a RAFIT map of the 2016 Goldmine Fire. Right image shows a RAFIT map of the same area following the impact of the 2019-20 fires.

This RAFIT assessment allowed a simple comparison of burn severity between the two fires. The RAFIT assessment shows that much of the area burned in the 2016 Goldmine Fire event was only subject to a cool burn or remained unburned in the 2019-20 fire season. Field verification of the 2019-20 RAFIT assessment in the Goldmine Fire area confirmed a strong correlation between the areas classified as RAFIT Class 5 in 2016 and areas that were not burned in the 2019-20 fires. To avoid any confounding requirements to distinguish between 2016 and 2019-20 fire impacts, assessment work focused only on the areas classified as Class 5 in the 2016 Goldmine Fire that were not subsequently impacted by fires in 2019-20. Limiting the study to areas that were not impacted by the 2019-20 fire season also helped maintain a safer worksite.

Seventeen slope-adjusted 0.05-hectare plots were selected at random from within RAFIT Class 5 areas of the 2016 Goldmine Fire to observe tree health and timber quality degradation. All trees greater than 10 centimetres in diameter at breast height over bark (DBHOB) were marked with a tree number and then the following metrics were recorded:

» DBHOB*

» Species Group (Gum, Messmate, Peppermint, Stringybark, Silvertop Ash, Yertchuk)

» Total tree height (in metres)**

» Tree Quality Code (TQC)
  - (1) Alive with healthy green canopy
  - (2) Dead upper canopy, compromised vigour, live foliage predominantly made up of epicormic shoots
  - (3) Dead

» Green (live) height – the height at which the tallest green branch stems from the trunk on the tree**

* DBHOB recorded with diameter tape

** Heights recorded with a Haglof Vertex Ultrasonic Hypsometer

A tree taper volume model was then applied to the height and diameter information to make predictions of total volume and green (live) volume for measured trees.

Previous sampling of fire-impacted stands has indicated that green (live) height can be used as a predictor of the upper extent of functional cambium within a tree. This hypothesis was further tested in this study through internal sampling on a set of 40 Silvertop Ash *(E. sieberi)* TQC2 trees from within the project area. TQC1 and TQC3 trees were excluded as green height to total height ratio in these TQCs was assumed to be either 1:1 (in TQC1) or 0:1 (in TQC3). Silvertop Ash was selected as the focus for the study as it made up a majority in the sample population and it represented the most commercially significant species within the study area at the time of data collection. Whilst no statistically significant difference was observed between species' green height to total height ratio in the plot sample population, focusing on Silvertop Ash in the destructive sampling also avoided any potential confounding effects of species on the study. Initially, standing measurements of DBHOB, total height and green height were taken. Trees were then felled, and internal cambium assessments were made using cross-sectional cuts starting from the crown end along the bole towards the butt until a live functional cambium was observed. Stump height, green (live) log length, log small end diameter over-bark (SEDOB) and log large end diameter over-bark (LEDOB) were then measured with a tape measure.

Results

Verification of live tree height method

Table 5: Results summary from internal assessment work on 40 Silvertop Ash *(E.sieberi)* trees from TQC2

Value	DBHOB (mm)	Vertex-measured total height (m)	Vertex-measured green (live) height (m)*	Tape-measured total green wood length including stump (m)	Difference between tape-measured green wood length and Vertex measured green (live) height
Range	125 – 388	15.0 – 23.6	2.5 – 17.8	2.5 – 16.4	-26% to 18%
Average	230	19.0	10.6	10.1	-4%
Standard Deviation	53	2.0	3.6	3.4	7%

There is a strong linear relationship between the Vertex-measured green (live) height and the tape-measured total green log length that is not significantly different to a 1:1 straight line through the origin ($p< 0.05$, $n = 40$, standard error = 0.89). These results support the hypothesis that green (live) tree height is a predictor of the upper extent of functional cambium within a tree. This is important as the functional cambium extent generally marks the delineation between green wood suitable for a range of timber products, and dead wood which is often only suitable for lower-value products such as firewood. The results provide a foundation for making stand level post-fire timber degradation assumptions based on this metric. Future work can build on this study to further improve understanding of long-term timber degradation post-fire.

Summary of tree mortality and timber degradation in the sample population

Table 6 provides a snapshot of timber degradation four years post-fire in a RAFIT Class 5 area. The analysis shows that tree mortality increases as DBHOB class decreases. Inferred from the predicted green log volume as a percentage of total log volume, it also demonstrates that the extent of timber degradation increases as diameter decreases.

Table 6: Tree mortality and timber degradation in the sample population

DBHOB class (mm)	Tree sample size (number)	Tree mortality (number and proportion of trees in TQC 3)	Avg. total height (m)	Avg. green (live) height (m)	Avg. green (live) height as proportion of avg. total height (%)*	Predicted avg. total log volume (m^3)	Predicted avg. green log volume (m^3)	Predicted green log volume as proportion of total log volume (%)
100-149	194	86 (44%)	11.3	2.4	23%	0.03	0.02	67%
150-299	316	21 (7%)	15.9	7.6	47%	0.13	0.1	77%
300-450	48	1 (2%)	20.0	12.9	64%	0.47	0.41	87%
>450	27	0 (0%)	22.2	15.9	72%	1.21	1.1	91%

* Note: the green (live) height as a proportion of total tree height is lower than the predicted green (live) log volume as a proportion of total log volume. This is due to the combined effect of bole taper (i.e. the tree trunk being thicker at the base than the top) and the trees dying from the top down.

Further analysis and interpretation of this data set combined with post-fire field observations from the 2019-20 fire season were used to derive a suite of assumptions about the future trajectory of timber degradation across NSW coastal hardwood forests. These assumptions were then incorporated into FRAMES, a process which is discussed in greater detail in the section below.

Integration of fire impact analysis into FRAMES

The FRAMES modelling system projects growth and simulated harvests on measured inventory data. The impact of the 2019-20 fires on the resource has been simulated by spatially attributing the plot database with RAFIT fire severity data and applying assessed fire damage assumptions to the trees in those plots based on burn severity class and region or sub-region.

The assessed fire damage assumptions were prepared from a range of sources. These include studies of other recent fires (see Goldmine Fire study above), drone photography and field visits where conditions were safe to allow site inspections. A series of workshops was held to elicit the base rule set for each region based on the cumulative experience of Forestry Corporation staff to calibrate observations of damage levels in the different RAFIT classes. These rule sets were then rechecked against follow-up field observations.

The observations collected by Forestry Corporation staff indicate that the impacts of the fires were broadly similar across the whole coastal native forest estate in relation to mapped fire severity, but these observations require fine-tuning at sub-regional scales to account for local factors affecting the recovery process.

When assessing the impact of fire on tree mortality and growth rates, it is important to note that many species are adapted to fire and that periodic fire is introduced into the landscape in the form of hazard reduction burning. Field inspections have identified that sites burned in RAFIT burn severity Class 2 exhibit the same trends that are seen in typical low intensity hazard reduction burns. There is no observed evidence of fire damage to growing stock in this category.

Figure 13: Example of forest impacted by fire at a severity assessed as RAFIT Class 2. Fire impact on growing stock is typically very low to nil.

Figure 14: Example of forest impacted by fire at a severity assessed as RAFIT Class 3. Fire impact on growing stock is very low to nil.

With the possible exception of Alpine Ash forest types in the Tumut Sub-Region, field observations in RAFIT burn severity Class 3 indicate that these stands are likely to survive and continue to grow and yield timber products as previously measured, albeit with some reduced growth in the first few years post-fire as the trees recover from fire-related impacts such as leaf scorch. The Alpine Ash resource in the Tumut Sub-Region is particularly sensitive to fire and mortality, especially in smaller trees. However, there will be some level of uncertainty about the actual impact on Alpine Ash until the next growing season, which was still three months away at the time this report was compiled.

RAFIT burn severity classes four and five have been the primary focus of field assessments. These assessments have found the fire impact has resulted in either tree death (particularly smaller trees), log degradation and/or reduced capability for growth.

The fire impacts identified in this process have been converted into plot level rules that the FRAMES Growth and Yield Simulator apply at a tree level. Factors observed that are being used include:

» Time of impact (either at point of fire or after a specified time period)
» Species impacted (some species are more resilient to fire)
» Tree size expressed by its diameter at breast height (generally smaller trees are more susceptible to fire)
» Tree quality (capability to produce high-quality logs may be compromised).

The rules that have been developed at a localised level are discussed below in the chapters relating to specific sub-regions. How these rules translate to growth and yield can be visualised in the following example extracted from modelling of Eden regrowth.

Table 7: RAFIT modelling rules applied in FRAMES Growth and Yield Simulator for Eden Region

RAFIT Class	Modelling rules applied
1 (no indication of fire)	1.1 No impact applied
2 (cool burn)	2.1 No impact applied.
3 (moderate burn)	3.1 No growth for five years after fire
4 (hot burn)	4.1 All trees less than 15 centimetres DBHOB are assumed to have died immediately 4.2 All other trees are assumed to have no growth for five years after fire 4.3 At 10 years after the fire, 50 per cent of high-quality and low-quality trees less than 50 centimetres in diameter degrade to pulp quality.
5 (crown burn)	5.1 All trees less than 15 centimetres DBHOB are assumed to have died immediately 5.2 All other trees are assumed to have no growth for five years after fire 5.3 At 10 years after the fire all high-quality and low-quality trees less than 50 centimetres diameter degrade to pulp quality.

Table 7 shows the rules developed for each burn severity class and Figure 15 below demonstrates how these rules impact trees when aggregated to the stand level. The lines represent the average number of high-quality trees per hectare that are expected to be present as the plots are grown forward through to 2050.

Plots in RAFIT classes one and two remain unaffected and follow a trajectory that incorporates natural regeneration and mortality (self-thinning).

Plots in RAFIT class three do not have any fire-related mortality, but the burn does trigger a regeneration event that in low basal area sites may increase the tree counts about 20 years after the fire.

Fire has a more significant impact on plots in RAFIT classes four and five. Firstly, all trees (high-quality and other quality classes) that have a diameter less than 15 centimetres are assumed to have died as a direct result of the fire severity. Whilst the Goldmine Fire recovery study showed some survivability in this diameter class, the trees were so heavily impacted by fire and the merchantable piece size so small that a decision was made to remove all trees in this diameter class from the model on the assumption that they were dead. Any surviving trees are not expected to grow for five years. Ten years after the fire, a secondary impact is implemented, being that any sawlog quality trees (both high and low-quality) with a diameter less than 50 centimetres are degraded down to pulp quality. This represents the likely impact of cambial damage, knot development from epicormic shoots in future timber growth, gum rings and compromised resilience to insect attack and fungal decay. We can see this in Figure 15 at year 2030, where the number of high-quality trees drops from about 140 per hectare down to around 70 per hectare (50 per cent) in RAFIT Class 4. In RAFIT Class 5, the remaining high-quality tree count drops to nearly zero, as there are very few high-quality trees in the Eden regrowth resource that have a diameter bigger than 50 centimetres. The post-fire regeneration event then increases the stocking levels of high-quality trees in 2040, 20 years after the fire.

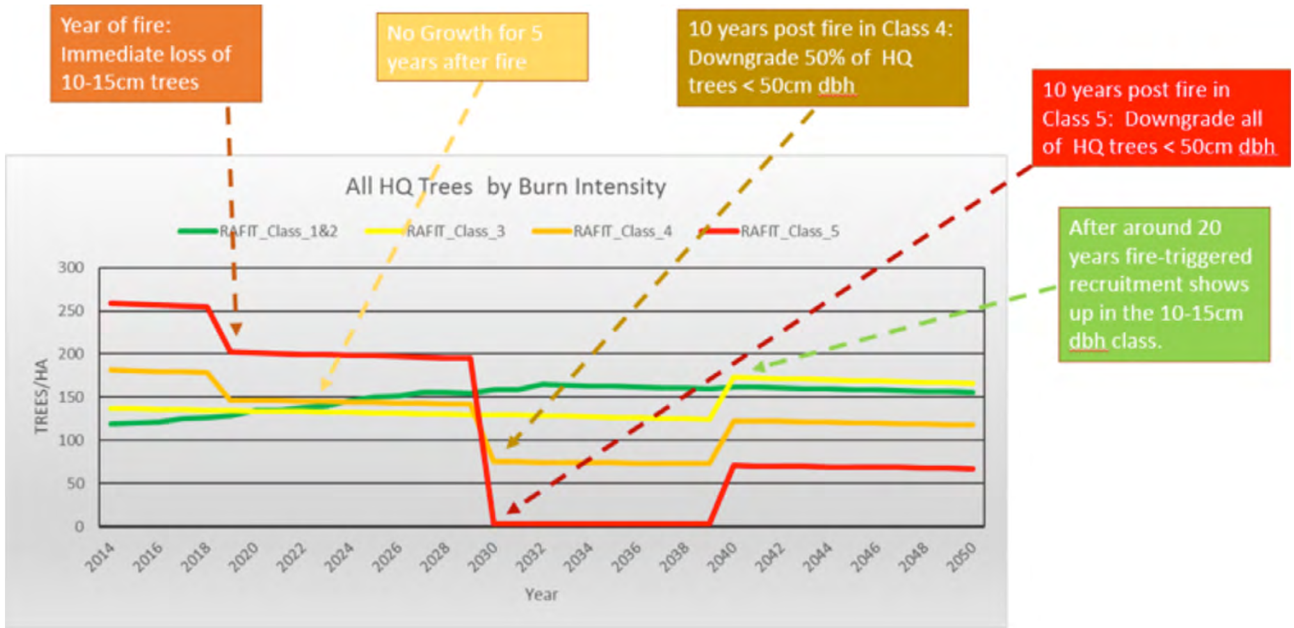


Figure 15: Fire impact on high-quality (HQ) growing stock in the Eden Region.

The impact of the fire on stand growth is demonstrated in Figure 16, which shows stand basal area change over time. Once again, RAFIT classes one and two remain unaffected and the plots follow a typical growth trajectory. The fire mortality of smaller trees in the stand is seen at year 2020, with classes four and five showing an actual drop in standing basal area. For the next five years the basal area remains static as trees use their resources to restore crowns. After 2025, the growth module is re-activated, and the stands' growth rates return to normal. Finally, the post-fire recruitment can be seen to slightly increase standing basal area when it is activated in 2040, 20 years after the fire.

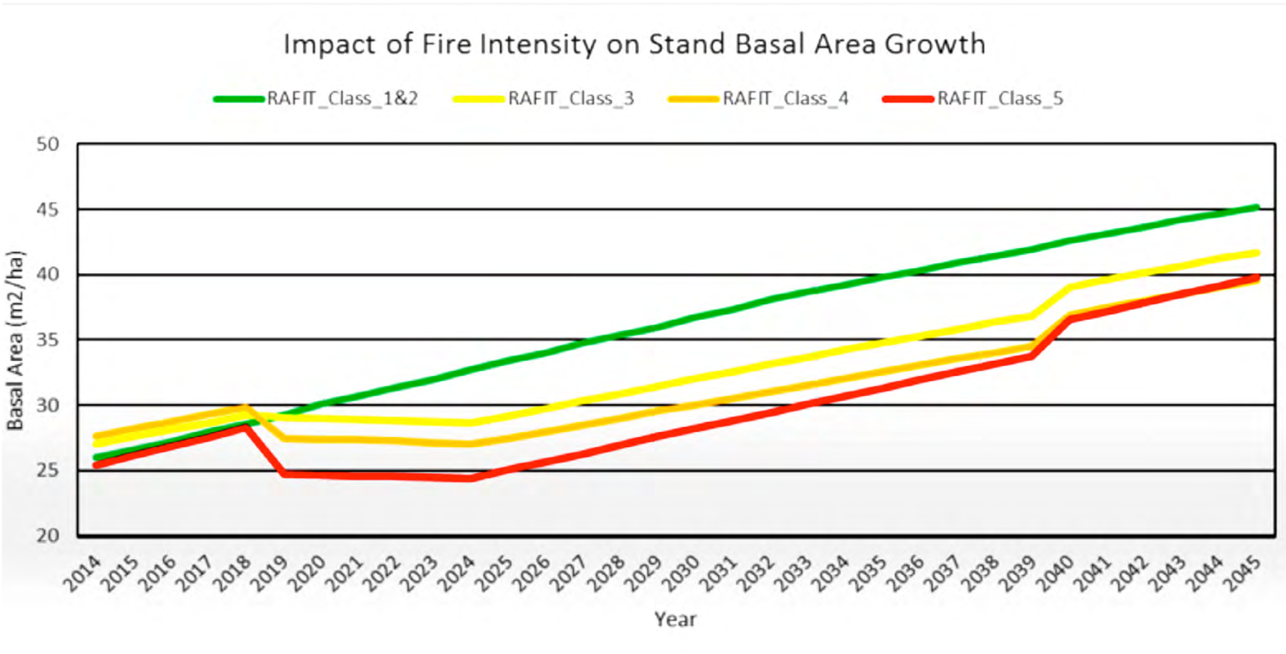


Figure 16: An example of fire impact on basal area growth in the Eden Region.

Wood supply models

Eden region

Approximately 80 per cent of the harvestable area across the Eden region was impacted by fire during the 2019-20 season. The fires were well established in Victoria before crossing the border in the south of the region and were characterised by the sudden spread of several high severity fire fronts that moved across from Victoria and burned through much of the Eden management area in matter of hours, driven by winds in excess of 90 kilometres per hour. Figure 17 shows the mapped fire extent, overlayed with RAFIT fire severity assessment. Figure 18, Figure 19 and Table 8 below provide a snapshot of fire impact on the timber resource.

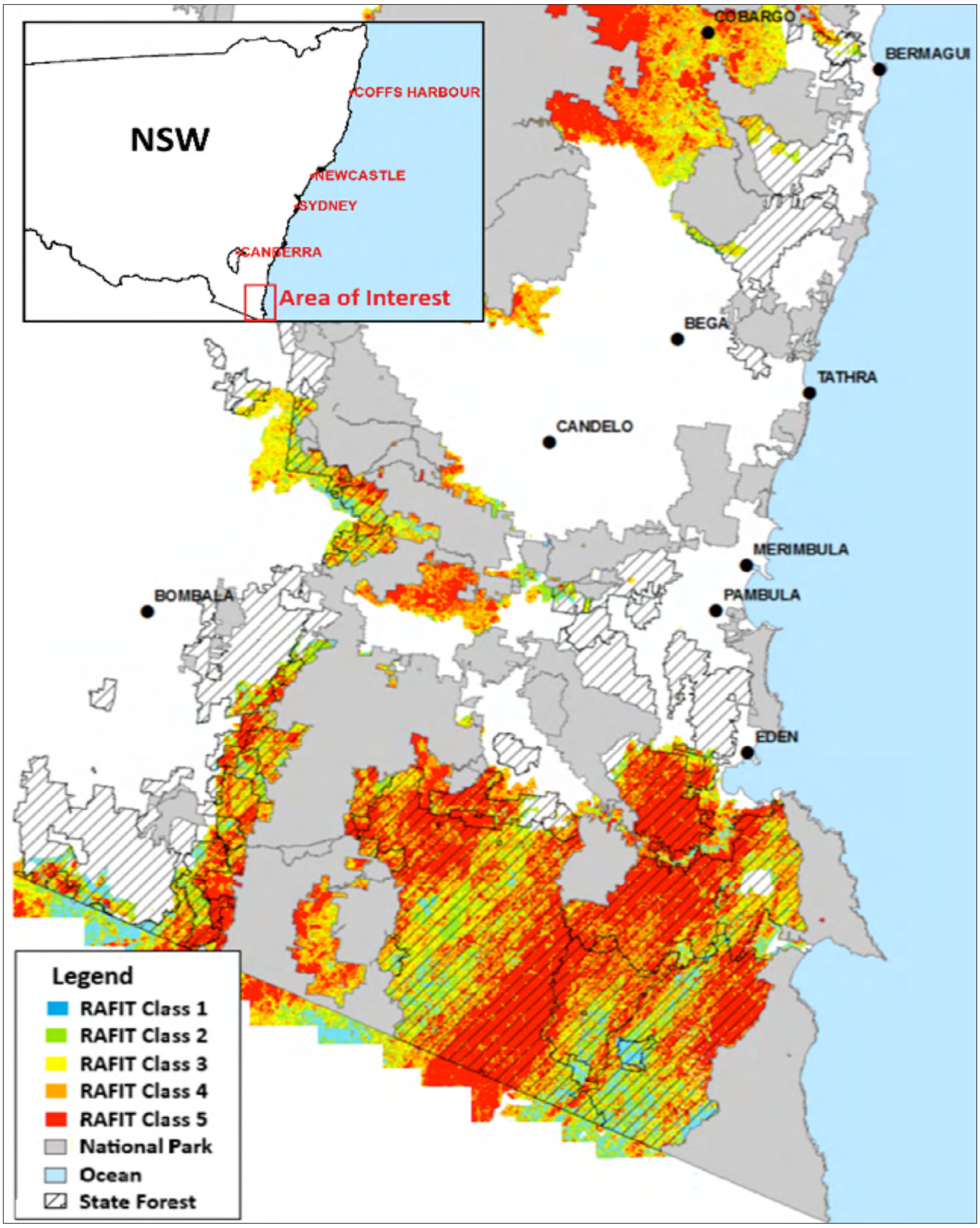


Figure 17: RAFIT fire severity mapping for the Eden Region (clipped to mapped fire extent of 2019-20 season).

Table 8: Inventory plot RAFIT class breakdown by locality for the Eden Region (2019-20 fire season)

Number of plots by RAFIT class - Eden Region							
Analysis Group	RAFIT 1	RAFIT 2	RAFIT 3	RAFIT 4	RAFIT 5	Total	RAFIT 4 and 5(%)
East	6	18	4	3	2	33	15%
North West	20	6	1	0	0	27	0%
South	3	22	20	31	13	89	49%
South East	2	17	28	24	16	87	46%
South West	1	10	3	2	1	17	18%
Total	32	73	56	60	32	253	36%
Percentage of total	13%	29%	22%	24%	13%		

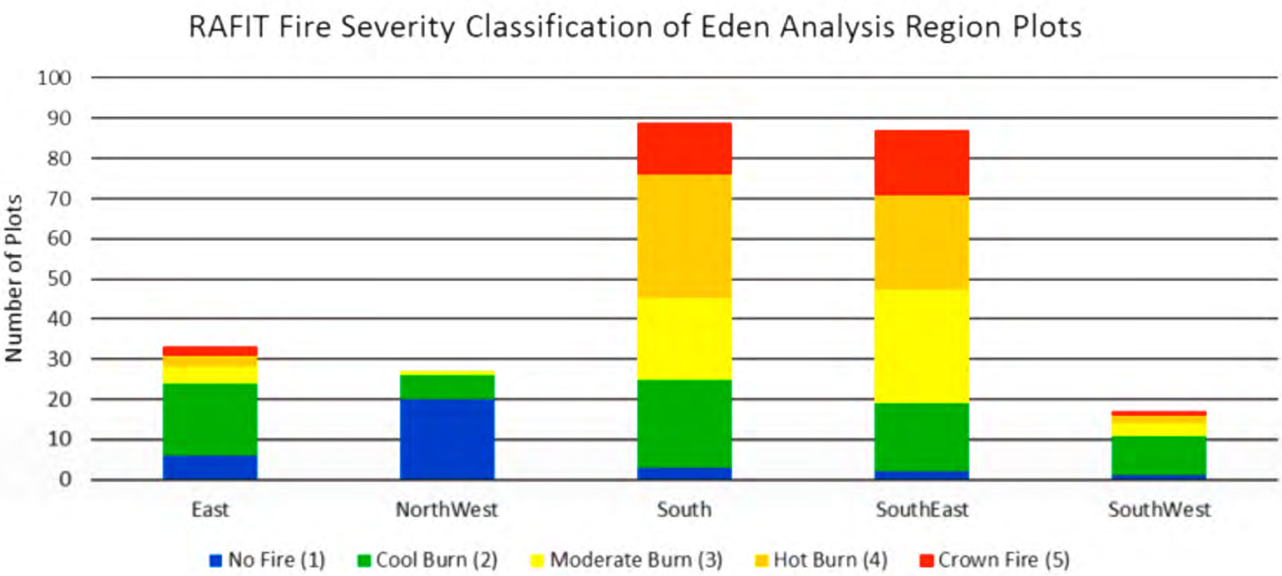


Figure 18: RAFIT class distribution by locality across the Eden Region (2019-20 fire season).

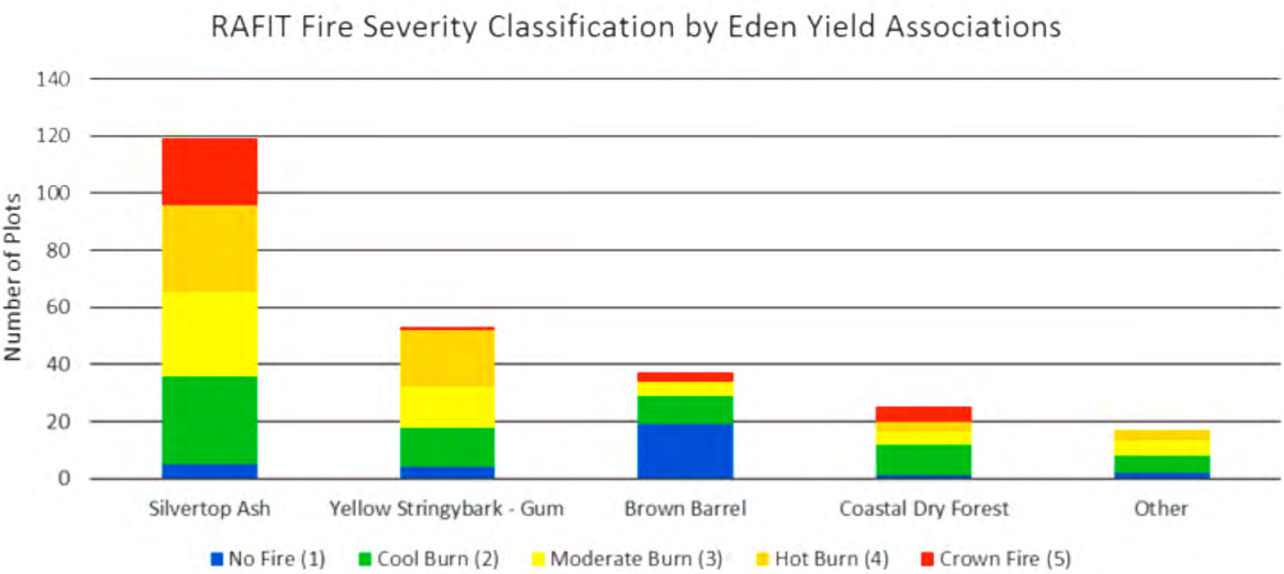


Figure 19: RAFIT class distribution by yield association group across the Eden Region (2019-20 fire season).

In summary, 36 per cent of strategic inventory plots in the region were impacted by hot or crown fire. The South and South East Timber Zones were worst affected, with close to 50 per cent of plots in each of these areas impacted by high severity fire. The dominant species in the region is Silvertop Ash, which represents about 50 per cent of the resource. Nearly half of the Silvertop Ash association was impacted by high severity fire, with a further 25 per cent impacted by moderate severity fire. The Yellow Stringybark-Gum associations were also heavily impacted by fire. However, this association is not as large, representing 20 per cent of the regional standing volume.

Plot level assumptions by burn class

The modelling assumptions applied to FRAMES that are specific to the Eden region native forests are detailed below.

RAFIT Class 1 and 2 (no burn and light burn)

» No impact.

RAFIT Class 3 (moderate burn)

» All trees survive however are assumed to have no growth for five years after fire.

RAFIT Class 4 (hot burn)

» Fire immediately kills all trees less than 15 centimetres DBHOB

» All other trees are assumed to have no growth for five years after fire

» At 10 years after the fire 50 per cent of high-quality and low-quality trees less than 50 centimetres diameter degrade to pulp quality.

RAFIT Class 5 (crown burn / scorched)

» Fire immediately kills all trees less than 15 centimetres DBHOB

» All other trees are assumed to have no growth for five years after fire

» At 10 years after the fire all high-quality and low-quality trees less than 50 centimetres diameter degrade to pulp quality.

Other modelling notes:

» Recruitment is generated 20 years after fire, so degradation does not impact the post-fire regrowth

» Spotted Gum is more resilient to fire. However, none of these species were present in areas impacted by fire assessed as RAFIT classes four or five within the Eden region, so no special measures were taken.

Fire impact on standing volume

Based on the Goldmine Fire study, timber quality in the Eden Region is projected to decline over 10 years. As such, quantitative impact of the fire is best demonstrated by projecting growth of the resource after the full degradation has taken place. Table 9 below reports the state of the resource when projected forward 15 years, and when compared to a no-fire scenario where the inventory data isn’t modified.

Table 9: Predicted fire impact on standing volumes after 15 years across the Eden Region

Predicted fire impact on Eden standing volumes after 15 years			
Product group	Standing volume (m^3)	Proportion of pre-fire volume	Fire losses (m^3)
HQ Large Silvertop Ash Logs	114,700	75%	-38,600
HQ Small Silvertop Ash Logs	196,900	62%	-120,200
HQ25 Silvertop Ash Logs	167,200	61%	-108,500
All Silvertop Ash HQ Logs	**478,800**	**64%**	**-267,200**
HQ18 Silvertop Ash Logs	315,100	58%	-232,800
Pulp Silvertop Ash Logs	2,822,400	95%	-147,400
All Silvertop Ash Logs	3,616,300	85%	-647,400
All HQ Large Logs	339,400	87%	-49,200
All HQ Small Logs	353,500	71%	-146,300
All HQ25 Logs	**269,300**	**66%**	**-135,800**
All HQ Logs	962,200	74%	-331,200
All HQ18 Logs	488,600	62%	-298,300
All Pulp Logs	7,418,300	94%	-454,100
All Logs	**8,869,100**	**89%**	**-1,083,600**

The growing stock changes (Table 9) show that high-quality growing stock is significantly impacted by fire. The smaller diameter log classes are most heavily impacted due to the modelled degradation of higher quality trees less than 50 centimetres in diameter to pulp quality after ten years in RAFIT classes four and five.

Pulp growing stock is also impacted by the fire. This impact is observed firstly through a decrease in pulp growing stock related to the forecast mortality in trees less than 15 centimetres in diameter in RAFIT classes four and five. The impact is also observed through an increase in pulp growing stock related to the forecast degradation of higher quality trees less than 50 centimetres in diameter to pulp quality after ten years in RAFIT classes four and five. Overall, the combination of these factors results in a six per cent reduction in pulp growing stock.

Also noted in Table 9 is that high-quality Silvertop Ash growing stock is more heavily impacted than high-quality growing stock for all species. This can be attributed to a greater proportion of Silvertop Ash-dominated inventory plots falling within RAFIT classes four and five than other forest types.

100-year wood flow

Annual sustainable yield volumes calculated for the Eden Region native forests are shown in the charts below. Included in each chart is a summary line reporting the outcome of the benchmark 2018 Regional Forest Agreement Review.

Separate charts are presented for broad product groupings and species groups. The presented data for product classifications in these figures are indicative only and actual supply of these grades of log will vary based on the annual harvesting program.

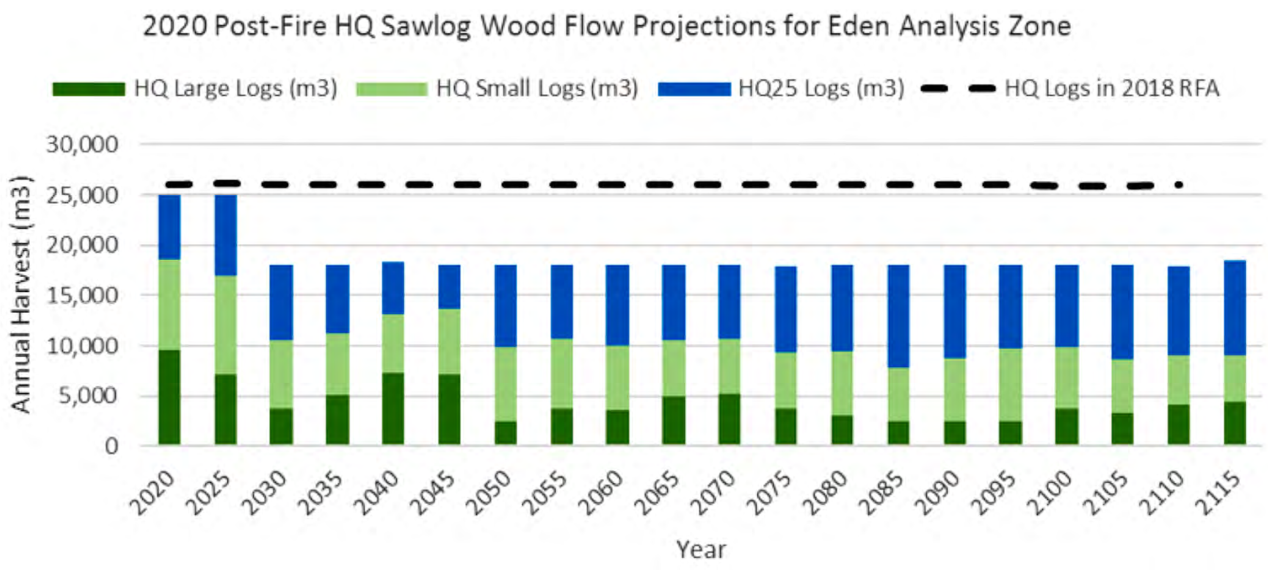


Figure 20: Post-fire high quality (HQ) log wood flow projections for the Eden Region.

A key challenge for the Eden resource is the likelihood that sawlog quality trees impacted by the hotter fires classified as RAFIT classes four and five will degrade to pulp after 10 years due to fire-triggered damage. To counter this impact, a strategy to harvest higher quantities of the severely-burned resource over these first two periods (10 years) has been modelled. The level of high-quality sawlog cut in these early periods was modelled to match the wood supply agreement levels, at 25,000 m^3 per year. After 10 years, the cut is reduced to the long-term sustainable level of 18,000 m^3 per year.

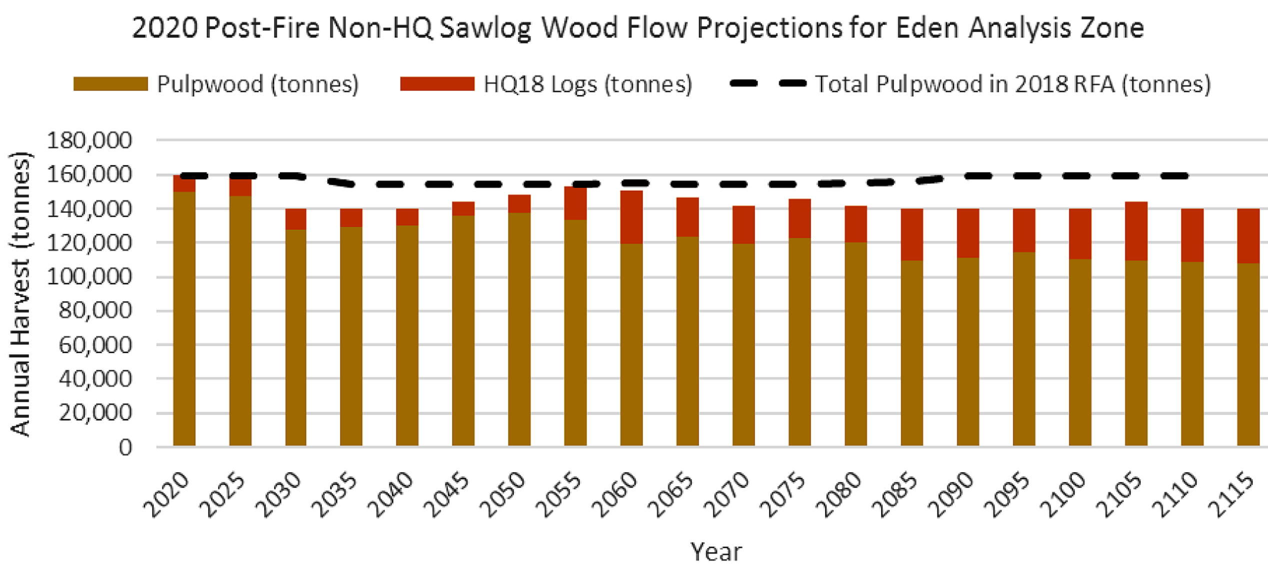


Figure 21: Post-fire wood flow projections for other product categories for the Eden Region.

Pulp log harvest volume is maintained at pre-fire production levels for the first 10 years of the model. This reflects the operational strategy to salvage high-quality timber before it degrades. The modelled concentration of harvesting in severely-burned areas will increase yield of all products, including pulp, as shown in Figure 21. Pulp production is smoothed after the increased production in the first 10 years, to the long-term sustainable level of around 140,000 tonnes per year. In the long term this is a 10 per cent decline in sustainable yield due to the fires.

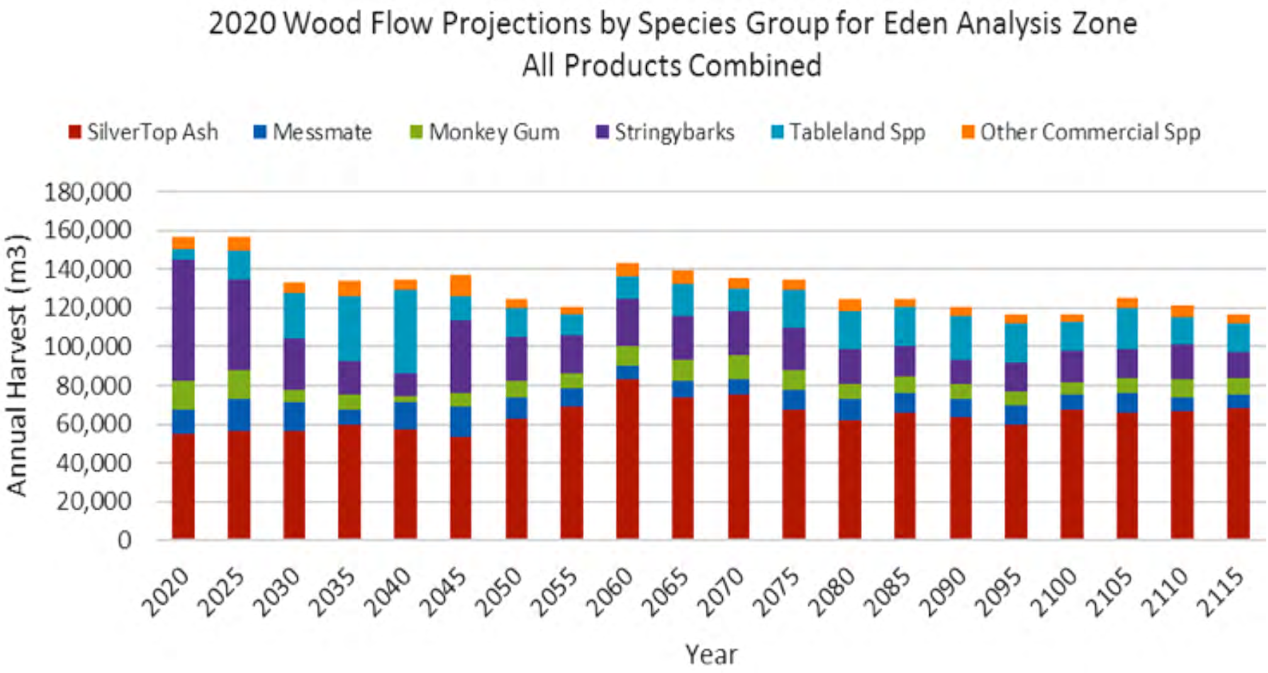


Figure 22: Post-fire total merchantable product wood flow projections by species group for the Eden Region.

Silvertop Ash dominates the species mix in Eden, contributing a third of total production in the first 20 to 30 years. This increases to over 50 per cent in the latter half of the model. With the Silvertop Ash (STA) stands being more heavily impacted by fire than other species groups, the peak in Silvertop Ash production seen in 2060 aligns with post-fire regeneration becoming available for harvest.

The wood flow model presented here does not follow a classic non-declining yield profile, as the two initial periods (10 years) are harvested at a higher rate than the remaining 90 years of the model. This strategy is driven by a focus on harvesting and regenerating severely fire-affected sites where the timber is expected to degrade over the course of the next 10-15 years. As such, the strategy allows the best possible recovery of high-quality timber from the forest and consequently the initial 10 year wood supply is above long-term sustainable yield.

The specific details of this strategy are laid out in the next section, which provides the tactical planning analysis for the first 20 years of the modelling period, covering the existing wood supply agreement period (10 years).

Validation: Eden Tactical Plan

A 20-year tactical plan has prepared for the Eden Region to assess and confirm Forestry Corporation's ability to meet wood supply agreement volumes for the Eden region, based on the preferred forest management approach of initially focusing harvesting and regeneration on severely-burned areas. This work provides additional spatial context to the plot-based strategic inventory for the Eden Region outlined in the previous section. Methods and tactical plan results are summarised below.

Methods

The following spatial layers were combined to produce a foundation layer set from which eligible harvesting units (coupes) for the 20-year tactical plan could be identified:

- event data layer - contains details of known harvesting events in the Eden region dating back to the 1970s including harvest date, area harvested, operation type and log product volume generated
- site class layer – displays low, medium and high-quality site class areas across the Eden Region
- coupe damage layer – displays coupe-level average RAFIT class burn severity from the 2019-20 fire season
- plot imputation layer – displays coupe-level imputation-derived product volume estimates
- 10m CIFOA base net area – a layer which shows the net area available for harvesting derived from the operating conditions of the current regulations, the Coastal Integrated Forestry Operations Approval (CIFOA).

Eligible coupes were then identified using the following criteria:

- Include all ex-alternate coupe areas older than 35 years in low site quality classes
- Include all ex-alternate coupe areas older than 25 years in medium and high site quality classes
- Include all ex-thinning and ex-single tree selection (STS) areas
- Exclude all areas with no mapped harvesting history in the event database.

Volume estimates for each coupe were then then written down by 20 per cent to account for wildlife habitat clumps, tree retention areas and other factors like slope and rock that limit the available and accessible harvestable area. A forecast year of harvesting was then ascribed to each coupe focusing on the most heavily burnt areas first.

Table 10: Eden Region 20 year (2020-2039) Tactical Plan: Imputation-derived merchantable volume available by RAFIT class

2020-2039 Tactical Plan: Imputation-derived merchantable volume available by RAFIT class (m^3)							
Previous harvest	Previous operation type	RAFIT 1 No vegetation loss	RAFIT 2 Cool burn / drought	RAFIT 3 Moderate burn	RAFIT 4 Hot burn	RAFIT 5 Crown burn	Total
1971-1980	Alternate Coupe	25,299	182,177	291,605	134,873	70,015	703,969
1971-1980	STS	-	4,896	3,007	93	-	7,996
1971-1980	**Total**	**25,299**	**187,073**	**294,612**	**134,966**	**70,015**	**711,964**
1981-1990	Alternate Coupe	167,892	431,293	236,134	287,818	108,655	1,231,791
1981-1990	STS	707	14,712	8,650	2,024	6,202	32,294
1981-1990	Thinning	-	-	63	1,125	-	1,188
1981-1990	**Total**	**168,598**	**446,005**	**244,846**	**290,967**	**114,857**	**1,265,274**
1991-2000	Alternate Coupe	77,845	168,155	51,251	152,336	45,516	495,103
1991-2000	STS	-	12,117	-	-	-	12,117
1991-2000	Thinning	8,146	5,660	4,142	7,778	467	26,193
1991-2000	**Total**	**85,991**	**185,932**	**55,393**	**160,114**	**45,983**	**533,413**
2001-2010	STS	-	9,557	-	-	-	9,557
2001-2010	Thinning	12,125	105,736	153,499	123,652	43,461	438,473
2001-2010	**Total**	**12,125**	**115,293**	**153,499**	**123,652**	**43,461**	**448,030**
2011-2020	STS	-	17,191	-	-	-	17,191
2011-2020	**Thinning**	**6,675**	**24,543**	**61,450**	**100,375**	**47,705**	**240,747**
2011-2020	Total	6,675	41,734	61,450	100,375	47,705	257,938
Grand Total		**298,687**	**976,038**	**809,799**	**810,074**	**322,021**	**3,216,619**

The tactical plan volumes (Table 10) show that there is approximately 3,200,000m^3 of harvestable standing volume within the eligible coupe list. Without allowing for the additional tree growth that would be expected within the 20-year tactical plan period, this volume is adequate to meet both the 1,600,000m^3 (rounded) ten-year wood supply agreement volume from 2020 to 2029 and the 1,400,000m^3 (rounded) long term sustainable yield volume from 2030 to 2039.

It should be noted that approximately 600,000m^3 of this predicted volume comes from stands that are currently younger than 40 years old that were burnt with high severity in RAFIT classes four and five. In the absence of high-severity fire, these stands would normally be excluded from alternate coupe harvesting until they were at least 40 years old. However, to recover any high-quality log volume prior to it degrading, these stands have been scheduled for harvesting in the first 10-year tactical plan period. This is expected to give rise to a higher proportion of smaller diameter log products being harvested in the next 10 years than previously forecast.

Figure 23 below shows the spatial distribution of target coupes in the first 10-year period (2020-2029) and second 10-year period (2030-2039) of the 20-year tactical plan by RAFIT class.

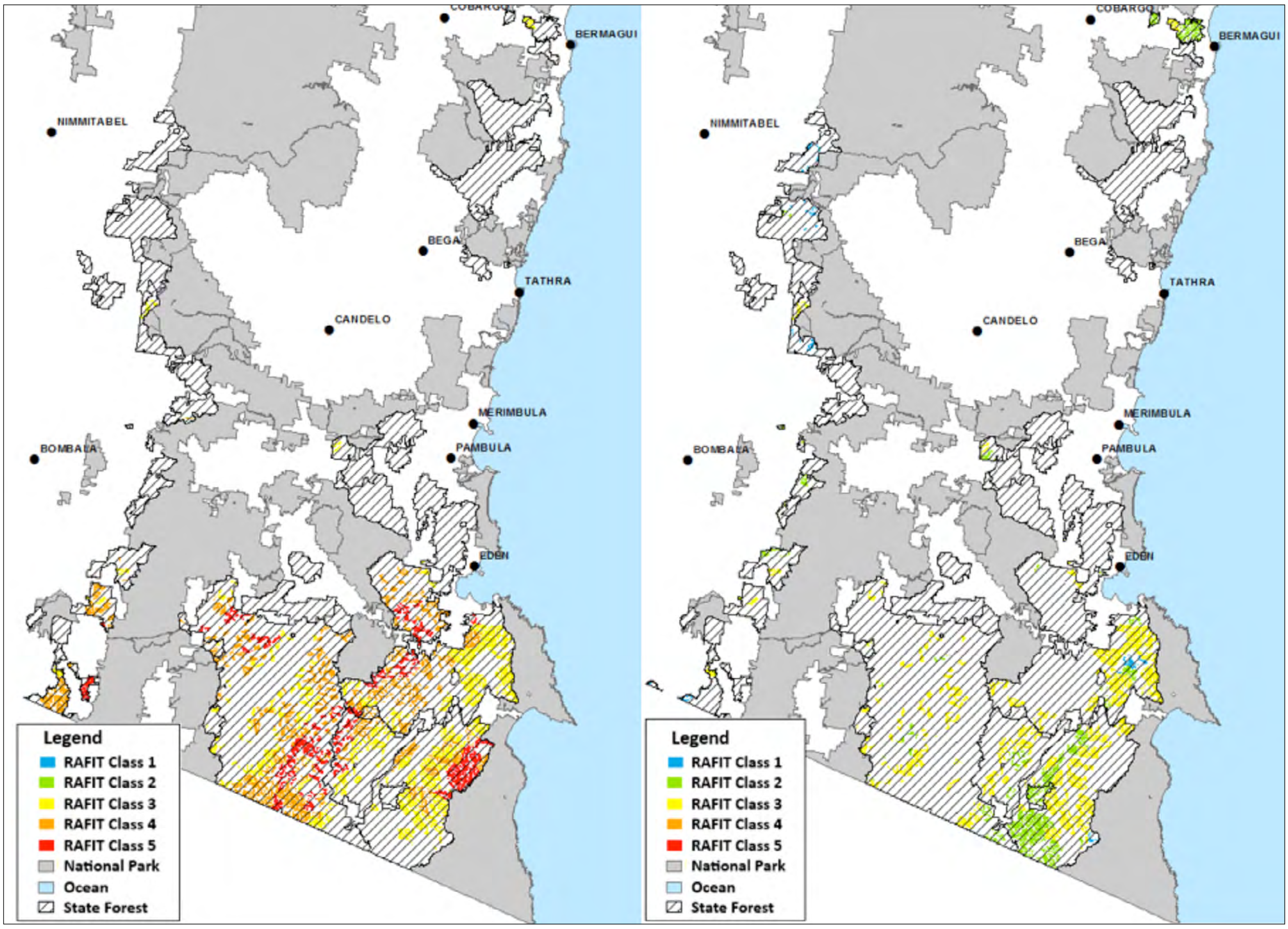


Figure 23: The image on the left shows the first 10-year period (2020 – 2029) of the Eden Region 20-year tactical plan. The image on the right shows the second 10-year period (2030 – 2039) of the Eden Region 20-year tactical plan. Target coupes are displayed by RAFIT class.

Southern Region - South Coast Sub-Region

Nearly 80 per cent of the harvestable area across the South Coast Sub-Region experienced moderate to high severity fire during the 2019-20 season. Over 40 per cent experienced crown fire conditions. Figure 24, Figure 25 and Table 11 below provide a snapshot of impacts of these fires on the South Coast Sub-Region timber resource.

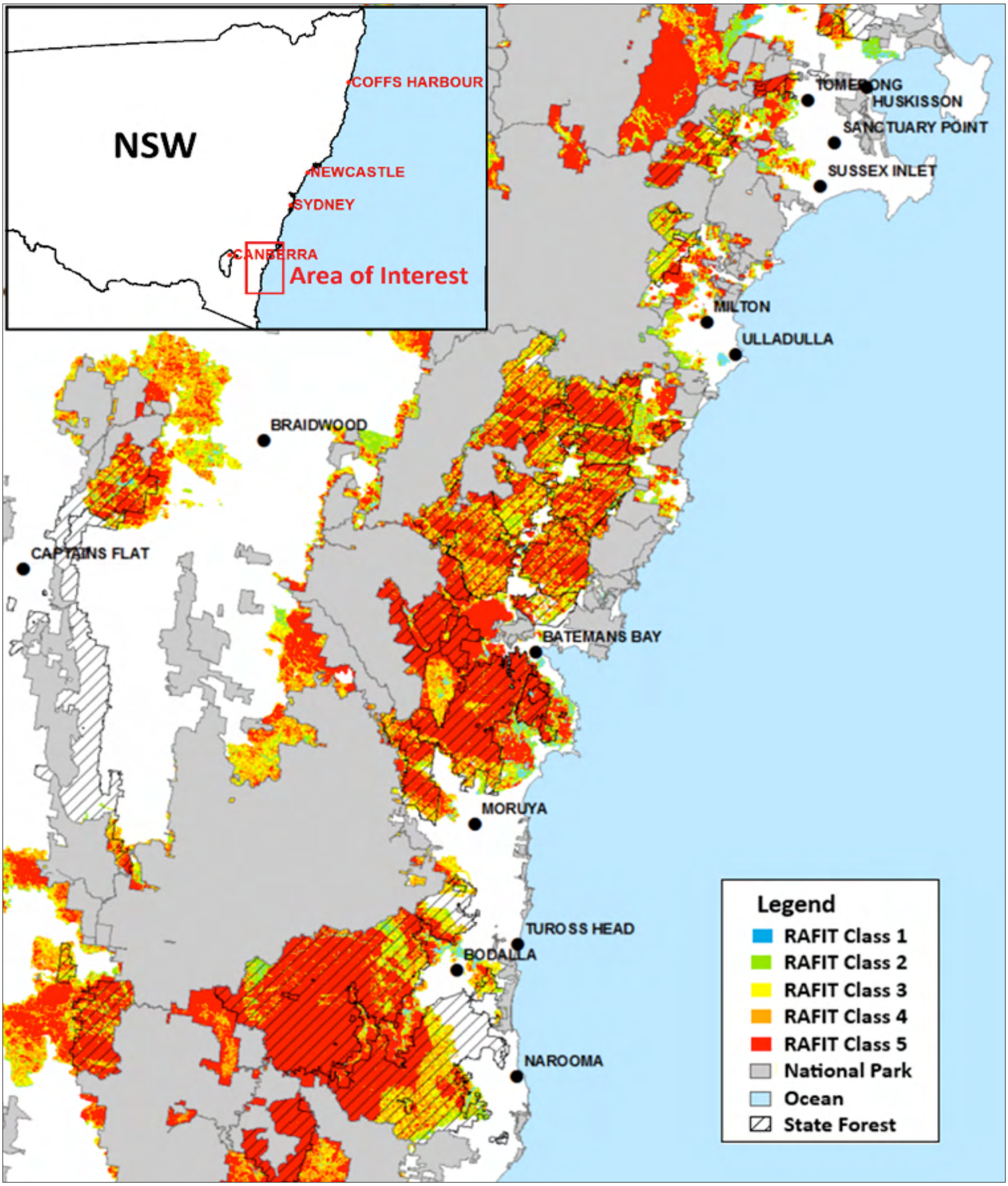


Figure 24: RAFIT fire severity mapping for South Coast Sub-Region (clipped to mapped fire extent of 2019-20 season).

Table 11: Inventory plot RAFIT class breakdown by locality for the South Coast Sub-Region (2019-20 fire season)

Number of plots by RAFIT Class – South Coast Sub-Region							
Analysis Sub-Region	No fire (1)	Cool burn (2)	Moderate burn (3)	Hot burn (4)	Crown fire (5)	Total	RAFIT 4 and 5 (%)
Batemans Bay coastal	2	9	31	30	82	154	73%
Batemans Bay foothills	1	9	15	22	55	102	75%
Narooma coastal	4	15	8	14	9	50	46%
Narooma foothills	23	7	19	27	49	125	61%
Tablelands	10	31	8	18	8	75	35%
Total	**40**	**71**	**81**	**111**	**203**	**506**	**62%**
Percentage of total	**8%**	**14%**	**16%**	**22%**	**40%**		

Severe fire impacts were widespread in the region, though slightly lower in the Narooma coastal zone and the tablelands. Figure 25 shows the distribution of fire severity by timber zone. Figure 26 shows the impact across yield associations.

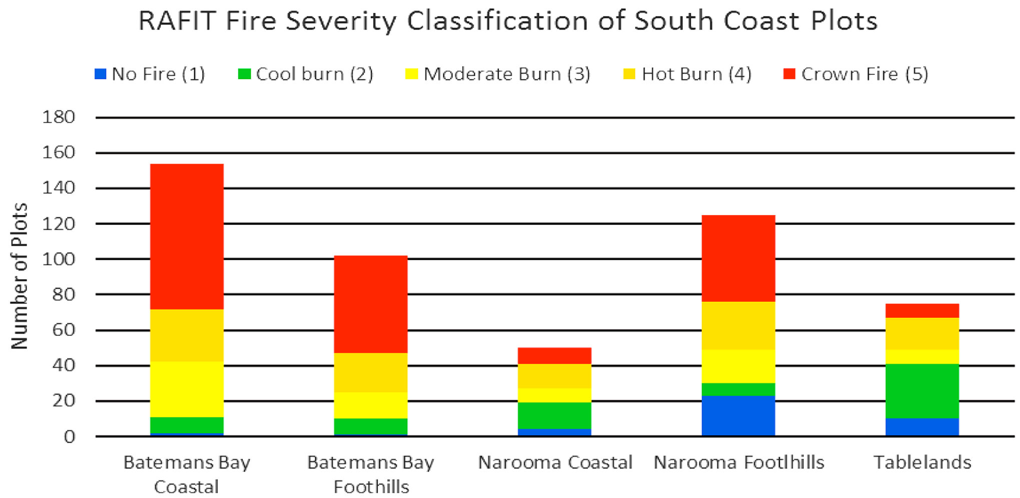


Figure 25: RAFIT class distribution by locality across the South Coast Sub-Region (2019-20 fire season).

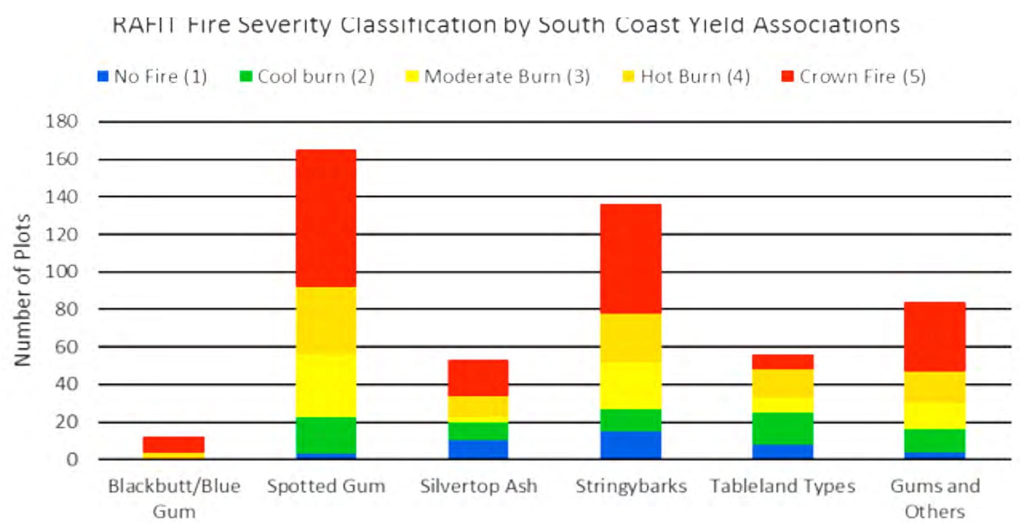


Figure 26: RAFIT class distribution by yield association group across the South Coast Sub-Region (2019-20 fire season).

Plot level assumptions by burn class

The modelling assumptions applied to FRAMES that are specific to the South Coast Sub-Region native forests are detailed below.

RAFIT Class 1 and 2 (no burn and light burn)

» No impact.

RAFIT Class 3 (moderate)

» All trees survive but are assumed to have no growth for five years after fire (due to a combination of impacts from fire and drought).

RAFIT Class 4 (hot)

» At year of fire, all trees less than 15 centimetres in diameter are killed. All surviving trees are assumed to have no growth for five years after fire.

» 10 years after fire 25 per cent of spotted gum trees less than 50 centimetres in diameter degrade to pulp. For all other species, 50 percent of those trees less than 50 centimetres in diameter degrade to pulp.

RAFIT Class 5 (crown burn / scorched)

» At year of fire all trees less than 15 centimetres in diameter are killed. All surviving trees are assumed to have no growth for five years after fire.

» 10 years after fire, 50 percent of Spotted Gum trees less than 50 centimetres in diameter degrade to pulp. For other species, 80 percent of those trees less than 50 centimetres in diameter degrade to pulp.

Other modelling notes:

» The extent of timber degradation in Spotted Gum trees less than 50 centimetres diameter in RAFIT classes four and five in the South Coast Sub-Region was set lower than other species based on field assessments which indicate markedly better recovery in Spotted Gum.

» The extent of timber degradation in trees less than 50 centimetres diameter in non-Spotted Gum species in RAFIT class five in the South Coast Sub-Region was set to 80 per cent instead of the 100 per cent setting applied for the Eden Region. This was based on field assessments which indicated marginally better forest recovery in the South Coast Sub-Region in RAFIT class five.

» Although a proportion of larger hollow-bearing trees was observed to have died in high severity fires, these trees are not typically merchantable and are not removed in the harvest modelling algorithm. As a result, no adjustments were made in the models for these trees.

» There was limited access to the Narooma foothills area during the assessment period due to safety concerns entering the area. The foothills area was subject to a significant proportion of very high intensity fire and the recovery of standing trees was ambiguous at the time of modeling. Sensitivity analysis of the mortality models will be undertaken to understand alternative impact and recovery outcomes, along with ongoing monitoring of tree mortality and timber degradation.

Fire impact on standing volume

As timber quality on the South Coast is projected to decline over 10 years, quantitative impact of the fire is best demonstrated by projecting growth on the resource after the full degradation is has taken place. The table below reports the state of the resource 15 years forward in the model, inclusive of growth and downgrades.

The fire impact is estimated to reduce the initial high-quality large log growing stock by approximately 10 per cent. As the impact is expected to be on trees less than 50 centimetres in diameter, the bigger impact is seen on high-quality small logs. After 15 years, the model shows a 24 per cent reduction in small Spotted Gum high-quality logs and a 39 per cent overall reduction in all species within the small high-quality log category. When the large high-quality logs are taken into consideration, overall the model predicts a 20 per cent reduction in high-quality logs as a direct result of the 2019-20 fires.

Table 12: Predicted fire impact on standing volumes after 15 years across the South Coast Sub-Region

Fire impact on South Coast standing volumes after 15 years			
Product	Standing volume (m^3)	Proportion of pre-fire volume	Fire losses (m^3)
HQ Large Spotted Gum Logs	584,600	90%	-67,900
HQ Small Spotted Gum Logs	219,100	76%	-70,400
All HQ Spotted Gum Logs	803,700	85%	-138,400
All HQ Large Logs	1,951,800	90%	-224,300
All HQ Small Logs	616,700	61%	-401,800
All HQ Logs	2,568,500	80%	-626,000

100-year wood flow

Annual sustainable yield volumes calculated for the native forest estate in the South Coast Sub-Region are shown in the charts below, combined with a summary line reporting the outcome of the benchmark 2018 Regional Forest Agreement Review.

Separate charts are presented for broad product groupings and species groups. The presented data for product classifications in these figures are indicative only and actual supply of these grades of log will vary based on the annual harvesting program.

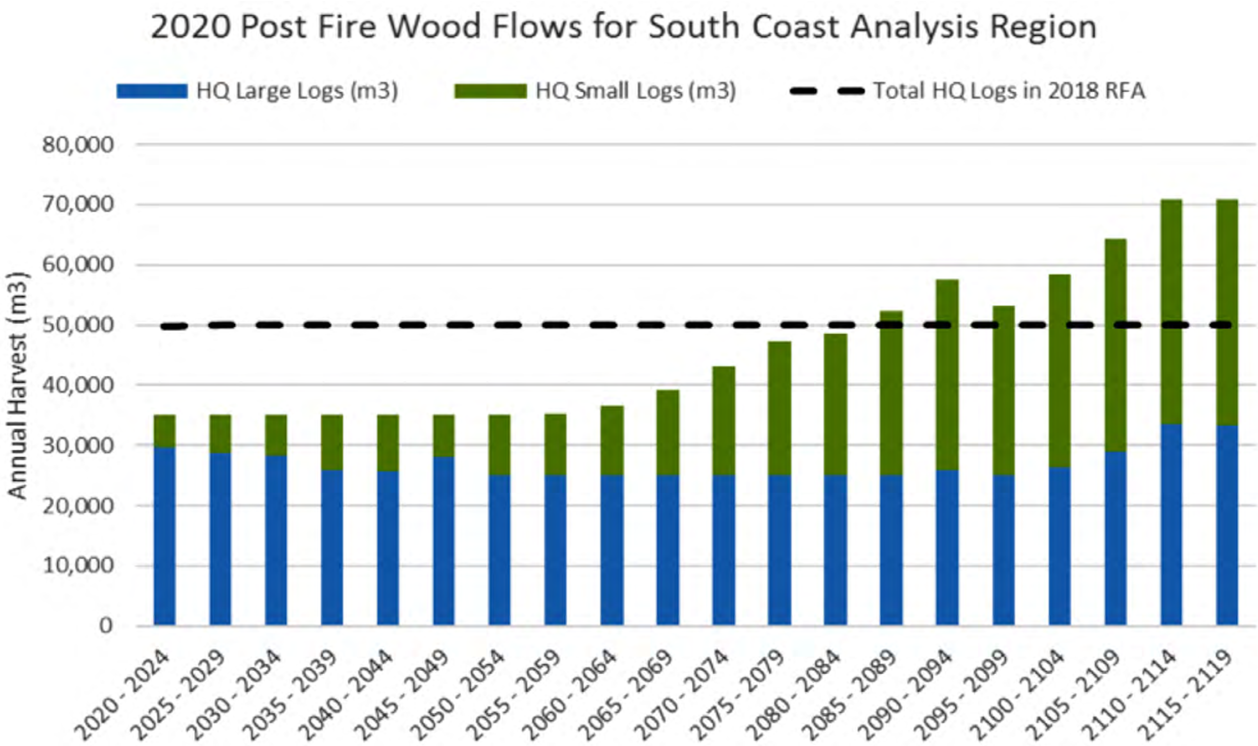


Figure 27: Post-fire high-quality (HQ) log wood flows for the South Coast Sub-Region.

Post-fire high-quality log wood flows are shown in Figure 27. This model focuses on recovery of high-quality growing stock to pre-fire levels. The total high-quality volume production is lower than pre-fire modelled levels until the latter half of the model, when stands regenerating following the fires begin to mature to commercial sizes. By contrast, to counteract the accumulation of pulp-grade growing stock that results from the fire damage to higher quality logs, pulp production in the first half of the model is forecast to be significantly higher than the pre-fire model.

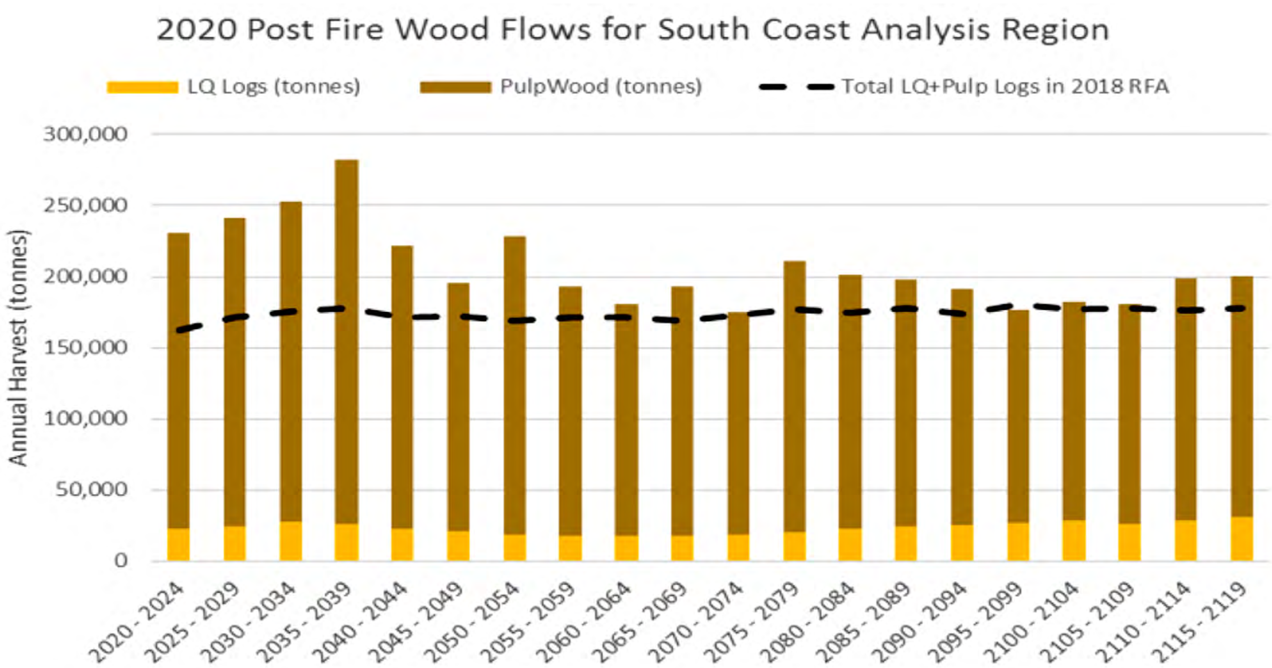


Figure 28: Post-fire low-quality and pulp-log wood flows for the South Coast Sub-Region.

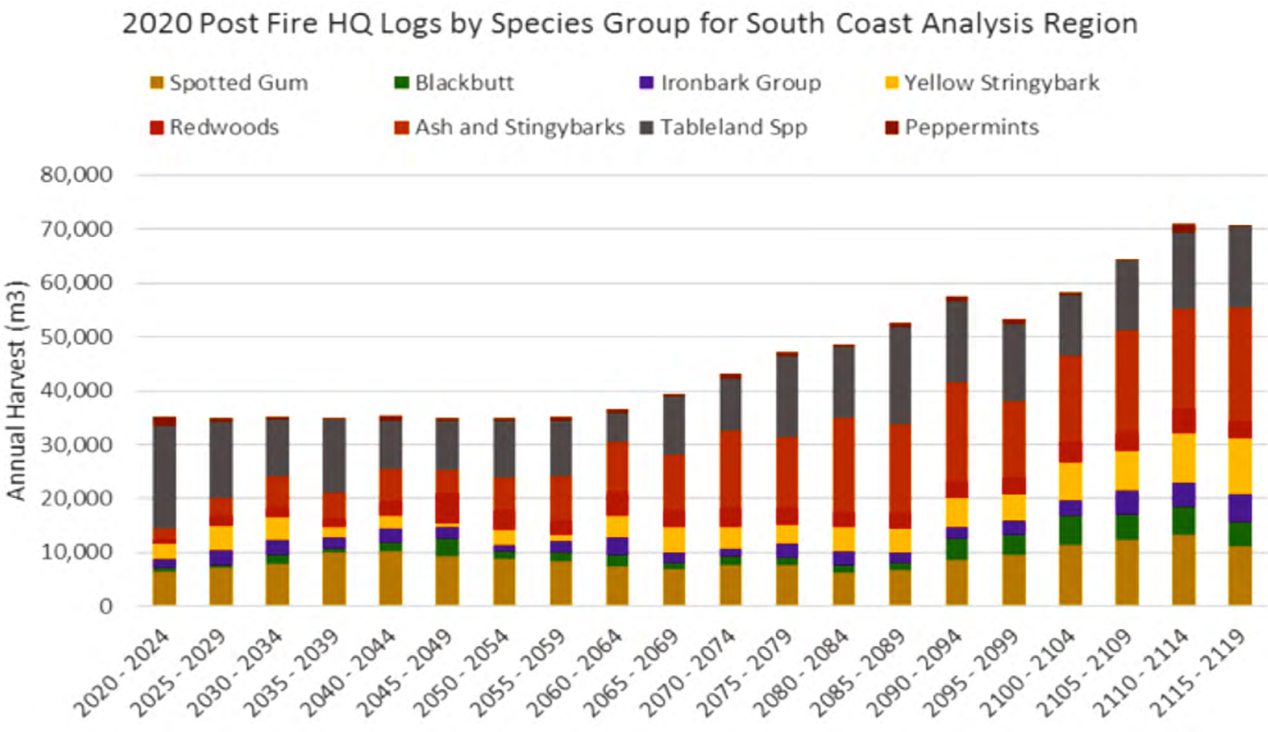


Figure 29: Post-fire high quality (HQ) log wood flows by species group for the South Coast Region.

Combined high-quality log predictions by species group are shown in Figure 29. Spotted Gum has historically been a key species for industry in the South Coast Sub-Region and widespread severe fire impacts were recorded across its distribution in the region. Whilst Spotted Gum post-fire recovery appears markedly better than many other species, Spotted Gum growth rates are also lower than the average of other species groups in the South Coast Sub-Region. Sustainable yield levels consequently remain comparatively low for a significant period while growing stock across the region recovers. Post-fire Spotted Gum modelled production levels are only forecast to return to pre-fire modelled production levels after 80 years.

As the tableland species were less affected by fire, there is a higher level of harvest of these species forecast in the early part of the model. Over time, as the fire-affected resource recovers from the fire, increased yields can be expected from the Ash and Stringybark group.

Southern Region - Tumut Sub-Region

Nearly 60 per cent of the harvestable area across the Tumut Sub-Region experienced moderate to high severity fire during the 2019-20 season. Nearly all the fire activity centred in the Bago-Maragle Timber Zone, where about half of the resource experienced hot or crown fire (RAFIT classes four and five). Virtually no fire activity was recorded in the Bondo and Micalong State Forests (referred to as Tumut Analysis Zone). All the fire impacts in the Tumut Sub-Region came from the Dunns Road Fire, which burned through the Bago and Maragle State forests in less than 24 hours. The figures and tables below provide a snapshot of the impacts of this fire on the timber resource in the Tumut Sub-Region.

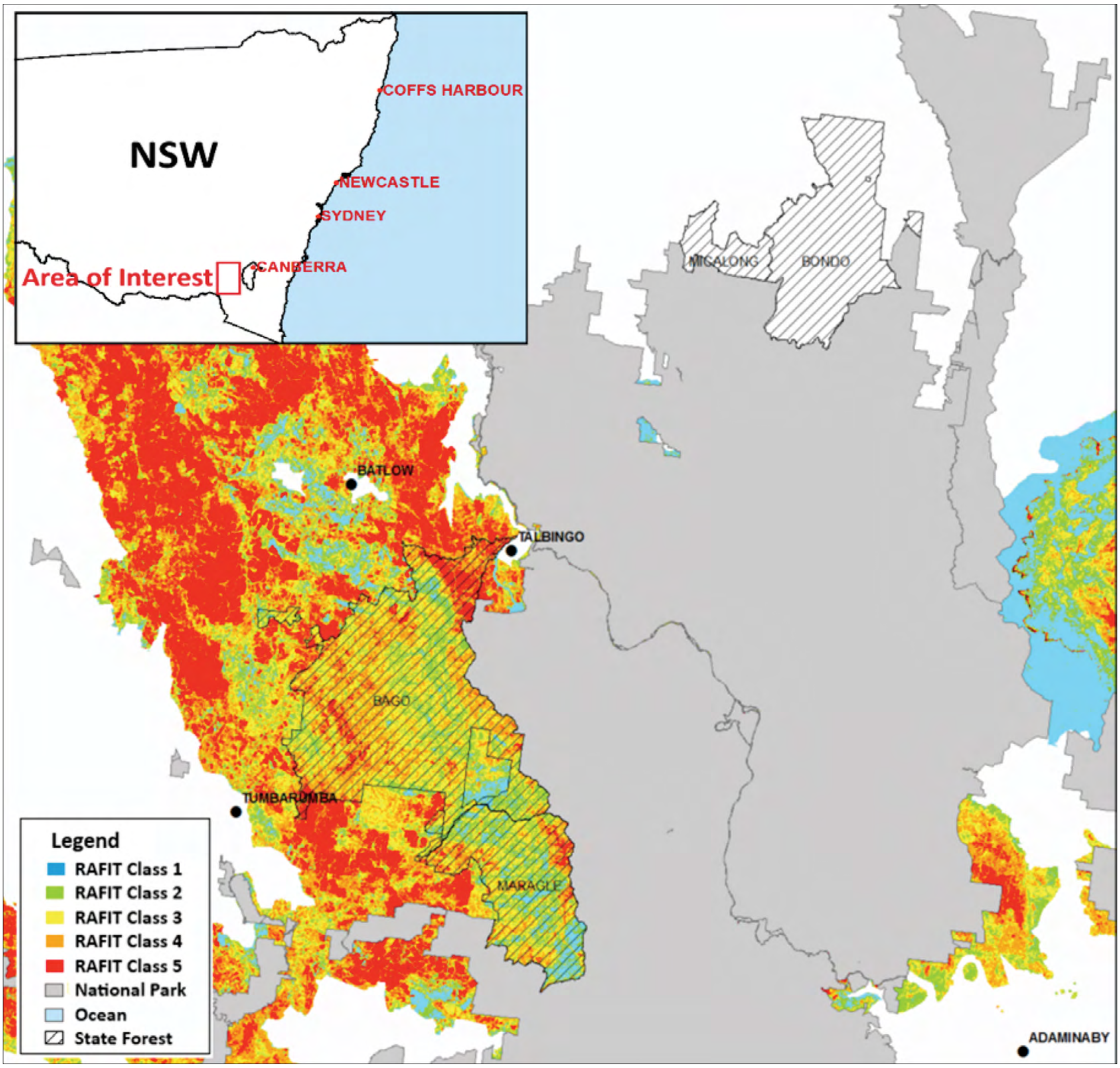


Figure 30: RAFIT imagery of the Tumut Sub-Region (clipped to mapped fire extent of 2019-20 season).

Table 13: Inventory plot RAFIT class breakdown by locality for the Tumut Sub-Region (2019-20 fire season)

Number of plots by RAFIT Class – Tumut Sub-Region							
Analysis group	No fire (1)	Cool burn (2)	Moderate burn (3)	Hot burn (4)	Crown burn (5)	Total	RAFIT 4 and 5 (%)
Bago Maragle	9	22	41	51	12	135	47%
Tumut	48	1	0	0	0	49	0%
Total	**57**	**23**	**41**	**51**	**12**	**184**	**34%**
Percentage of total	**31%**	**13%**	**22%**	**28%**	**7%**		

Table 14: Inventory plot RAFIT class breakdown by yield association group for the Tumut Sub-Region

Number of plots by yield association group and RAFIT class – Tumut Sub-Region							
Analysis group	No fire (1)	Cool burn (2)	Moderate burn (3)	Hot burn (4)	Crown burn (5)	Total	RAFIT 4 and 5 (%)
Alpine Ash types	12	12	14	15	7	60	37%
Other hardwoods	45	11	27	36	5	124	33%
Total	**57**	**23**	**41**	**51**	**12**	**184**	**34%**
Percentage of total	**31%**	**13%**	**22%**	**28%**	**7%**		

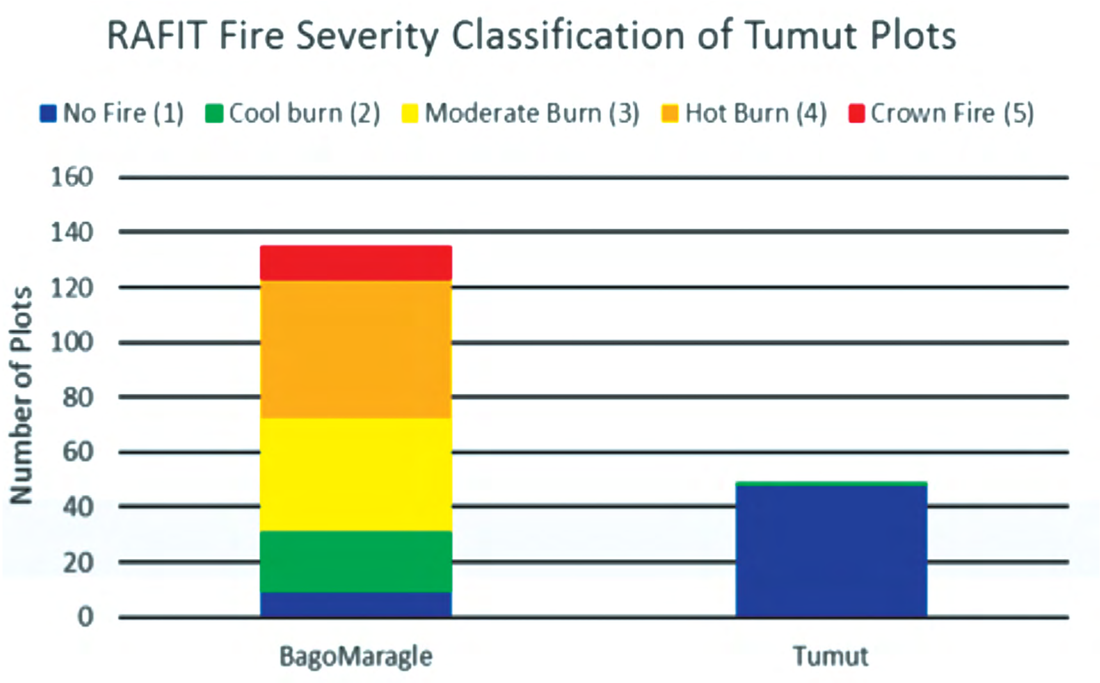


Figure 31: Fire severity distribution across the Tumut Sub-Region.

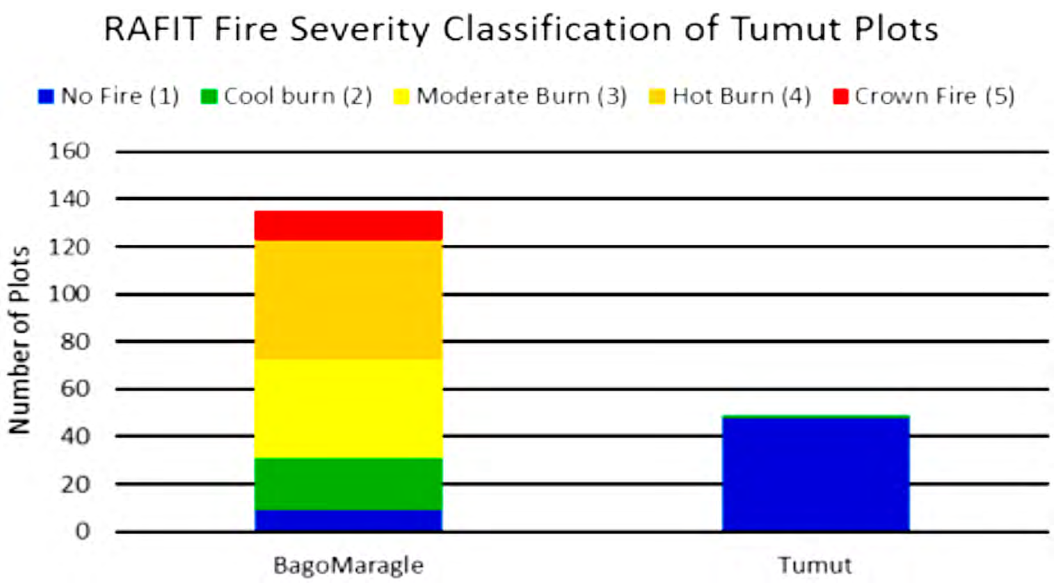


Figure 32: Fire severity distribution across the yield associations of Tumut Sub-Region.

Plot level assumptions by burn class

The modelling assumptions applied to FRAMES that are specific to the Tumut Sub-Region native forests are detailed below. A key feature of this resource is the presence of Alpine Ash species, which grows fast and produces high-quality sawlog products. Unfortunately, Alpine Ash is also highly susceptible to fire and as a result this resource is modelled to reflect significant mortality for moderate and hotter fire areas.

At the time of assessment there was limited access to many parts of the forest and the extent of tree mortality was not able to be fully assessed. Tree mortality will be re-assessed in 2021 using remote sensing to determine the actual levels of mortality.

RAFIT Class 1 and 2 (no burn and light burn)

» No impact.

RAFIT Class 3 (moderate)

» All trees in non-Alpine Ash forest types survive but are assumed to have no growth for five years after fire.

» All Alpine Ash trees less than 30 centimetres in diameter assumed to have been immediately killed by fire.

RAFIT Class 4 (Hot)

» All Alpine Ash trees assumed to have been immediately killed by fire

» All other species with diameters less than 15 centimetres also assumed to have been immediately killed

» No growth applied for five years after fire in all Non-Ash forest types

» 10 years after fire, 50 per cent of high-quality or low-quality non-Alpine Ash species less than 50 centimetres in diameter degrade to pulp.

RAFIT Class 5 (crown burn / scorched)

» All Alpine Ash trees assumed to have been immediately killed by fire

» All other species with diameters less than 15 centimetres also assumed to have been immediately killed

- No growth applied for five years after fire in all Non-Alpine Ash forest types
- 10 years after fire, 80 per cent of high-quality or low-quality non-Alpine Ash species less than 50 centimetres in diameter degrade to pulp.

Fire impact on standing volume

As Alpine Ash stands of the Tumut Sub-Region are killed by moderate to high severity fires, quantitative impact of the fire can be demonstrated in the same year of fire occurrence. Table 15 below reports the post-fire state of the resource.

The modelled reduction in high-quality large log growing stock from the Tumut Sub-Region is predominantly made up of Alpine Ash and is the largest such reduction in any region. This is due to the fire-sensitive nature of the Alpine Ash species, which drives modelled mortality impacts in RAFIT classes four and five. Losses in other species are negligible, so the overall reductions in the combined high-quality sawlog resource reflect the weighted impact of the Alpine Ash losses. The modelling projects a 74 per cent reduction in the available standing large high-quality log resource and a 76 per cent reduction in the total high-quality log resource.

Previous experience with fire-killed Alpine Ash indicates existing high-quality trees will degrade through low-quality to pulp quality within two to three years of the fire event. Thereafter, the standing timber continues to dry and degrade to waste quality before eventually decaying, falling to the ground and adding to the coarse woody debris pool some years after. To minimise the impact of the 2019-20 fire season on long-term sustainable Alpine Ash production in the region, an effort should be made to recover and process as much fire-killed Alpine Ash sawlog volume as possible within the next two years before it degrades and becomes unmerchantable. Failure to do so would place unnecessary pressure on live forests elsewhere to meet demand for hardwood timber.

Table 15: Fire impact on standing volumes for the Tumut Sub-Region (2019-20 fire season)

Fire impact on Tumut standing volumes in 2020			
Product	Standing volume (m^3)	Proportion of pre-fire volume	Fire losses (m^3)
HQ large Alpine Ash logs	685,000	62%	-415,300
HQ small Alpine Ash logs	322,200	76%	-101,500
All HQ Alpine Ash logs	1,007,200	66%	-516,800
All HQ large logs	1,185,500	74%	-418,300
All HQ small logs	460,000	82%	-102,300
All HQ logs	1,645,500	76%	-520,600

100-year wood flow

Annual sustainable yield volumes calculated for the Tumut Sub-Region native forests are shown in the charts and tables below, combined with a summary line reporting the outcome of the benchmark 2018 Regional Forest Agreement Review.

Separate charts are presented for broad product groupings and species groups. The presented data for product classifications in these figures are indicative only and actual supply of these grades of log will vary based on the annual harvesting program.

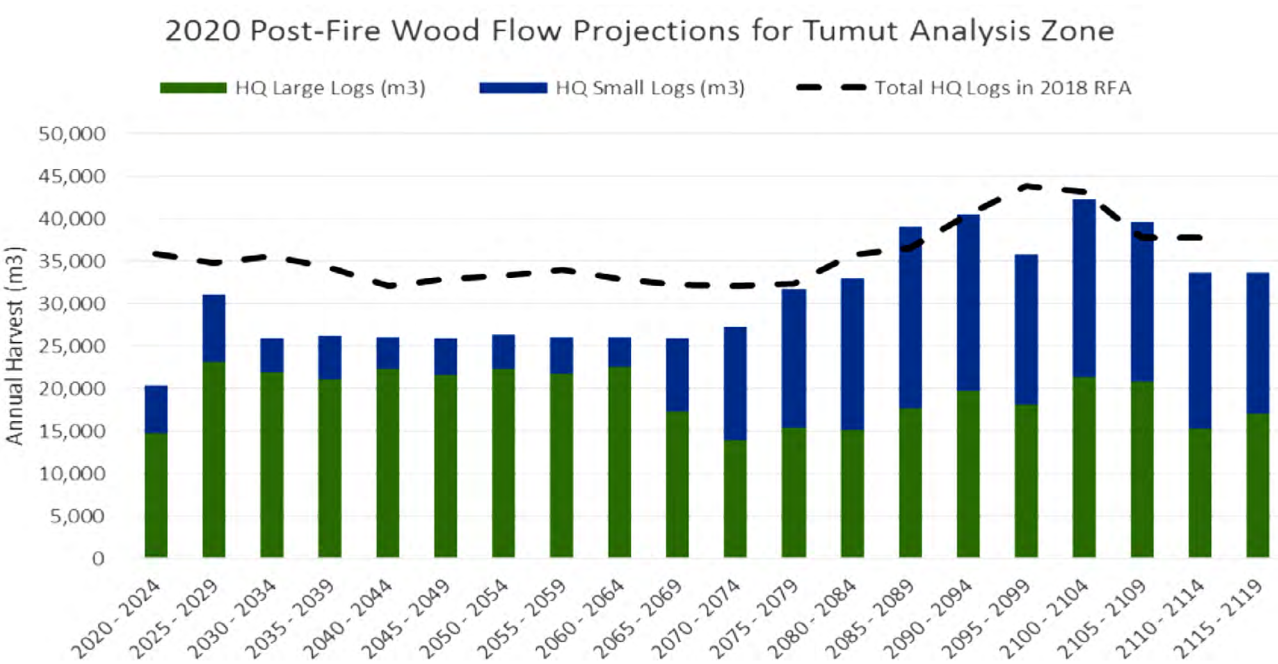


Figure 33: Tumut Sub-Region post-fire high-quality log production*

* Period 1 (2020-2024) does not include fire-killed Alpine Ash, Table 16 provides detail.

Table 16: Period 1 (2020-2024) Tumut Sub-Region Alpine Ash annualised harvest program including fire-killed volume in first two years

Tumut period 1 annualised Alpine Ash volume breakdown (m³)							
Year	2020-21	2021-22	2022-23**	2023-24	2024-25	5-year total	5-year average
Fire-killed Alpine Ash HQL available	200,000	200,000	0	0	0	400,000	80,000
Fire-killed Alpine Ash HQS available	50,000	50,000	0	0	0	100,000	20,000
Fire-killed Alpine Ash LQ available	12,500	12,500	0	0	0	25,000	5,000
Fire-killed Alpine Ash Pulp available	50,000	50,000	0	0	0	100,000	20,000
Live Alpine Ash HQL	0	0	18,500	18,500	18,500	55,500	11,100
Live Alpine Ash HQS	0	0	8,000	8,000	8,000	24,000	4,800
Live Alpine Ash LQ	0	0	2,500	2,500	2,500	7,500	1,500
Live Alpine Ash Pulp	0	0	22,000	22,000	22,000	66,000	13,200

** Fire-killed Alpine Ash salvage window of opportunity ceases in 2022-23 due to expected timber degrade.

Aside from the first two years of the model, where a large volume of fire-killed Alpine Ash log is projected to be extracted, high-quality large log yields are forecast to be lower than pre-fire modelled levels until a pulse of post-fire high-quality small log regeneration comes online in the latter half of the model. At that point, the high-quality ratio of large to small log production is forecast to change from around 4:1 to 1:1.

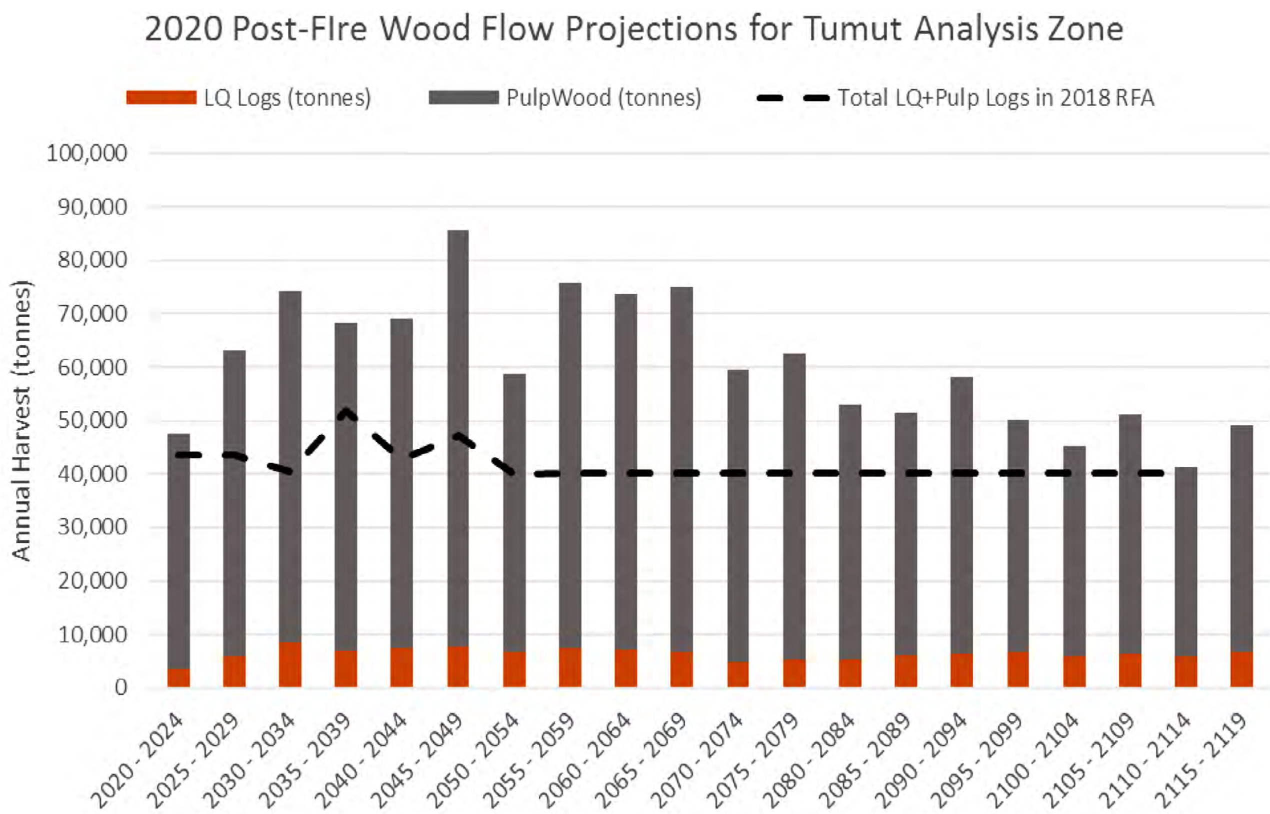


Figure 34: Tumut Sub-Region post-fire low quality (LQ) and pulp log production*

* *Period 1 (2020-2024) volume does not include fire-killed Alpine Ash salvage, see Table 16 for more detail.*

Post-fire pulp log yields are forecast to be higher than pre-fire modelled levels partly due to the degrade of non-Alpine Ash stands to pulp quality after 10 years, and partly due to the introduction of an improved thinning model. A change in growing stock constraints for both high-quality large and high-quality small logs also allows the model greater flexibility to manage the resource around substantial volumes of post-fire regeneration while maintaining relatively smooth production levels across the life of the model.

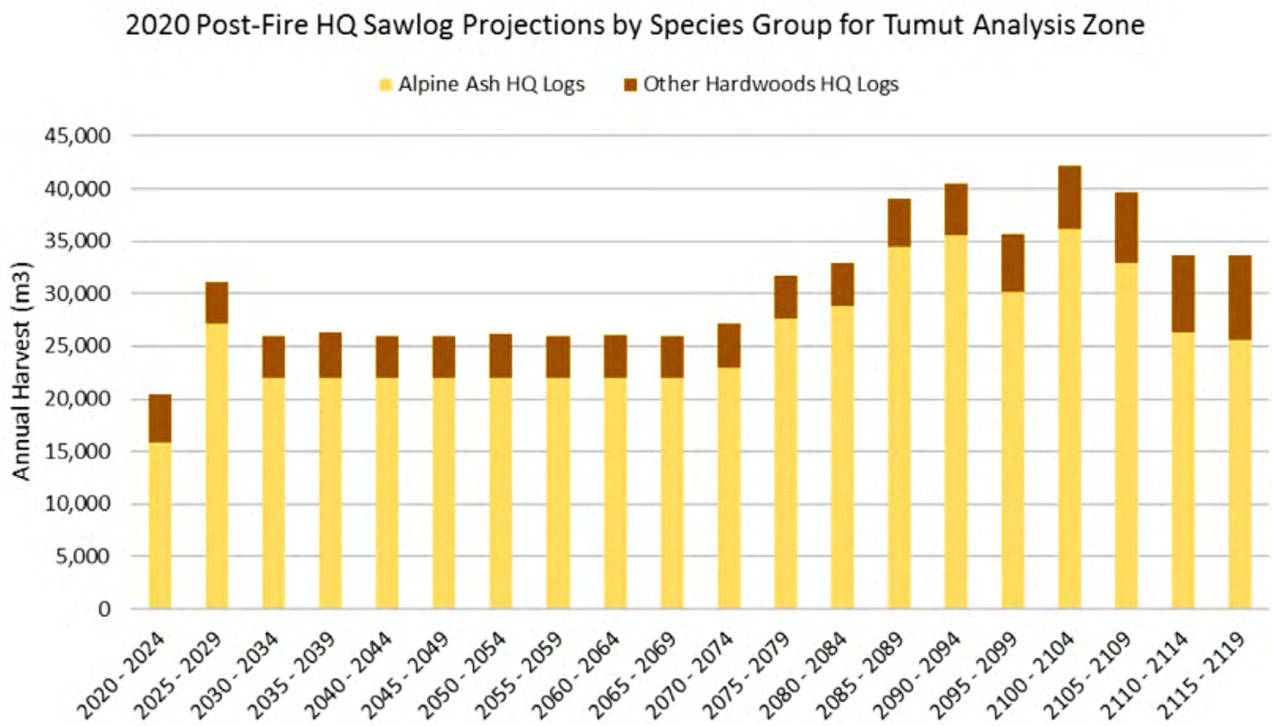


Figure 35: Tumut Sub-Region post-fire high-quality sawlog projections by species group*

*Period 1 (2020-24) volume does not include fire-killed Alpine Ash salvage, see Table 16 for more detail.

The yields of other hardwood high-quality logs presented in Figure 35 are largely a by-product of a model which focuses on the more highly-sought-after Alpine Ash volume. Assumed defect percentages in the other hardwood high-quality resource are quite conservative and there is potential that hardwood high-quality production could be higher. However, more recovery studies are required to understand defect and timber recovery in mature hardwood logs.

North Coast

The 2019 fire season started on the far North Coast in late July and continued until early January 2020. Over 200,000 hectares of harvestable area experienced moderate severity or hotter fire. The figures and tables below provide a snapshot of the distribution of these fires on the North Coast Region timber resource.

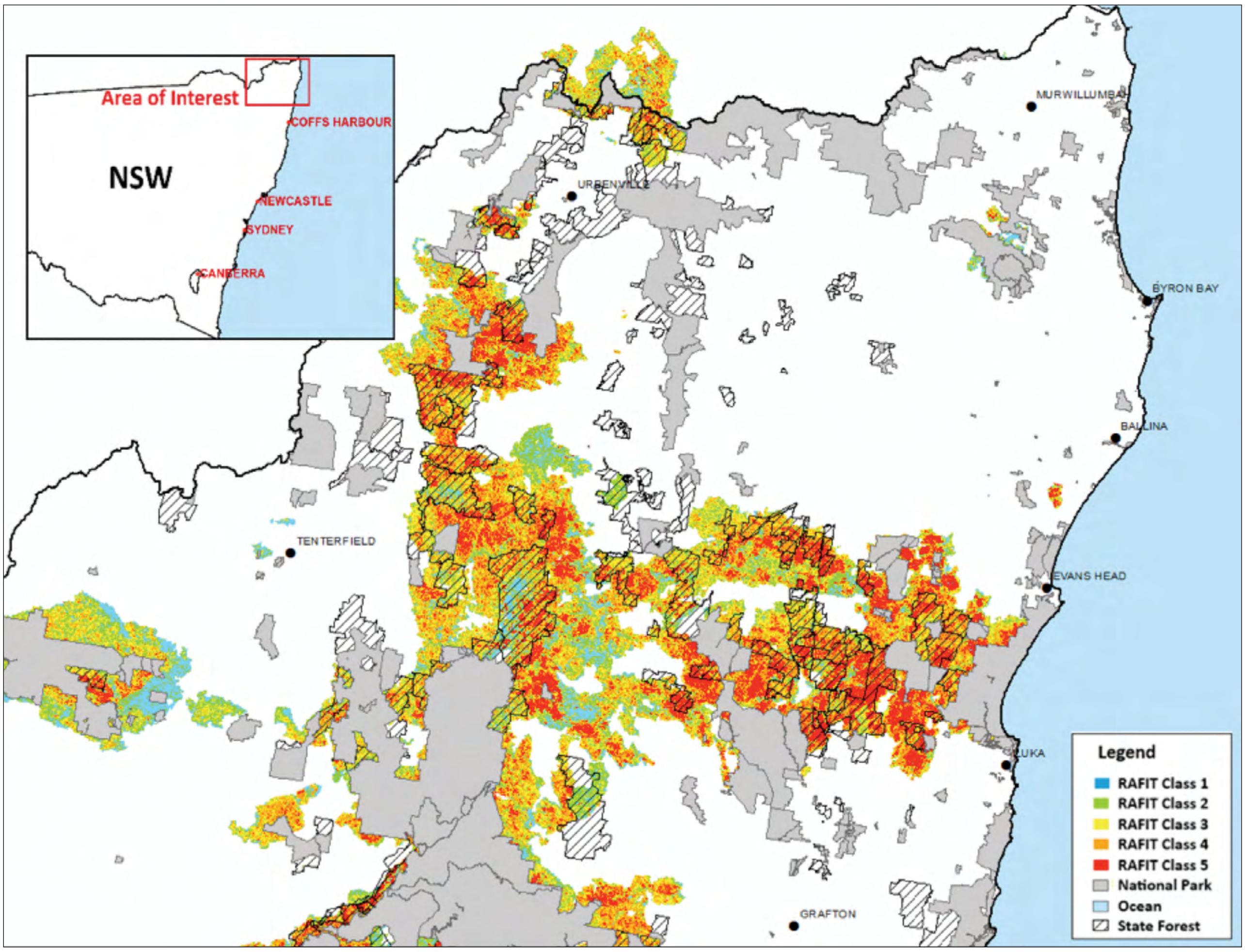


Figure 36: RAFIT fire severity mapping for Far North Coast (clipped to mapped fire extent of 2019-20 season).

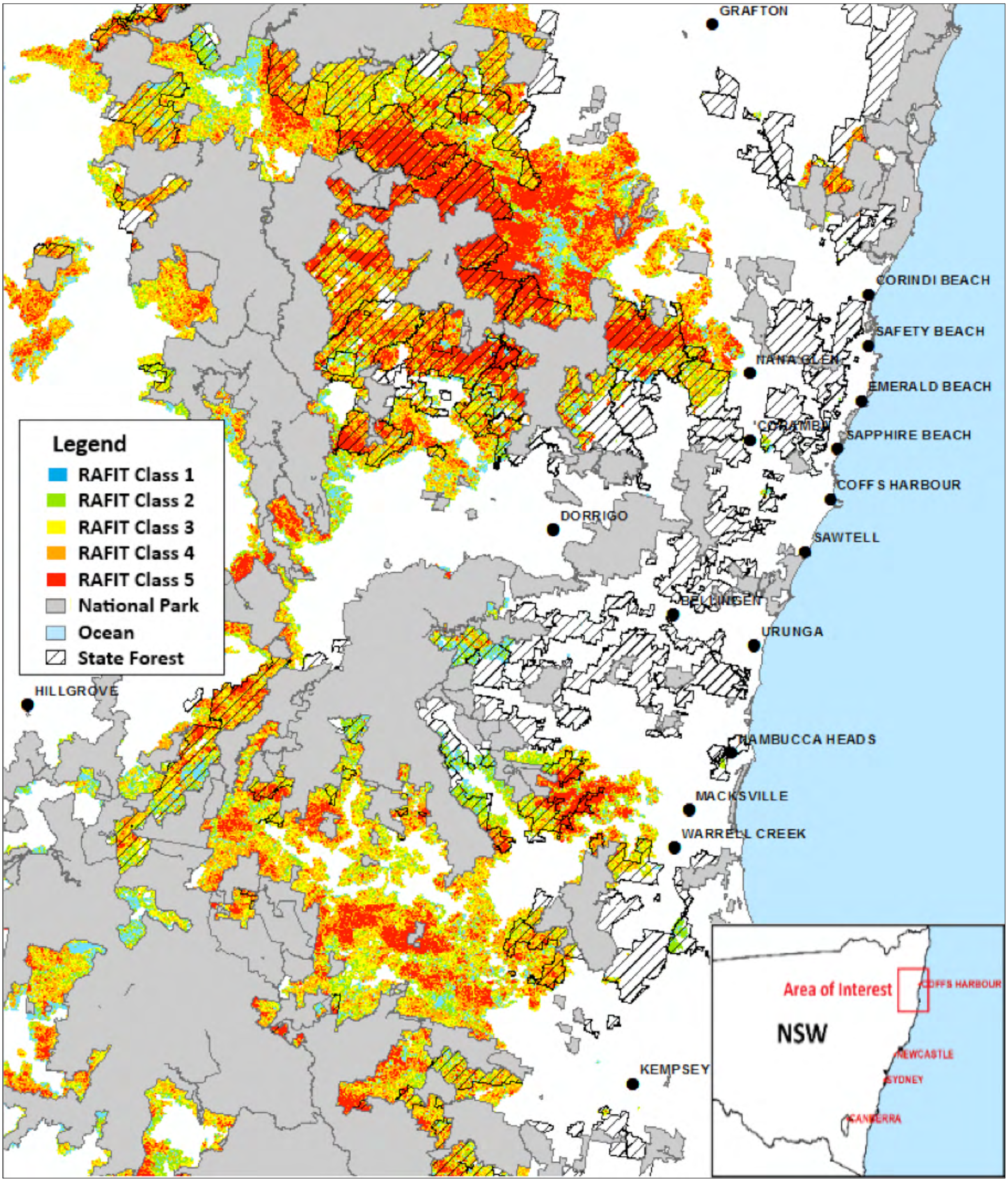


Figure 37: RAFIT fire severity mapping for the Mid North Coast (clipped to mapped fire extent of 2019-20 season).

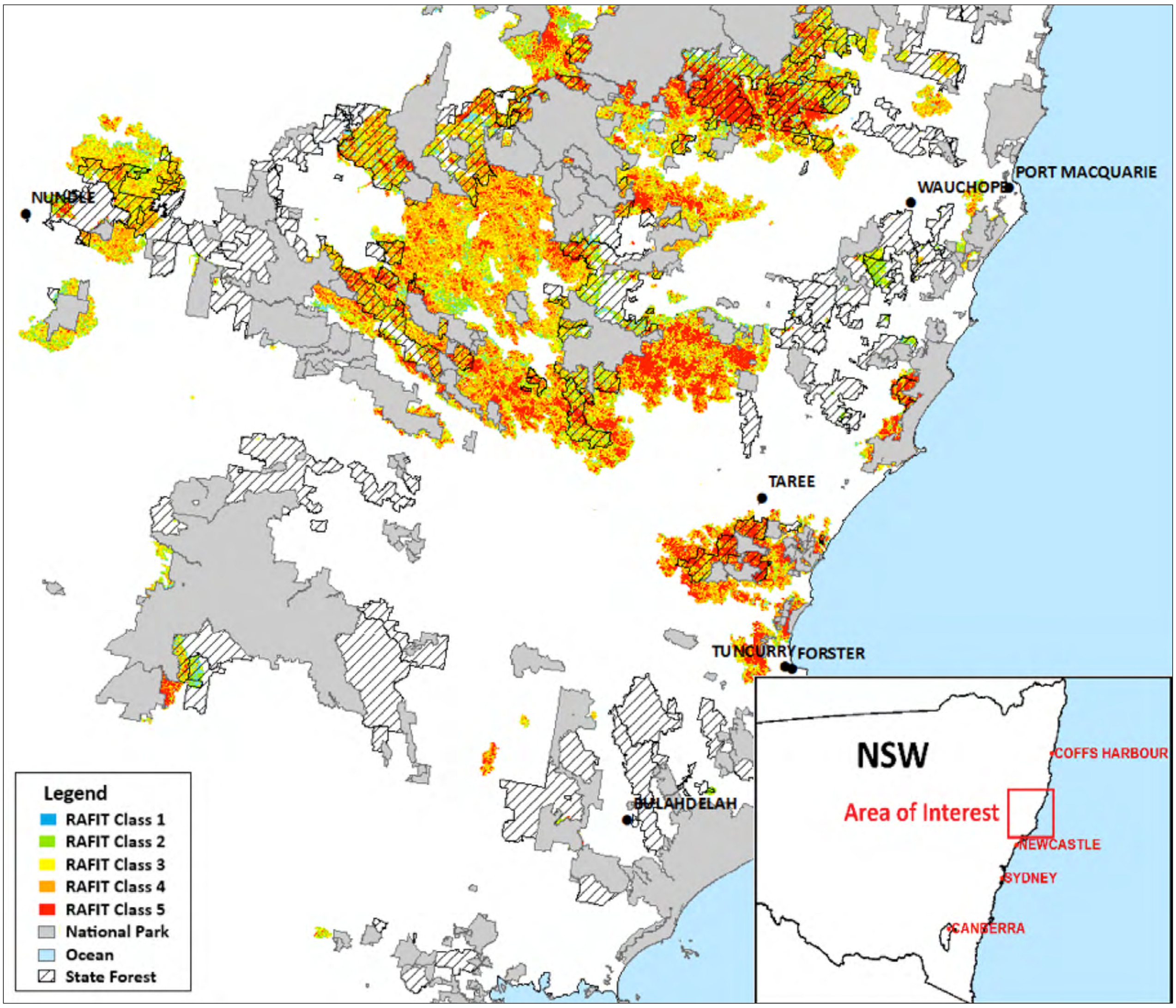


Figure 38: RAFIT fire severity mapping for the Lower North Coast (clipped to mapped fire extent of 2019-20 season).

Table 17 summarises the extent of native forest impacted by fire in the region. Supply zone one experienced significant spread of high severity fire over a number of fire events. These were widespread in the western areas and almost completely covered the Spotted Gum forests between Casino and Grafton. Supply zone two also experienced large-scale fires, particularly in the western extent with the Liberation Trail fire also spreading towards the east into the Coffs Harbour Management Area. Similarly, the western extent of supply zone three behind Wauchope, and the tablelands area in supply zone six were also heavily impacted by severe fire.

Many of the highly productive forests, including most of the high productivity Blackbutt forests in the eastern extents of supply zones two, three and four, were not heavily impacted by fires. Also, the lower parts of supply zones four and five were not heavily impacted. These localities are dominated by New England and dryer forest types.

Table 17: RAFIT fire severity area statistics for North Coast Region

North Coast native forest base net area by RAFIT class (hectares)							
Supply zone	1&2: No fire or cool burn	3: Moderate burn	4: Hot burn	5: Crown fire	Total	RAFIT 4 Percentage	RAFIT 5 Percentage
SZ 1: Far North Coast	25,700	15,200	24,200	14,800	79,900	30%	19%
SZ 2: Coffs-Grafton	33,200	25,200	25,000	28,100	111,500	22%	25%
SZ 3: Mid North Coast	45,800	19,300	10,100	9,100	84,300	12%	11%
SZ 4: Taree	41,500	13,900	7,300	5,200	67,900	11%	8%
SZ 5: Hunter	26,700	7,700	3,100	400	37,900	8%	1%
SZ 6: Walcha-Styx	14,600	10,900	12,700	4,500	42,700	30%	11%
Total North Coast	**187,500**	**92,200**	**82,400**	**62,100**	**424,200**	**19%**	**15%**
Percentage of area	**44%**	**22%**	**19%**	**15%**	**100%**		

Overall, 62,000 hectares (15 per cent) of the region experienced the more severe crown fire, with supply zone two (25 per cent) and supply zone one (19 per cent) hardest hit. As Figure 39 shows, hot and crown fires were more prevalent in supply zones one and two.

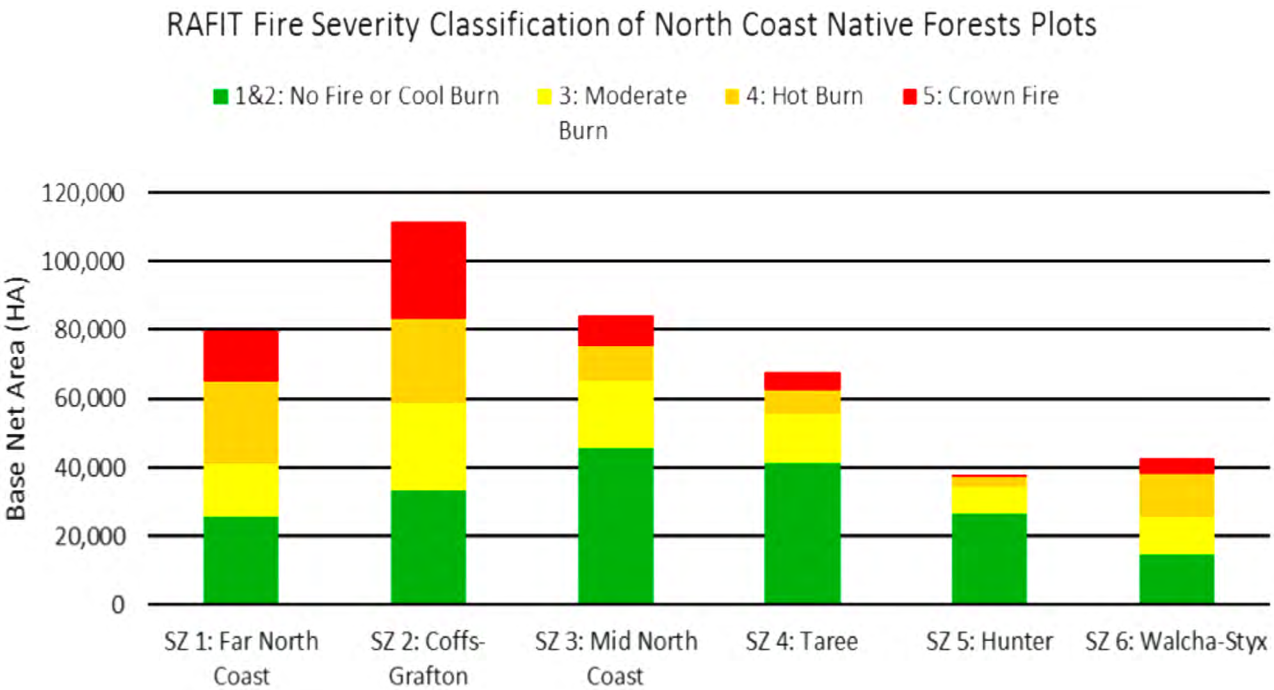


Figure 39: RAFIT fire severity distribution across North Coast supply zones.

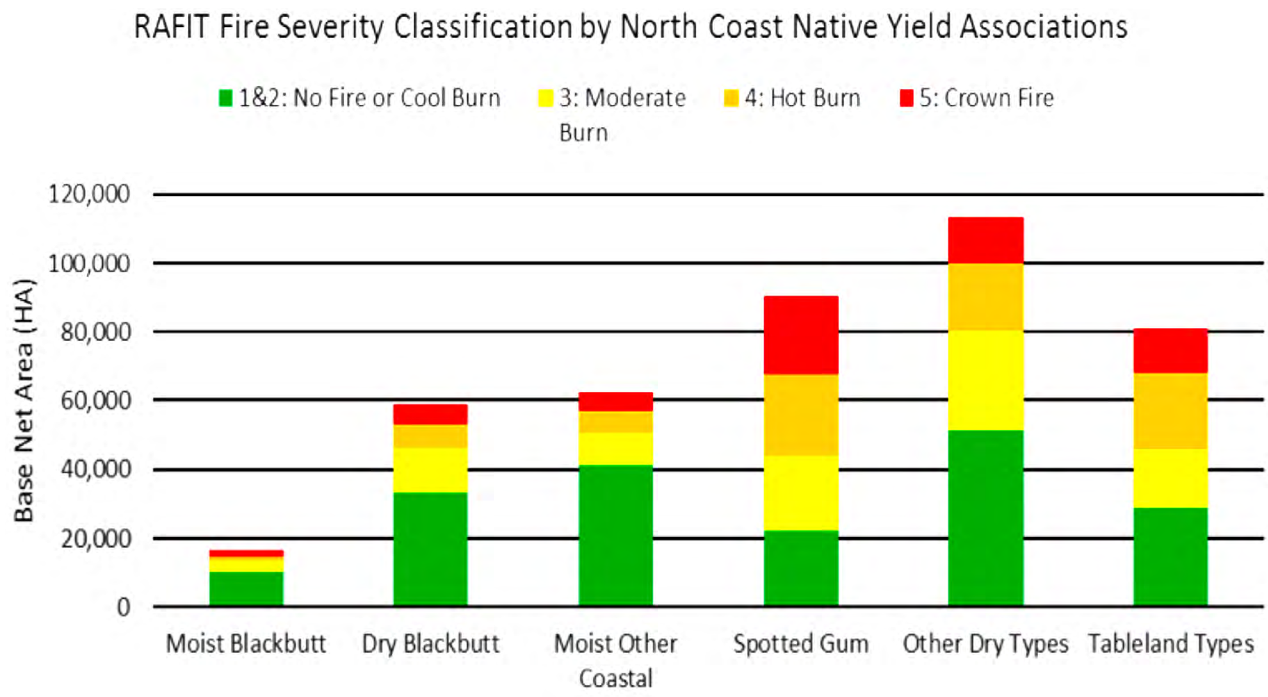


Figure 40: RAFIT fire severity distribution across North Coast yield association groups.

Figure 40 breaks down the fire severity distribution by yield association group. The larger tracts of lesser severity fire in the highly productive Blackbutt and moist coastal types are shown in the left hand columns. Spotted Gum associations (which are nearly all in the upper half of the region in supply zones one and two) have been more heavily impacted, as well as dryer types and the tableland associations.

Plot level assumptions by burn class

The modelling assumptions applied to FRAMES that are specific to the North Coast native forests are detailed below.

RAFIT Class 1, 2 and 3 (no burn, light and moderate burn)

» No impact.

RAFIT Class 4 (hot burn)

» Fifty per cent of trees of trees less than 30 centimetres in diameter immediately killed by fire.

» Ten per cent of trees greater than 30 centimetres in diameter also killed.

RAFIT Class 5 (crown burn / scorched)

» Plots falling into tracts where harvesting was undertaken between 2015 and 2019 are assumed to have 90 per cent of trees present immediately killed by fire. This applies to four per cent of the region.

» If not recently harvested (the remaining 96 per cent of the region), then all trees less than 30 centimetres in diameter are assumed to have been killed. Fifty per cent of trees greater than 30 centimetres are assumed to have been killed. All surviving trees are assumed to have no growth for one modelling period (four years) after fire.

Other modelling refinements for the fire analysis:

» Stand quality is being used to refine the silviculture applied. Plots with higher pre-merchantable high-quality growing stock levels are grown longer to optimise the utilisation of those trees. The structural classifications have been refined for the 2020 work to cater for a broader high-quality tree size range.

» The modelling of plots in the Intensive Harvest Zone has been refined to improve site utilisation. The silviculture applied to plots is now tailored to their structure and merchantability.

There are 1821 active plots used for native forest modelling on the North Coast. Table 17 summarises the count of plots by locality and burn class. Overall, 19 per cent of the active plots in the region were impacted by a hot fire (RAFIT Class 4), and 17 per cent by crown fire (RAFIT Class 5). The plot locations are randomly distributed across a grid and the distribution of impacts very closely reflectst the mapped area reports above in Table 17.

Table 18: Inventory plot RAFIT class breakdown by Supply Zone for the North Coast Region (2019-20 fire season)

Number of plots by RAFIT class - North Coast Region							
Supply zone	No fire (1)	Cool burn (2)	Moderate burn (3)	Hot burn (4)	Crown burn (5)	Total	RAFIT 4 and 5 (%)
SZ 1: Far North Coast	29	65	56	92	63	305	51%
SZ 2: Coffs-Grafton	39	93	98	100	113	443	48%
SZ 3: Mid North Coast	47	207	129	59	60	502	24%
SZ 4: Taree	56	89	63	40	43	291	29%
SZ 5: Hunter	32	47	26	17	19	141	26%
SZ 6: Walcha-Styx	2	44	40	38	15	139	38%
Total	**205**	**545**	**412**	**346**	**313**	**1821**	**36%**
Percentage of total	**11%**	**30%**	**23%**	**19%**	**17%**	**100%**	

Fire impact on standing volume

The North Coast timber resource can be categorised into four components: plantations; even-aged native forest stands in the Intensive Harvest Zone (current intensive harvest areas); unharvested native forest in the Intensive Harvest Zone planned for future intensive harvest; and native forest in the Selective Harvest Zone. The fourth category represents the majority (84 per cent) of the area modelled.

North Coast plantations

Over 10 per cent of the hardwood plantation estate was affected by wildfire during the 2019-20 fire season. The impact on hardwood plantations was far more extensive in the lower value and younger Dunns White Gum *(E.dunni)* and Spotted Gum *(Corymbia variegata)* plantations found in the far northern areas. As a consequence, sawlog production from the hardwood plantation estate has not been significantly compromised in the wood supply model by the direct impacts of the fire.

Some mature sawlog plantations have been burned, and these have been prioritised for salvage harvesting. The current crop of plantations in these areas that will be salvage harvested has been removed from the sustainability modelling and added to the landbank for re-establishment.

Overall, the impact on the production of high-quality logs from timber plantations is only seen in the short term. In the first four years of the model, there is a reduction of approximately 10 per cent in production of high-quality sawlogs from hardwood plantations. The re-establishment of these plantation areas will ensure there is minor to no impact on high-quality sawlog production from hardwood plantations in the medium to long term.

Figure 41: Liberation Trail fire burning in a Blackbutt timber plantation at Wild Cattle Creek State Forest, November 2019.

Figure 42: Flooded Gum *(E.grandis)* 1997 age-class thinning operation at Yabbra State Forest, June 2020.

North Coast native forest current intensive harvest tracts

Intensive harvesting refers to a silvicultural method that opens the canopy to promote regrowth. Areas that have been harvested previously using this silvicultural treatment are characterised by young, even-aged regrowth. This category focuses on areas that have been previously harvested using this silvicultural treatment, which is approximately 12,000 hectares of forest in total. The impact of the 2019-20 fires on areas previously harvested using intensive harvesting is shown in Table 19. Approximately 1,700 hectares of this young resource (14 per cent) was killed by fire. Regeneration levels on these sites are being assessed and supplementary planting undertaken where natural levels are too low.

Table 19: Fire impact on even-aged regrowth areas previously harvested in the Intensive Harvest Zone

Fire impact on even-aged regrowth areas previously harvested in the Intensive Harvest Zone				
Stand type	Not burned (ha)	Fire-affected (ha)	Total (ha)	Fire-affected (%)
Blackbutt-dominated stands	8,700	1,200	9,900	12%
Stands dominated by other species	1,600	500	2,100	24%
Total	**10,300**	**1,700**	**12,000**	**14%**

North Coast native forest selective and future Intensive Harvest Zones

Table 20 reports the fire impact on standing high-quality timber volumes in the native forest resource that have previously been harvested using selective harvesting methods, including areas available for intensive harvesting but not yet harvested using this silvicultural technique. The key species Blackbutt and Spotted Gum are shown separately and have also been combined with all other species to quantify the overall fire impact.

Table 20: Fire impact on North Coast Region standing volumes in 2020

Fire impact on North Coast Region standing volumes in 2020 (Native forest selective and future Intensive Harvest Zones)				
Product	Standing volume pre-fire (m^3)	Standing volume post-fire (m^3)	Proportion of standing volume remaining (%)	Reduction in available volume (m^3)
HQ Large Blackbutt logs	1,490,000	1,390,000	93%	-100,000
HQ Small Blackbutt logs	540,000	490,000	91%	-50,000
All HQ Blackbutt logs	2,030,000	1,880,000	93%	-150,000
HQ Large Spotted Gum logs	580,000	480,000	83%	-100,000
HQ Small Spotted Gum logs	490,000	420,000	86%	-70,000
77All HQ Spotted Gum logs	1,070,000	900,000	84%	-170,000
All HQ large logs	5,710,000	5,090,000	89%	-620,000
All HQ small logs	3,180,000	2,800,000	88%	-380,000
All HQ logs	8,890,000	7,890,000	89%	-1,000,000

The fire is estimated to reduce the high-quality log growing stock by approximately 10 per cent. A large proportion of the impacted resource was in lower yielding and less productive forests. Overall, there was slightly less impact on Blackbutt (seven per cent), as much most of this resource was spared from the more intense fire. The impact on Spotted Gum was higher, with an estimated 16 per cent reduction from the pre-fire state.

100-year wood flow

The combined annual sustainable yield volumes for North Coast plantations and native forests are shown in the figures below. The summary line on each table projects the estimated volumes previously calculated during the benchmark 2019 Coastal IFOA Review.

Separate charts are presented for timber source, broad product groupings as well as species and timber source. The data for product classifications in these figures are indicative only and actual supply of these grades of log will vary based on the annual harvesting program.

The North Coast has four key yield sources that contribute to supply:

- » hardwood plantations
- » areas of young even-aged regeneration currently in the Intensive Harvest Zone (referred to as Current Regen)
- » areas in the intensive harvest zone that are mature or near maturity now, dominated by Blackbutt, and where the next silvicultural operation planned is will promote the next future crop of regeneration
- » areas managed less intensively under the selective harvest prescriptions.

The high-quality log yields contributed by each source are shown below in Figure 43, with an overview of contribution proportions shown in Figure 44.

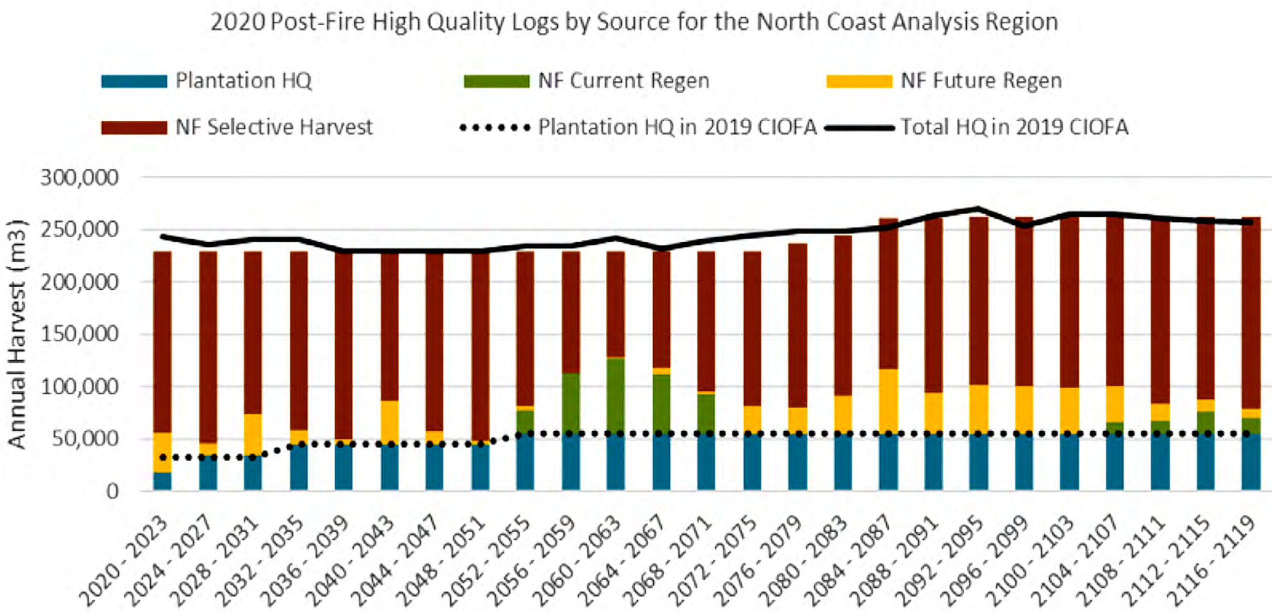


Figure 43: Post fire high-quality (HQ) log wood flows for the North Coast Region by source.

Plantation establishment incentive initiatives in the late 1990s and early 2000s have resulted in a hardwood plantation resource age class distribution that is currently dominated by young pre-mature stands. Over the next 20 to 30 years, the resource will transition to a smoother balance of age-classes. At that point we see the steady production of 55,000m^3 per year, just over 20 per cent of total high-quality log yield.

Yields from the intensive harvest zone contribute around 15 per cent of total high-quality log supply. The young 'current regen' resource matures after 30 years, with harvesting distributed over a 20-year window to 2070. Operations in these stands will create another crop of young regrowth that starts to mature early next century. Harvesting in the 'future regen' cohort (of currently mature or near-mature stands) is distributed over the next 25-30 years. Yields from this cohort shown after 2070 reflect subsequent harvesting of this crop.

Yields from the selective harvest resource consist of timber harvested from the native forests not described above. This is the majority of the native forest on the North Coast, representing 83 per cent of the combined estate area. This category of forest includes a broad range of site qualities and forest types. Yields from this zone contribute 65 per cent of the long-term high-quality product mix on the North Coast.

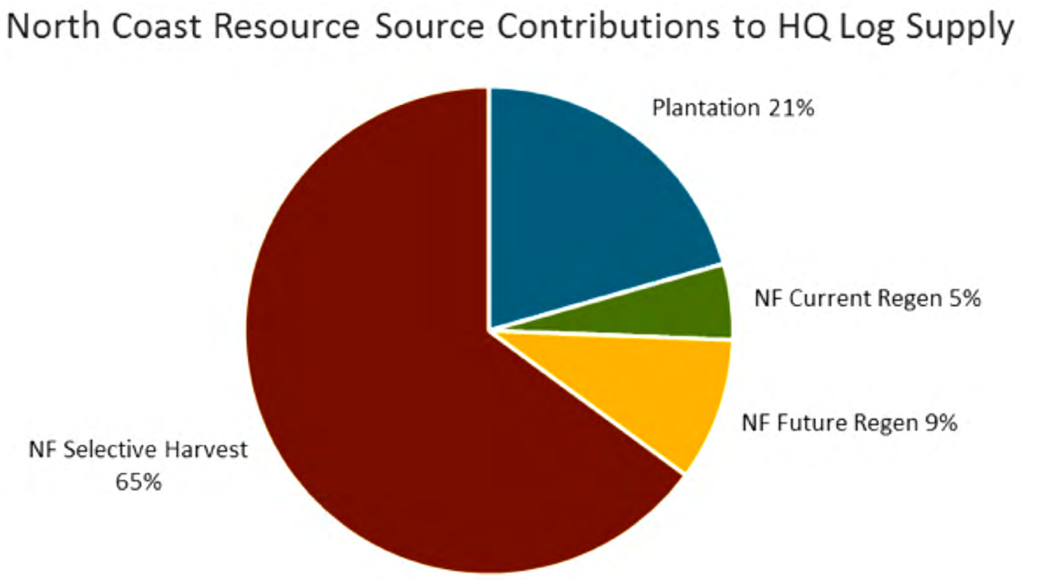


Figure 44 : High-quality (HQ) log contribution trends by yield source.

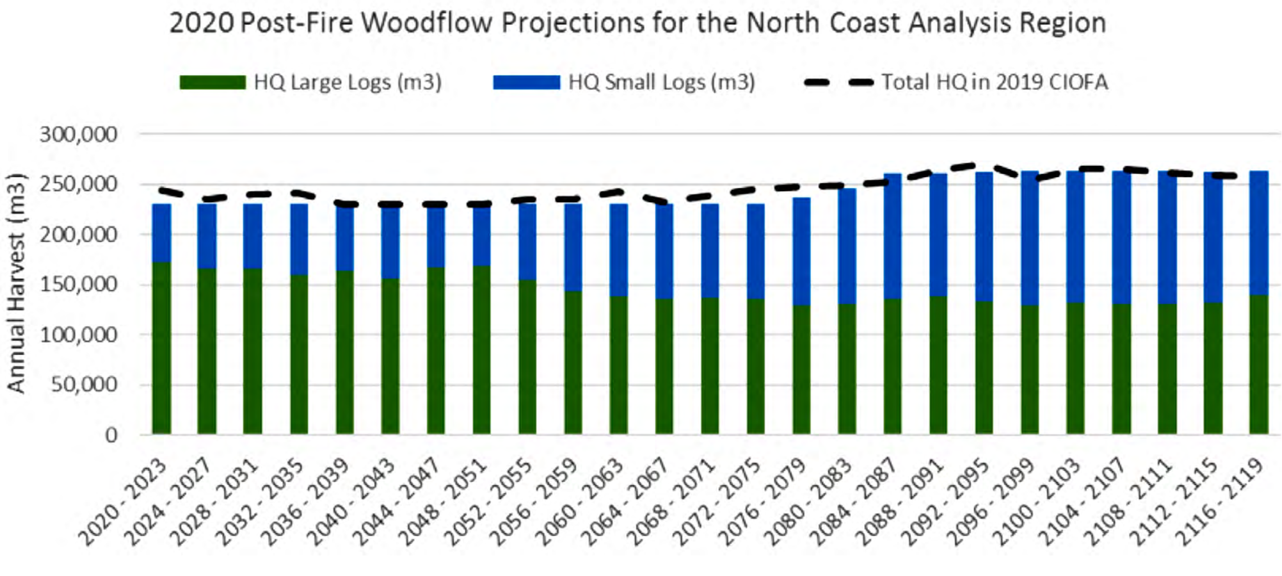


Figure 45: Post-fire woodflow projections for high-quality logs by log size, North Coast Region.

High-quality log supply by product size is shown in Figure 45. The total yield of high-quality timber products has not been significantly impacted by the fire, with the main reductions in the first four periods ranging from four to six per cent. Although full yield recovery is achieved after 65 years, the fires have caused a small (one per cent) drop in the overall supply of high-quality logs on the North Coast.

Harvest levels of high-quality large logs are modelled to remain relatively steady over the full 100 years, although the average of around 160,000m^3 per year in the first 50 years drops to 130,000m^3 per year in the latter periods. This coincides with an overall increase in total high-quality logs in the small log class. The size ratio change is in line with a long-term trend in the sawmilling industry to improve technology and performance and optimise for a mix including a higher proportion of high-quality small logs.

The impact of the fire on high-quality volume is not evenly spread across species, and this has allowed the sustainable yield impacts to be less than the reported 11 per cent loss of standing volume. Factors driving the sustainable yield outcome include:

- Supply is dominated by the Blackbutt and the Big 3 group (Tallowwood, Blue Gum and Brushbox) which are some of the fastest growing species in NSW. These forest types were not significantly impacted by fire in either native forest or plantation sources.
- The large growing stock base and growth performance of the faster growing species coupled with a slightly smaller log profile in the long term combine to mitigate the impact on overall high quality volume sustainability.

Supply of lower quality logs (Figure 46) is also slightly lower, although this drop is not likely to be significant in an operational sense, as the potential supply shown is higher than current market demand.

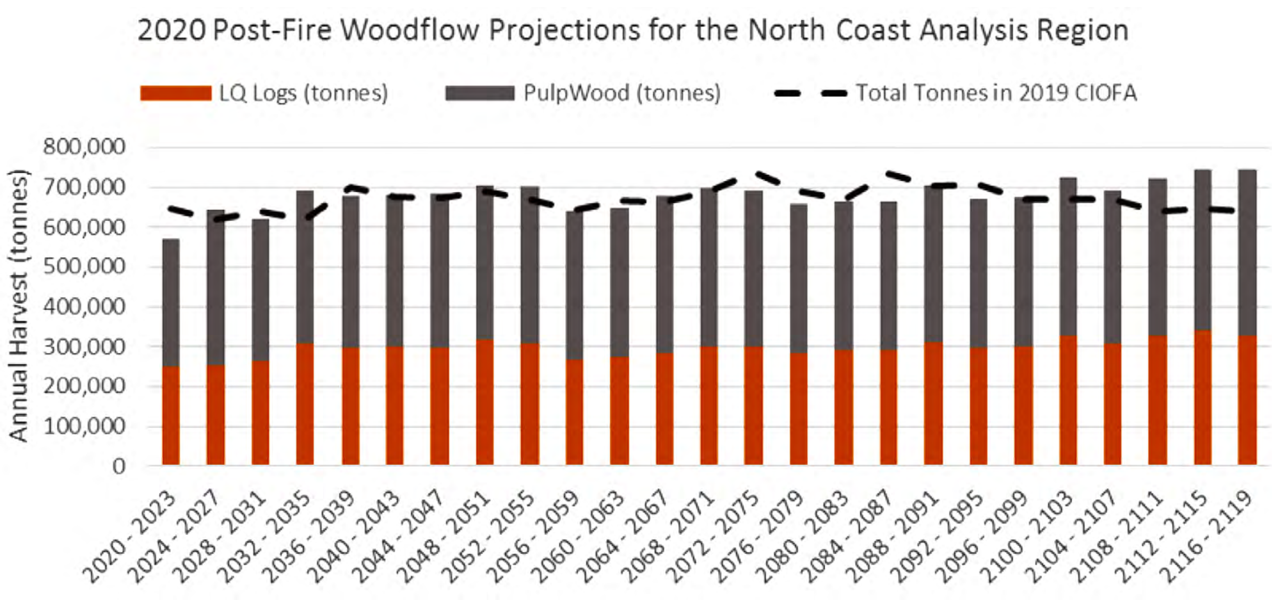


Figure 46: Post-fire woodflow projections for low-quality logs, North Coast Region.

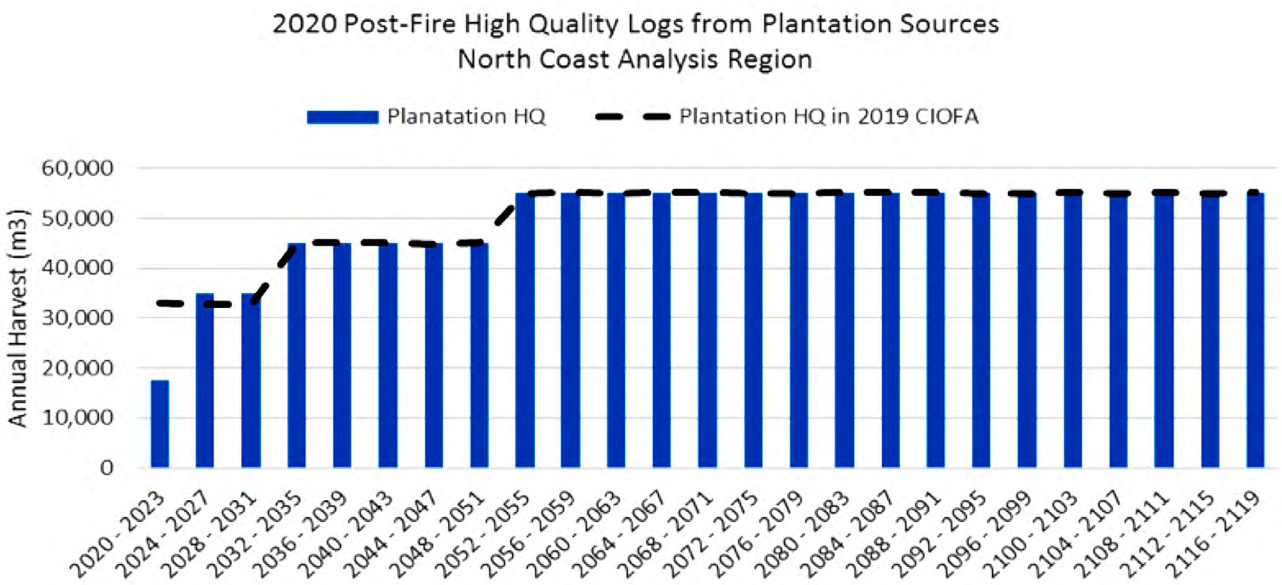


Figure 47: North Coast post fire high-quality (HQ) log wood flows from plantations, relative to the 2018 RFA model.

The plantation resource is largely unaffected. The loss of mature plantations contributes 10 per cent of the reduction in high-quality logs observed in the first period. The remaining deficit in the first period is due to increased harvesting that occurred in hardwood plantations in the first half of 2020, prior to the commencement of the model. This was required to supply timber to the North Coast industry while operations in native forest were reduced as a precautionary measure following the fires and while ongoing operating approvals were managed in conjunction with the regulatory authority. As most of the other fire-associated damage was in younger plantation stands, there are no significant impacts on plantation wood supply after the first period.

High-quality volumes by species groupings

The North Coast wood supply model focuses on five main species groupings. Due to their importance to the market, Blackbutt and Spotted Gum are included individually in the analysis and have their own sustainable yield objectives. Three further species groupings are also used in the model:

- Big 3 Hardwoods: Sydney Blue Gum *(Eucalyptus saligna)*, Tallowwood *(E.microcorys)* and Brush Box *(Lophostemon confertus)*.
- New England Hardwoods: high-quality log species that occur in association in tablelands forests across northern NSW, including New England Blackbutt *(E.andrewsii)*, Mountain Gums, Messmate *(E.obliqua)* and Brown Barrel *(E.fastigata)*, peppermint and stringybark species.
- Other Hardwoods: all other species not covered in the previous two groups.

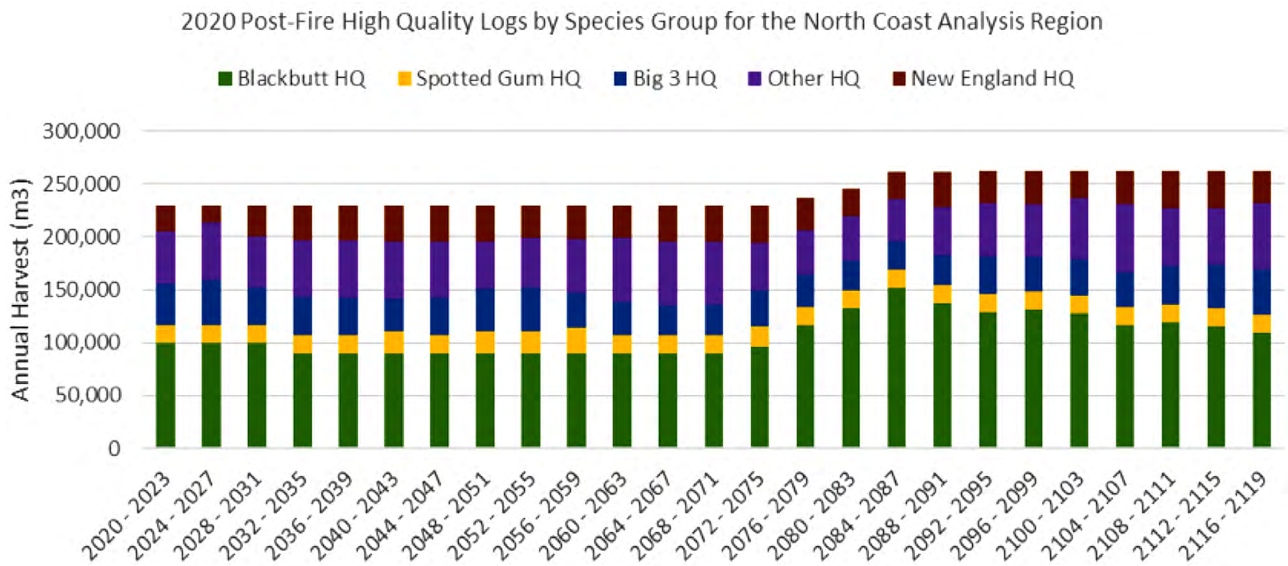


Figure 48: North Coast post-fire high-quality (HQ) log overview by species group.

Overall supply of high-quality logs by species group is shown in Figure 48. Just over 40 per cent of the species mix is Blackbutt. Spotted Gum contributes around seven per cent of the mix, down from nine per cent in the 2019 review due to fire losses. Fire impacts on the Spotted Gum resource are discussed in more detail below. The Big 3 group makes up just under 15 per cent of the total high-quality species mix in the long term. However, the model assumes this species group will be harvested at slightly higher levels in the first three periods to help balance reductions in the Spotted Gum resource due to the impact of fires. Yields from the Other Hardwoods group contribute just over 20 per cent of the total species mix. The model also assumes these species are harvested at slightly higher rates than the 2019 levels for the first three periods to help balance the short-term losses in the New England Group. Yields from the New England species group are forecast to increase in the long term by eight per cent as tracts of post-fire regeneration mature.

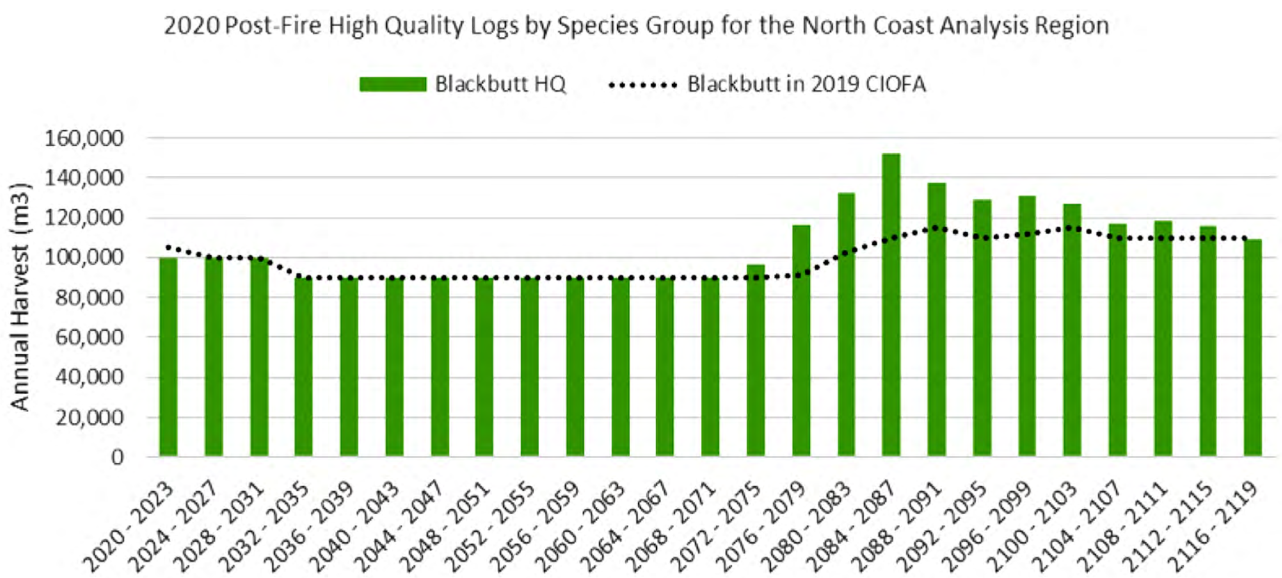


Figure 49: High-quality Blackbutt log wood flows, North Coast Region.

As a significant proportion of the Blackbutt forest types were not impacted by fire, high-quality Blackbutt log supply can be maintained at or close to levels determined by the 2019 CIFOA review. The early periods of the model project harvesting of unburned growing stock. As this species is one of the fastest-growing species in NSW, the growing stock is forecast to recover sooner than other species. This rapid recovery of even-aged post-fire regrowth contributes to a projected increase in the availability of high-quality Blackbutt logs from 2070.

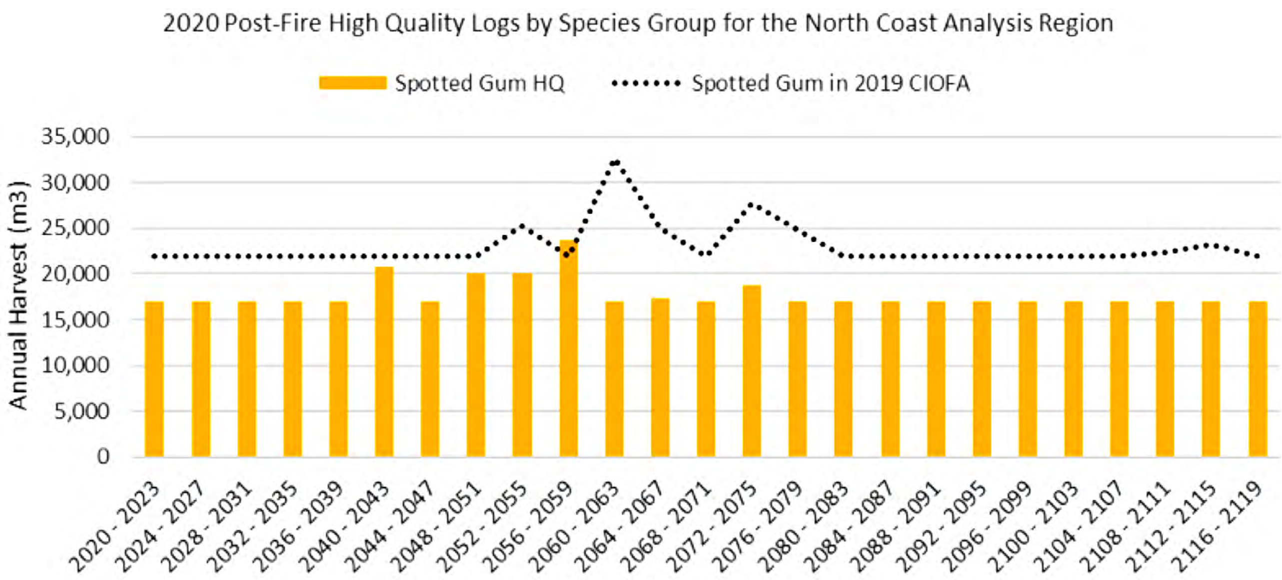


Figure 50: High-quality Spotted Gum log wood flows, North Coast Region.

The Spotted Gum resource on the North Coast was heavily affected by fire, with large tracts of the species impacted by the crown fires experienced in supply zones one and two. Spotted Gum also grows significantly slower than Blackbutt, typically taking more than 80 years for a native forest site dominated by Spotted Gum that has been reset by fire to reach maturity again. The combination of these factors means Spotted Gum supply is projected to be 17 per cent lower than the pre-fire forecast that was completed in 2019. The long-term sustainable yield for this species must therefore be reduced to 17,000 m^3 a year for this species on the North Coast.

Future directions for RFA modelling

The next review of Sustained Yield modelling for the NSW RFA regions is due in 2024.

In the intervening years, inventory will be substantially updated, with an emphasis on updating measurements from fire-affected forest stands.

Inventory in unburnt areas has been continuing since the 2019-20 fire season. Measurements to update inventory data in fire-affected areas will start in early 2021, subject to a risk assessment for hazards in target forests. Many inventory plots may continue to be too dangerous to remeasure for some time, as crown collapse in dead trees continues to occur.

Recovery monitoring has been implemented in many fire-affected State forests, involving repeated photography at fixed locations. Information collected during this monitoring program will be used to validate and refine the assumptions on fire recovery and degradation applied to pre-fire inventory for the models presented in this update.

This information will be progressively fed into interim sustainable yield models and the impact of the improved information will be continually evaluated.

Any significant changes to model outcomes arising from updated or improved information may trigger further updates of the sustainable yield modelling outside of the five-yearly cycle set out in the RFAs.