Project Plan SP 2018-134

Development of a systematic approach to monitoring and reporting on the outcomes of prescribed burns and bushfires

Fire Science

Project Core Team

Supervising Scientist	Lachie Mccaw
Data Custodian	Lachie Mccaw
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Project status as of Sept. 16, 2019, 10:23 a.m.

Approved and active

Document endorsements and approvals as of Sept. 16, 2019, 10:23 a.m.

Project Team	granted
Program Leader	granted
Directorate	granted
Biometrician	granted
Herbarium Curator	not required
Animal Ethics Committee	not required

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Biodiversity and Conservation Science Program

Fire Science

Departmental Service

Service 9: Prescribed Burning and Fire Management

Project Staff

Role	Person	Time allocation (FTE)
Research Scientist	Valerie Densmore	0.4
Supervising Scientist	Lachie Mccaw	0.2
Research Scientist	Katherine Zdunic	0.3

Related Science Projects

This project relates to SCP 2019-048 regarding the use of remote sensing and spatial analysis to assess and track post-fire vegetation recovery. This area of overlap may provide grounds for useful collaboration between the projects, thus consultation about project development and findings between Val Densmore and Katinka Ruthroff are ongoing.

Proposed period of the project

Nov. 8, 2018 – June 30, 2020

Relevance and Outcomes

Background

Prescribed burning is conducted on lands managed by DBCA to minimise the risk that bushfire will have adverse effects on communities, infrastructure and the natural environment and to implement appropriate fire regimes that maintain or improve ecosystem health and resilience. To achieve these primary objectives, DBCA staff prepare comprehensive plans designed to produce fire behaviours within a prescribed range suited to the inherent vegetation type(s) and any special considerations necessary for fire-sensitive species and communities, built assets and heritage values within or near the burn boundary. Prescribing, approving and implementing burn plans adhere to corporate procedures and require substantial resources. However, DBCA does not currently have a systematic approach to assessing, monitoring and reporting on the outcomes of planned burning. Elements of these activities may be done routinely or expressly to meet statutory reporting obligations including fire management performance indicators and Permits to Take Declared Rare Flora, but this occurs in an ad-hoc way. The lack of a systematic approach to monitoring and reporting on the outcomes of prescribed burning creates a corporate risk that the Department's prescribed burns are not achieving corporate objectives and/or that public faith in the department will be compromised by a lack of accountability.

Multiple methods to assess and monitor the severity of planned and unplanned fires have been developed and tested for a range of vegetation types both in Australia and worldwide. Most methods utilise satellite imagery due to the size and inaccessibility of many burned areas and to promote a standardised and objective approach. The differential normalised burn ratio (NBR) is currently the standard technique to assess fire severity (Key & Benson 2006, Miller & Thode 2007, Walz *et al.* 2007, Boer *et al.* 2008, Miller *et al.* 2009, Hoe *et al.* 2018), but this method has several limitations to be addressed to make it an accurate and ecologically-meaningful metric. The NBR combines spectral reflectances in the visible near-infrared and mid-infrared bands to detect the removal of surface litter, exposed soil, and altered cover, greenness and water content of vegetation (Key & Benson 2006, Holmes *et al.* 2018, Massetti *et al.* 2019). Images are acquired before and after a fire event to calculate differences between them, helping to account for spectral variation related to vegetation type rather than fire effects. The timing of images is critical because NBR is sensitive to seasonal moisture fluctuations and drought as well as fire effects (Key & Benson 2006, Wallace *et al.* 2006). The method relies on passive satellite imagery that can fail to distinguish the effect of fire on surface or understorey vegetation when overstorey foliage cover is not significantly affected (Boer *et al.* 2008). Thus, the accuracy of NBR decreases in closed forest and when fire severity is low. The ability to distinguish between low and moderate severity classes in a wide range of vegetation types is also an ongoing concern when using NBR (Cocke *et al.* 2005, Miller & Thode 2007, Miller *et al.* 2009, Hoe *et al.* 2018). Dividing the NBR by the square root of the pre-fire NBR may increase the ability to distinguish low and moderate severity classes (Miller & Thode 2007). To verify and improve classification accuracy, NBR images also need to be ground-truthed, often using a variation of the composite burn index (CBI) proposed by the FIREMON project (Key & Benson 2006).

The CBI is a plot-based method that quantifies fuel removal, scorch and regeneration of existing or new plants across all strata within a vegetation community (Key & Benson 2006). To sufficiently validate NBR classifications, plots must equate to the spatial resolution of satellite imagery (e.g., 30 m for Landsat 8, or 10 m for Sentinel 2), located randomly within an area that has relatively homogenous severity, closely timed to when post-fire images were captured, and at an adequate sampling rate to achieve the desired level of accuracy (Key & Benson 2006, Reinke & Jones 2006, Miller *et al.* 2009, Holmes *et al.* 2018). This latter stipulation requires approximately 1% of the total burn area is sampled to achieve error rates around 2% (Reinke & Jones 2006, Holmes *et al.* 2018), or a minimum of 50 plots within each category of interest (Brogaard & Olafsdottir 1997, Key & Benson 2006). It is argued that plots may be distributed across several burns that have occurred during the same season and in the same vegetation type (Key & Benson 2006). The validity of using CBI has also been questioned, as accuracies typically range between 50 – 80% and the relative contribution of strata is not weighted when the overall CBI score is calculated. A modified CBI, called the GeoCBI, considers the fraction of vegetation cover (FCOV) by each stratum and has been shown to improve classification accuracy (De Santis & Chuvieco 2009).

To assess burn outcomes on land managed by DBCA, the metrics used to classify fire severity must be simple to implement, repeatable, instructive to fire managers and conservation staff and have a demonstrated ecological basis (Gibbons & Freudenberger 2006). The feasibility and ecological relevance of NBR and GeoCBI have not been systematically assessed for the variety of vegetation types that undergo prescribed burning in WA. In addition, other metrics have been proposed in the literature but not tested in WA, including the relative NBR (Miller *et al.* 2009) and Vertical Structure Perpendicular Index (VSPI; Massetti *et al.* 2019). Developing a best-practice method to assess burn outcomes will require expertise and consultation across multiple disciplines, including remote sensing, fire behaviour, fire ecology and species conservation.

Aims

This project aims to develop the framework for a systematic approach to assessing and reporting on the outcomes of prescribed burns and bushfires and to develop and test a variety of reporting tools and metrics related to environmental outcomes.

Expected outcome

This project is anticipated to improve the ability to quantify spatial patterns of fire severity centred within an ecological framework. A tool will be developed that will link three to four categories of burn severity derived from satellite imagery to field assessments that delineate habitat features that can be used as direct or proximal evidence of fauna habitat, live vegetation cover, and post-burn recovery of flora. An associated outcome will be determining the confidence to which actual burnt areas can be delineated from satellite imagery for different vegetation/fuel types and structures. The tool will be a semi-automated process that offers reasonable (i.e., 75%) accuracy in an initial assessment for all prescribed burns and bushfires, with the opportunity to further refine or investigate particular areas through targeted field verification as needed. The tool(s) developed in this project will support cost-effective and meaningful reporting on the extent to which prescribed burning has achieved specified objectives and success criteria for biodiversity management, bushfire risk mitigation and other land management values, such as forest regeneration. A systematic approach to assessment and reporting will contribute to the refinement of prescribed burn implementation and planning processes, including objectives that are measurable, achievable and relevant to particular land management values. Applying the same approach to quantify spatial patterns of fire severity following bushfires will enable comparisons that inform the effectiveness of the overall fire management program.

Knowledge transfer

Regional fire services staff, Regional and district fire coordinators, District duty officers, Forest Management Branch, Ecosystem Health Branch

Development of a prescribed burn and fire assessment tool appropriate for use by Fire Management District staff responsible for planning, implementing and reporting on burn outcomes. This tool will be transferred by support at the Corporate level and training select fire operations officers, such as participants in the Fire Management Development Program.

Knowledge will be transferred by publishing the tool and important findings in technical reports, scientific papers and more popular forms including Landscope articles.

Tasks and Milestones

Ground-truthing approach based on GeoCBI will be assessed and modified as necessary to improve ecological relevance and accuracy for a range of forest types, including Southern Jarrah and Northern Jarrah – November 2019

Complete a pilot study calculating NBR for spring and autumn burns conducted across a range of vegetation types within the SW Land Division – January 2020

Assess accuracy of ground-truthing approach in NBRs – May 2020

Train FMDP participants to calculate NBR and conduct ground-truthing at their annual training week – June/July(?) 2020

Validate the feasibility of assessment method against prescribed burns for Autumn 2020-Spring 2021

Provide manual(s) and worksheets to key FMS and FMB personnel to enable adoption as a systematic framework for data collection and reporting on burn outcomes – Summer 2021

References

Boer, M.M., Macfarlane, C., Norris, J., Sadler, R.J., Wallace, J., Grierson, P.F. (2008) Mapping burned areas and burn severity patterns in SW Australian eucalypt forest using remotely-sensed changes in leaf area index. Rem Sens Enviro. 112: 4358 – 4369.

Brogaard, S., Olafsdottir, R. (1997) Ground-truths or Ground-lies?: environmental sampling for remote sensing application exemplified by vegetation cover data. (Lund electronic reports in physical geography; Vol. 1). Dept of Physical Geography, Lund University.

Cocke, A.E., Fulé, P.Z., Crouse, J.E. (2005) Comparison of burn severity assessments using Differenced Normalized Burn Ratio and ground data. Int J Wild Fire. 14:189 – 198.

De Santis, A., Chuvieco, E. (2009) GeoCBI: A modified version of the Composite Burn Index for the initial assessment of the short-term burn severity from remotely sensed data. Rem Sens Enviro. 113:554 – 562.

Gharun, M., Possell, M., Jenkins, M.E., Poon, L.F., Bell, T.L., Adams, M.A. (2017) Improving forest sampling strategies for assessment of fuel reduction burning. For Ecol Manag. 392:78 – 89.

Gibbons, P., Freudenberger, D. (2006) An overview of methods used to assess vegetation condition at the scale of the site. Ecol Manag Rest. 7: S10 – S17.

Hoe, M.S., Dunn, C.J., Temesgen, H. (2018) Multitemporal LiDAR improves estimates of fire severity in forested landscapes. Int J Wild Fire. 27:581 – 594.

Holmes, A.W., Rudiger, C., Harris, S., Tapper, N. (2018) Determining the minimum sampling frequency for ground measurements of burn severity. Int J Wild Fire. 27:387 – 395.

Key, C.H., Benson, N.C. (2006) Landscape assessment: ground measure of severity, the composite burn index; and remote sensing of severity, the normalized burn ratio. pp. LA-8 – LA-41. In: Lutes, D.C., Keane, R.E., Caratti, J.F., Key, C.H., Benson, N.C., Sutherland, S., Gangi, L.J. (eds.) FIREMON: Fire effects monitoring and inventory system. Gen. Tech. Rep. RMRS-GTR-164-CD. Fort Collins, CO. USDA Forest Service, Rocky Mountain Research Station.

Massetti, A., Rüdiger, C., Yebra, M., Hilton, J. (2019) The Vegetation Structure Perpendicular Index (VSPI): a forest condition index for wildfire predictions. Rem Sens Enviro. 224:167 – 181.

Miller, J.D., Thode, A.E. (2007) Quantifying burn severity in a heterogeneous landscape with a relative version of the delta Normalized Burn Ratio (dNBR). Rem Sens Enviro. 109:66 – 80.

Miller, J.D., Knapp, E.E., Key, C.H., Skinner, C.N., Isbell, C.J., Creasy, R.M., Sherlock, J.W. (2009) Calibration and validation of the relative differenced Normalized Burn Ratio (RdNBR) to three measure of fire severity in the Sierra Nevada and Klamath Mountains, California, USA. Rem Sens Enviro. 113:645 – 656.

Reinke, K., Jones, S. (2006) Integrated vegetation field surveys with remotely sensed data. Ecol Manag Rest. 7: S18 – S23.

Wallace, J., Behn, G., Furby, S. (2006) Vegetation condition assessment and monitoring from sequences of satellite imagery. Ecol Manag Rest. 7: S31 – S36.

Walz, Y., Maier, S.W., Dech, S.W., Conrad, C., Colditz, R.R. (2007) Classification of burn severity using Moderate Resolution Imaging Spectroradiometer (MODIS): a case study in the jarrah-marri forest of southwest Western Australia. J Geophys Res. 112: G02002, doi:10,1029/2005JG000118.

Study design

Methodology

Data from prescribed burns conducted across major vegetation types within the southwest land division (SWLD) will be used to develop an assessment tool that couples remote sensing and field surveys. Vegetation types will include northern and southern jarrah forest/woodland, karri forest, banksia woodland, kwongan heath and wandoo woodland, although additional vegetation types may be added. Vegetation maps will be created for a select number of burns prior to burn implementation using a remotely piloted aircraft (RPA) to photograph along multiple transects that traverse a mixture of vegetation types, according to DBCA's corporate dataset. Resulting images from the RPA will be used with satellite imagery from Sentinel-2 to define classification parameters to facilitate automatic georeferencing of vegetation types across the SWLD using ArcGIS.

The remote sensing component will initially entail using differential normalised burn ratios (DNBR) constructed for each burn or burn cell of interest. To define a post-burn date range, areas treated and implementation dates for prescribed burns will be obtained using the reporting system embedded within the electronic prescribed fire plan (EPFP) with follow-up consultation with relevant fire officers when needed. Subject to the availability of suitable (i.e., cloud-free) images, Sentinel-2 normalised burn ratio (NBR) images will be obtained from Landgate's Aurora website within a date range of one week to two months after burn implementation. An NBR image dated as close as possible to one year prior will also be obtained. Where Sentinel-2 imagery is not available, images from bands 5 and 7 of Landsat 8 will be used to construct the pre and post-burn NBRs. The pre-burn NBR is subtracted from the post-burn NBR to obtain the DNBR. In addition to DNBR, relative DNBR and the vegetation structure perpendicular index (VSPI) will also be trialled on a comparison basis. The relative DNBR is derived by dividing the DNBR by the square-root of the preburn NBR. The VSPI will be calculated according to the methodology published by Massetti *et al.* (2019).

A field assessment form will be developed using the GeoCBI (De Santis & Chuvieco 2009) modified to reflect the fire response strategies of Australian flora and to capture the gain or loss of primary fauna habitat, such as coarse woody debris and midstorey foliage. The field assessment form will be tested iteratively against field observations and DNBR classifications of burn severity to identify parameters that should be adjusted, included or removed. Regular consultations with departmental fauna officers and researchers will also be held to develop the assessment form. To conduct ground-truthing, the initial DNBR will be classified into four categories from unburnt to high severity using the Jenks Natural Breaks algorithm. Between 10 - 20 points will be distributed across each of the top three categories in each vegetation type with occasional points included in areas classified as 'unburnt' for confirmation. As much as possible, points will be distributed across the burn area that are accessible by internal roads or burn cell boundaries. At each point, a 20 m radius plot will be assessed using the field form to tally an overall severity score and geographic coordinates recorded. Severity scores will then be compared to pixel values on the DNBR at the respective geographic position. User's and producer's accuracies will be assessed using error matrices and Kappa statistics (Miller *et al.* 2009). The number of points needed to achieve a suitable degree of accuracy will be tested as per Gharun *et al.* (2017).

Once a field assessment tool has been developed, the entire process will be tested using participants in the FMDP program. Feedback will be sought on ease of use and accuracy. If possible, the construction of the initial classified DNBR will be automated as much as possible to further facilitate ease of use. Following any necessary modifications to address issues raised at this stage, the final tool will be presented to managers from Fire Management Services, Forest Management and Ecosystem Health Management branches to enable adoption of the burn assessment tool across the SWLD.

Biometrician's Endorsement

granted

Data management

No. specimens

Herbarium Curator's Endorsement

not required

Animal Ethics Committee's Endorsement

not required

Data management

The project will utilize data from the DPaW corporate fire report database managed by Fire Management Services Branch.

Budget

Consolidated Funds

Source	Year 1	Year 2	Year 3
FTE Scientist	0.4	0.4	
FTE Technical	0.3	0.3	
Equipment		1000	
Vehicle	2500	13000	
Travel		5000	
Other		4000	
Total	2500	23000	

External Funds

Source	Year 1	Year 2	Year 3
Salaries, Wages, Overtime			
Overheads			
Equipment			
Vehicle			
Travel			
Other			
Total			