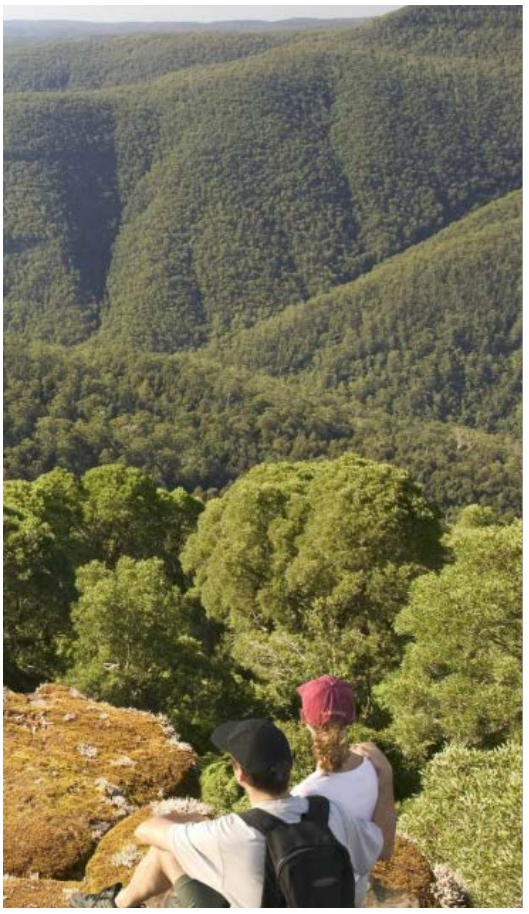
NSW GOVERNMENT

Natural Resources Commission

NSW Forest Monitoring and Improvement Program

Insights for NSW forest outcomes and management

November 2022



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Acknowledgement of Country

The Natural Resources Commission acknowledges and pays respect to traditional owners and Aboriginal peoples. The Commission recognises and acknowledges that traditional owners have a deep cultural, social, environmental, spiritual and economic connection to their lands and waters. We value and respect their knowledge in natural resource management and the contributions of many generations, including Elders, to this understanding and connection.

List of acronyms

CSIRO	Commonwealth Scientific and Industrial Research Organisation
DPE	Department of Planning and Environment
DPI	Department of Primary Industries
EES	Energy, Environment and Science
FFDI	Forest Fire Danger Index
FMIP	Forest Monitoring and Improvement Program
IFOA	Integrated Forestry Operations Approval
NSW	New South Wales
RFA	Regional Forest Agreement
SOC	Soil organic carbon

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Executive summary

NSW forests whether they be national parks, state forests, Aboriginal land, private land or Crown land are under sustained threats, putting at risk many of the services and values they provide. These findings are the consensus of independent scientific advisors, senior forest managers and research commissioned by the Natural Resources Commission (the Commission) over the three years of the Forest Monitoring and Improvement Program (FMIP).

The FMIP has reviewed existing data and commissioned new monitoring and research to substantially advance our understanding of the status of NSW forests, how they have changed over the last 30 years, and their outlook. Learning from the past 30 years and looking forward to 2050, now is the time for the NSW Government to proactively and holistically set the future directions for NSW forests in collaboration with communities, industry and First Nations people.

NSW forests are dynamic systems that provide essential environmental, social, economic and cultural services for the people of NSW across a range of tenures. These services are degrading, and without major intervention they will continue to degrade. The unprecedented bushfires of 2019-2020 will not remain an outlier. The research community had predicted the likelihood of such an event and the scientific consensus is that similar scale events will become increasingly frequent in the future.

Other drivers such as invasive species, population growth, economic growth and intensification of urban and agricultural land uses will continue to place increasing demands and pressure on NSW forests. Business-as-usual management approaches and reactive policy decision making will lead to sub-optimal outcomes at best, or ecosystem and industry collapse under worst case scenarios.

Forest use and management is a highly contested space. For example, the native forestry sector is subject to significant community scrutiny and policy shifts. Other jurisdictions are experiencing major policy shocks as decisions have been made on the future of native timber harvesting – for example, ceasing future harvesting in Western Australia and Victoria - with some stakeholders questioning the strength of the evidence base for those decisions. All sectors that rely on NSW forests – for example, nature-based tourism, apiary, water supply utilities - are now subject to the additional stress of a shifting climate in which droughts, floods and fires are likely to occur more frequently and intensely.

In NSW, the Regional Forest Agreements (RFAs) were renewed in 2018 on the premise that the RFAs would continue to be implemented through the NSW Forest Management Framework, which included a commitment to enhanced monitoring and research. The FMIP was the NSW Government's response to address knowledge gaps and deliver an improved evidence base to inform NSW forest management. At the same time, there have been a series of inquiries into bushfires, koalas and most recently, the forestry industry.

While these inquiries have recommended opportunities to improve forest outcomes, there is a risk that decision making and investment in response to these inquiries is occurring in isolation of each other and a wider international context – for example - increasing demand for sustainable forest products and new market initiatives for natural capital.

Recent NSW and Australian State of the Environment reports identify the same repeated issues of species decline, increasing risks and inadequate management responses. A more strategic focus on NSW forests across all tenures, drawing on the extensive evidence base collected through the FMIP, is essential to ensure they are more resilient and continue to provide their diverse services for future generations.

NSW forests are exhibiting many indicators of stress and degradation

Findings emerging from the FMIP indicate that NSW forests are under significant pressure from increasing shocks such as extended periods of drought and increasing fire frequency and severity coupled with ongoing threats such as pests and weeds.

Findings for key themes include:

- **forest canopy cover extent** –relatively stable on public land between 1995-2019, with increases of up to 12 percent on private land, followed by a steep decline due to the 2019-20 wildfires, particularly affecting state forests and national parks and subsequently followed by recovering canopy cover after significant rain events post-fires.
- **forest carbon** – the forests of NSW contain a large store of carbon (total forest carbon stock estimates between 1990-2019 were consistently over 2,250 million tonnes), with significant carbon emissions from NSW coastal forests due to fire – the 2019-20 wildfires alone released around 90 million tonnes of forest biomass carbon. A detailed account of carbon stored in all NSW forests 1990 to the end of 2020 found a net loss of carbon primarily due to the 2019-20 wildfires. The frequency and severity of future bushfires will likely determine the scale of future net carbon losses.
- **biodiversity** –
    - fauna occupancy trends could only be assessed for 28 of 520 fauna species; of those assessed, some such as the Powerful Owl and Sooty Owl show signs of recovery from a near zero base between 1998 and 2011, while the Greater Glider declined in the same period and koalas were stable in north-east hinterland forests since regular monitoring started in 2015.
    - introduced species, particularly feral cats and foxes, were widespread across both northern and southern coastal forests and pose a significant threat to biodiversity.
    - only 10 percent of forested vegetation in the NSW Regional Forest Agreement areas are currently within their recommended fire frequency thresholds, with large areas at risk of a decline in plant biodiversity due to increased fire frequency. As noted above, the scientific consensus is that fire frequency and intensity will increase across NSW.
- **forest water catchments** – catchment water flows have been declining in forested areas over the last 30 years, especially on the south coast of NSW. Almost half of the 90 catchments analysed showed statistically significant decreases in stream flows in this period, presenting a major challenge to water security for all water users during droughts.
- **soil health and stability** – soil organic carbon has fluctuated, with minor declines 2010 to 2019 driven largely by climate and wildfires, and significant declines expected following the 2019-20 wildfires; in general, more heavily disturbed private forests were found to have less soil organic carbon, particularly grazed forests.
- **Aboriginal cultural values** – large knowledge gaps remain around Aboriginal cultural values in NSW forests across public and private tenures, with Aboriginal people not adequately involved in land management and decision making.
- **productive capacity and sustainability** – total hardwood supply in the Coastal IFOA region declined between 2003-19 for both high and low quality logs, with additional significant short-term reductions in hardwood supply and projected sustainable timber yields following the 2019-20 wildfires, particularly on the south coast.

In the past decade the most significant driver of observed change was the 2019-20 wildfires. Initial FMIP baselines and trends studies were extended to assess the impacts of these fires, with analysis showing sharp declines in indicators such as forest canopy cover extent and forest carbon stocks across both state forests and national parks. Hot, dry climatic conditions were a

key factor exacerbating the severity, extent and impacts. These fires were more intense in southern coastal NSW than in northern coastal NSW.

Forest canopy recovery is already underway following the 2019-20 wildfires, particularly on the NSW north coast. However, affected areas are considered particularly vulnerable in the next 5 to 10 years, with a risk that subsequent disturbances or threats could undermine forest recovery and carbon capture in these areas. In addition to threats from fire and drought, other factors such as loss and degradation of habitats and invasive species also continue to have a negative impact on biodiversity and forest values and may affect post-fire forest recovery. It is uncertain what the cumulative impacts maybe from the shock of the fires, followed by extensive flooding and the future resumption of intensive harvesting.

Forests face a challenging future under climate change

The climate across NSW is predicted to become more variable in the future, with increasing periods of both drought and intense rainfall, bringing heightened fire and flood risks. Under various climate scenarios, maximum temperatures are expected to rise between 0.4-1°C now and into the near future (2020-2039) and 1.8-2.6°C in the far future (2060-2079). The consensus of the scientific community is that the predicted swings between drought and floods are just as significant as the overall heating of the climate.

FMIP research indicates future climate and disturbance regime scenarios will have adverse impacts on NSW forests, affecting forest carbon, soil organic carbon, soil alkalinity, streamflow quantity, surface water quality and forest productivity. Many forest dependent flora and fauna species are predicted to lose significant proportions of their habitat. As a result, one FMIP study found the potential occupancy of 70 percent of assessed fauna species will decline by 2070 under future climate change predictions.

Critically, there is a risk that higher frequency and intensity of disturbances will trigger ongoing cycles of decline in key areas such as forest regeneration and soil organic carbon by reducing the capacity for, or likelihood of, full recovery after each event. In this case, forests will become a net carbon emitter in the coming decades, undermining key Government commitments to achieve net zero carbon emissions by 2050. Other Government commitments for biodiversity and sustainable production outcomes will also be under pressure.

NSW regions like the Australian Alps and South Coast, that have significant areas dedicated to the reserve system, are anticipated to be at highest risk from projected changes in climate and fire regimes. Other forest ecosystems such as temperate and sub-tropical rainforests are also under increasing risk.

Strategic action is needed to prevent loss of future forest values and services

In the absence of a strategic approach, existing stressors will combine with increased threats from climate change and repeated shocks from natural disturbances like droughts, fires and floods and lead to ongoing declines in the resilience, health and productivity of NSW forests. These threats do not recognise tenure boundaries, nor likely to be mitigated by piecemeal solutions which may result in only incremental outcomes.

In this context, it is likely that the many values and services provided and supported by NSW forests – including their role in carbon capture and storage and water security - may change in the future, particularly in high-risk regions.

More positive futures are possible with increased recognition of – and investment in – the social, cultural and economic values of forests, and by actively addressing emerging risks from climate change. This is recognised in the *NSW Climate Change Adaption Strategy* that outlines priorities and actions for NSW to adapt to climate change. To support this, a targeted strategy for NSW forests outlining the best course of action needs to be carefully assessed and debated based on the best science and dialogue with the community and industry.

Success will rely on mutual understanding and bipartisan support for proposed actions to improve future outcomes for NSW forests. The FMIP has delivered the foundations for this work including scenario analysis, modelling and projections based on historical datasets, research and expert advice.

This report identifies key opportunities to maintain and improve forest values, improve forest resilience and reduce risk exposure over the long-term.

The **Commission recommends** the NSW Government:

1 Prepare an overarching cross-tenure strategy for *NSW forests towards 2050* to systematically address the threats of climate change and other stressors. In developing this strategy, Government should:

- 1.1 assess the full range of environmental, social, economic and cultural values and uses of forests across tenures supported by the future forest scenarios developed under FMIP
- 1.2 identify and assess:
  - i. most at-risk forest-dependent ecosystems, threatened species and forest-dependent communities and industries under climate change
  - ii. areas demonstrating strongest trajectories of recovery post 2019-20 wildfires
  - iii. potential options and trade-offs between management response and outcomes.
- 1.3 identify strategic investments and actions to pro-actively protect assets, reduce risks and accelerate outcomes
- 1.4 ensure it provides for increased Aboriginal involvement in decision making and forest management
- 1.5 in preparing the strategy:
  - i. consult meaningfully with community, Aboriginal peoples, industry and scientific experts, including preparing regionally targeted future forests scenarios as a means of engagement
  - ii. consider the rights and interests of respective land-owners
  - iii. draw on the latest science and data, including baselines developed under the FMIP.

2 Establish a dedicated fund to:

- i. Support implementation of the *NSW forests towards 2050 strategy*
- ii. Support rapid response to protect forest assets and address risks during or after significant climate events
- iii. Trial large scale research-based interventions across tenures to reduce vulnerability to wildfires, including use of Indigenous burning practices.

3 Accelerate Aboriginal self-determination and co-management of NSW forests through a variety of mechanisms, including whole of Country planning, joint management, and Indigenous Land Use Agreements.

4 Incorporate latest climate science and forest data into upcoming review of the Coastal Integrated Forestry Operations Approval and other existing regulatory mechanisms across tenures.

5 Review and update the *NSW Forestry Industry Roadmap* in collaboration with industry incorporating the latest climate science, economic data and industry outlooks.

6 Continue long-term independent research and monitoring to improve evidence base for adaptive decision making, namely:

- i. improving tracking forest carbon balances for national and state carbon accounting to support NSW Government's commitments to achieving net zero carbon emissions by 2050

ii. extending existing monitoring programs for public and private production forests to document how these forests are changing, the effectiveness of management and support periodic regulatory reviews and bilateral NSW and Australian Government commitments to ecological sustainable forest management
iii. ensuring consistent methods and datasets are applied across tenure to provide reliable performance information on management and outcomes.

1 Forest monitoring and research insights

Forests deliver a wide range of ecological, social, cultural and economic benefits for the people of NSW. Forest management seeks to maintain these benefits into the future, including through active interventions to address key threats or emerging risks such as a changing climate or intensification of land use. Forest management is undertaken across a range of tenures, including state forests, national parks, private native forests, Aboriginal land and Crown forested land. Decisions we make now about how our forests are managed will determine the extent to which these benefits can be delivered in the future. As such, it is critical that these decisions are evidenced-based and forward-looking.

Over the last four years, the NSW Forest Monitoring and Improvement Program (FMIP, see **Attachment A**) has commissioned a series of monitoring and research projects to determine the status of NSW forests, understand how they have been changing over the last 30 years and what their future outlook may be. These projects have generated baseline, driver and trend evidence across themes such as forest ecosystem health, biological diversity, soil and water resources, productive capacity and sustainability, and forest carbon, as well as insights into Aboriginal cultural values.

These projects have been instrumental in providing an empirical foundation for informed decision-making regarding forest management supported by ongoing monitoring and evaluation. This report brings together the findings from the FMIP – along with relevant findings from other related programs such as the Coastal Integrated Forestry Operations Approval (IFOA) monitoring program – to identify overarching lessons for forest management in NSW into the future. Findings for each FMIP theme are summarised in further detail in **Attachment A**, **Table B**.

1.1 Variable trends in forest indicators between 1995-2019

Prior to 2019, trends in forest indicators assessed under the FMIP varied, with examples of increasing, stable, fluctuating or declining trends to be found across the various FMIP themes.

Forest canopy cover extent showed a gradually increasing trend across NSW since 1995. By 2018, forest canopy cover extent in the Regional Forest Agreement regions[1] had increased by around 5 percent compared with 1995 figures (from 8.6 million hectares to 9.1 million hectares – an increase of around 518,580 hectares – see **Figure 1**).[2]

Most increases were on private land, where forest canopy cover increased by around 12 percent or 441,480 hectares. This is attributed to a thickening of cover in private tenures adjacent to public forest estates, or preservation of existing cover that is regenerating and thickening over time.[3] Forest canopy cover extent on national parks and state forests during this time remained largely stable.

Forest carbon was also largely stable across NSW during this period (**Figure 2**), with some regional variation driven by natural disturbances (fire, drought, natural regeneration) and anthropogenic activities (land clearing, reforestation, prescribed fire and timber harvesting).[4]

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1 Regional Forest Agreements cover the Eden, North East and Southern regions of NSW. Forestry activities in these regions are regulated by the Coastal IFOA. Refer to **Section 3**, **Figure** for a map of these areas.

2 Natural Resources Commission - NSW Government (2022): NSW Forest Monitoring and Improvement Program RFA Historic Forest Cover Extent - 1995 to 2019. Version 1.0. Terrestrial Ecosystem Research Network. (Dataset). https://doi.org/10.25901/sayz-pb50

3 FMIP Project FE1: Baselines, drivers and trends for forest extent, condition and health – reporting by Spatial Vision to Natural Resources Commission (2021)

4 Roberts, G., Waterworth, R., de Ligt, R., McKenzie-McHarg, H., Francis, M., Roxburgh, S., Paul, K., Ximenes, F., (2022) *Carbon Balance of NSW Forests – Methodology and Baseline Report*, NSW Natural Resources Commission, commissioned by the NSW Forest Monitoring Steering Committee, Sydney, NSW

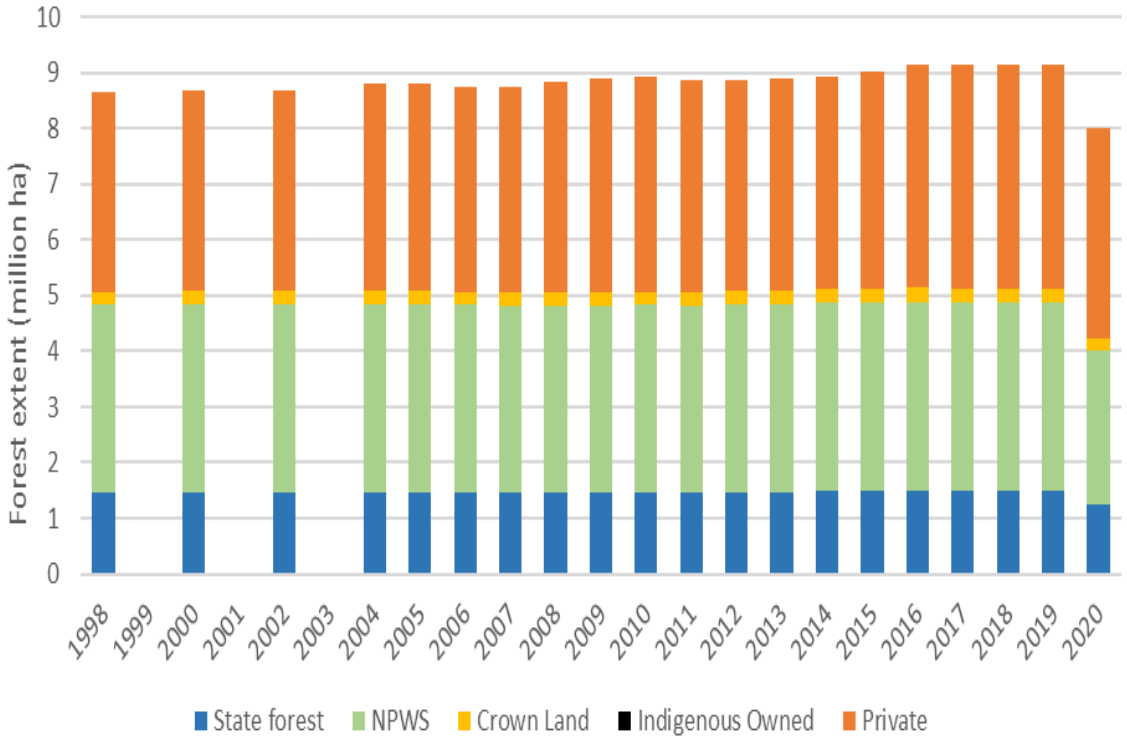


Figure 1: Change in forest canopy cover extent by tenure in the Regional Forest Agreement area (1998-2020)[5]

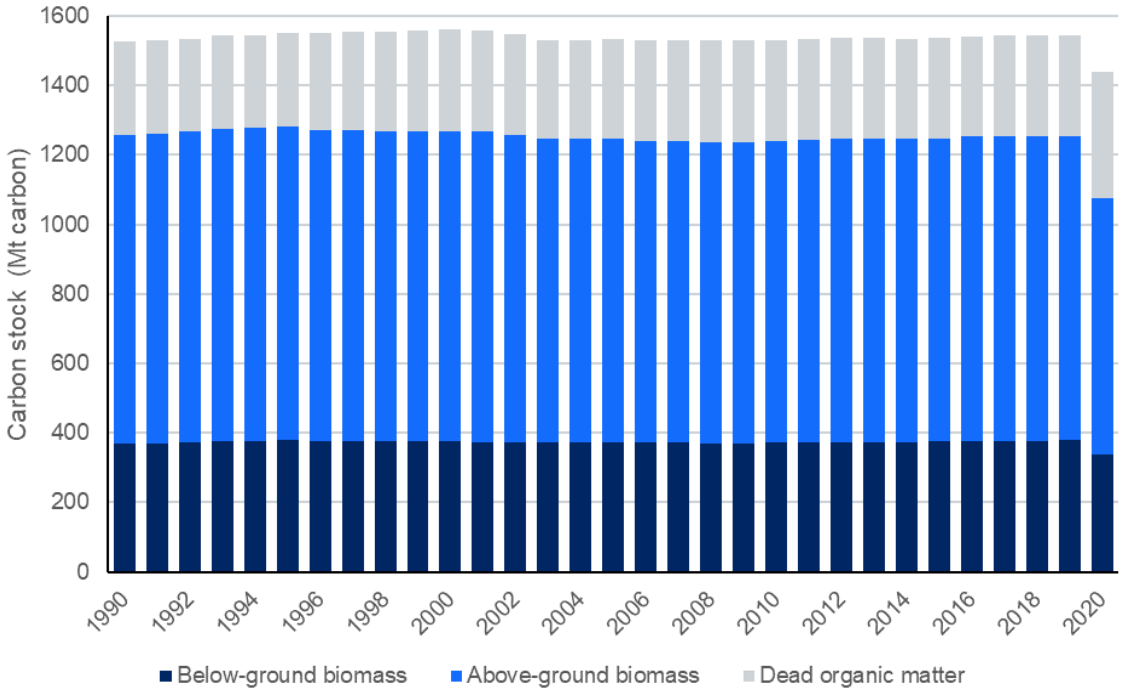


Figure 2: Total forest carbon for forests in the Regional Forest Agreement area (1990-2020)[6]

5 Spatial Vision (2022). *Forest Monitoring – Extent, Condition and Health – Overview Report*, unpublished report to the Natural Resources Commission

6 *Ibid.*

In contrast, FMIP studies indicated that soil organic carbon declined slightly over the last three decades, with significant fluctuations during this period attributed to climatic conditions such as temperature and rainfall.[7]

The quantity of streamflow has also been declining in forest catchments over the last 30 years, especially on the south coast of NSW (**Figure 3**).[8] This decline has been attributed largely to climatic variables such as rainfall, along with drought-related groundwater depletion and regeneration of vegetation following drought, fire or harvesting. Forested catchments supply water for a wide range of uses in NSW, so an ongoing, long-term reduction in streamflows from forested catchments has major implications for future water security in NSW.

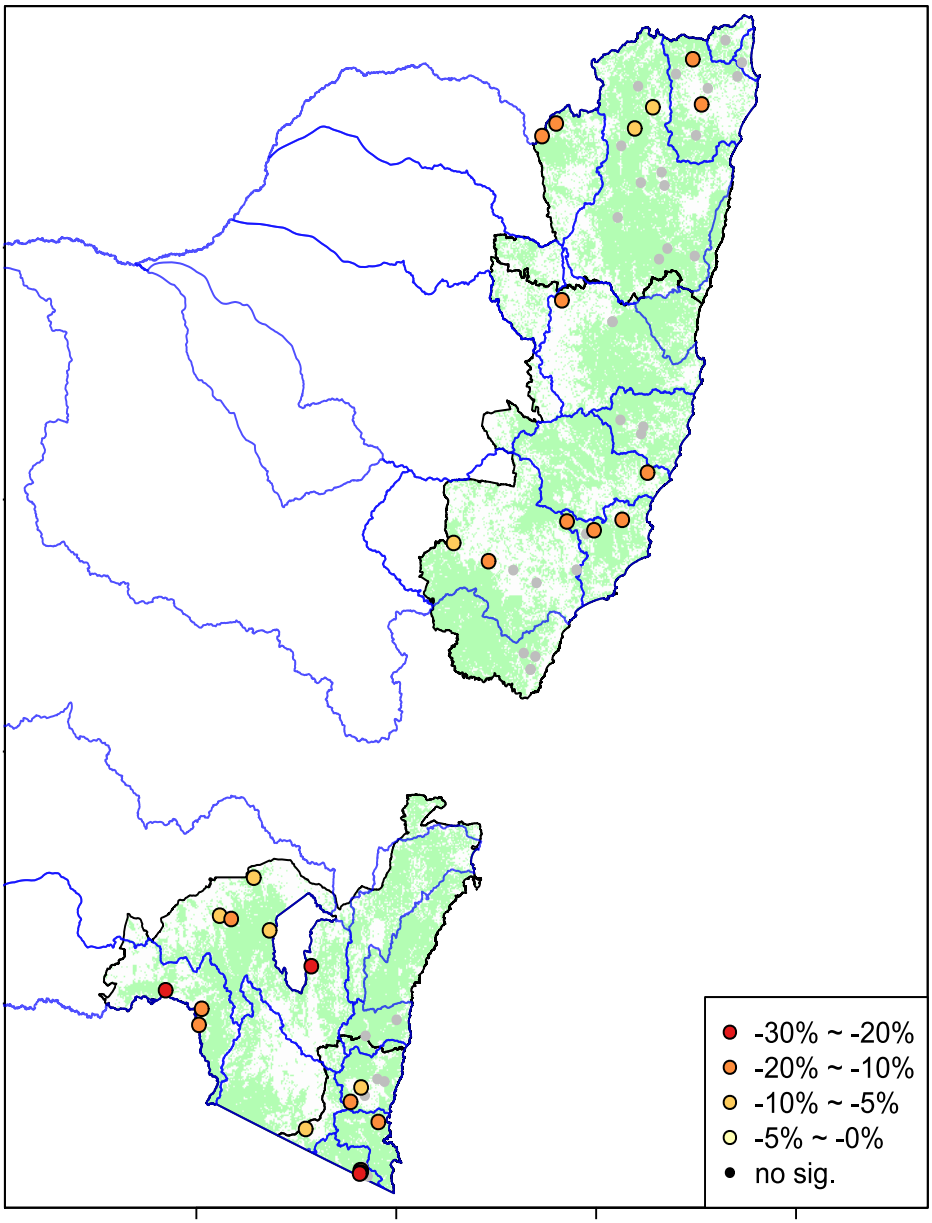


Figure 3: Magnitude of long-term trends in mean annual flow (percentage per decade)[9]

7 Moyce, MC; Gray, JM; Wilson, BR; Jenkins, BR; Young, MA; Ugbaje, SU; Bishop, TFA; Yang, X; Henderson, LE; Milford, HB; Tulau, MJ (2021). *Determining baselines, drivers and trends of soil health and stability in New South Wales forests: NSW Forest Monitoring & Improvement Program*, NSW Department of Planning, Industry & Environment and University of Sydney.

8 Guo, D., Hou, X., Saft, M., Webb, J.A., Western, A.W. (2010) *Report for NRC Forest Baseline & Trend Indicators - Project 3 Task 2 - Long-term trends of Water Quality and Quantity in NSW RFA forests*. University of Melbourne.

9 *Ibid.*

There were two major droughts during the assessment period, the Millennium drought from 1997 to 2009 (with an extremely dry period in 2002-03), and the 2017-19 drought.[10] Notably, the periods of drought and extreme dry conditions align with the recent fire history of Coastal NSW (**Figure 4**), with major fire events in both 2002-03 and 2019-20 following dry periods.

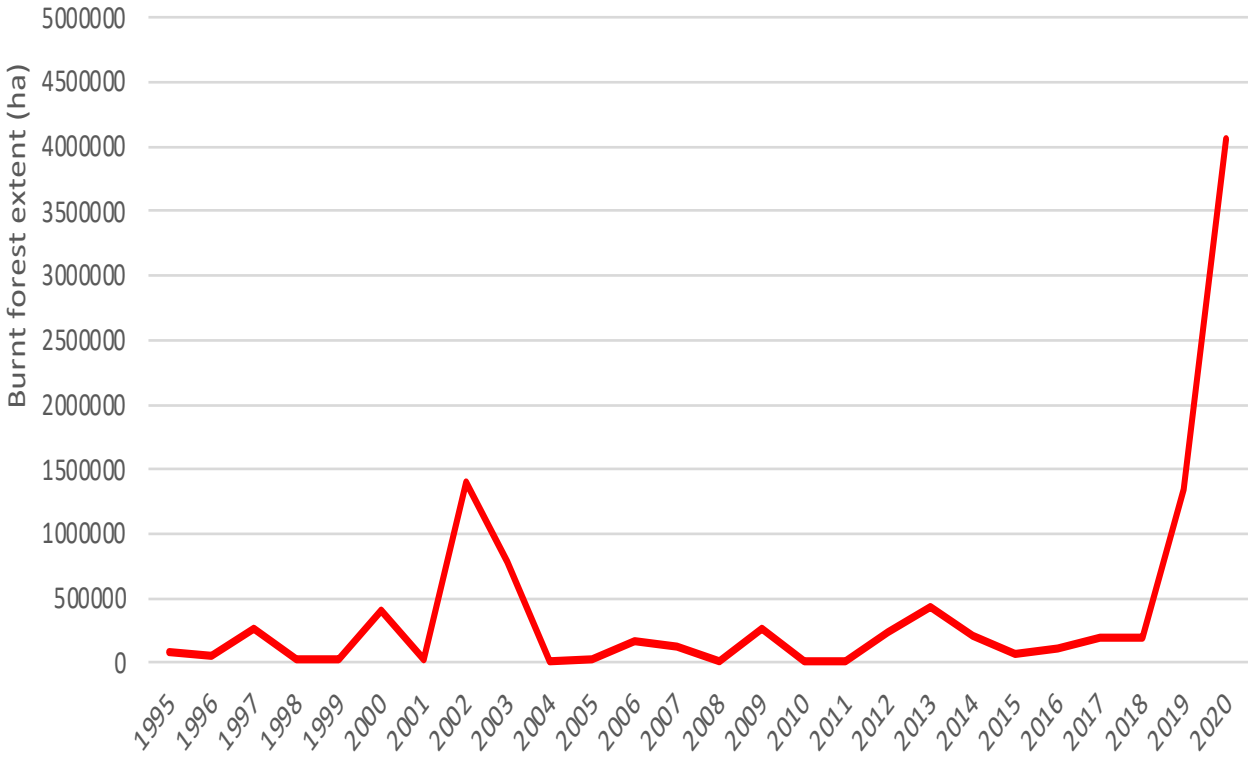


Figure 4: Fire history (burnt forest extent, hectares) for coastal NSW 1995-2020[11]

Total hardwood supply from public native forests and hardwood plantations in the Coastal IFOA region was observed to have declined in the period between 2003 and 2019 driven by resource availability, markets and supply chains (**Figure 5**). Hardwood pulplogs and low quality logs showed the largest decrease (around 40 percent by volume), while high quality hardwood sawlog supply decreased by around 15 percent. Overall hardwood supply and high-quality log supply were aligned to wood supply agreement allocations. On the North Coast IFOA sub-region, high and low quality hardwood supply declined by around 20 percent, while on the South Coast and Eden IFOA sub-regions high quality levels were maintained but there were significant declines for other hardwood products. All hardwood product volumes in the Tumut subregion varied considerably.

10 Bureau of Meteorology (2022). Previous Droughts, Commonwealth of Australia
11 Rural Fire Service composite wildfire layer, from 1995 to 2020

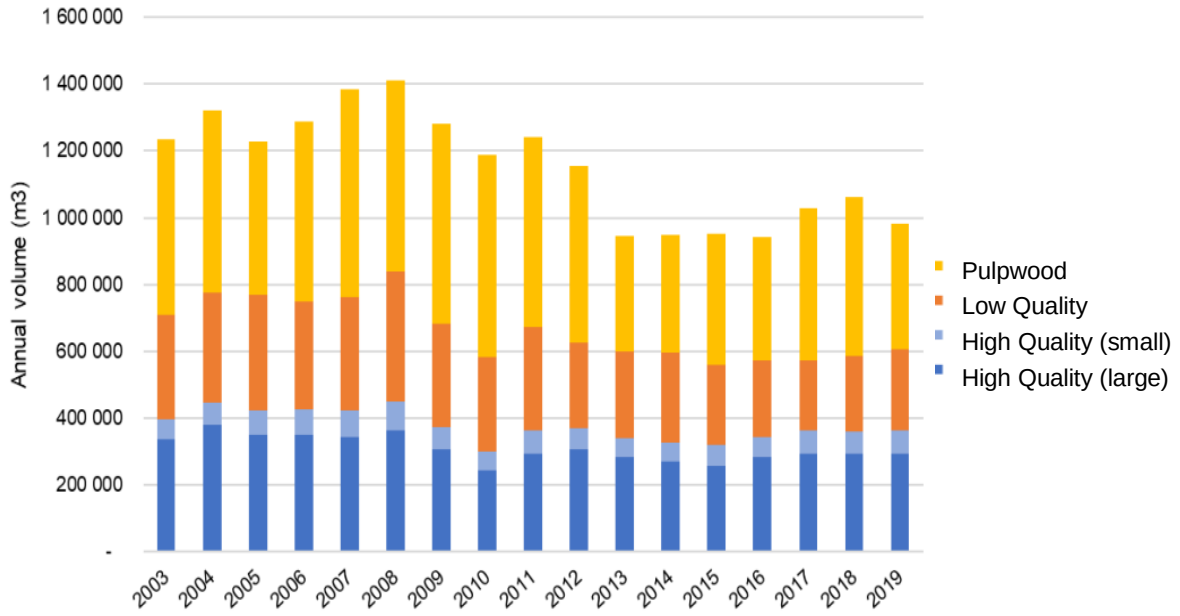


Figure 5: Hardwood supply from native forests and hardwood plantations in the Coastal IFOA region by type[12]

1.2 Significant declines in forest values due to wildfires

By far the largest change in forest indicators during the last 25 years occurred as a direct result of the 2019-20 wildfires. The data and analysis undertaken by the FMIP in establishing long-term baselines and trends for forest indicators allowed for rapid insights to be generated as to the scale of the impacts from this major fire event.

The 2019-20 fires were unprecedented in their extent (**Figure 6**) and severity (**Figure 7**), resulting in the largest total area burnt in a single recorded fire season in eastern Australia.[13] The 2019-20 event affected more than twice as much forested area compared with the 2002-03 fire event (**Figure 4**). Around 60 percent of forested areas across national parks and state forests were burnt in 2019-20.

12 Indufor (2022). *Coastal Integrated Forestry Operations Approval Monitoring Program - Monitoring wood supply baseline and trends*. Report prepared for the NSW Forest Monitoring and Improvement Program, Natural Resources Commission, Sydney N.S.W.

13 Bureau of Meteorology (2020) *Annual Climate Summary for New South Wales – 2019*, Bureau of Meteorology, Commonwealth of Australia, Canberra, ACT

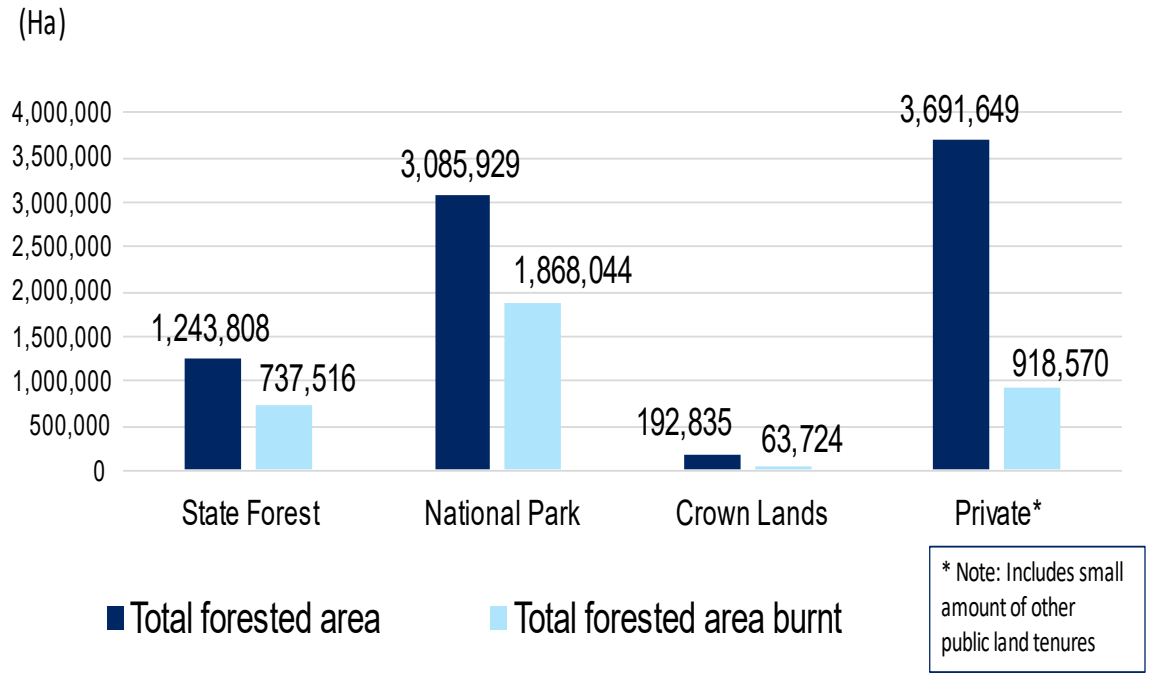


Figure 6: Fire extent for the 2019-20 fire season[14]

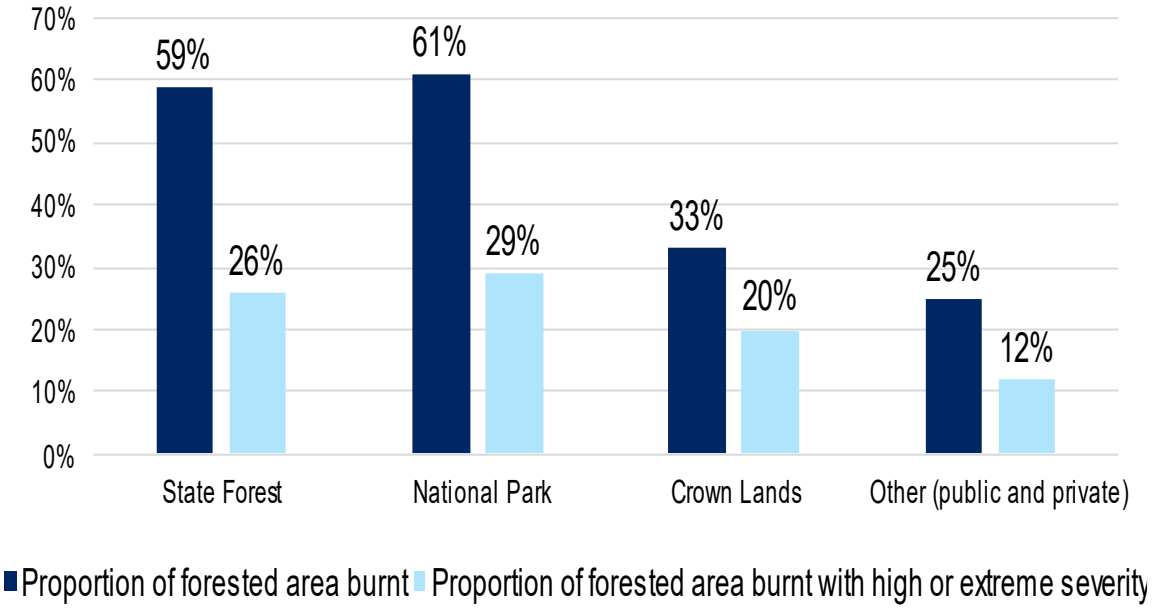


Figure 7: Fire severity for the 2019-20 fire season[15]

14 Bradstock. R, Bedward, M., & Price, O. (2021). *Risks to the NSW Coastal Integrated Forestry Operations Approvals Posed by the 2019/2020 Fire Season and Beyond*, Centre for Environmental Risk Management of Bushfires, University of Wollongong and the NSW Bushfire Risk Management Research Hub, commissioned by the NSW Forest Monitoring Steering Committee, Sydney, NSW

15 *Ibid.*

Hot, dry climatic conditions prior to the 2019-20 fire season exacerbated the severity, extent and impacts of the fires.[16] The final report of the NSW Bushfire Inquiry identified a range of causes and contributing factors, including extremely dry fuel on the ground due to prolonged and widespread drought, as well as repeated, extremely bad fire weather days combined with hot, low humidity nights.[17]

Regarding the impact of past forest management and timber harvesting, there is significant debate around the extent to which disturbance history influenced the 2019-20 wildfires. The 2019-20 wildfires burnt an extensive area, of which more than 90 percent had either never been harvested or had not been harvested within the last 20 years.[18] One study reported that past forest management, including previous timber harvesting, was not found to have increased the fire extent or severity of the 2019-20 wildfires.[19] Analysis across State Forests in the Coastal IFOA area also showed that patterns of burning and fire severity during the 2019-20 wildfires were unrelated to harvesting activities that had occurred within the previous 20 years (between 2000-2019).[20] However, another recent study suggests that timber harvesting increased the probability of high-severity fire in 2019-20.[21] Recent research in forests on the NSW south coast also shows a link between timber harvesting and increased risk of wildfire in fire-prone forests.[22]

Forest canopy cover extent

The 2019-20 fires led to significant impacts across coastal NSW and disproportionately affected public land tenures such as state forests and national parks. In the Regional Forest Agreement regions there were declines in forest canopy cover extent across public and private tenures between 2018 and 2020 as a result of the fires. On state forests and national parks, the fires reduced the forest canopy cover extent to levels significantly lower than the 1995 figures for these tenures (**Figure 8**). In contrast, the magnitude of previous gains in forest canopy cover on private land, combined with proportionally lower fire extent and severity, meant that there remained a net increase in forest canopy cover extent on private land post-fire.

16 Bowman, D.M.J.S., Williamson, G.J., Gibson, R.K. et al. (2021) The severity and extent of the Australia 2019–20 Eucalyptus forest fires are not the legacy of forest management. *Nat Ecol Evol* 5, 1003–1010.

17 NSW Department of Premier and Cabinet (2020), *Final Report of the NSW Bushfire Inquiry*, Sydney, NSW.

18 Bowman, D.M., Williamson, G.J., Price, O.F., Ndalila, M.N. and Bradstock, R.A., 2021. Australian forests, megafires and the risk of dwindling carbon stocks. *Plant, Cell & Environment*, *44*(2), pp.347-355.

19 Bowman, D.M.J.S., Williamson, G.J., Gibson, R.K. et al. (2021) The severity and extent of the Australia 2019–20 Eucalyptus forest fires are not the legacy of forest management. *Nat Ecol Evol* 5, 1003–1010.

20 Bradstock. R, Bedward, M., & Price, O. (2021), *Risks to the NSW Coastal Integrated Forestry Operations Approvals Posed by the 2019/2020 Fire Season and Beyond*, Centre for Environmental Risk Management of Bushfires, University of Wollongong and the NSW Bushfire Risk Management Research Hub, commissioned by the NSW Forest Monitoring Steering Committee, Sydney, NSW

21 Lindenmayer, D.B., Zylstra, P., Kooyman, R. et al. (2022). Logging elevated the probability of high-severity fire in the 2019–20 Australian forest fires. *Nat Ecol Evol* 6, 533–535.

22 Wilson, N., Bradstock, R. and Bedward, M. (2022). Disturbance causes variation in sub-canopy fire weather conditions, *Agricultural and Forest Meteorology*, Volume 323, 2022, 109077, ISSN 0168-1923

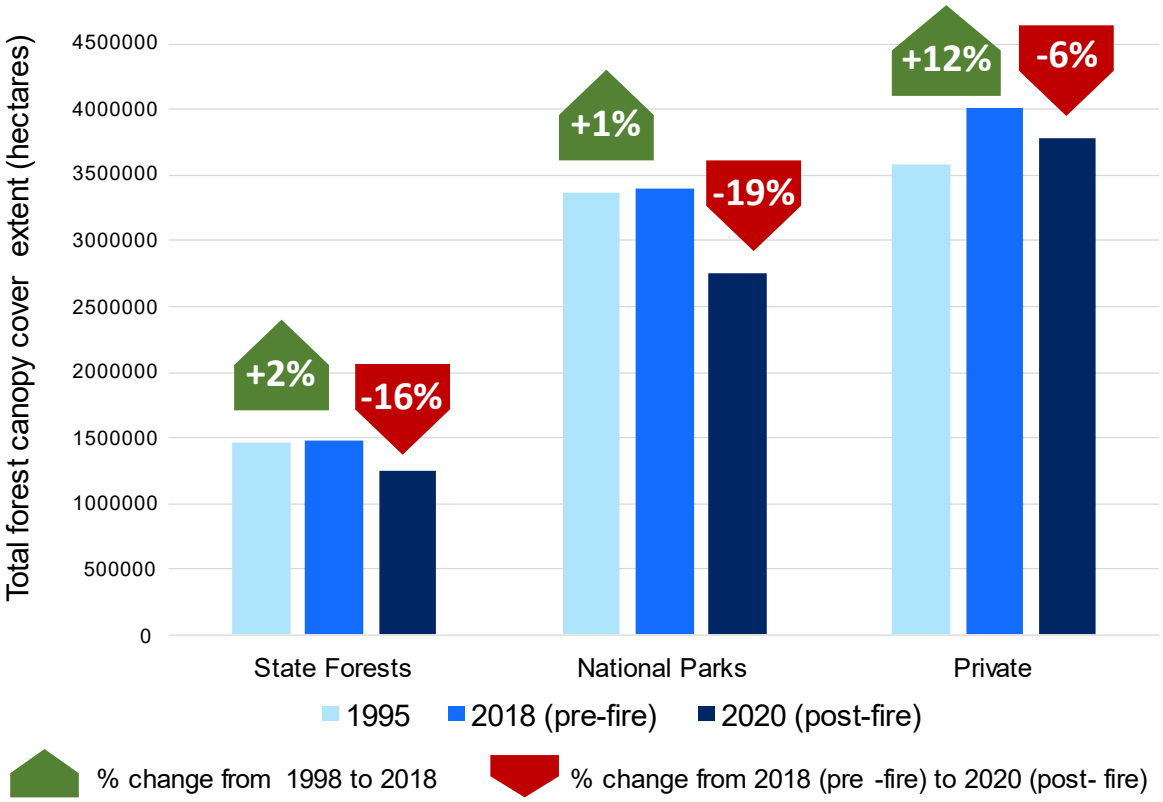


Figure 8: Change in forest canopy cover extent across NSW Regional Forest Agreement regions[23]

Despite the significant impacts on forest canopy cover, NSW forests have already started to recover and regenerate. A study monitoring vegetation recovery across NSW after the 2019-20 wildfires has observed that over 75 percent of burned areas in sub-tropical bioregions in north-east NSW already had greater than 80 percent spectral recovery after one year.[24] This study found that post-fire recovery generally aligned with regional climate and productivity, with better rates of recovery in warmer areas with conditions more conducive to fast growth and slower recovery in alpine and montane bioregions with cold climates and slower growth rates.[25]

23 Natural Resources Commission - NSW Government (2022): NSW Forest Monitoring and Improvement Program RFA Historic Forest Cover Extent - 1995 to 2019. Version 1.0. Terrestrial Ecosystem Research Network. (Dataset).

24 Gibson, R.K. and Hislop, S. (2022), Signs of resilience in resprouting Eucalyptus forests, but areas of concern: 1 year of post-fire recovery from Australia's Black Summer of 2019–2020, *International Journal of Wildland Fire* doi:10.1071/WF21089

25 *Ibid.*

Forest carbon and carbon emissions

The 2019-20 fire season also resulted in significant carbon emissions from NSW coastal forests, including:

- around 90 million tonnes of forest biomass carbon released to the atmosphere
- around 63 million tonnes of carbon moving from the living to dead organic matter pools.[26]

Figure 9 emphasises the magnitude of this event compared with releases in other years within the assessment period.

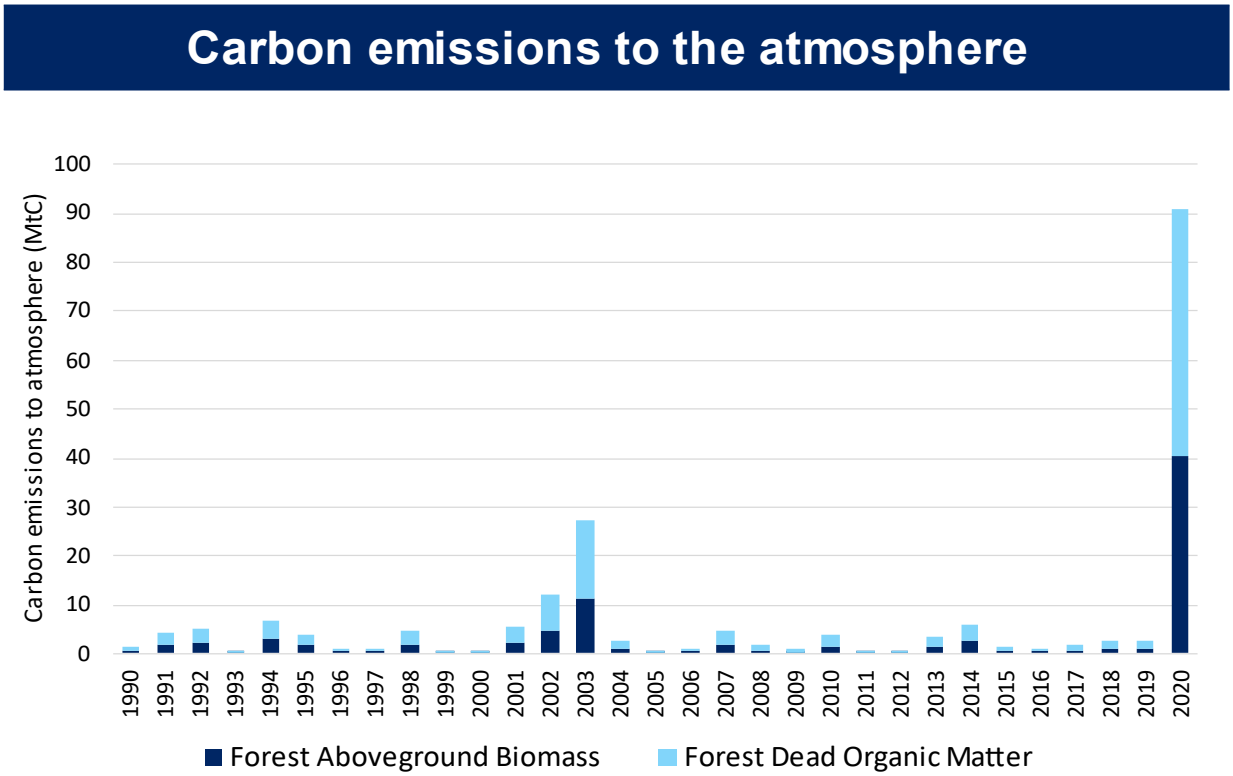


Figure 9: Movements of carbon from forest aboveground biomass and dead organic matter to the atmosphere as a result of the 2019-20 fire season[27]

Overall, considering all gains and losses of carbon over the period 1990 to 2020, the forest carbon stock[28] in NSW is now estimated to be 164 million tonnes less in 2020 than in 1990 (a decrease of around 7 percent).[29] A significant amount of the carbon emitted during the wildfires is expected to be recaptured as the forests recover. However, the extent to which these emissions are fully offset by vegetation regrowth depends on the capacity of the affected forests to recover and the potential impact of subsequent disturbances. **Sections 1.3.2, 1.4.3** and **2.2** explore these issues in more detail.

26 Roberts, G., Waterworth, R., de Ligt, R., McKenzie-McHarg, H., Francis, M., Roxburgh, S., Paul, K., Ximenes, F., (2022) *Carbon Balance of NSW Forests – Methodology and Baseline Report*, NSW Natural Resources Commission, commissioned by the NSW Forest Monitoring Steering Committee, Sydney, NSW

27 Roberts, G., Waterworth, R., de Ligt, R., McKenzie-McHarg, H., Francis, M., Roxburgh, S., Paul, K., Ximenes, F., (2022) *Carbon Balance of NSW Forests – Methodology and Baseline Report*, NSW Natural Resources Commission, commissioned by the NSW Forest Monitoring Steering Committee, Sydney, NSW

28 Note**:** this figure includes aboveground biomass, belowground biomass, dead organic matter, and harvested wood products in use. Soil carbon and harvested wood products in land fill were not included in this result.

29 Roberts, G., Waterworth, R., de Ligt, R., McKenzie-McHarg, H., Francis, M., Roxburgh, S., Paul, K., Ximenes, F., (2022) *Carbon Balance of NSW Forests – Methodology and Baseline Report*, NSW Natural Resources Commission, commissioned by the NSW Forest Monitoring Steering Committee, Sydney, NSW

The regional variation in change in forest carbon following the fires in 2020 compared with the 1990 baseline is shown in **Figure 15**, with the largest losses in the south coast and alpine regions (see **Sections 0** and **1.5** for more discussion on regional differences).

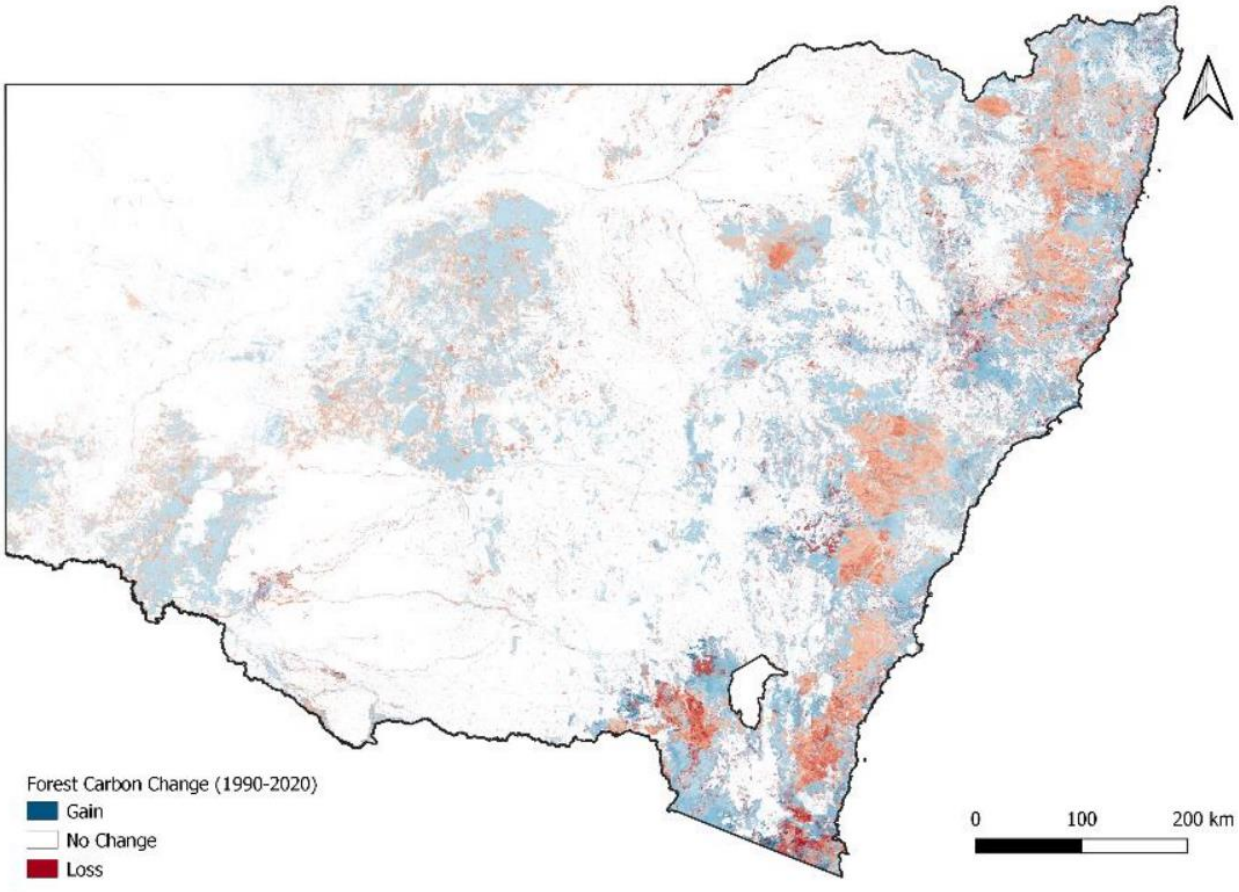


Figure 10: Spatial Output of change in forest carbon within NSW between 1990 and 2020, including above ground biomass, below ground biomass, and dead organic matter. Harvested wood products in use and soil carbon are not included[30]

Soil organic carbon

The impact of major wildfire events on soil organic carbon levels is also significant and subject to longer recovery periods than forest carbon stocks. Although soil sampling data from areas burnt in the 2019-20 fires is not yet available, FMIP-funded modelling predicts that the potential loss of soil organic carbon immediately following a wildfire event ranges between 40 and 60 percent (**Figure 11**).[31] The Commission cautions that this modelling does not represent the predicted loss of soil organic carbon from the 2019-20 fires. It does, however, give an insight into the potential impacts of wildfire by calculating the theoretical loss of soil organic carbon if forested areas in the Regional Forest Agreement region were burnt with a uniform intensity fire.

30 Roberts, G., Waterworth, R., de Ligt, R., McKenzie-McHarg, H., Francis, M., Roxburgh, S., Paul, K., Ximenes, F., (2022) *Carbon Balance of NSW Forests – Methodology and Baseline Report*, NSW Natural Resources Commission, commissioned by the NSW Forest Monitoring Steering Committee, Sydney, NSW

31 Moyce, M.C.; Gray, J.M.; Wilson, B.R.; Jenkins, B.R.; Young, M.A.; Ugbaje, S.U.; Bishop, T.F.A.; Yang, X.; Henderson, L.E.; Milford, H.B.; Tulau, M.J. (2021). *Determining baselines, drivers and trends of soil health and stability in New South Wales forests: NSW Forest Monitoring & Improvement Program*, NSW Department of Planning, Industry and Environment and University of Sydney.

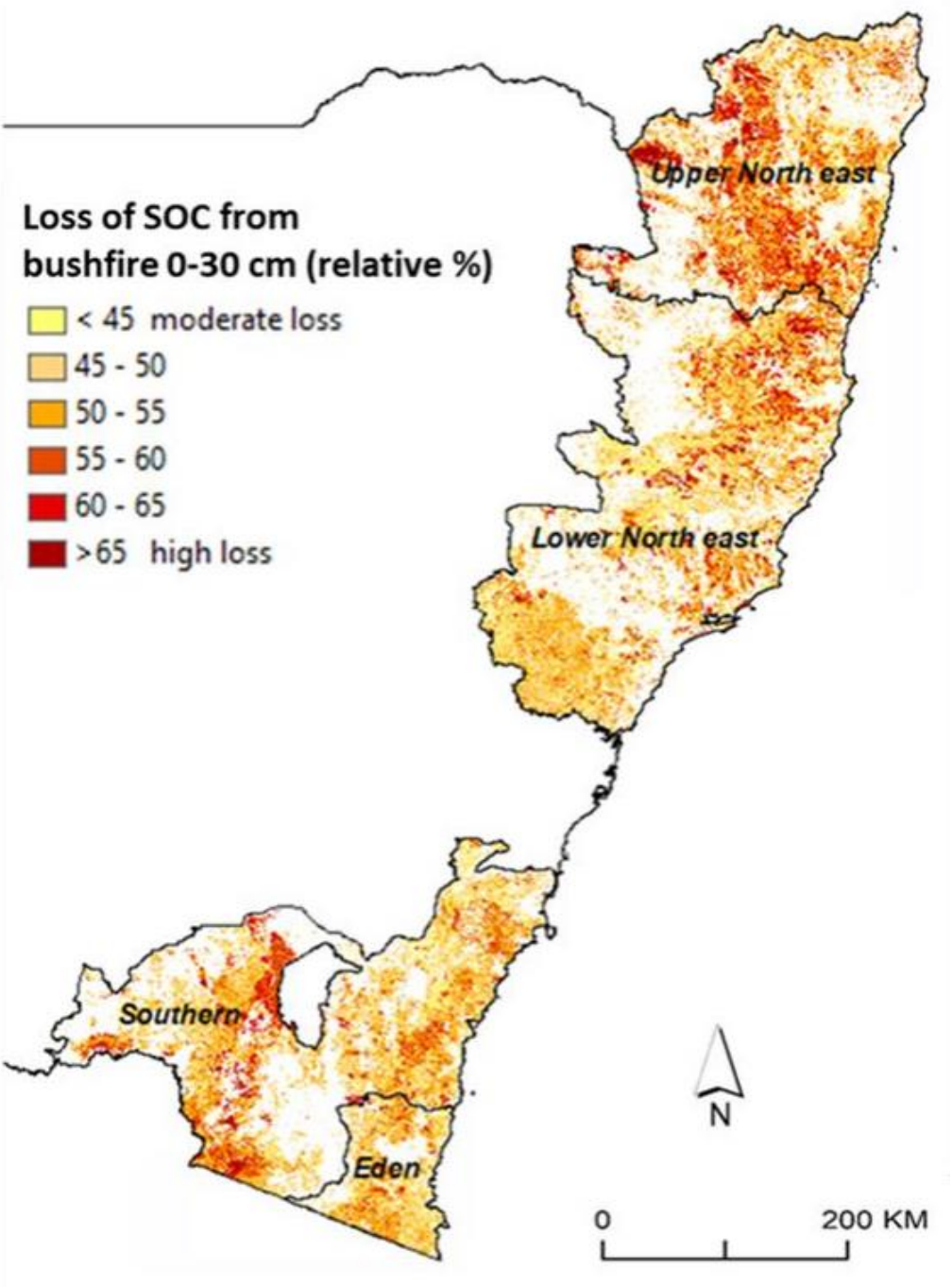


Figure 11: Predicted relative change (percentage) in surface soil organic carbon (SOC) concentrations immediately following a wildfire event[32,33]

Post-fire recovery of soil organic carbon was estimated to be around 60 percent after 20 years, with full recovery after around 75 years. These recovery estimates do not account for additional bushfires during this time, and there is a risk that some areas could enter a cycle of declining soil organic carbon if subjected to repeated fire events and/or other disturbances such as grazing, timber harvesting or land clearing.

32 Model was run with the variable representing the number of years since bushfire (wildfire) set to the immediate aftermath of bushfire hypothetically applied across the entire RFA study region.

33 Moyce MC, Gray JM, Wilson BR, Jenkins BR, Young MA, Ugbaje SU, Bishop TFA, Yang X, Henderson LE, Milford HB, Tulau MJ, (2021). *Determining baselines, drivers and trends of soil health and stability in New South Wales forests: NSW Forest Monitoring & Improvement Program*, NSW Department of Planning, Industry and Environment and University of Sydney.

Biodiversity and species habitat

The 2019-20 fires also had extensive impacts on the habitat of hundreds of species (**Figure 12, Figure 13**). Research indicates that fire events are an important driver in species occupancy for many flora and fauna species across coastal NSW, including hundreds of flora species identified as being fire responsive, some of which are associated with long-unburnt sites.[34]

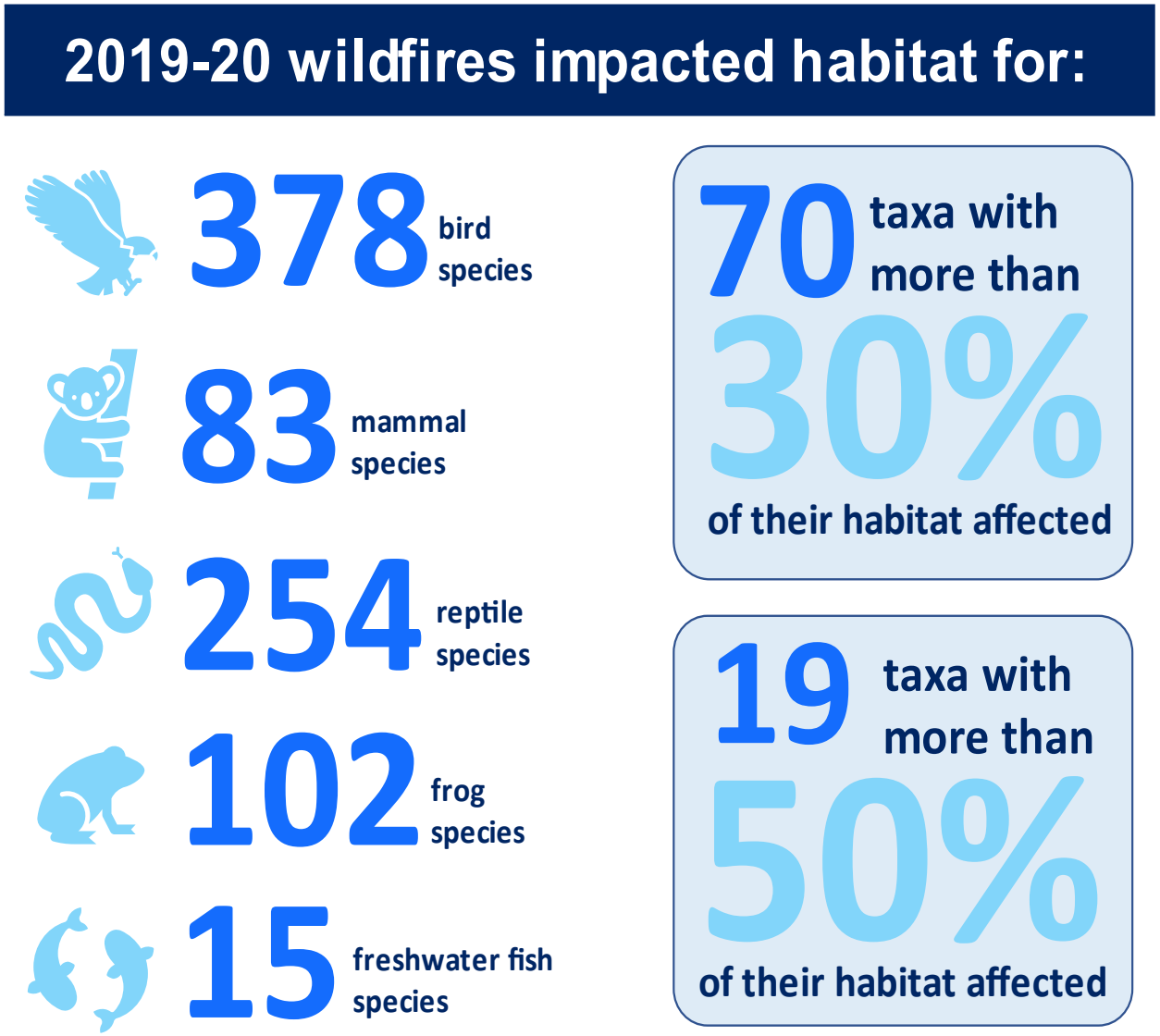


Figure 12: Species with habitat impacted by the 2019-20 fire season[35]

[34] Kavanagh,R., Law, B., Drielsma, M., Gonsalves, L., Beaumont, L., Jenkins, R., Wilson, P.D., Binns, D., Thinley, P., Bulovic, N., Lemckert, F., Brassil, T., & Reid, N. (2022), *NSW Forest Monitoring and Improvement Program Project 2: Baselines, drivers and trends for species occupancy and distribution – Final Report*. Report prepared for the Natural Resources Commission as part of the NSW FMIP

[35] Ward, M., Tulloch, A.I.T., Radford, J.Q., Williams, B.A., Reside, A.E., Macdonald, S.L., Mayfield, H.J., Maron, M., Possingham, H.P., Vine, S.J., O'Connor, J.L., Massingham, E.J., Greenville, A.C., Woinarski, J.C.Z., Garnett, S.T., Lintermans, M., Scheele, B.C., Carwardine, J., Nimmo, D.G., Lindenmayer, D.B., Kooyman, R.M., Simmonds, J.S., Sonter, L.J. and Watson, J.E.M. (2020). Impact of 2019–2020 mega-fires on Australian fauna habitat. *Nature, Ecology and Evolution*. 4: 1321–1326.

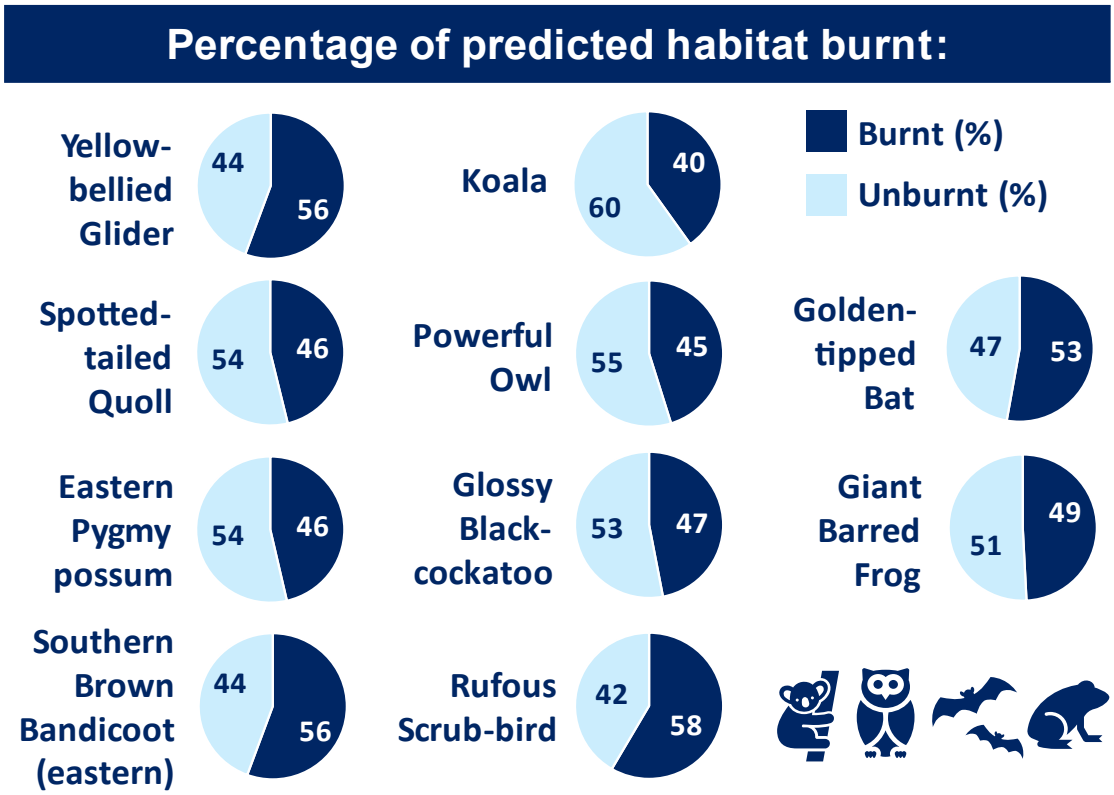


Figure 13: Percentage of predicted habitat burnt in 2019-20 for species in forested Coastal IFOA areas[36]

The FMIP also funded research into the impact of the 2019-20 wildfires on koalas and their habitat across north-eastern NSW.[37] For local koala populations, declines in koala density were observed in areas with a greater extent of medium or high fire severity. Koalas were temporarily absent in some areas where high fire severity dominated the landscape, although surveys one year after the fires showed koalas were returning to these areas. In contrast, in unburnt or predominantly low fire severity areas, koalas continued to be widespread, with little to no signs of decreased local population density post-fire compared with pre-fire local population density. At the regional scale, the broader population[38] of koalas across north-east NSW has been resilient to the 2019-20 wildfires, with no initial decline in post-fire occupancy detected.

Following the fires, only 10 percent of forests in coastal NSW are within their recommended fire frequency thresholds, with large areas at higher risk of a loss of plant diversity.[39] There have been significant increases in the proportion of area in the 'vulnerable' and 'too frequently burnt' categories that indicate a risk of decline in plant diversity (**Figure 14)**. Half of the state forest and national park area in coastal NSW is now classified as 'vulnerable', meaning the 2019-20 fires effectively doubled the extent of vulnerable forested vegetation on these tenures.

36 Bradstock. R, Bedward, M., & Price, O. (2021). *Risks to the NSW Coastal Integrated Forestry Operations Approvals Posed by the 2019/2020 Fire Season and Beyond*, Centre for Environmental Risk Management of Bushfires, University of Wollongong and the NSW Bushfire Risk Management Research Hub, commissioned by the NSW Forest Monitoring Steering Committee, Sydney, NSW

37 Natural Resources Commission (2022), *Summary paper - koala and habitat response after the 2019-20 wildfires*, prepared for the NSW Forest Monitoring and Improvement Program.

38 Also referred to as the metapopulation, which is a group of separate but interacting populations (also known as subpopulations) that are distributed across a region.

39 Bradstock. R, Bedward, M., & Price, O. (2021). *Risks to the NSW Coastal Integrated Forestry Operations Approvals Posed by the 2019/2020 Fire Season and Beyond*, Centre for Environmental Risk Management of Bushfires, University of Wollongong and the NSW Bushfire Risk Management Research Hub, commissioned by the NSW Forest Monitoring Steering Committee, Sydney, NSW

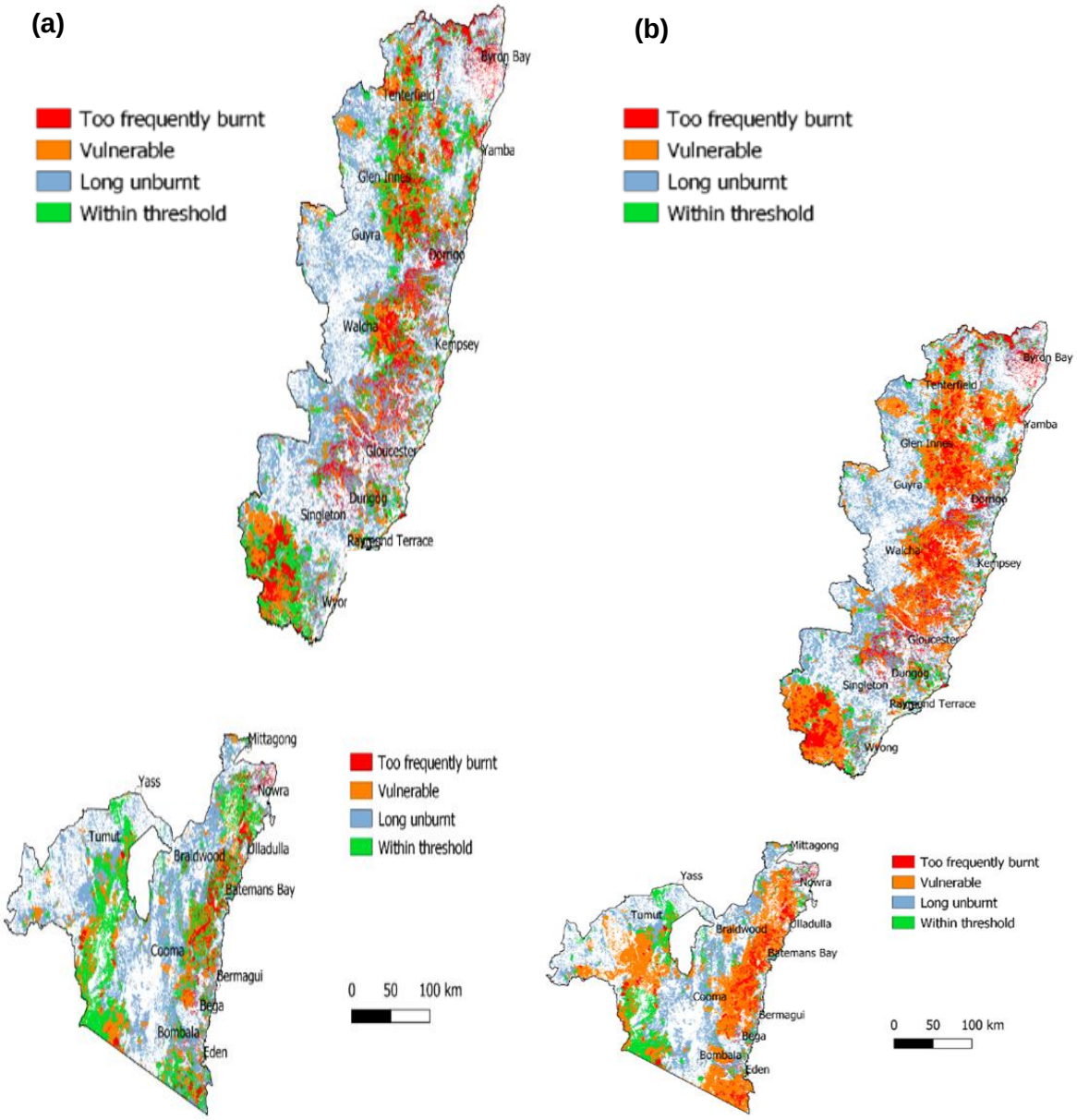


Figure 14: The status of 'threshold' categories indicating plant biodiversity responses to fire frequency across the Coastal IFOA area in (a) mid-2019 and (b) following the 2019-20 fires[40]

40 Bradstock. R, Bedward, M., & Price, O. (2021). *Risks to the NSW Coastal Integrated Forestry Operations Approvals Posed by the 2019/2020 Fire Season and Beyond*, Centre for Environmental Risk Management of Bushfires, University of Wollongong and the NSW Bushfire Risk Management Research Hub, commissioned by the NSW Forest Monitoring Steering Committee, Sydney, NSW

1.2.1 2019-20 wildfires were more intense in southern coastal NSW

In terms of the spatial distribution of impacts, the fires were more intense in southern coastal NSW than in northern coastal NSW, reducing the overall forest canopy cover extent in the south to well below 1995 baseline levels and releasing almost twice as much forest carbon (**Figure 15**).

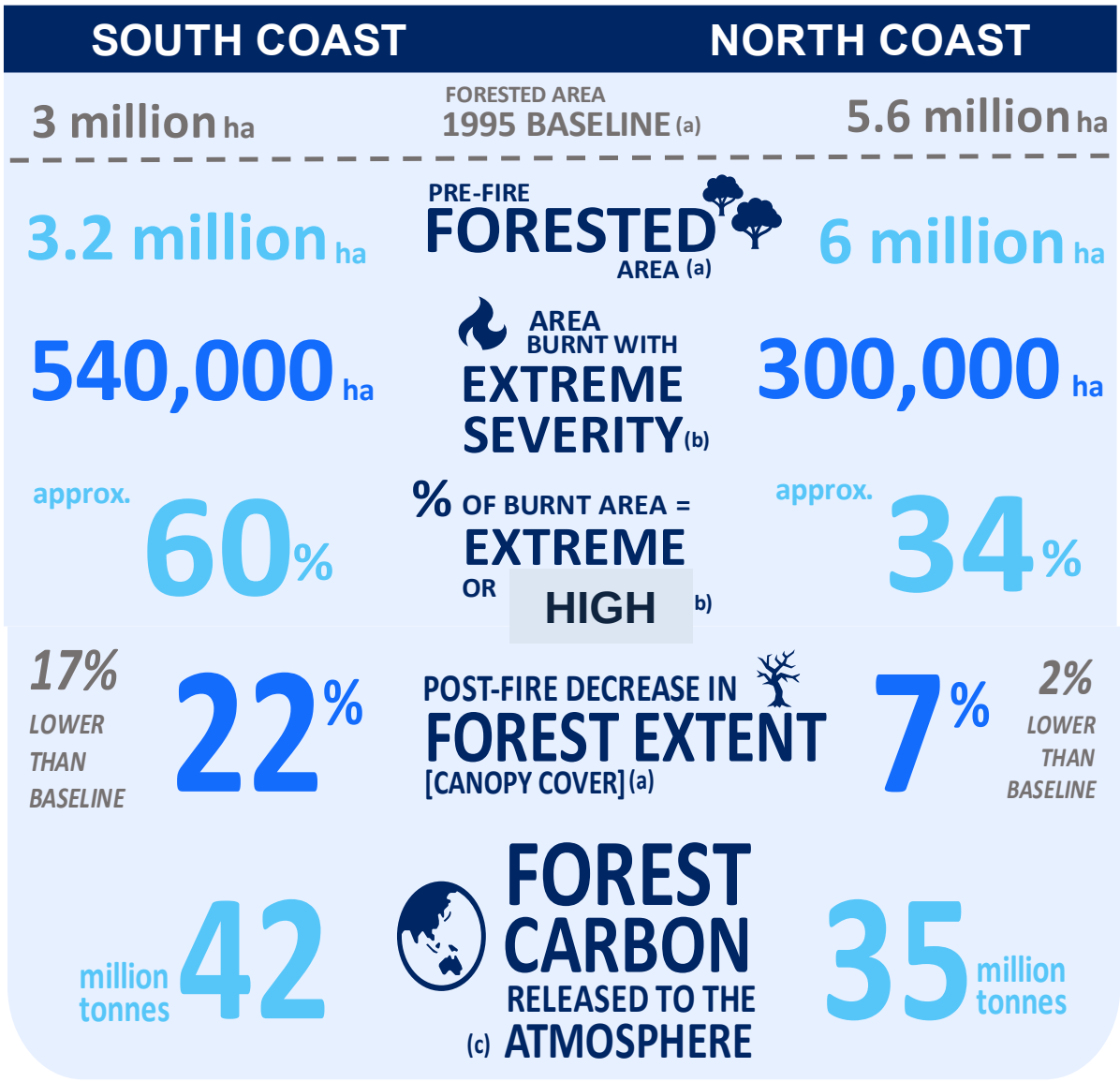


Figure 15: Comparison of impacts from the 2019-20 wildfires on the south and north coast [41]

[41] (a) Natural Resources Commission - NSW Government (2022): NSW Forest Monitoring and Improvement Program Historic Forest Cover Extent - 1995 to 2019 for RFA regions. Version 1.0. Terrestrial Ecosystem Research Network. (Dataset). https://doi.org/10.25901/sayz-pb50
(b) 2019-20 wildfire severity mapping available at https://datasets.seed.nsw.gov.au/dataset/fire-extent-and-severity-mapping-fesm
(c) Natural Resources Commission - NSW Government (2022): NSW Forest Carbon Stock - Aboveground, Belowground and Dead Organic Matter Carbon Mass 1990-2020. Version 1.0.0. Terrestrial Ecosystem Research Network. (Dataset). https://doi.org/10.25901/1qm2-8b33N. **Note:** these figures are for the northern and southern parts of the Regional Forest Agreement area. An additional 14 million tonnes of emissions related to the 2019-20 wildfires occurred outside the Regional Forest Agreement area.

1.2.2 Wildfires affected socio-economic values

Alongside impacts on ecological values, there have also been well-documented socio-economic impacts associated with the 2019-20 wildfires for both local communities and industries.[42] This includes the loss of 26 lives, along with the loss of 2,476 homes, other property and infrastructure, and livestock.[43] There was widespread disruption due to evacuations and significant community resources and organisation required for volunteer firefighting efforts.

There were also impacts on physical and mental health, air quality and drinking water, local industries and tourism. In January 2020, Canberra measured the worst air quality index of any major city in the world due to fine particle air pollution generated by the NSW wildfires.[44] This has the potential to directly impact human health even during relatively short exposures.

Some large tourism operators in the NSW Blue Mountains region had all bookings cancelled at the height of the wildfires in early 2020. Overall, tourist visitation declined by 40 percent from 2019 due to the combined effects of wildfires, extreme floods and COVID. An estimated 600 jobs were lost, with $118 million lost in direct revenue to the tourism industry.[45]

The 2019-20 wildfires led to a significant short-term reduction in wood supply (**Figure 16**) and short-term projected sustainable yields across the coast, particularly on the south coast. Of the 1.2 million hectares of forested State Forest area under the Coastal IFOA, 59 percent was burnt, almost half of which burnt at high or extreme severity.[46] A *force majeure* was declared for many wood supply agreements in both the south and north coast IFOA regions, and forestry operations ceased. Forestry operations resumed in early 2020, at first under site specific operating conditions[47] and subsequently under voluntary measures[48].

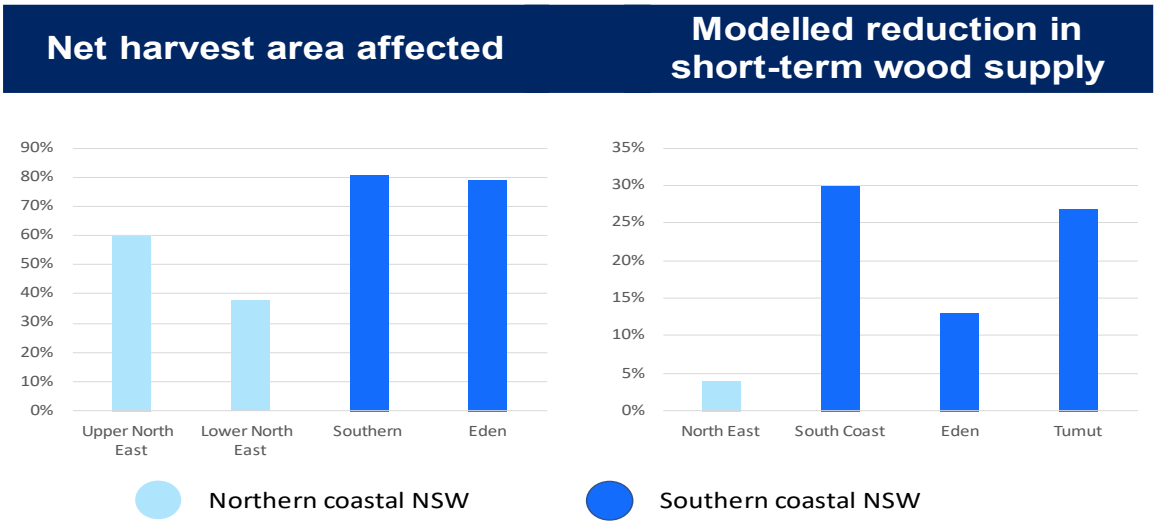


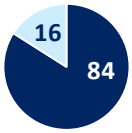
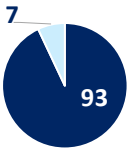
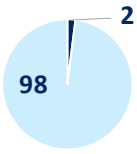
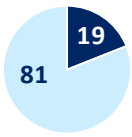
Figure 16: Overview of fire impact on net harvest area[49] and short-term wood supply[50]

42 NSW Department of Premier and Cabinet (2020), *Final Report of the NSW Bushfire Inquiry*, Sydney, NSW.
43 *Ibid.*
44 UN Environment Programme – The impacts of the Australian bushfires. Accessed at https://www.unep.org/news-and-stories/story/ten-impacts-australian-bushfires
45 REMPLAN (nd) Tourism Industry Profile 2021 Blue Mountains City Council
46 Bradstock. R, Bedward, M., & Price, O. (2021). *Risks to the NSW Coastal Integrated Forestry Operations Approvals Posed by the 2019/2020 Fire Season and Beyond*, Centre for Environmental Risk Management of Bushfires, University of Wollongong and the NSW Bushfire Risk Management Research Hub, commissioned by the NSW Forest Monitoring Steering Committee, Sydney, NSW
47 See EPA website for further details.
48 See Forestry Corporation of NSW website for further details.
49 Forestry Corporation (2020). *Impact of fires 2019-20*. Website Available at: https://www.forestrycorporation.com.au/operations/fire-management/fire-impact-of-2019-20
50 Forestry Corporation of NSW (2020). *2019–20 Wildfires NSW Coastal Hardwood Forests Sustainable Yield Review*. Available at: 2019–20 Wildfires (nsw.gov.au)

Timber production was most significantly affected in the South Coast and Eden subregions (
Table 1). This is attributed to the greater extent and severity of fire on the south coast, as well as the lack of plantation resources to supplement harvesting of native forests in this region. In contrast, loss of supply of high quality logs from native forests on the north coast was offset by early harvesting of hardwood plantations.

The reductions in wood supply from the 2019-20 wildfires had flow-on impacts to the forest industry in affected regions, including forest operations, log haulage, timber processing, and allied services. Employees in these fields are reported to have experienced reductions in work shifts and redundancies, with a stand down of 74 harvest and haulage jobs and 6 sawmill jobs reported in March 2021.[51]

Table 1: Change in high quality log supply in 2020 compared to average of preceding five years[52]

Subregion	Actual wood supply reduction in 2020 vs. average of preceding five years	
	Reduction in high quality supply	Notes
South Coast	-84% 	▪ Down from 47,225 to 7,545 cubic metres ▪ Primarily spotted gum ▪ Tablelands species harvest was extremely limited (less than 200 cubic metres harvested)
Eden	-93% 	▪ Down from 19,505 to 1,380 cubic metres ▪ Primarily silvertop ash ▪ Pulpwood supply also fell by 75 percent
Tumut **high quality alpine ash*	-2% 	▪ Limited change in alpine ash supply from 22,510 to 22,155 cubic metres ▪ Production supplemented by fire salvage operations
North Coast	-19% 	▪ Down from 256,500 to 207,830 cubic metres ▪ Native forest supply reduced by 58 percent, but supply was supplemented by plantation harvest ▪ Blackbutt availability increased due to plantation harvesting, but north coast spotted gum supply fell by 92 percent and blue gum, tallowwood and brush box decreased by 35 percent.
	% Expected high quality supply delivered % Reduction compared with previous 5 years	

[51] NSW Government Budget Estimates 2020-2021, Supplementary Questions, Portfolio Committee No. 4 – Industry, Deputy Premier, Regional NSW, Industry and Trade. Hearing: Friday 26 February 2021; Answers due by: 24 March 2021.

[52] Forestry Corporation of NSW production data.

1.2.3 Post-fire surveys highlighted gaps in the understanding and management of Aboriginal cultural values

The 2019-20 wildfires had significant impacts on Aboriginal cultural values within NSW forests, including damage to cultural value sites and artefacts and preventing access and/or cultural practices in some areas. For example, post-fire site assessments for Aboriginal cultural values carried out as part of the FMIP identified burnt scar trees and areas where stone artefacts have been made brittle or exposed to erosion risks.[53] Aboriginal people were concerned that cultural sites will be deregistered or devalued in these cases where tangible cultural values are damaged or lost.

Positively, priority sites were able to be actively protected on Aboriginal managed lands and other key sites on other tenures (including rock art and bora grounds) were reported to be unaffected. The post-fire site visits also allowed for continuation of cultural obligations to Country and revealed cultural values, including scar trees, artefact scatters and cultural resource sites, that had been previously inaccessible due to vegetation.

An overarching finding of the case studies was that, with the exception of Aboriginal managed lands, Aboriginal cultural values were poorly understood and managed across all tenures during the fire event. Aboriginal people also reported a general lack of access to cultural sites and barriers to carrying out cultural practices or caring for Country, particularly on private land. As such, there is a need to improve Aboriginal peoples' involvement in land management and decision making – including the identification, management, and monitoring of cultural values.

1.3 NSW forests are currently vulnerable and under pressure

NSW forests are already under stress from the impacts of the 2019-20 wildfires, increasing their vulnerability to future disturbances that are expected to occur with increasing frequency and severity. In addition, existing threats, such as invasive species and habitat loss and degradation continue to impact forest values in NSW forests.

1.3.1 Fire-affected areas are at higher risk during the post-fire recovery phase

Research indicates that, in general, eucalypts are highly resilient to fire, with the forest canopy expected to recover over time following a wildfire.[54] As mentioned in **Section 1.2**, a study has confirmed vegetation recovery is already underway in fire-affected areas, particularly in sub-tropical bioregions in north-east NSW.[55]

However, during the post-fire recovery phase forest health and condition are impacted and short-term losses of potential suitable habitat – including hollow bearing trees, nesting and food resources – are expected for many priority threatened species.[56] Further, the size and intensity of the 2019-20 fires, along with impacts from harvested areas, means refugia availability and habitat connectivity are likely to have been affected across the broader landscape.

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53 Firesticks Alliance Indigenous Corporation (2022), *Aboriginal Cultural values and renewal in NSW forests post-wildfires - Synthesis report*, Firesticks Alliance Indigenous Corporation.

54 Bradstock. R, Bedward, M., & Price, O. (2021), *Risks to the NSW Coastal Integrated Forestry Operations Approvals Posed by the 2019/2020 Fire Season and Beyond*, Centre for Environmental Risk Management of Bushfires, University of Wollongong and the NSW Bushfire Risk Management Research Hub, commissioned by the NSW Forest Monitoring Steering Committee, Sydney, NSW

55 Gibson, R.K. and Hislop, S. (2022), Signs of resilience in resprouting Eucalyptus forests, but areas of concern: 1 year of post-fire recovery from Australia's Black Summer of 2019–2020, *International Journal of Wildland Fire* doi:10.1071/WF21089

56 Bradstock. R, Bedward, M., & Price, O. (2021), *Risks to the NSW Coastal Integrated Forestry Operations Approvals Posed by the 2019/2020 Fire Season and Beyond*, Centre for Environmental Risk Management of Bushfires, University of Wollongong and the NSW Bushfire Risk Management Research Hub, commissioned by the NSW Forest Monitoring Steering Committee, Sydney, NSW

Forest regeneration and seed banks may also be impacted, particularly given the extreme nature of the 2019-20 fire event, which can have medium- to long-term consequences for species habitat and recolonisation. Regeneration can also be adversely affected if additional fire events occur in burnt areas that are still recovering. Affected areas are therefore considered particularly vulnerable to impacts from subsequent disturbances such as timber harvesting or fire in the next 5 to 10 years while burnt forested areas recover and regenerate.[57]

Critically, in some places the severity of the fires was such that the recovery period may be lengthy, and ability to achieve full recovery for forest condition and fauna occupancy is uncertain. For example, there may be small areas of forest loss where intense fire in particular forest types results in the conversion of previously forested areas to a non-forest vegetation type, such as woodland or grassland. The Australian Alps bioregion has been identified as an area of particular concern due to a low rate of vegetation recovery observed post-fire.[58]

Recently, coastal NSW has also experienced a series of extreme rainfall events in the period between 2020 and 2022, resulting in widespread and severe flooding in many areas. These events are likely to have had mixed outcomes in the context of NSW forests, with heavy rainfall and flooding further impacting socio-economic, soil and water values in areas that were already affected by fire. However, the increased rainfall and flooding are also expected to contribute to accelerated regeneration of fire-affected vegetation in some areas.

1.3.2 Forest recovery post-fire has implications for carbon balances

It is a commonly used assumption in carbon accounting that the forest carbon lost due to fire will be reabsorbed by the forests as they recover and regenerate in the 10-15 years post-fire.[59] However, the extent to which the forests are able to recapture the lost carbon depends on the capacity of the forests to fully recover post-disturbance, along with the absence of subsequent disturbances in the recovery period.

As highlighted in the previous section (**Section 1.3.1**), there is concern that increasingly frequent and severe droughts and fires are undermining forests' ability to fully recover after these events. Poor forest recovery is likely to reduce the amount of carbon able to be stored by the forest, resulting in net carbon emissions.[60] Similar cycles of decline relating to long post-fire recovery periods and shorter intervals between disturbance events have also been identified as a risk for soil organic carbon (see **Section 1.2**).

Projected changes in climate and fire regimes in future – including shorter recovery intervals between disturbance events – may further exacerbate this issue (see **Section 1.4**). A recent study indicates that burnt area and frequency of megafires is already increasing, with decreases in the mean number of years since the last fire observed over the last four decades.[61]

The potential shift towards reduced carbon storage and increased carbon emissions from NSW forests over time is important in the context of Government commitments to achieve net zero carbon emissions by 2050. Opportunities to better understand and manage the carbon balance of NSW forests to try and mitigate these risks are discussed in **Section 2.2**.

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57 *Ibid.*

58 Gibson, R.K. and Hislop, S. (2022), Signs of resilience in resprouting Eucalyptus forests, but areas of concern: 1 year of post-fire recovery from Australia's Black Summer of 2019–2020, *International Journal of Wildland Fire* doi:10.1071/WF21089

59 Australian Government (2020), *Estimating greenhouse gas emissions from bushfires in Australia's temperate forests: focus on 2019-20*, Australian Government Department of Industry, Science, Energy and Resources.

60 Bowman, D.M., Williamson, G.J., Price, O.F., Ndalila, M.N. and Bradstock, R.A., 2021. Australian forests, megafires and the risk of dwindling carbon stocks. *Plant, Cell & Environment*, *44*(2), pp.347-355.

61 Canadell, J.G., Meyer, C.P., Cook, G.D., Dowdy, A., Briggs, P.R., Knauer, J., Pepler, A. and Haverd, V., 2021. Multi-decadal increase of forest burned area in Australia is linked to climate change. *Nature communications*, 12(1), pp.1-11.

1.3.3 Other threats and drivers of change affecting NSW forests

While the unprecedented 2019-20 wildfires caused the largest step changes in forest indicators during the assessment period, other factors – such as loss and degradation of habitat and invasive species – pose an ongoing threat to biodiversity and forest values.[62]

Habitat loss and degradation

Habitat loss and degradation can arise as a result of anthropogenic disturbances such as vegetation clearing and land-use change, timber harvesting and grazing.

The impacts of vegetation clearing and land-use change resulting in permanent habitat loss are well known.[63] While the *NSW 2021 State of the Environment* report reported a decline in primary forest clearing[64] since 1990, secondary forest clearing (clearing of regrowth) was identified as an ongoing issue.[65] For example, cleared areas were estimated to have been greater than areas of regrowth in more than half of the last 14 years. The legacy of past clearing continues to impact the function of forest ecosystems including habitat for fauna.[66] Forest clearing also leads to a shift from living biomass to dead organic matter and eventual loss to the atmosphere, impacting the carbon cycle and net emissions.[67]

Timber harvesting generally results in local, short-term impacts on habitat followed by forest recovery and regeneration, with different silviculture types having greater or lesser impacts. FMIP analysis shows that at the state scale, timber harvesting within NSW is a comparatively minor disturbance type in comparison to other sources of forest cover loss (**Figure 17**).[68]

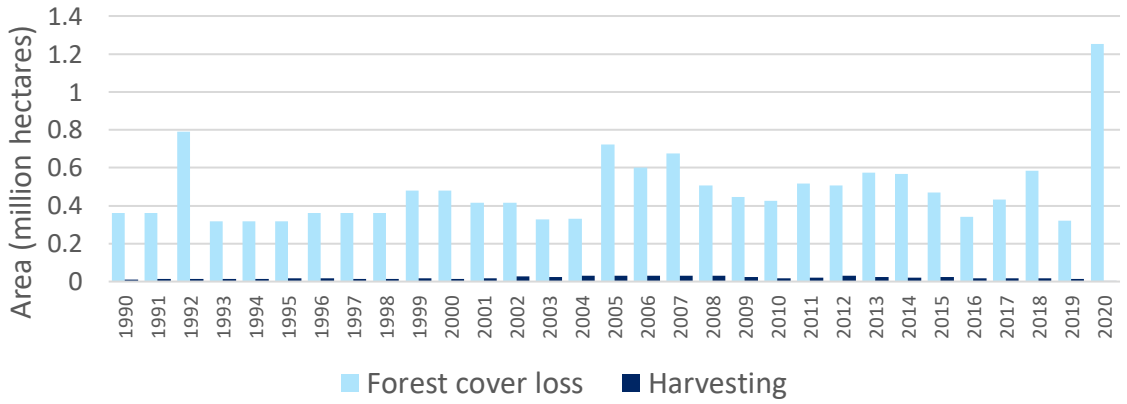

Figure **17**: **State-wide comparison of the area of forest cover loss in comparison with area harvested (excluding plantations)[69]**

62 Commonwealth of Australia (2021) *Australia State of the Environment 2021*, Commonwealth of Australia, Canberra, ACT

63 Department of Planning and Environment, https://www.environment.nsw.gov.au/topics/animals-and-plants/threatened-species/nsw-threatened-species-scientific-committee/determinations/final-determinations/2000-2003/clearing-of-native-vegetation-key-threatening-process-listing

64 Land which has been a forest since 1972

65 NSW Environment Protection Authority (2021), *NSW State of the Environment 2021*, State of NSW and the NSW Environment Protection Authority

66 Australia State of the Environment Report 2016, https://soe.environment.gov.au/

67 Moyce MC, Gray JM, Wilson BR, Jenkins BR, Young MA, Ugbaje SU, Bishop TFA, Yang X, Henderson LE, Milford HB, Tulau MJ, (2021). *Determining baselines, drivers and trends of soil health and stability in New South Wales forests: NSW Forest Monitoring & Improvement Program*, NSW Department of Planning, Industry and Environment and University of Sydney.

68 Roberts, G., Waterworth, R., de Ligt, R., McKenzie-McHarg, H., Francis, M., Roxburgh, S., Paul, K., Ximenes, F., (2022) *Carbon Balance of NSW Forests – Methodology and Baseline Report*, NSW Natural Resources Commission, commissioned by the NSW Forest Monitoring Steering Committee, Sydney, NSW

69 Roberts, G., Waterworth, R., de Ligt, R., McKenzie-McHarg, H., Francis, M., Roxburgh, S., Paul, K., Ximenes, F., (2022) *Carbon Balance of NSW Forests – Methodology and Baseline Report*, NSW Natural Resources Commission, commissioned by the NSW Forest Monitoring Steering Committee, Sydney, NSW

Appropriate rule sets, including areas permanently excluded from harvesting, can effectively distribute the impacts of timber harvesting in space and time.[70] However, species occupancy analysis identified relationships between harvesting and impacts on the distribution of some fauna species.[71] Further, this study identified nine rainforest and wet sclerophyll plant species that are likely to be sensitive to timber harvesting, noting that rainforest areas are excluded from harvesting under current protections.[72] There is also potential for cumulative impacts on forest recovery, habitat and water quality values in harvested landscapes that are also subject to fire.[73]

The impact of harvesting on forest carbon stocks is another consideration, with studies showing that sites subject to harvesting had lower carbon stocks than comparable undisturbed areas, particularly due to removal of large trees.[74]

Disturbance due to grazing activities in forests can also lead to ecosystem degradation. For instance, areas subject to increased ground disturbance, in particular forests in which grazing is permitted, were found to have lower concentrations of soil organic carbon and higher bulk density (suggesting poorer soil structure and condition) than less disturbed areas.[75]

Invasive species

According to the national *State of the Environment 2021* report, invasive species are the most common pressure on species listed under the *Environment Protection and Biodiversity Conservation Act 1999*.[76] FMIP species occupancy research highlighted feral cats and foxes as key pest species driving extinction processes, particularly for terrestrial mammals.[77] Introduced herbivores were also identified as a threatening factor for native species, such as rabbits, goats, pigs, cattle, horses and deer.[78]

A NSW National Parks and Wildlife Service fauna species monitoring program (WildCount) used remote cameras to monitor fauna in selected national parks and conservation reserves between 2012-2016. This monitoring program found that introduced species, particularly feral cats and foxes, were widespread across both northern and southern coastal forests. For example, feral cats and foxes were estimated to occur on every second monitoring site in southern NSW and

70 Mori, A.S. and Kitagawa, R. (2014). Retention forestry as a major paradigm for safeguarding forest biodiversity in productive landscapes: a global meta-analysis. *Biological Conservation*. 175: 65-73.

71 Kavanagh,R., Law, B., Drielsma, M., Gonsalves, L., Beaumont, L., Jenkins, R., Wilson, P.D., Binns, D., Thinley, P., Bulovic, N., Lemckert, F., Brassil, T., & Reid, N. (2022), *NSW Forest Monitoring and Improvement Program Project 2: Baselines, drivers and trends for species occupancy and distribution – Final Report*. Report prepared for the Natural Resources Commission as part of the NSW Forest Monitoring and Improvement Program.

72 *Ibid.*

73 Bradstock. R, Bedward, M., & Price, O. (2021), *Risks to the NSW Coastal Integrated Forestry Operations Approvals Posed by the 2019/2020 Fire Season and Beyond*, Centre for Environmental Risk Management of Bushfires, University of Wollongong and the NSW Bushfire Risk Management Research Hub, commissioned by the NSW Forest Monitoring Steering Committee, Sydney, NSW

74 Roxburgh, S.H., Wood, S.W., Mackey, B.G., Woldendorp, G. and Gibbons, P. (2006), Assessing the carbon sequestration potential of managed forests: a case study from temperate Australia. Journal of Applied Ecology, 43: 1149-1159. https://doi.org/10.1111/j.1365-2664.2006.01221.x

75 Moyce MC, Gray JM, Wilson BR, Jenkins BR, Young MA, Ugbaje SU, Bishop TFA, Yang X, Henderson LE, Milford HB, Tulau MJ, (2021). *Determining baselines, drivers and trends of soil health and stability in New South Wales forests: NSW Forest Monitoring & Improvement Program, Final report v1.1* for NSW Natural Resources Commission by NSW Department of Planning, Industry and Environment and University of Sydney.

76 Commonwealth of Australia (2021) *Australia State of the Environment 2021*, Commonwealth of Australia, Canberra, ACT

77 Kavanagh,R., Law, B., Drielsma, M., Gonsalves, L., Beaumont, L., Jenkins, R., Wilson, P.D., Binns, D., Thinley, P., Bulovic, N., Lemckert, F., Brassil, T., & Reid, N. (2022), *NSW Forest Monitoring and Improvement Program Project 2: Baselines, drivers and trends for species occupancy and distribution – Final Report*. Report prepared for the Natural Resources Commission as part of the NSW Forest Monitoring and Improvement Program.

78 *Ibid.*

were determined to have the fourth and fifth highest occupancy, respectively, of mammal species in Southern and Eden region forests.[79]

Invasive weed species such as lantana and blackberry can also pose a risk to NSW forests by changing the structure and composition of forested areas, resulting in habitat and species loss. Lantana alone is listed as a threat to 96 threatened species, populations and ecological communities listed under the *Biodiversity Conservation Act 2016.*[80]

Ongoing issues around weeds and invasive species were also raised during a recent NSW Parliamentary Inquiry, particularly in relation to the management of weeds in forested areas such as state forests and softwood plantations.[81] The inquiry reported that forestry operations in state forests can result in infestations of weeds and other invasive species, often with significant costs to adjacent private landholders. The inquiry committee recommended a review of weed management to ensure all landholders contribute to coordinated weed control.

1.4 Recent natural disasters indicate a challenging future

Climate and climate-driven disturbances are expected to continue to lead to future changes in NSW forests. Climate across NSW is predicted to become more variable in the future, with periods of drought and intense rainfall both increasing, bringing heightened fire and flood risk.

Notably, impacts from climate related disturbances are often interlinked, such that one disturbance can exacerbate another, placing forests at even higher future risk. For example, droughts may increase the severity of fires and threaten the rate and vigour of regeneration and recovery after fires. Fires may also fundamentally change forest hydrology and/or exacerbate erosion impacts from intense rainfall. As such, the 2019-20 fire season provides an example of the kind of disturbance expected more frequently in future with a changing climate.[82,83]

1.4.1 Warmer climate, changing annual rainfall and more intense rainfall events

Higher temperatures, more hot days and increased evapotranspiration are forecast for the north and south coast in the near future (2020-39), with these trends strengthening in the far future (2060-79).[84,85] There is evidence that regional climate drivers (Indian Ocean Dipole and El Niño/Southern Oscillation) are intensifying and promoting cycles of intense biomass growth followed by drought.[86]

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79 Kavanagh,R., Law, B., Drielsma, M., Gonsalves, L., Beaumont, L., Jenkins, R., Wilson, P.D., Binns, D., Thinley, P., Bulovic, N., Lemckert, F., Brassil, T., & Reid, N. (2022), *NSW Forest Monitoring and Improvement Program Project 2: Baselines, drivers and trends for species occupancy and distribution – Final Report*. Report prepared for the Natural Resources Commission as part of the NSW Forest Monitoring and Improvement Program.

80 NSW Environment Protection Authority (2021), *NSW State of the Environment 2021*, State of NSW and the NSW Environment Protection Authority

81 New South Wales Parliament (2022). *Report No. 54: long term sustainability and future of the timber and forest products industry*. Legislative Council, Portfolio Committee No. 4 – Customer Service and Natural Resources.

82 Canadell, J.G., Meyer, C.P., Cook, G.D., Dowdy, A., Briggs, P.R., Knauer, J., Pepler, A. and Haverd, V., 2021. Multi-decadal increase of forest burned area in Australia is linked to climate change. *Nature communications*, 12(1), pp.1-11.

83 Boer, M.M., Resco de Dios, V. and Bradstock, R.A., (2020). Unprecedented burn area of Australian mega forest fires. *Nature Climate Change*, 10(3), pp.171-172.

84 NSW Department of Planning, Industry and Environment (2021). *Draft Regional Water Strategy - North Coast*. At: https://www.industry.nsw.gov.au/__data/assets/pdf_file/0005/354245/nc-strategy.pdf

85 NSW Department of Planning, Industry and Environment (2020). *Draft Regional Water Strategy - South Coast*. At: https://www.industry.nsw.gov.au/__data/assets/pdf_file/0020/329015/draft-rws-sc-strategy.pdf

86 Alluvium (2020). *Review of the current state of knowledge for the monitoring of forestry impacts on waterway health in NSW coastal forests*. Report for the Natural Resources Commission.

Two scenarios from the NSW and Australia Regional Climate Modelling (NARCliM) project have been used in recent research[87] commissioned under the Coastal IFOA monitoring program:

- a 'warmer/wetter' scenario88 modelling the lower limits of likely change to fire conditions
- a 'hotter/little change in rainfall' scenario89 representing more extreme conditions driven by increased temperatures without an increase in rainfall.

The range of maximum temperature rise between these two scenarios is between 0.4-1°C in the near future (2020-2039) and 1.8-2.6°C in the far future (2060-2079).[90]

In the near future, the increases in temperature are expected to be accompanied by a decrease in annual rainfall, particularly on the NSW south coast.[91] Conversely, in the long term, trends for annual rainfall are expected to shift again, with increased rainfall expected across much of the state. Areas within the Australian Alps and South Eastern Highlands bioregions are an exception, with projections showing long-term decreases in annual rainfall in both the near and far future.

Despite an expected decrease in total annual rainfall in the near future, intense rainfall events are expected to increase under climate change.[92,93] More short-duration intense rainfall events are likely due to increased convection and thunderstorms, with hourly rainfall intensities predicted to increase by around 20 percent for every degree of warming.[94] There is also potential for more frequent east coast lows and associated prolonged rainfall events and flooding due to intensification of El Niño/Southern Oscillation cycles.[95] There is already evidence that the intensity of short duration (hourly) extreme rainfall events has increased.[96] There is also some evidence emerging that rainfall systems may be starting to stall in one place for longer periods of time, leading to greater inundation in the affected area than would be expected based on previous patterns in rainfall system dynamics.[97]

87 Bradstock. R, Bedward, M., & Price, O. (2021), *Risks to the NSW Coastal Integrated Forestry Operations Approvals Posed by the 2019/2020 Fire Season and Beyond*, Centre for Environmental Risk Management of Bushfires, University of Wollongong and the NSW Bushfire Risk Management Research Hub, commissioned by the NSW Forest Monitoring Steering Committee, Sydney, NSW

88 MIROC3.2 ensemble projecting an increase in precipitation (wetter) and an increase in temperature (warmer)

89 ECHAM5 ensemble projecting a larger increase in temperature (hotter) with little change in precipitation (little change)

90 AdaptNSW NSW Climate Change Snapshot: https://climatechange.environment.nsw.gov.au/Climate-projections-for-NSW/Climate-projections-for-your-region/NSW-Climate-Change-Downloads

91 State of NSW and Office of Environment and Heritage (2018). *Climate Change Impacts on Three Key Soil Properties in New South Wales - 2nd edition*. Sydney, NSW.

92 NSW Department of Planning, Industry and Environment (2021). *Draft Regional Water Strategy - North Coast*. At: https://www.industry.nsw.gov.au/__data/assets/pdf_file/0005/354245/nc-strategy.pdf

93 NSW Department of Planning, Industry and Environment (2020). *Draft Regional Water Strategy - South Coast*. At: https://www.industry.nsw.gov.au/__data/assets/pdf_file/0020/329015/draft-rws-sc-strategy.pdf

94 Alluvium (2020). *Review of the current state of knowledge for the monitoring of forestry impacts on waterway health in NSW coastal forests*. Report for the Natural Resources Commission.

95 *Ibid.*

96 NSW Government (2022) *2022 Flood Inquiry Volume Two: Full report*, NSW Government, Sydney

97 *Ibid.*

1.4.2 Increasing fire risk and impacts

Climate change is expected to bring increased fire risk in the future – for example, increasing burned area, fire intensity and frequency of forest megafires – as drying climatic conditions are likely to favour more intense drying cycles that pre-condition catchments for major wildfire events.[98] [99] [100]These projections apply to both the north and south coast and indicate increased risks during both prescribed burning periods (spring) and the peak fire risk season (summer).[101] Recent research[102] used the 'warmer/wetter' and 'hotter/little change in rainfall' climate change scenarios (see **Section 1.4.1**) to predict how fire regimes and future fire weather in the NSW coastal area may change in the remainder of this century. This study showed that for most days the Forest Fire Danger Index (FFDI) under the current climate (1990-2009) had low to moderate fire danger scores, with progressively fewer days in higher fire danger categories. The current pattern of low to moderate fire danger is expected to continue under the 'warmer/wetter' climate change scenario. However, the 'hotter/little change in rainfall' scenario shows a strong shift towards higher fire danger conditions, becoming pronounced over the course of this century.

The potential effects of climate change on annualised expected area burned by wildfires were also assessed for each climate change scenario in the period 2060 to 2079 (**Figure 18**). The analysis relied on modelled case study landscapes that were chosen to represent conditions at the geographical limits of the southern and north-eastern regions covered by the Coastal IFOA.

As in the fire danger index review, the 'warmer/wetter' scenario shows minor reductions in area burnt. In contrast, the 'hotter/little change in rainfall' climate scenario shows a substantial increase in area burnt over time, with landscapes around the southeast corner of NSW and the Blue Mountains showing the widest scope for change and upper northeast NSW the least likelihood of change.

98 Canadell, J.G., Meyer, C.P., Cook, G.D., Dowdy, A., Briggs, P.R., Knauer, J., Pepler, A. and Haverd, V., 2021. Multi-decadal increase of forest burned area in Australia is linked to climate change. *Nature communications*, 12(1), pp.1-11.

99 Boer, M.M., Resco de Dios, V. and Bradstock, R.A., (2020). Unprecedented burn area of Australian mega forest fires. *Nature Climate Change*, 10(3), pp.171-172.

100 King Karen J., de Ligt Robert M., Cary Geoffrey J. (2011) Fire and carbon dynamics under climate change in south-eastern Australia: insights from FullCAM and FIRESCAPE modelling. *International Journal of Wildland Fire* **20**, 563-577.

101 Office of Environment and Heritage (2014) *North Coast Climate change snapshot*. Sydney.

102 Bradstock. R, Bedward, M., & Price, O. (2021). *Risks to the NSW Coastal Integrated Forestry Operations Approvals Posed by the 2019/2020 Fire Season and Beyond*, Centre for Environmental Risk Management of Bushfires, University of Wollongong and the NSW Bushfire Risk Management Research Hub, commissioned by the NSW Forest Monitoring Steering Committee, Sydney, NSW

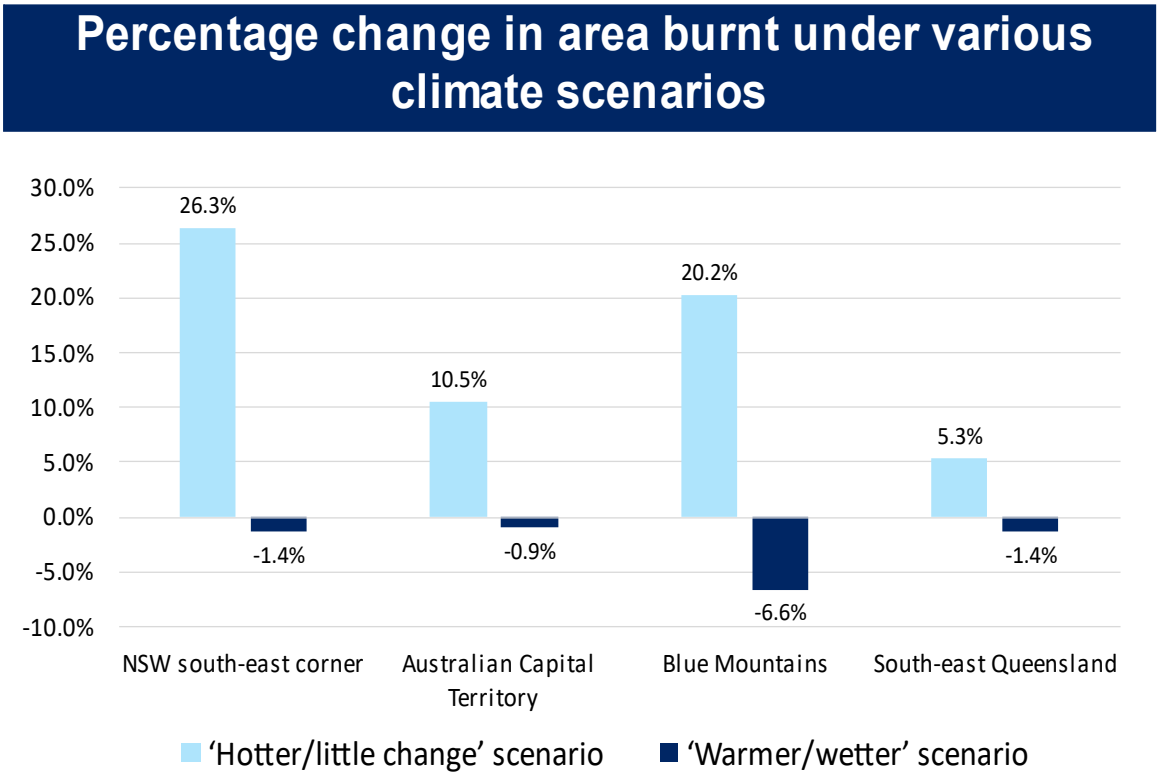

Figure 18: Simulated change in expected annual area burned by wildfire (approximate average) for selected landscapes under two far future climate scenarios (2060-2079)[103]

1.4.3 Impacts across forest indicators and values

Many of the FMIP research projects indicate there will be adverse impacts across a range of critical forest indicators under future climate and disturbance regime scenarios, including species habitat, forest carbon, soil organic carbon, soil alkalinity, and water quality.

Species habitat

The combined effects of climate change and fire represent the most significant threat to the biodiversity of eastern NSW forests.[104] Climate change is likely to affect species habitat through a range of mechanisms, including changing temperatures, soil pH, and shifts in the spatial and temporal distribution of food resources. Similarly, an increase in the frequency and severity of fires is likely to decrease the long-term availability and resilience of wildfire refugia and reduce the density of key habitat features such as large hollow-bearing trees and fallen logs.

Climate projections used as part of FMIP research into baselines, drivers and trends for species occupancy and distribution suggest that potential occupancy of 54 of 78 threatened fauna species will decline by 2070, with seven species[105] particularly impacted.[106] Fire – including variables such as years since fire and number of fires (or fire count) – was a primary driver or

103 *Ibid.*

104 Kavanagh,R., et al. (2022), *NSW Forest Monitoring and Improvement Program Project 2: Baselines, drivers and trends for species occupancy and distribution – Final Report*. Report prepared for the Natural Resources Commission as part of the NSW Forest Monitoring and Improvement Program.

105 Specifically the Rufous Bettong (*Aepyprymnus rufescens*), Rufous Scrub-bird (*Atrichornis rufescens*), Stuttering Frog (*Mixophyes balbus*), Barking Owl (*Nixox connivens*), Powerful Owl (*Ninox strenua*), Greater Glider (*Petauroides Volans*) and Sooty Owl (*Tyto tenebricosa*)

106 Kavanagh,R., Law, B., Drielsma, M., Gonsalves, L., Beaumont, L., Jenkins, R., Wilson, P.D., Binns, D., Thinley, P., Bulovic, N., Lemckert, F., Brassil, T., & Reid, N. (2022), *NSW Forest Monitoring and Improvement Program Project 2: Baselines, drivers and trends for species occupancy and distribution – Final Report*. Report prepared for the Natural Resources Commission as part of the NSW Forest Monitoring and Improvement Program.

correlate for one quarter of all fauna species investigated and had a minor association with a further 11 percent of species modelled. Of the 81 climate-sensitive plant species identified, modelling predicted that 59 percent of species will have less medium to high-suitability habitat by 2070 due to climate change, whereas 37 percent will have more. Research into changing fire regimes in the Coastal IFOA area also found that suitable habitat was predicted to decline under projected 2030 and 2070 climate change scenarios for 14 of the 24 threatened fauna species assessed.[107]

If increases in fire extent and intensity are consistent with climate change forecasts, wildfire refugia will become increasingly important for the long-term viability of native forest-dependent plant and animal species. However, more extreme fire weather and/or drought in future may also undermine protection from fire currently offered by topographic position, context, or forest structure.[108,109] As a result, persistent fire refugia that have previously been sheltered from fire or experienced only low severity fires might be more likely to burn under changing fire regimes.[110] The 2019-20 wildfires already affected ecosystems that typically do not burn[111], including an estimated 8.6 percent of the 112,145 ha of rainforest in the Gondwana Rainforest of Australia World Heritage Area.[112,113]

Forest extent, forest carbon and carbon emissions

Disturbances such as drought and fire lead to a decrease in forest canopy cover extent and the release of forest carbon, both of which are expected to be mitigated to some extent by forest regrowth and recovery. However, as outlined in **Section 1.3.2**, forest recovery – and associated ecological value, long-term commercial viability and carbon sequestration – is at risk under predicted future climates.[114] Decreasing forest canopy cover extent and increasing forest carbon emissions may therefore become a more significant issue in future if forest recovery and regeneration in disturbed areas is undermined by repeated disturbances (see **Section 2.2** for further discussion of carbon emissions).

Soil organic carbon and alkalinity

In NSW, studies show soil organic carbon storage near the surface is strongly determined by climate, particularly water availability.[115] Climate change is predicted to contribute to a future decline in soil organic carbon over most forested areas in coastal NSW.[116]

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107 Bradstock. R, Bedward, M., & Price, O. (2021), *Risks to the NSW Coastal Integrated Forestry Operations Approvals Posed by the 2019/2020 Fire Season and Beyond*, Centre for Environmental Risk Management of Bushfires, University of Wollongong and the NSW Bushfire Risk Management Research Hub, commissioned by the NSW Forest Monitoring Steering Committee, Sydney, NSW

108 Krawchuk, M.A., Meigs, G.W., Cartwright, J.M., Coop, J.D., Davis, R., Holz, A., Kolden, C. and Meddens, A.J.H. (2020). Disturbance refugia within mosaics of forest fire, drought, and insect outbreaks. *Frontiers in Ecology and the Environment*. 18: 235-244.

109 Nitschke et al. (2020). Spatial and temporal dynamics of habitat availability and stability for a critically endangered arboreal marsupial: implications for conservation planning in a fire-prone landscape. *Landscape Ecology* 35: 1553-1570.

110 Krawchuk, M.A., Meigs, G.W., Cartwright, J.M., Coop, J.D., Davis, R., Holz, A., Kolden, C. and Meddens, A.J.H. (2020). Disturbance refugia within mosaics of forest fire, drought, and insect outbreaks. *Frontiers in Ecology and the Environment*. 18: 235-244.

111 NSW Department of Premier and Cabinet (2020), *Final Report of the NSW Bushfire Inquiry*, Sydney, NSW.

112 Nolan, R.H., Boer, M.M., Collins, L. Resco de Dios, V., Clarke, H., Jenkins, M., Kenny, B. and Bradstock, R.A. (2020). Causes and consequences of eastern Australia's 2019-20 season of mega-fires. *Global Change Biology.* 26: 1039-1041.

113 Peacock, R. J, and Baker, P.J. (2022) *Informing post-fire recovery planning of northern NSW rainforests*. Bushfire and Natural Hazards CRC, Melbourne.

114 Bowman, D.M., Williamson, G.J., Price, O.F., Ndalila, M.N. and Bradstock, R.A., 2021. Australian forests, megafires and the risk of dwindling carbon stocks. *Plant, Cell & Environment*, *44*(2), pp.347-355.

115 Hobley, E., Wilson, B., Wilkie, A., Gray, J. and Koen, T., 2015. Drivers of soil organic carbon storage and vertical distribution in Eastern Australia. *Plant and Soil*, *390*(1), pp.111-127

116 Moyce MC, Gray JM, Wilson BR, Jenkins BR, Young MA, Ugbaje SU, Bishop TFA, Yang X, Henderson LE, Milford HB, Tulau MJ, (2021). *Determining baselines, drivers and trends of soil health and stability in New South Wales forests: NSW Forest Monitoring & Improvement Program, Final report v1.1* for NSW Natural

While the magnitude of decline in soil organic carbon varied between different climate model projections, the modelling indicates there will be an ongoing loss of soil organic carbon and associated soil condition (**Figure 19**). A mean relative loss of 17 percent is projected across the north coast, rising to over 37 percent relative loss in the south.

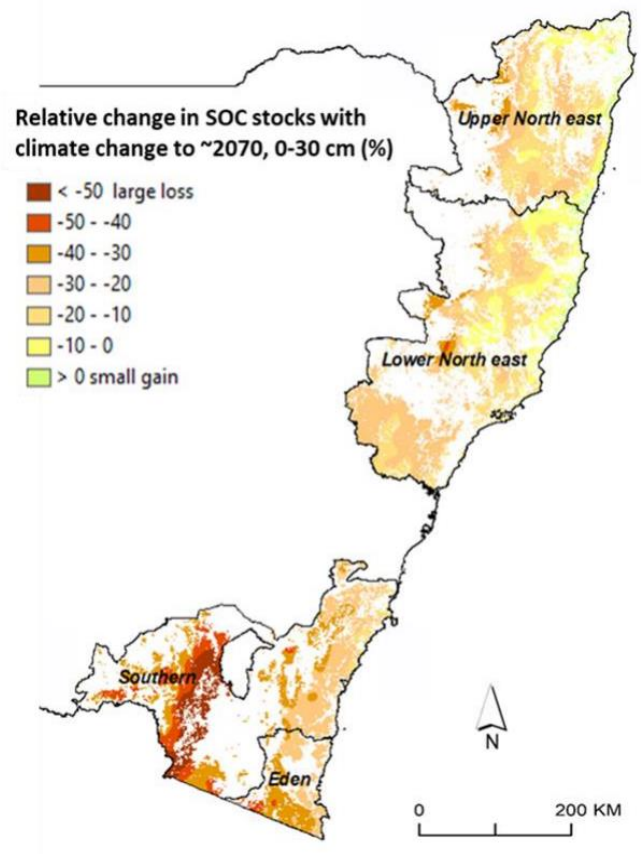

Figure 19: Predicted relative change (%) in surface soil organic carbon (SOC) concentrations with projected climate change to approx. 2070[117]

The greatest predicted losses in soil organic carbon are shown in areas with currently high soil organic carbon stocks, which has significant implications for carbon balances and government emissions targets. Highland regions, particularly in the southern Alps, are predicted to lose the largest quantity of soil organic carbon. As highlighted in **Section 1.2**, increased fire activity is likely to be a factor in this decline, as repeated disturbance events combined with long recovery periods will prevent soils from fully recovering organic carbon once lost.

Similar analysis for changes in soil pH in the same study[118] suggests a slight increase to more alkaline soils over coastal NSW by 2070. While these changes may seem minimal, any changes in soil pH may affect natural ecosystems that have established under particular pH ranges. Where significant increases or decreases (for instance 0.2 pH units or more) are predicted, there is a likelihood that native ecosystems will be adversely affected. Again, the most pronounced increases are evident in the southern region, particularly in the alpine regions where increases of more than 0.3 pH units are predicted.

Resources Commission by NSW Department of Planning, Industry and Environment and University of Sydney.

117 Moyce MC, Gray JM, Wilson BR, Jenkins BR, Young MA, Ugbaje SU, Bishop TFA, Yang X, Henderson LE, Milford HB, Tulau MJ, (2021). *Determining baselines, drivers and trends of soil health and stability in New South Wales forests: NSW Forest Monitoring & Improvement Program, Final report v1.1* for NSW Natural Resources Commission by NSW Department of Planning, Industry and Environment and University of Sydney.

118 *Ibid.*

Water quality, flows and waterway health

Forecasts of larger and more intense wildfires are concerning given that wildfires can trigger widespread increases in erosion rates with major implications for water quality and waterway health.[119] Typically, the infiltration capacity of forest soil is reduced after a fire and sediment transport into streams increases. For example, after high severity wildfire sediment transport into waterways is often 1-2 orders of magnitude higher than background rates.[120]

Large scale disturbances such as the 2019-20 fires can also fundamentally change forest hydrology and increase the recovery time for waterways, particularly if regeneration is suppressed by multiple fires.[121] Recent research[122] assessing the impacts of the 2019-20 bushfires on Coastal IFOA outcomes suggested it was likely that the fires increased the potential for significant soil erosion during the rainfall events that followed, particularly on ridges and upper slopes. Following the 2019-20 wildfires, modelled soil erosion risk increased by 143 percent in state forests and 113 percent in national parks, with the highest average post-fire erosion rates predicted in the NSW North Coast and South East Corner bioregions.[123]

Similarly, the projected rise in intense rainfall events also has the potential to affect water quality in forested catchments, with increases in erosion rates and sediment delivery expected with the predicted increased intensity and duration of rainfall events. Reducing sources of erosion and sedimentation arising from forestry activities – particularly by improving the forest road network and drainage crossings – will become increasingly important in this context.
In addition, more frequent cycles of drought and recovery are also likely to further exacerbate recent trends around declining stream flow quantity in forest catchments (**Section 1.1**), with the potential for associated impacts on water quality.

1.5 South coast and alpine regions are most at risk

1.5.1 High risk regions following the 2019-20 wildfires

The South Coast

South coast forests support a range of biodiversity, cultural, social and economic values. For example, this region includes key habitat areas such as the Murrah Koala Flora Reserves, which provide habitat for the last significant koala population on the NSW south coast, as well as other threatened species such as the long-nosed potoroo, yellow-bellied glider and powerful owl.[4] Over 40 percent of the South East Corner bioregion is dedicated to the reserve system.

119 Bradstock. R, Bedward, M., & Price, O. (2021). *Risks to the NSW Coastal Integrated Forestry Operations Approvals Posed by the 2019/2020 Fire Season and Beyond*, Centre for Environmental Risk Management of Bushfires, University of Wollongong and the NSW Bushfire Risk Management Research Hub, commissioned by the NSW Forest Monitoring Steering Committee, Sydney, NSW

120 Alluvium (2020). *Review of the current state of knowledge for the monitoring of forestry impacts on waterway health in NSW coastal forests*. Report for the Natural Resources Commission.

121 Guo, D., Hou, X., Saft, M., Webb, J.A., Western, A.W. (2010) *Report for NRC Forest Baseline & Trend Indicators - Project 3 Task 2 - Long-term trends of Water Quality and Quantity in NSW RFA forests*. University of Melbourne.
Bradstock. R, Bedward, M., & Price, O. (2021). *Risks to the NSW Coastal Integrated Forestry Operations Approvals Posed by the 2019/2020 Fire Season and Beyond*, Centre for Environmental Risk Management of Bushfires, University of Wollongong and the NSW Bushfire Risk Management Research Hub, commissioned by the NSW Forest Monitoring Steering Committee, Sydney, NSW

122 Bradstock. R, Bedward, M., & Price, O. (2021). *Risks to the NSW Coastal Integrated Forestry Operations Approvals Posed by the 2019/2020 Fire Season and Beyond*, Centre for Environmental Risk Management of Bushfires, University of Wollongong and the NSW Bushfire Risk Management Research Hub, commissioned by the NSW Forest Monitoring Steering Committee, Sydney, NSW

123 NSW and Department of Planning, Industry and Environment (2020). *NSW Fire and the Environment 2019–20 Summary Biodiversity and landscape data and analyses to understand the effects of the fire events*. Available at: NSW Fire and the Environment 2019-20: Summary

As described throughout **Sections 1.2** and **0**, the 2019-20 wildfires were more intense in southern coastal NSW than in northern coastal NSW, both in terms of extent and intensity. Many state forests and national parks were affected, including the north-western edges of the Murrah Koala Reserves. There was a large shift into higher risk categories for vegetation on the south coast based on fire frequency thresholds. The fires also impacted the timber industry, with substantial declines in wood supply and sustainable yield forecasts. The south coast was also shown to have experienced the largest declines in catchment flows over the last 30 years, and to be under pressure from invasive species such as cats and foxes.

The south coast forests – along with the species, communities and industries that depend on them – are therefore considered particularly vulnerable to subsequent disturbances and impacts in the short-term during the post-fire recovery period.

Australian Alps

The Australian Alps bioregion (the Alps) in NSW has been highlighted as an area of concern based on an analysis[124] of post-fire vegetation recovery, as this area:

- had the lowest proportion of post-fire recovery in this study
- is generally dominated by slow-growing, fire-sensitive species and is likely to be sensitive to environmental change
- has had recent increases in fire frequency that exceed the historical average
- includes areas with positive flammability feedback dynamics, this is where recently burned forests are more flammable than mature forests.

Much of the Australian Alps is part of the Kosciuszko National Park, dedicated for conservation outcomes and recreation. This is the largest national park in NSW and contains unique glacial landscapes and unusual assemblages of plants and animals that are not found elsewhere.[125] A recent survey confirmed that there is a koala population in the south-eastern region of Kosciuszko National Park, as well as other threatened species including the southern greater glider and the yellow-bellied glider.[126]

The 2019-20 fires affected a third of the national park (around 231,000 hectares or 34 percent).[127] A study focusing on adjacent alpine areas in Victoria, specifically areas dominated by *Eucalyptus pauciflora* subsp. *niphophila* (Snow Gum, Myrtaceae), showed that woodland structure in areas dominated by this species has been altered due to frequent fire.[128] Areas subject to fire twice within a decade were shown to have no saplings above the treeline, despite saplings being common pre-fire. Fire frequency also affected the stand structure of subalpine woodlands, highlighting the risk to recruitment in sensitive alpine areas subject to frequent fires.

Alongside the fire impacts, the Alps region is under pressure from threats such as pests, weeds and dieback. For example, a study in Kosciuszko National Park showed that grazing pressure from pest animals – predominantly from feral horses, but also from deer – has increased in recent decades, with significant environmental impacts.[129] Impacts associated with feral horse populations include changing vegetation structure, damage to stream banks and reduction in

124 Gibson, R.K. and Hislop, S. (2022), Signs of resilience in resprouting Eucalyptus forests, but areas of concern: 1 year of post-fire recovery from Australia's Black Summer of 2019–2020, *International Journal of Wildland Fire,* 31, 545-557.
125 Department of Planning, Industry and Environment (2006). *Kosciuszko National Park Plan of Management*.
126 Marsh, KJ; Skewes, J; and Lindemayer, D (2022). *Koala surveys in Kosciuszko National Park - Final report*, report by Australian National University for the NSW National Parks and Wildlife Service
127 Department of Planning, Industry and Environment (2020). *Resort Round-up Newsletter Autumn 2020*.
128 Naccarella A, Morgan JW, Cutler SC, Venn SE (2020) Alpine treeline ecotone stasis in the face of recent climate change and disturbance by fire. *PLoS ONE* 15(4): e0231339
129 Ward-Jones, J., Pulsford, I., Thackway, R., Bishwokarma, D. and Freudenberger, D. (2019), Impacts of feral horses and deer on an endangered woodland of Kosciuszko National Park. *Ecol Manag Restor*, 20: 37-46.

water quality.[130] They also threaten native fauna due to changes in vegetation, competition for food resources and destruction of burrows.[131]

Weeds are also an issue, with non-native species being spread across the region by activities like grazing, construction, tourism and recreation (including ski resorts).[132] Weed management is complicated in high conservation value alpine regions as various control options, including the use of specific herbicides, may not be suitable in these areas.[133]

To the south east of the Alps, extensive dieback of the dominant eucalypt species (*Eucalyptus viminalis*, known as the manna gum, white gum or ribbon gum) has also been observed across the Monaro plains, which may have serious ecological implications for that region and surrounding areas, including the Alps.[134] Further, dieback incidents are reportedly spreading to different eucalypt species and new areas, including to the southern areas of Namadgi National Park in the Australian Capital Territory, which adjoins the Alps region to the north-east.[135]

1.5.2 Future pressures and threats due to climate change

Looking further ahead, regions like the Australian Alps and South Coast are also anticipated to be at highest risk from projected changes in climate and fire activity.

Specifically, these regions are expected to experience increases in temperature in both the near- and far-future (**Figure 20**) and decreases in annual rainfall in the near-future (**Figure 21**). Notably, **Figure 21(b)** shows that areas around the Alps are not expected to experience the longer-term increases in annual rainfall forecast across other areas of the state.

The southern alps are also predicted to lose the largest quantity of soil organic carbon under climate change scenarios, while also experiencing the most pronounced increases in soil pH, with predicted increases of more than 0.3 pH units.[136]

A recent paper highlighted three key threats for the Australian Alps due to climate change: reduced snow cover (depth and duration); increased fire frequency and severity; and a shift in vegetation composition from alpine to sub-alpine vegetation communities.[137] In addition, weeds that are currently limited by climatic conditions to sub-alpine environments are expected to expand their distribution under the warmer conditions forecast in climate change projections.[138]

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130 Driscoll, D.A., Worboys, G.L., Allan, H., Banks, S.C., Beeton, N.J., Cherubin, R.C., Doherty, T.S., Finlayson, C.M., Green, K., Hartley, R., Hope, G., Johnson, C.N., Lintermans, M., Mackey, B., Paull, D.J., Pittock, J., Porfirio, L.L., Ritchie, E.G., Sato, C.F., Scheele, B.C., Slattery, D.A., Venn, S., Watson, D., Watson, M. and Williams, R.M. (2019), Impacts of feral horses in the Australian Alps and evidence-based solutions. *Ecol Manag Restor*, 20: 63-72. https://doi.org/10.1111/emr.12357

131 *Ibid.*

132 Frances M. Johnston, Catherine M. Pickering (2001). Alien Plants in the Australian Alps, *Mountain Research and Development*, 21(3), 284-291

133 *Ibid.*

134 Ross C, Brack C. 2015. Eucalyptus viminalis dieback in the Monaro Region, NSW. *Australian Forestry* 78: 243–253. doi:10.1080/00049158.2015.1076754

135 C. Ross & C. Brack (2017) Monaro dieback: simple answers are too simple, *Australian Forestry*, 80:2, 113-114, DOI: 10.1080/00049158.2017.1311762

136 Moyce MC, Gray JM, Wilson BR, Jenkins BR, Young MA, Ugbaje SU, Bishop TFA, Yang X, Henderson LE, Milford HB, Tulau MJ, (2021). *Determining baselines, drivers and trends of soil health and stability in New South Wales forests: NSW Forest Monitoring & Improvement Program, Final report v1.1* for NSW Natural Resources Commission by NSW Department of Planning, Industry and Environment & University of Sydney.

137 Hoffmann, A.A., Rymer, P.D., Byrne, M., Ruthrof, K.X., Whinam, J., McGeoch, M., Bergstrom, D.M., Guerin, G.R., Sparrow, B., Joseph, L., Hill, S.J., Andrew, N.R., Camac, J., Bell, N., Riegler, M., Gardner, J.L. and Williams, S.E. (2019), Impacts of recent climate change on terrestrial flora and fauna: Some emerging Australian examples. *Austral Ecology*, 44: 3-27. https://doi.org/10.1111/aec.12674

138 Frances M. Johnston, Catherine M. Pickering (2001). Alien Plants in the Australian Alps, *Mountain Research and Development*, 21(3), 284-291

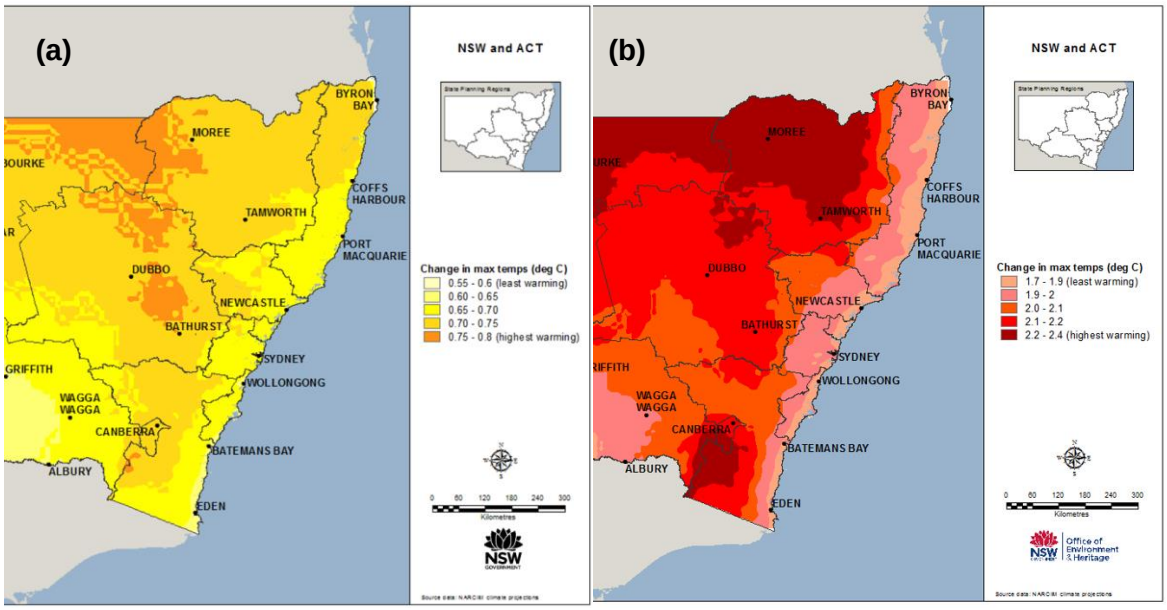

Figure 20: Projected changes in mean daily annual maximum temperatures for (a) near-future change period (1990-2009 to 2020-39) and (b) far-future change period (1990-2009 to 2060-79)[139]

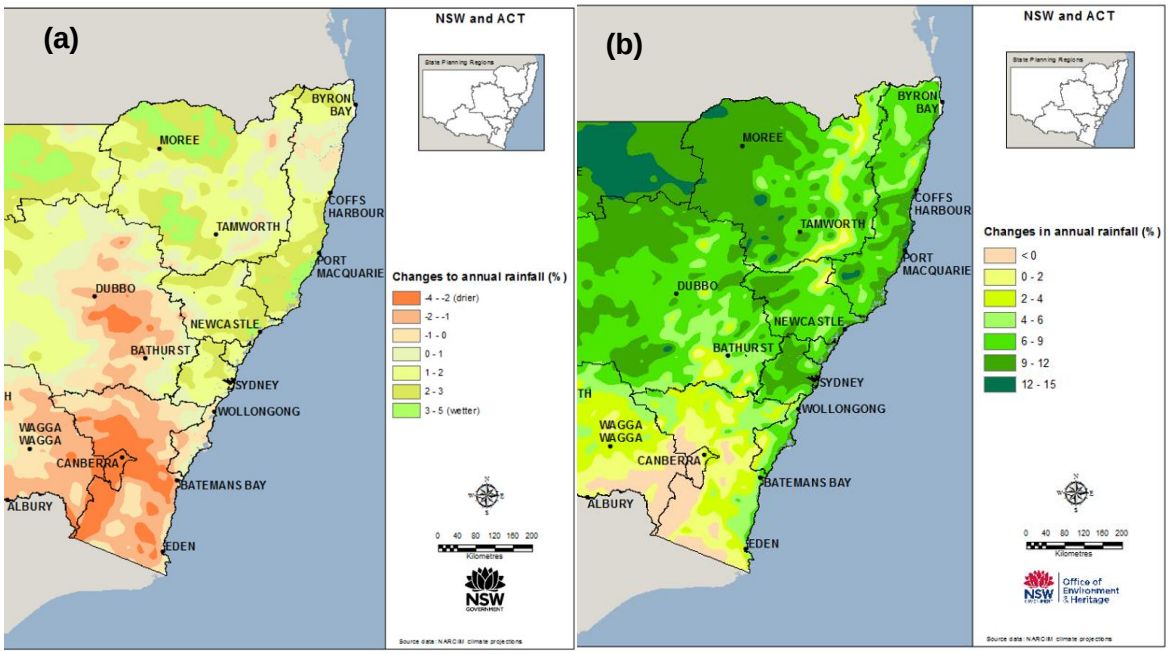

Figure 21: Projected changes in mean annual precipitation for (a) near-future change period (1990-2009 to 2020-39) and (b) far-future change period (1990-2009 to 2060-79)[140]

139 AdaptNSW NSW Climate Change Snapshot: https://climatechange.environment.nsw.gov.au/Climate-projections-for-NSW/Climate-projections-for-your-region/NSW-Climate-Change-Downloads

140 *Ibid.*

2 Managing the natural capital within NSW forests

The findings presented in the first section of this report provide insights into the status and trajectory of NSW's forests, and the future challenges forests and forest managers are facing. In this section, this evidence is used to inform a discussion about what can be done to protect, maintain and enhance future forest values.

2.1 Action is needed to prevent loss of future forest values

In future forest scenarios developed under the FMIP, a panel of leading experts in forestry, resilience and future thinking concluded that a business-as-usual approach would result in reduced and declining forest values.

Without intervention, existing pressures – such as land-use change, habitat fragmentation and degradation, and invasive species – will combine with new threats from climate change and repeated shocks from disturbances like droughts, fires and floods. The result will be ongoing declines in the resilience, health and productivity of NSW forests, particularly in higher risk areas such as alpine regions and the south coast of NSW. It is therefore likely that the values and services currently supported by NSW forests in high-risk regions may decrease in the future.

There is potential for more positive future pathways in which the social and economic values of forests and emerging risks from climate change are recognised and actively managed across all tenures. Recent natural disasters have highlighted the central role of the environment in human well-being, and there is increasing community demand for leadership and investment in environmental management to protect our natural resources and the associated benefits and services they provide.

A central theme of the recent *2021 Australian State of the Environment report*[141] is the importance of the environment to human wellbeing. It sets out the ongoing challenges and threats facing our environment and the concerning declining trends observed for many environmental values. The report calls for a more strategic focus on planning for a sustainable future, new, reliable sources of funding and integrated policies and management actions to address drivers of environmental change.

The NSW Government is increasingly recognising the value of natural capital and is currently developing a *NSW Natural Capital Statement of Intent*, which will guide and inform government decision-making around environmental assets and services.[142] This approach highlights the interlinkages between the economy and environmental assets and services, and the importance of natural capital in shifting towards a sustainable, low-carbon emission future that strikes a balance between maintaining and enhancing natural capital and promoting economic growth.

The *NSW Climate Change Adaptation Strategy* also sets out range of priorities to prepare and respond to climate change. The Government has committed over $93 million over the next 8 years to deliver the strategy, including initiatives such as scenario analysis and risks assessment. Information generated under the FMIP – such as scenario analysis, fauna models and baseline data – are critical inputs to inform strategic actions.
Given this policy context and likely future challenges, the time is right for renewed and sharper focus on forests and the essential values and services they provide, supported into the future by strategic, coordinated management and adequate investment through long-term funding. In the following sections we set out initiatives that will address these challenges.

141 Commonwealth of Australia (2021) *Australia State of the Environment 2021*, Commonwealth of Australia, Canberra, ACT
142 NSW Government (2022). *Consultation Draft NSW Natural Capital Statement of Intent*.

2.2 Understanding and managing carbon balances

Direct coordinated action is needed to address the growing climate risk, including actions to monitor and reduce carbon emissions. In relation to NSW forests, relevant NSW Government plans and objectives include:

- NSW Government's overarching objective to achieve net zero emissions by 2050, supported by the NSW Climate Change Adaptation Strategy[143] and the Net Zero Plan Stage 1: 2020-2030[144]
- NSW National Parks and Wildlife Service's **net zero to carbon positive by 2028** action plan, whereby carbon sequestration in national parks eventually exceeds emissions associated with park management activities, including the following targets:
  - **2025 target**: reduce carbon emissions by 55 percent
  - **2028 target**: reach net zero and become carbon positive[145]
- NSW Environment Protection Authority's draft **climate change policy**[146] and **action plan**[147] to meet their statutory objectives and obligations and support NSW Government's broader objectives, including committing to being **carbon-neutral by 2030**
- Forestry Corporation of NSW must meet the Australian Standard for Sustainable Forest Management to retain their sustainable forest management certification, which includes a criterion around **maintaining forests' contribution to the carbon cycle**.

NSW forests are a significant carbon resource contributing to the global carbon cycle, with the potential to either deliver beneficial carbon capture or contribute to carbon emissions. The findings presented within this report suggests that, without a major intervention, NSW forests may shift from a carbon storage to net carbon emitter in the coming decades, undermining key Government carbon emission commitments.

However, a key goal of sustainable forest management is maintaining or enhancing forest carbon stocks. With appropriate management and interventions, NSW forests can contribute to mitigating carbon emissions through carbon capture and storage. Monitoring, modelling and research is needed to determine which approaches and interventions – such as prescribed burning, mechanical thinning and harvesting, assisted regeneration, and/or tree retention/avoided losses – will maximise carbon storage while also maintaining productivity and addressing risks from increased fire activity.[148]

As highlighted previously in this report, there are underlying assumptions within current carbon accounting around the capacity of forest recovery to effectively offset carbon emissions associated with forestry activities and other disturbances such as fire and drought. These emissions are currently considered to be temporary and are not included in long-term net carbon emission totals. However, there is a significant risk that climate change and changing disturbance regimes may undermine the ability of affected areas to recover, leading to a

143 NSW Government (2022) *NSW Climate Change Adaptation Strategy*, NSW Government.
144 Department of Planning, Industry and Environment (2020). *Net Zero Plan Stage 1: 2020–2030*, Environment, Energy and Science (in Department of Planning, Industry and Science) on behalf of the NSW Government
145 NSW Department of Planning, Industry and Environment (2021). *NSW National Parks and Wildlife Service - Carbon Positive by 2028*, Environment, Energy and Science, Department of Planning, Industry and Environment
146 State of New South Wales and the NSW Environment Protection Authority (2022), *Environment Protection Authority Climate Change Policy – Draft for consultation*. NSW Environment Protection Authority, Parramatta NSW.
147 State of New South Wales and the NSW Environment Protection Authority (2022). *Environment Protection Authority Climate Change Action Plan 2022–25 – Draft for consultation*. NSW Environment Protection Authority, Parramatta NSW.
148 Bowman, D.M., Williamson, G.J., Price, O.F., Ndalila, M.N. and Bradstock, R.A., 2021. Australian forests, megafires and the risk of dwindling carbon stocks. *Plant, Cell & Environment*, *44*(2), pp.347-355.

commensurate increase in carbon emissions and jeopardising Government's ability to meet its stated emissions targets. Accordingly, forest recovery needs to be monitored to determine whether the rate of recovery (and thus carbon capture) is meeting expectations, with the capacity to trigger active interventions to improve regeneration outcomes as needed.

At the state scale, ongoing monitoring and assessment of trends in forest carbon are needed to determine whether the range of chosen management approaches being applied across NSW forests are achieving the desired carbon storage outcomes, and whether overall emissions targets are being met. The FMIP delivered a comprehensive spatial and temporal analysis of the carbon balance in NSW forests from 1990 to 2020.[149] This research advanced the understanding of forest carbon balances and trends across NSW over the past 30 years, laying a foundation for ongoing assessment and accountability around forest carbon and carbon emissions in NSW.

In addition, investment in soil monitoring needs to increase to support accurate carbon accounts and management. For example, in the last decade less than 50 soil carbon measurements have been collected by government across NSW Regional Forest Agreement regions.[150]

2.2.1 Strengthening regulation with the best available science

To support Government policy objectives and statutory obligations for climate change, the Government should incorporate the latest climate science and forest data for upcoming regulatory reviews such as for the Coastal Integrated Forestry Operations Approval (CIFOA) and Land Management Codes – Native Vegetation.

The recently approved PNF Codes of Practice includes a new mechanism to adaptively respond to impacts to unforeseen events, recognising the increasing risk of wildfires, droughts and dieback under predicted changes in climate.[151] There is no such 'force majeure' mechanism in the Coastal IFOA for instance.

Similarly, the revised bilateral RFA agreements recognise 'climate change is driving more extreme weather events' that will impact NSW forests. Both governments have committed new information, including climate change risks and adaptation responses will continue to support RFA implementation. For example, NPWS must identify and integrate relevant climate risks and adaptation responses into the monitoring, evaluation and reporting requirements in Regional ESFM Plans and plans of management under the NSW *National Parks and Wildlife Act 1974*.[152]

149 Roberts, G., Waterworth, R., de Ligt, R., McKenzie-McHarg, H., Francis, M., Roxburgh, S., Paul, K., Ximenes, F., (2022) *Carbon Balance of NSW Forests – Methodology and Baseline Report*, Mullion Group.

150 Moyce, M.C.; Gray, J.M.; Wilson, B.R.; Jenkins, B.R.; Young, M.A.; Ugbaje, S.U.; Bishop, T.F.A.; Yang, X.; Henderson, L.E.; Milford, H.B.; Tulau, M.J. (2021). *Determining baselines, drivers and trends of soil health and stability in New South Wales forests: NSW Forest Monitoring & Improvement Program*, NSW Department of Planning, Industry and Environment and University of Sydney.

151 See for example, Private Native Forestry – Code of Practice for Northern NSW. Available at https://www.lls.nsw.gov.au/__data/assets/pdf_file/0019/1401661/PNF-Code-Northern-NSW.pdf

152 Cl 48(i) DEED OF VARIATION IN RELATION TO THE REGIONAL FOREST AGREEMENT FOR THE NORTH EAST REGION – Commonwealth of Australia ,and The State of New South Wales

2.3 Addressing threats, increasing resilience and managing risks

Forest owners and managers have a chance now to wisely and proactively invest in improving the health and resilience of forest ecosystems, and addressing anticipated future threats and risks, to avoid major shocks and maintain forest values into the future.

Government should adopt a future-focused approach that draws and expands on the future forest scenarios work initiated under the FMIP.[153] Eight exploratory scenarios have been identified representing different plausible futures for NSW forests to 2050, ranging from optimistic to pessimistic. These scenarios have been developed by experts in forest science, forestry and resilience and future thinking with input from all NSW Government agencies responsible for managing or monitoring NSW forests across all tenures. This work brings forest planning and management in line with best practice approaches used in infrastructure and transport planning.

The future forest scenarios are designed to prompt further exploration of the implications of alternative policy and forest management decisions. These decisions should also be informed by a risk assessment process to identify and target at-risk regions, forest ecosystems, species and/or production systems for proactive management. Priority areas could include areas that are likely to be subject to increased natural disturbances due to climate change, or ecosystems and species that are on a declining trajectory due to ongoing pressures and threats. Evidence such as the FMIP's baseline, status and trend information as informed by future monitoring, climate change scenarios and forest modelling should inform the risk assessment.

Strategic interventions and actions to mitigate priority risks can then be identified, including:

- managing immediate, ongoing threats to forest values such as pests, weeds and clearing
- accelerating or ensuring achievement of forest management outcomes, such as post-fire recovery and regeneration
- managing risks associated with changing climate and increased fire, drought and intense rainfall events.

These intervention strategies, including their intent and potential actions, are outlined further in **Table 2**. However, a strategy outlining the best course of action needs to be carefully assessed and debated based on the best science and dialogue with the community and industry. Success will rely on mutual understanding and broad support for proposed actions. Importantly, any actions need to be supported by monitoring and assess the success or otherwise of the interventions.

Table 2: strategies for interventions in priority areas

Strategy	Intent	Potential actions
Managing immediate, ongoing threats to forest values	Improving the management of existing threats such as habitat loss and degradation and invasive species to increase the health and resilience of forest ecosystems so these areas are better able to endure or adapt to increasing threats and pressures in future	▪ Reducing loss of forest extent due to land clearing ▪ Addressing total grazing pressure in forests, and removing grazing in high-risk areas ▪ Investing in pest and weed control, prioritising horse, fox, feral cat and deer control

153 Cork, S., Ferrier, S., Kanowski, P., & Lade, S. (2022) *NSW Future Forest Scenarios report*, Australian National University.

Strategy	Intent	Potential actions
Active management to accelerate or ensure the achievement of forest management outcomes	Applying targeted and active management interventions to achieve outcomes with a greater degree of control and certainty than naturally occurring processes or passive approaches	▪ Accelerating the provision of essential habitat for fauna with artificial tree hollows[154] that can require 100 years or more to naturally develop ▪ Native forest reforestation and assisted natural regeneration for production and biodiversity outcomes s ▪ Adopting Aboriginal land management practices such as cultural burns to improve forest and soil health
Managing risks associated with changing climate and increased fire, drought and intense rainfall events	Managing emerging and future risks expected as a result of climate change, including heightened fire, drought and flood risks.	▪ Revised fire hazard reduction activities and investment in new rapid response fire suppression technologies ▪ Improving forest road networks to reduce sedimentation in extreme rainfall events ▪ Investing in protection of species at high risk from climate change, including potential assisted migration of species

The Commission notes recent significant issues-based investments towards priority species such as koalas. While these investments have the potential to enhance outcomes for other species, there are likely opportunity costs for other species such as hollow-dependent birds and mammals. In addition, it is likely that increased investment is needed to address broader issues and risks, such as widespread pests and weeds, or sedimentation from the forest road network.

The Commission also notes the NSW Government is investing to improve NSW fire management in response the 2020 independent bushfire inquiry. While the NSW Government periodically reports on progress, an independent assessment on the impact of new fire management technologies on fire frequency and severity and the flow-on effects for forest values and services may be warranted in the future.

When identifying potential management options, decision makers should consider a wide range of approaches and knowledge sources. In particular, identifying opportunities to better involve and learn from Aboriginal peoples, including using Aboriginal land management practices such as cultural burning to improve forest ecosystem health where appropriate (see **Section 0**).

Ideally, forest values should be enhanced across all tenures, including within the reserve system (such as national parks) as well as on multi-use forest tenures (such as state forests) and on private land. As such, any actions and interventions should therefore be strategic, coordinated and applied across all tenures as needed.

154 For example, approaches see Biodiversity Conservation Trust Guideline for Artificial Hollows for Private Land Conservation Agreements (2020)

2.4 Securing values through dedicated funding

The 2019/20 wildfires were unprecedent in their size and severity. The fires were closely followed by floods in 2021 and 2022 directly impacting the health of NSW forests and the values they support for the community and biodiversity.

Governments funded programs in direct response to support community recovery and address immediate impacts on NSW forests – for example, relief programs for wildlife rehabilitators[155] and habitat and species.[156] Funding has shifted to support medium to longer term activities for landscape rehabilitation.[157]

The community has welcomed these initiatives. However, the continued demand for funding is likely given the growing consensus that similar scale events will become increasingly frequent in the future. Reactive, one-off funding decisions to address such events may lead to sub-optimal outcomes, or the permanent loss of key natural and economic assets at worst.

Along with the opportunity to establish a strategic outlook and action plan for NSW forests **(Section 2.3)**, governments also have the opportunity to arrange for a dedicated fund to implement the strategy and respond to significant events. Without additional investment at a forest ecosystem scale there is a real risk that NSW will not be able to secure the asset value and services that NSW forests can provide into the future.

The Commission recognises the competing demands on government budgets particular post-COVID and recent natural disasters. It may be prudent for the government and agencies to consider alternative funding sources that can spread the costs required to secure outcomes from NSW forests between state government and the major commercial and community beneficiaries. For example, the Government could consider recycling land, building and heritage assets, and introducing new levies, micro levies or similar taxes. There also may be more opportunities for greater efficiencies with for instance more effective use of competitive tendering to deliver management activities at a larger, cross-tenure scale.

2.5 Strengthening Aboriginal decision making and management

Recent Aboriginal-led case studies exploring cultural values assessments in NSW forests highlighted that there are significant knowledge gaps around Aboriginal cultural values, particularly where Aboriginal people lack access to, or involvement in, land and its management. There is an opportunity and strong desire from case study participants to build on the outcomes achieved and strengthen the participation of Aboriginal peoples in forest management and decision making.

The case studies also demonstrated the opportunities offered by Aboriginal-owned and managed tenures, specifically Indigenous Protected Areas. These areas benefit from resourcing for Ranger groups, the ability to lead planning and management from a Country and landscape perspective, locally based training and employment, opportunities for youth education and involvement, and access to and sharing of knowledge from Elders and knowledge holders.

There have been several recent NSW Government initiatives that offer opportunities to expand Aboriginal peoples' involvement and leadership in land management – this is in line with the Closing the Gap targets for increasing legal rights and interests in land and water. A key example is the proposal to expand and develop the model for Aboriginal joint management of

155 https://www.environment.nsw.gov.au/topics/animals-and-plants/native-animals/helping-wildlife-in-emergencies/bushfire-relief-for-wildlife-rehabilitators
156 https://www.dcceew.gov.au/environment/biodiversity/bushfire-recovery/funding-support
157 https://www.dcceew.gov.au/environment/biodiversity/bushfire-recovery/activities-and-outcomes/phase-2#approved-projects

the NSW national park estate, in consultation with Aboriginal people and other national park stakeholders. This offers an opportunity to increase Aboriginal involvement in land management and custodianship, including the ability to trial new joint management models and approaches.

The expansion of Aboriginal land management, cultural fire, and ranger programs has also been explored by other agencies including Local Land Services and the Forestry Corporation of NSW. These programs offer a way of improving environmental, social and economic outcomes, including by enhancing Aboriginal peoples' connection to Country, sharing knowledge of land and water management, and providing meaningful training and career pathways.

A key recommendation emerging from the Aboriginal-led case studies is support for 'whole of Country' planning processes. These processes help Aboriginal groups to proactively develop and share their aspirations and desired outcomes for Country with other land managers and highlight opportunities for partnership, training, investment and leadership.

The Commission and Local Land Services have advanced an early proposal to pilot a Whole-of-Country plan in collaboration with the Banbai Rangers and Guyra and Tamworth Local Aboriginal Land Councils, and NSW Department of Aboriginal Affairs. The pilot aligns with the NSW Government's Closing the Gap land and water targets and has received support and endorsement from key partner agencies including Aboriginal Affairs NSW, NSW Aboriginal Land Council, Department of Planning and Environment, NSW National Parks and Wildlife Service and Forestry Corporation of NSW.

2.6 Informing decision making and providing assurance

To provide relevant evidence and assurance, there is a clear need for increased, long-term investment in monitoring, evaluation and research for forest management, as well as ongoing funding for existing monitoring programs for the Coastal IFOA, Private Native Forestry Codes and Regional Forest Agreements.

As highlighted previously, forest values are already under pressure, with threats expected to increase further over time based on climate change projections. As the climate changes, we will need to identify and apply interventions to increase forest resilience and maintain carbon balances, many of which may be new approaches that involve a shift away from some long-accepted forest management practices. In this context, it is essential that we make informed decisions about how these areas are managed to try to maintain the values of these forests, based on best available knowledge and evidence.

Arguably, we are entering a state of heightened uncertainty and that existing knowledge is not necessarily going to be a good predictor of the future. Decision makers will increasingly need to draw on new research and monitoring, scenarios, data and modelling approaches to provide assurance of current management and predict what future forests will look like under various climate change and management scenarios. This will help identify key risks, priority areas for investment and appropriate land management actions and policy. Government will also need evidence to be able to predict and measure the effectiveness of various intervention options in different contexts.

The Commission notes that funding for cross-tenure forest monitoring overseen by the NSW Forest Monitoring Steering Committee ceased in Financial Year 2022, and that going forward forest monitoring on the reserve system will be carried out separately by NPWS. However, the Commission still considers cross-tenure monitoring – based on consistent methods and datasets - is critical to reliably evaluate management effectiveness and performance.

The Forest Monitoring Steering Committee will continue to oversee existing legal mandates to monitor the effectiveness of the Coastal IFOA and Private Native Forestry Codes. The

Environment Protection Authority's draft *Climate Change Action Plan 2022–25*[158] highlights the role of the FMIP in ensuring climate risks in native forestry are identified and consequences are appropriately managed under the IFOAs and Private Native Forestry codes. This aligns with Priority 1 under the broader *NSW Climate Change Adaptation Strategy*[159] to develop robust and trusted metrics and information on climate change risk.

The Local Land Services have recently committed $1.5 million over two years to commence monitoring, assessments and model improvements under the new Private Native Forestry Codes. A similar amount and long-term commitment to meet Coastal IFOA monitoring obligations is also needed when funding ceases in Financial Year 2023.

The current mandate to oversee monitoring on production forests could be further extended to other NSW IFOAs, including the River Red Gum IFOA. Further, the mandate to coordinate monitoring for Regional Forest Agreements should be formally reinstated in-line with bilateral agreements between the NSW and Australian Governments. This will ensure the NSW Government has the necessary evidence to support its commitments under the *NSW Forestry Industry Roadmap* and to continue to meet its broader national and international obligations for ecological sustainable forest management.

158 State of New South Wales and the NSW Environment Protection Authority (2022). *Environment Protection Authority Climate Change Action Plan 2022–25 – Draft for consultation*. NSW Environment Protection Authority, Parramatta NSW.

159 NSW Government (2022) *NSW Climate Change Adaptation Strategy*, NSW Government.

Attachment A – Forest Monitoring and Improvement Program overview

The FMIP delivers monitoring, evaluation, and reporting for NSW forests to improve the strategic and adaptive management of these forests over time. The FMIP was developed by the NSW Forest Monitoring Steering Committee, which is independently chaired by the Natural Resources Commission.

The NSW Forest Steering Committee is also overseeing the Coastal Integrated Forestry Operations Approval (Coastal IFOA) Monitoring Program and the Private Native Forestry Codes of Practice Monitoring Program. These programs evaluate whether the forestry activities under each instrument are achieving objectives and outcomes.

Although the FMIP is a state-wide, cross-tenure program, the various monitoring and research programs focus on different spatial scales, most often targeting the area covered by the Regional Forest Agreements and Coastal IFOA (**Figure A**).

Forest monitoring programs and research projects

The FMIP is generating data and applying a range of analytical approaches to build a stronger evidence base to inform forest management. Over the last three years, the FMIP has invested over $6 million in research projects to define baselines and identify past trends and drivers of change for NSW forests. As well as providing insights into the past trajectories and current status of NSW forests, these projects provide a foundation and tools for evaluating future scenarios, risks and management options.

Research projects have collected baseline, driver and trend evidence for the following themes:

- forest ecosystem health
- biological diversity
- soil and water resources
- productive capacity and sustainability
- contribution to global carbon cycles.

In addition, the FMIP has invested in a range of other projects focused on areas such as Aboriginal values and renewal post-fire, koala and habitat response post-fire, quantifying forest-dependent jobs, promoting citizen science, and developing future scenarios for NSW forests.

Up to 40 partners have been involved in these projects, including leading universities, Aboriginal organisations, consultancies and NSW agencies. A range of scientific approaches have been used including retrospective analysis to develop baselines, field monitoring and remote sensing, and various modelling approaches.

In addition, there have also been projects commissioned under the Coastal IFOA Monitoring Program that have delivered findings that can help inform broader forest management under the FMIP. Priority monitoring and actions will also soon commence for the Private Native Forestry Monitoring Program.

Relevant FMIP and Coastal IFOA Monitoring Program monitoring and research projects are shown in **Table A**, and the key findings from each are summarised in **Table B**. More information about the completed and ongoing research projects can be found on the Commission's website.

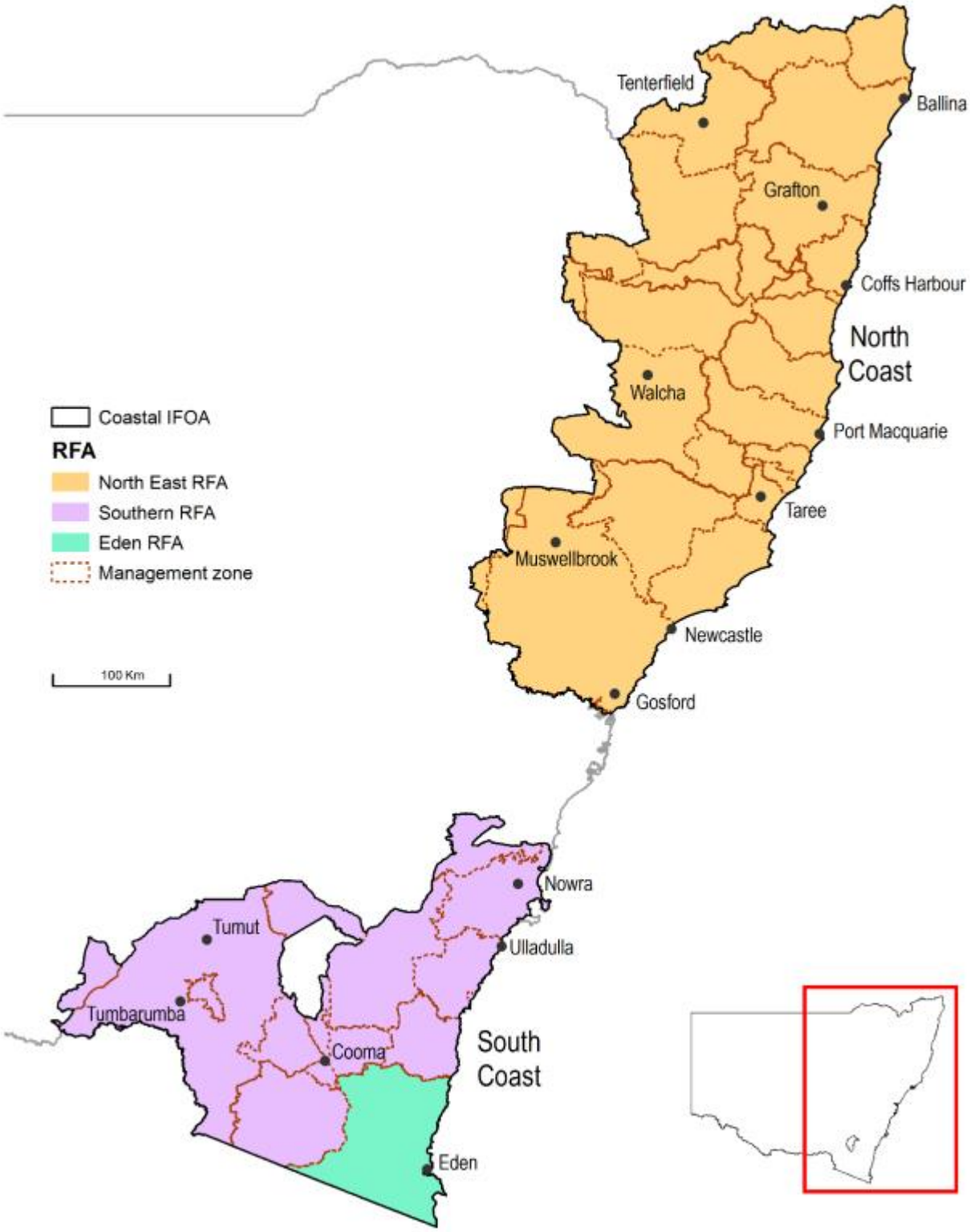

Figure A: Map showing the area of NSW covered under the Regional Forest Agreements (RFA) and Coastal IFOA

Table A: FMIP and Coastal IFOA Monitoring Program monitoring and research projects

Theme	Project title	Research team(s)	Description	Reference
Forest ecosystem health	FMIP Project FE1: Baselines, drivers and trends for forest extent, condition and health	Spatial Vision, RMIT University and PF Olsen	Sourcing historical and current datasets to establish and interpret drivers of trends in forest extent, condition and health, with an initial focus on NSW Regional Forest Agreement regions. Determining forest extent using the Landsat 25 metre grid resolution to provide annual temporal coverage from 1988 to 2019 for eastern NSW.	Spatial Vision (2022) Forest monitoring – Extent Methodology Associated dataset Spatial Vision (2022) Forest monitoring – Condition methodology Associated dataset Spatial Vision (2022) Forest monitoring – Forest loss and recovery Associated dataset
Biological diversity	FMIP Project BD1: Baselines, drivers and trends for species occupancy and distribution	University of New England, Macquarie University, NSW DPI – Forest Science, and NSW DPE	Establishing baselines in species occupancy using historical data and indicators and modelling from the NSW Biodiversity Indicators Program. Species occupancy modelling and environmental niche modelling analyses for priority fauna species. Flora community analyses for each Regional Forest Agreement region and preparation of a list of priority plant species. Analysing species trends since the 1990s where sufficient data exists.	Kavanagh,R., Law, B., Drielsma, M., Gonsalves, L., Beaumont, L., Jenkins, R., Wilson, P.D., Binns, D., Thinley, P., Bulovic, N., Lemckert, F., Brassil, T., & Reid, N. (2022), *NSW Forest Monitoring and Improvement Program Project 2: Baselines, drivers and trends for species occupancy and distribution – Final Report*.
	Project BD4: Koala and habitat response post-wildfires	Australian National University, University of Western Sydney and NSW DPI – Forest Science	Building on the Commission's koala research program, researchers from the Australian National University, University of Western Sydney and the NSW Department of Primary Industries will investigate how koalas, and their habitat – for example, occupancy and nutritional content of regeneration trees - respond in a post-fire landscape on the NSW north coast.	Natural Resources Commission (2022), *Summary paper - koala and habitat response after the 2019-20 wildfires*,

Theme	Project title	Research team(s)	Description	Reference
Soil and Water resources	FMIP Project SW1: Baselines, drivers and trends for forest water catchments	University of Melbourne	Delivering baselines, drivers and trends for water quality and quantity in the NSW Regional Forest Agreement areas.	Guo, D., Hou, X., Saft, M., Webb, J.A., Western, A.W. (2010) *Report for NRC Forest Baseline & Trend Indicators - Project 3 Task 2 - Long-term trends of Water Quality and Quantity in NSW RFA forests*, University of Melbourne.
	FMIP Project SW2: Baselines, trends and drivers for soil stability and health in forest catchments	NSW DPE, the University of Sydney and the University of New England	Delivering baselines, drivers and trends for soil stability and health in forest catchments across the NSW Regional Forest Agreement areas.	Moyce, M.C.; Gray, J.M.; Wilson, B.R.; Jenkins, B.R.; Young, M.A.; Ugbaje, S.U.; Bishop, T.F.A.; Yang, X.; Henderson, L.E.; Milford, H.B.; Tulau, M.J. (2021). *Determining baselines, drivers and trends of soil health and stability in New South Wales forests: NSW Forest Monitoring & Improvement Program*, NSW Department of Planning, Industry and Environment and University of Sydney.
	FMIP Project SW3: Evaluating forest road network to protect forest waterways	Alluvium and the NSW Soil Conservation Service		Alluvium (2022). *Evaluating forest road networks to protect water quality in NSW: final report*, Alluvium, unpublished report.
Productive capacity and sustainability	FMIP Project PC1: Baselines and trends in wood supply	Indufor	Establishing historical baselines and trends in wood supply from NSW coastal native state forests, specifically historic actual wood supply and drivers of change in wood supply in the period 2003-2019.	Indufor (2022). *Coastal Integrated Forestry Operations Approval Monitoring Program - Monitoring wood supply baseline and trends*. Report prepared for the NSW Forest Monitoring and Improvement Program, Natural Resources Commission, Sydney N.S.W.
Contribution to global carbon cycles	FMIP Project CC1: Carbon balance of NSW forests	Mullion Group, NSW DPI and the CSIRO	Quantifying the carbon balance of NSW forests and how this may change under different policy, management and climate scenarios.	Roberts, G., Waterworth, R., de Ligt, R., McKenzie-McHarg, H., Francis, M., Roxburgh, S., Paul, K., Ximenes, F., (2022) *Carbon Balance of NSW Forests – Methodology and Baseline Report*, Mullion Group.

Theme	Project title	Research team(s)	Description	Reference
Aboriginal values and management	FMIP Project AV2: Aboriginal values and renewal post-fire - Case studies	Firesticks, Coffs Harbour, Tamworth and Brungle-Tumut Local Aboriginal Land Councils	The Coffs Harbour, Tamworth and Brungle-Tumut Local Aboriginal Land Councils will lead on-ground values and renewal assessment in their respective regions. The case studies will be guided by local steering groups and undertake assessments of diverse Aboriginal values before and after the 2019-20 wildfires. Actions will be identified to support cultural restoration and renewal in the forests. These case studies are part of a broader approach to develop a model to assess Aboriginal values across forest tenures, through Aboriginal-led, country-based assessments, monitoring, and research.	Firesticks Alliance Indigenous Corporation (2022), *Aboriginal Cultural values and renewal in NSW forests post-wildfires - Synthesis report*, Firesticks Alliance Indigenous Corporation. Banbai Rangers and McKemey, M. (2021) 'Aboriginal cultural values and renewal assessment in NSW forests post-wildfires - Banbai case study report'. Report prepared for the NSW Forest Monitoring and Improvement Program, Natural Resources Commission, Sydney N.S.W. Coffs Harbour and District LALC with Gumbaynggirr Elders and Knowledge Holders (2022) Aboriginal cultural values and renewal assessment in NSW forests post-wildfires Gumbaynggirr Lands. Report prepared for the NSW Forest Monitoring and Improvement Program, Natural Resources Commission, Sydney N.S.W. Herrington, S & Byron, N. (2022) Aboriginal Cultural values and renewal assessments in NSW forests post – wildfires Case Study Report. Brungle-Tumut LALC. Report prepared for the NSW Forest Monitoring and Improvement Program, Natural Resources Commission, Sydney N.S.W
Future scenarios	FMIP Project: NSW Future Forest Scenarios Project	Australian National University, CSIRO	Developing scenarios for the future of NSW forests. These will include alternative futures that emphasise different forest values and community expectations from the short to long-term.	Cork, S., Ferrier, S., Kanowski, P., & Lade, S. (2022) *NSW Future Forest Scenarios report*, Australian National University.

Theme	Project title	Research team(s)	Description	Reference
Other	Coastal IFOA Project: Implications of changing fire intensity and regimes on Coastal IFOA objectives and outcomes	NSW Bushfire Risk Management hub, University of Wollongong	Evaluating: ▪ specific risks to achieving the Coastal IFOA objectives and outcomes as result of the legacy landscape scale impacts of the NSW 2019-20 wildfire season ▪ broad implications of predicted changing fire regimes on the achievement of the Coastal IFOA's objectives and outcomes options to mitigate risks.	Bradstock. R, Bedward, M., & Price, O. (2021). *Risks to the NSW Coastal Integrated Forestry Operations Approvals Posed by the 2019/2020 Fire Season and Beyond*, Centre for Environmental Risk Management of Bushfires, University of Wollongong and the NSW Bushfire Risk Management Research Hub.

Summary of key findings from monitoring and research projects

Table B: Key findings from FMIP and Coastal IFOA Monitoring Program monitoring and research projects

	Status and trend	Outlook
Forest extent and condition *Gradual increase – particularly on private land – followed by reduction due to 2019-20 wildfires* *Robust datasets in place and improving*	▪ Pre-fire, overall forest canopy cover extent had increased between 1995-2020 in coastal NSW by around 5.1 percent, with most increases on private land. ▪ The 2019-20 wildfires caused a significant reduction in forest canopy cover in coastal NSW to below 1995 levels - the fires were more extensive and severe on the South Coast and affected national parks and state forests to a greater extent than private land. ▪ Affected areas are considered particularly vulnerable to impacts from subsequent disturbances in the next 5 to 10 years while burnt forested areas regenerate ▪ Only 10 percent of forested vegetation in the Coastal IFOA area are currently within their recommended fire frequency thresholds, while larger areas – including 60-70 percent of national parks and state forests – are now in classed as 'vulnerable' and 'too frequently burnt' and are at risk of a decline in plant diversity.	▪ Future climates with more prolonged drought, and more frequent and severe heatwaves and bushfires may change the function and structure of many forest types. ▪ Multiple severe fires in quick succession can reduce regenerative capacity of the forest, potentially impacting ecosystem recovery and future timber supply. ▪ Long-term resilience of wildfire refugia may be reduced by more extreme fire weather, with previously sheltered areas potentially affected by more severe or extensive fire.
Forest carbon *Period of stability followed by large release of carbon due to 2019-20 wildfires* *Poor datasets for soil carbon*	▪ Total forest carbon remained relatively stable from 1990 to 2019, varying between 1,438 and 1,559 million tonnes. ▪ There has been a net loss of forest carbon within NSW between 1990 and the end of 2020, estimated at around 164 Mt of carbon (excluding soil) under a 'mid' growth scenario. ▪ The net loss is primarily driven by the 2019-20 fire season, which resulted in significantly larger changes in forest carbon than at any other point in the preceding three decades.	▪ Temporary nature of carbon emission impacts relies on forests' ability to recover and regenerate after disturbance, which may be undermined in the future by more frequent and intense disturbance events.

	Status and trend	Outlook
	▪ It is expected that the 2019-20 emissions due to wildfire will largely be offset by carbon reabsorption during regeneration over the next 10-15 years.	
Biological diversity *Significant habitat impacts from 2019-20 fire, including impacts on koalas* *Analysis significantly improved knowledge base* *Need significant investment in long-term, large scale monitoring*	▪ Few fauna occupancy trends could be assessed due to lack of data, with mixed results from available survey data – for example, surveys showed Powerful Owl and Sooty Owl occupancy around Eden recovered significantly from a near zero base between 1988 and 2011, while the Greater Glider declined significantly in the same period. ▪ Invasive pest and weed species (particularly cats and foxes) and habitat loss and degradation (particularly from clearing and land use change) are identified as key threats to biodiversity. ▪ Candidate Old Growth forest was used as a surrogate for logging history and severity, and was found to not feature as strongly as expected in most fauna species occupancy or habitat models. Candidate Old Growth was positively associated with the distribution of four fauna species in north coast forests. ▪ Similarly, few flora species were found to have a positive association with 'undisturbed' sites mapped as Candidate Old Growth, inferring that few species have been adversely impacted by native timber harvesting up to 2000. However, it is noted that many species were recorded too infrequently for rigorous analysis. ▪ Nine rainforest and wet sclerophyll forest plant species, including three epiphytes, were identified as likely to be sensitive to timber harvesting, noting that harvesting is excluded within identified rainforest areas. ▪ The 2019-20 wildfires impacted on the habitat of 378 bird, 83 mammal, 254 reptile, 102 frog, and 15 freshwater fish species - 70 species had more than 30 percent of their habitat impacted by the fires, with 19 having more than 50 percent of their habitat affected. ▪ Twice as much suitable species habitat is now classed as impacted by high frequency fire.	▪ Combined effects of climate change and fire, along with pests and weeds, represent the most significant threat to the biodiversity of eastern NSW forests. ▪ Species occupancy modelling for future climate projections suggest that potential occupancy of 54 of 78 threatened fauna species assessed will decline by 2070; of these, seven species will be particularly affected. ▪ Suitable habitat was predicted to decline under projected 2030 and 2070 climate change scenarios ('warmer/wetter' and 'hotter/little change') for 14 of 24 threatened fauna species assessed ▪ For 81 climate-sensitive flora species, climate modelling predicted that 48 species will have less medium to high-suitability habitat by 2070 due to climate change, whereas 30 species will have more.

	Status and trend	Outlook
	▪ The 2019-20 wildfires impacted local koala populations - koalas were absent in some areas where high fire severity dominated the landscape, with localised recovery after a year.	
Soil resources *Concentrations have varied over time and space* *Analysis significantly improved knowledge base but more monitoring is needed*	▪ Modelled estimates of soil organic carbon concentrations have varied, with decreases in the mid-1990s followed by increases in mid-2010s. The significant fluctuations in this period are likely to have been driven by climatic conditions. ▪ Areas subject to increased ground disturbance from land use activity (particularly in forests in which grazing is permitted) have lower concentrations of soil organic carbon than less disturbed areas. ▪ Researchers modelled the likely relative loss of soil organic carbon during a fire event and found it to be substantially high, ranging between 40 and 60 percent. Post-fire recovery of soil organic carbon was estimated to be around 60 percent after 20 years, with full recovery after around 75 years. ▪ Soil carbon models for coastal NSW decline around the time of the 2019-20 wildfires, after reaching a high point around 2016-17. ▪ The researchers reported critical data gaps relating to soil health due to a lack of sustained monitoring.	▪ Further future decline in soil organic carbon due to climate change, with greatest losses in areas with currently high soil organic carbon stocks, such as the southern alps. ▪ Potential for ongoing cycles of decline in soil organic carbon if areas are subjected to repeated fire events and/or other disturbances (such as grazing, timber harvesting or land clearing) that prevent the recovery of soil organic carbon levels between disturbance events. ▪ A slight rise in soil pH (more alkaline) expected, again highest in the southern alps, affecting ecosystems that have established under particular pH ranges.
Forest catchments *Long term trend of declining flows* *Lack of data impacting water quality analysis* *Analysis significantly*	▪ Flows have been declining in forest catchments over the last 30 years, especially on the south coast of NSW. ▪ Over a third of the coastal forested catchments assessed showed significant annual flow reductions of 10 to 20 percent in this period. Wetter catchments and catchments with a greater percentage of area used for grazing experienced greater percentage decline in flow. ▪ At the catchment scale, historical changes in flow are generally more heavily affected by hydro-climatic drivers than fire events, although some impacts on streamflow due to fire events were observed.	▪ More frequent cycles of drought and recovery are likely to further exacerbate recent trends around declining flows. ▪ Ongoing declines in catchment flows are likely to have adverse impacts on forest health, groundwater recharge and water quality. ▪ Increased fire activity and intense rainfall events are likely to lead to more

	Status and trend	Outlook
improved knowledge base but more monitoring is needed	▪ There was a correlation between a larger proportion of undisturbed catchment and a greater flow reduction, however the flow reduction is also highly variable for catchments that are rarely disturbed by fire and harvesting. This suggests no clear link between the spatial differences in long-term flow trends and the history of fire and harvesting. ▪ With the currently available data, there is little evidence that the 2019-20 fire has a substantial impact on the quantity of streamflow at the catchment scale, compared with long-term historical conditions. ▪ Lack of data prevented analysis of water quality indicators.	erosion with major implications for water quality and waterway health.
Aboriginal values *Need for greater access and involvement in land management*	▪ There are significant knowledge gaps around Aboriginal cultural values due to Aboriginal peoples' lack of access or involvement in land management and custodianship ▪ The 2019-20 fires impacted many cultural values and practices – some cultural values have been destroyed or are at higher risk, for example scar trees, rock art and stone artefacts ▪ Except for Aboriginal managed lands, Aboriginal people are not adequately involved in land management and decision making, including identifying and managing cultural values. ▪ Proposal arising from case studies to pilot Whole-of-Country planning in collaboration with the Banbai Rangers and Guyra and Tamworth Local Aboriginal Land Councils.	▪ Cultural values at risk of damage or loss from increased fire activity and intense rainfall events, with concern that sites may be deregistered or devalued as a result. ▪ Opportunities for improved cultural values and outcomes through greater involvement in land management and decision making, including through expansion of Aboriginal-owned and managed tenures, specifically Indigenous Protected Areas, and Whole-of-Country planning processes.
Productive capacity and sustainability *Wood supply and sustainable yield forecasts reduced*	▪ The 2019-20 fires reduced the available wood supply across both public and private land, particularly on the South Coast where around 80 percent of net harvest area was affected. ▪ Short-term sustainable yield forecasts were revised to account for the impact of the 2019-20 wildfires given the loss of wood products and regrowth, with around 30 percent reductions for the South Coast and Tumut subregions.	▪ Increased fire activity is likely to impact harvest planning and sustainable yield. ▪ Climate change will challenge the effectiveness of fire hazard reduction burning.

	Status and trend	Outlook
Social and economic benefits *Forest-dependent employment differs significantly across NSW* *Interim method in place to determine forest dependent jobs* *Significant data gaps exist*	▪ Forest-dependent employment differs significantly across NSW, particularly in relation to direct and indirect employment related to forest management, production of timber and wood products, sporting, health, and fitness events, and organised and informal tourism and recreation activities. ▪ Typically, forest-dependent employment is greatest in forest areas located in closer proximity to major population centres. This is due to the intensity of use of the forest estate, both for timber harvesting and production purposes and for recreation and tourism activities. ▪ Data available on organised tourism and recreation activities in NSW forests provides a strong base for robust estimation of direct and indirect employment, however there are significant data gaps for informal tourism and recreation.	▪ Forests will continue to provide important social and economic benefits to NSW communities through the provision of employment. ▪ Challenges remain to accurately quantify forest-dependent jobs without further engagement with industry and commitment from NSW agencies.