Project Overview

Supporting post-fire ecological resilience and recovery planning in NSW forests

Forest Monitoring and Improvement Program - Foundational Project

Project details
Project title
Supporting post-fire ecological resilience and recovery planning in NSW forests
Project summary
National[1][2] and global[3][4] trends of increasing wildfire activity associated with warmer and drier spring seasonal climate conditions are placing increased emphasis on planning and monitoring post-fire ecological recovery across NSW forests. Post-fire ecological resilience and recovery planning aims to rapidly assess the immediate effects of wildfires and identify where mitigation and recovery actions need to be identified and implemented. The focus of the project is to develop new remote sensing tools and techniques for forest managers to undertake the required risk assessment and subsequently plan and report on post-fire ecological recovery efforts. In developing these reporting and planning tools the project will address several of the key aims of the Program Framework 2019-2024, namely forest managers immediate decision making needs for planning post-fire ecological recovery actions, identifying where performance thresholds and baselines have been met to trigger post-fire recovery planning and by providing the public with transparent, independent, accessible, and robust evidence of forest fire management performance benchmarked against fire frequency and severity thresholds. The project will address Program Framework deliverable 3.2 by establishing a multi-partner collaboration across several research organisations, fire-fighting authorities and land managers. The monitoring tools and techniques developed by this project will also enhance forest managers reporting of Montreal Indicator 3.1b: Area of forest burnt by planned and unplanned fire, and Biodiversity Indicator Program Theme 3 (ecosystem quality), Indicator 3.2c Inappropriate fire regimes. The post-fire ecological resilience and recovery planning monitoring component of the project is expected to deliver a remote sensing method that measures the proportion of vegetative regrowth since a fire event relative to unburnt pixels, at regular post-fire intervals. It will deliver this method by; a) undertaking a global literature review of existing remote imagery trend analysis techniques, performing preliminary tests and planning model training and validation fieldwork b) developing the remote imagery trend analysis model and field validation c) and finally refining the model, undertaking operational testing with fire-fighting authorities and providing recommendations for implementation as an operational monitoring and reporting technique supporting post-fire ecological resilience and recovery planning and reporting against the Montreal and Biodiversity Indicator Program indicators. It will significantly enhance the ability of NSW agencies to monitor and report on both wildfire and prescribed fire ecological impacts on forests. For example it will support the NSW NPWS Burned Area Assessment Team's efforts in providing a rapid and integrated post-fire rehabilitation and fire recovery assessment of an area.[5] The project, through the NSW RFS IT infrastructure will include a

[1] Di Virgilio, G., Evans, J. P., Blake, S. A., Armstrong, M., Dowdy, A. J., Sharples, J., & McRae, R. (2019). Climate change increases the potential for extreme wildfires. *Geophysical Research Letters*, 46(14), 8517-8526.
[2] Clarke, H., Lucas, C., & Smith, P. (2013). Changes in Australian fire weather between 1973 and 2010. *International Journal of Climatology*, *33*(4), 931-944.
[3] Abatzoglou, J.T., and A.P. Williams. (2016). Impact of anthropogenic climate change on wildfire across western US forests. *PNAS*, 113: 11770–11775.
[4] Westerling, A.L., H.G. Hidalgo, D.R. Cayan, and T.W. Swetnam. (2006). Warming and earlier spring increase western US forest wildfire activity. *Science*, 313: 940–943.
[5] New South Wales. National Parks and Wildlife Service & New South Wales. Office of Environment and Heritage (2012). Living with fire in NSW national parks: a strategy for managing bushfires in national parks and reserves, 2012-2021. Sydney South, NSW Office of Environment and Heritage

public facing search and discovery image server where fire extent and severity data will be made freely available.

Project objectives

The project aims to provide a scientifically robust, standardised, remote sensing system of mapping the immediate post-fire extent and severity to support recovery planning to restore environmental damage arising from high-impact or inappropriate fire regimes. With this accurate and timely information, forest managers will be better equipped to plan, monitor and report on post-fire ecological recovery over time. The products will provide information, at the state-wide level, on the loss or change in organic matter caused by fire, and the subsequent re-accumulation of organic matter to pre-fire or surrounding unburnt conditions. Various surrogate measures of biomass are captured by optical satellite sensors such as Landsat and Sentinel 2. For example, well-known vegetation indices measure reflectance properties of vegetation influenced by chlorophyll and water content. Sub-pixel fractional cover models represent the relative cover of photosynthetic material, based on calibration with high quality biophysical field measurements. A combination of these indices is used in the fire extent and severity algorithms and will be explored for appropriate application in the fire recovery modelling.

The project will build upon an existing research partnership between two fire-fighting authorities (NSW RFS and NSW NPWS) and DPIE Science which aims to develop an operational processing system for mapping and reporting on fire severity. This project will however develop the process for monitoring of post-fire ecological resilience recovery over time, leveraging significant cost savings by utilising the automated processing design already developed through the NSW RFS and NSW NPWS partnership. The alignment of recovery monitoring products with extent and severity products will therefore provide information for reporting on Montreal Indicator 3.1b: Area of forest burnt by planned and unplanned fire and, Biodiversity Indicator Program Theme 3 (ecosystem quality), Indicator 3.2c Inappropriate fire regimes.

Field validation will help to develop the method and assess the performance of the modelling. Alignment of field data collection with collaborative partners existing monitoring programs will aim to enhance compatibility and synchronicity across related forest monitoring programs and drive further monitoring cost efficiencies.

Outline of project methods

Three main stages of works are anticipated in the research and development of a fire recovery monitoring method. These are outlined below.

1. Literature review, preliminary tests and fieldwork planning.
An extensive literature review will initially guide exploration of existing methods as a baseline to then systematically test innovative options for improvements and efficiencies. Sentinel 2 satellite imagery will most likely be the selected platform, due to the high temporal and spatial resolution of imagery and to align with the fire extent and severity mapping system. Various recovery indices and algorithms used by other researchers on other remote sensing platforms may be adjusted for application on Sentinel 2. The similar configuration of spectral bands of Sentinel 2 and Landsat platforms allows for the potential future application of a post-fire ecological resilience and recovery mapping method to the historic Landsat archive dating from 1986[6], which would also align with the aim of mapping historic fire extent and severity for NSW. A fieldwork plan will also be developed in the initial stage, to identify case study fires suitable for initial assessment of post-fire severity and subsequent periodic site re-visits to train and validate the recovery model.

2. Model development and field validation.
Candidate recovery monitoring approaches will be systematically compared and assessed using field validation and where possible, high resolution post-fire aerial photograph or satellite image interpretation. Landsat-based fire severity mapping will help to identify sites for field sampling of recovery of different (longer) time since fire, to validate recovery models across longer time

[6] Goodwin, N. R., & Collett, L. J. (2014). Development of an automated method for mapping fire history captured in Landsat TM and ETM+ time series across Queensland, Australia. Remote Sensing of Environment, 148, 206–221.

periods. Field validation will include post-fire fieldwork at regular intervals (e.g. 3 or 6-monthly) with the primary goal of providing information on the sensitivity of the candidate recovery models at detecting changes in vegetative regrowth. This will help to inform the appropriate time-steps to trigger automated re-capture of post-fire snapshots to build a time-series of recovery maps. During this phase of model development and validation, project partners, collaborators and end users will be consulted for peer-review and advice on the suitability of a proposed model. Modelling fuel re-accumulation curves as a function of fire severity for different fuel types is a key objective of research being conducted by NSW Bushfire Risk Management Research Hub researchers including Dr Rachel Nolan of the Hawkesbury Institute for the Environment (Western Sydney University), Dr Owen Price of the Centre for Environmental Risk Management of Bushfires (University of Wollongong) and collaborators including Dr Marta Yebra of the Fenner School of Environment and Society (Australian National University). There are well-known limitations of a remote sensing approach to mapping recovery in surface and near surface fuel layers in forested ecosystems. Collaborative partnerships with these groups will be explored for the potential of integrated modelling of different data inputs to enhance limitations of scale and resolution between different approaches.

3. Model refinement, operational testing and recommendations.
Final model refinements will be tested and applied where appropriate. An automation method will be designed for operationalising the recovery monitoring procedure, through integration with the existing fire extent and severity mapping procedure. A comprehensive analysis of the strengths and limitations of the recovery monitoring system will be made with recommendations for future refinements and operations of the fire mapping system.

In addition, the following provides a brief summary of the methods for the related but separately funded component of the project (fire extent and severity mapping), planned for completion between 2019-2021:

- Modify the Sentinel 2 severity algorithm for application to Landsat for historic extent and severity mapping
- Develop additional training data from new fires flown for high resolution ADS (Airborne Digital Sensor) imagery
- Research potential model refinements to improve low and moderate severity mapping by testing the effects of including contextual/neighbourhood-based severity indices and masking non-woody vegetation.
- Field validation, targeting hazard reduction burns and quantify the accuracy of low severity mapping and analysis under a dense forest tree canopy
- Operation and monitoring of the NSW fire extent and severity mapping system.

The project will be researched and developed by the lead investigator, who has a strong academic background in fire ecology and remote sensing and a well-developed network of distinguished fire scientists, remote sensing experts and operational managers of fire-fighting authorities.

Expected project outcomes

The expected project outcome is an improvement in the environmental management of severe fire effects on forested vegetation communities by targeting of post-fire recovery actions to land which has exceeded the nominated fire severity threshold. This will be achieved by the project delivering a remote sensing method that measures the proportion of vegetative regrowth since a fire event relative to unburnt pixels, at regular post-fire intervals. The processing system will be designed with automated triggers for re-mapping at regular intervals for each fire that is initially mapped for extent and severity. This will include forest wildfire and hazard reduction burns that are greater than 10ha in size, primarily requested to be mapped by the NSW RFS. A rate of post-fire ecological recovery product will be derived at the end of the time-series, to quantify per pixel rates of recovery using the full time-series of data for a given fire event.

The project will deliver a method for mapping fire severity to support post-fire ecological resilience and recovery planning for fires since mid-2016 using Sentinel 2 satellite imagery. The operational system will be integrated with RFS IT infrastructure, with a request location, monitored by the

DPIE automated processing system. The RFS IT infrastructure will include a public facing search and discovery image server where fire extent and severity data will be made available. The project will also deliver a tested method of applying the Sentinel 2 algorithm to Landsat imagery, for standardised, historic fire extent and severity mapping and recovery monitoring.

The data products delivered by the post-fire ecological resilience and recovery planning project are expected to be used by fire-fighting authorities, land managers, fire and climate researchers, in research, reporting, planning, decision making and indicator reporting. Multiple snapshots of fire recovery mapping at regular intervals across a time-series will provide near-real time information for reporting for Montreal Indicator 3.1b: Area of forest burnt by planned and unplanned fire and Biodiversity Indicator Program Theme 3 (ecosystem quality), Indicator 3.2c, Inappropriate fire regimes. Fire recovery mapping will also support land managers utilising the NSW NPWS Burned Area Assessment Team's efforts in providing a rapid and integrated post-fire rehabilitation and fire recovery assessment of an area. These assessments are critical for targeting flora and fauna recovery and other rehabilitation activities.

Demonstration of how project objectives contribute to the overall NSW Forest Monitoring and Improvement Program Framework

The NSW Forest Monitoring and Improvement Program Framework seeks to improve adaptive forest management through integrated monitoring, evaluation and research. The program supports feasible, scientific projects that address important information needs by Government or the community that align with Montreal ESFM criteria, and are scalable across time and space. The NSW fire extent, severity and recovery mapping project significantly contributes to this framework.

The project has demonstrable impact on decision making and community information needs. For example, fire extent mapping will be incorporated into the NSW state-wide fire history database, representing a single point of truth between all fire management agencies. The mapping will significantly improve the accuracy, detail and consistency in the NSW fire history database. Fire severity maps will be developed as input into fire behaviour analyses, for planning bushfire risk mitigation and hazard reduction burns. Fire severity products will continue to support National Parks and Wildlife Service (NPWS) burnt area assessment teams (BAAT) for fires in NSW National Parks as well as for inter-state teams (QLD/Vic/NSW), for planning and prioritising objectives of the field deployment teams. Severity and recovery mapping products will also provide important data for fire and ecological research by external institutes, including the Western Sydney University, and The University of Wollongong through the NSW Bushfire Risk Management Research Hub.

The project supports the reporting on several key Montreal Process Criteria and Indicators for Ecologically Sustainable Forest Management, including:
Criterion 1: Conservation of Biological Diversity/1.1a. and b. Ecosystem Diversity
The proposed fire recovery mapping will contribute important information for monitoring the area of forests by successional stage and age class.
Criterion 3: Maintenance of Forest Ecosystem Health and Vitality/3b. Area of forest affected by abiotic agents, such as fire.
The project will deliver a consolidated fire extent mapping database for NSW, accessible to end users from all fire management agencies. This will provide consistent mapping to report on the area of forests affected by fire.
Criterion 5: Maintenance of Forest Contribution to Global Carbon Cycles/5a. Total forest ecosystem carbon pools and fluxes.
The combination of complimentary mapping products of fire extent, severity and recovery, derived from the same satellite platform, method and spatial resolution will greatly contribute to accurate reporting of data regarding forest carbon cycles.

In addition, the project constitutes a significant development in the ability to report for the Biodiversity Indicators Program, managed by DPIE, on indicator *3.2c Inappropriate fire regimes*. This indicator is recognised as being dependent on spatial data of fire extent and severity history, which will evolve as methods for detecting fire severity evolve.

The NSW Forest Monitoring and Improvement Program's Framework identifies that the program should continually evolve and respond to emerging risks. Similarly, the National Parks and Wildlife 'Living with Fire in NSW National Parks' strategy for managing bushfires in NSW national parks identifies adaptive fire management planning and recovery planning processes as a key objective. In the long term, fire regime spatial data based on fire extent, severity and recovery mapping, will provide significant insight into questions and analysis around predictions and adaptive management of forests in NSW. For example, trends may show that with climate change, fires are becoming larger and more severe, with slower recovery rates that are threatening the health and resilience of forests. Early detection of such emerging risks will allow responsive and adaptive management, which are key objectives of these state-wide NSW government agency programs.

Demonstration of how the proposal will answer the fundamental evaluation question - What are the forest changes and ecological impacts from fire?

Spatial mapping of fire extent, severity and recovery, with standardised procedures for on-going capture at the state-wide level will contribute important new information for monitoring and reporting on post-fire ecological resilience and recovery planning in NSW forests. Fire extent and severity mapping will capture the immediate effect of the fire relating to the loss (consumption) or change (scorch or partial consumption) in organic matter. Post-fire ecological resilience and recovery monitoring, reporting and planning cannot be automated and reported publically without this project development. Over time, this dataset of extent, severity and recovery will represent a powerful tool for understanding and reporting on the drivers and changes to fire regimes across the vast landscapes of NSW.