BURN SEVERITY ESTIMATION IN NORTHERN AUSTRALIA TROPICAL SAVANNAS USING RADIATIVE TRANSFER MODEL AND SENTINEL-2 DATA

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ABSTRACT

In this study, the burn severity of several wildfires ignited at northern Australian tropical savannas area were estimated using the Forest Reflectance and Transmittance (FRT) radiative transfer model (RTM) and Sentinel-2A Multi-Spectral Instrument (MSI) satellite data. To alleviate the spectral confusion between *severe* (SV) and *not-severe* (NSV) burnt levels caused by sparse tree distribution, the MODIS Vegetation Continuous Fields (VCF) tree cover percentage data was used to constrain the inversion. The results showed that the accuracy of burn severity estimation significantly improves when considering the tree coverage, with overall accuracy for two study sites increasing from 65% to 81% and kappa coefficient from 0.35 to 0.55. Future work will focus on extending the methodology to other ecosystems.

Index Terms— Burn severity, tree cover, Radiative transfer model, Sentinel-2A.

1. INTRODUCTION

Accurate knowledge of burn severity is critical to quantify the impact of fire on key ecological processes and is essential for fire-related forest management activities [1, 2]. Burn severity estimation based on remotely sensed data are cost-efficient and can provide a spatial comprehensive view [3]. However, all methods to retrieve burn severity using optical remotely sensed data share a limitation, they may increase the proportion of high burn severity classes in regions with low tree-cover and underestimate burn severity in regions with dense tree-cover. Because the spectral signature of dead leaf litter is similar with the spectrum of a scorched tree [4], the background char and dead leaf litter will have different contribution to the signal achieved by remote sensing sensors with tree cover variation.

This study proposed a novel method to modify the overestimation errors for low burn severity estimation caused by sparse tree coverage using the Forest Reflectance and Transmittance (FRT) radiative transfer mode (RTM).

2. METHODS

2.1 Study area and data sampling

Two study sites of northern Australia tropical savannas after by fires were selected (Fig. 1). Field sampling was carried out short-term post-fire on the 19 October 2016 and the 27 July 2016 for site 1 and 2, respectively [5]. Following Edwards et al. (2018) [6], the burn severity of these two study sites will be classified into *severe* (SV) and *not-severe* (NSV) burnt level in this study. There was a total of 303 (SV: 182, NSV: 121) and 179 (SV: 16, NSV: 163) field plots for study site 1 and study site 2, respectively.

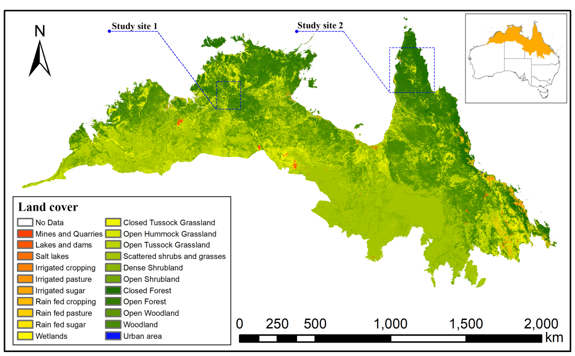

Fig. 1. Location of the two study sites. The base map is the Dynamic Land Cover Dataset Version 2.1 from Geoscience Australia cover 2014~2015.

2.2 Satellite data and processing

Nine spectral bands of Sentinel-2A MSI data were used and the spatial resolution was unified to 20 m for estimating the burn severity. The atmospheric correction of Sentinel-2A MSI data was implemented by using the Sen2Cor Tool (version 2.3.1) [7], which converts L1C data to Bottom-of-Atmosphere (BOA) reflectance (L2A) data. The tree cover percentage extracted from MOD44B Version 6 Vegetation Continuous Fields (VCF) product was used to constrain the model inversion process.

2.3 Retrieval of burn severity using FRT-RTM

Four consecutive phases were carried out to estimate the burn severity based on RTM: (i) model selection to simulate the reflectance corresponding to different burn severities. The Forest Reflectance and Transmittance (FRT) RTM (version 04.2013) [8] was selected for burn severity estimation because it can simulate the canopy reflectance by considering three vegetation strata. (ii) sensitivity analysis to ascertain the sensitive parameters for burn severity simulation. (iii) forward modeling which includes the parameterization of the RTM based on the sensitivity analysis results and generation of the look-up table (LUT) and (iv) RTM model inversion by finding the simulated spectral reflectance spectrum (stored in the LUT) that matches best with the observed spectrum using Spectral Angle Mapper (SAM) classification algorithm as the merit function.

3. RESULTS

The confusion matrix of binary burn severity estimation results between field measured and estimated burn severity based on RTM (global optimal search) and RTM plus tree cover (RTM+TC) was counted (Table 1). The RTM and global optimal search method derived a low commission accuracy

(38%) for NSV and low omission accuracy (50%) for SV burnt level in study site 1. This is because many plots are located at low tree covered areas, and thus the background charcoal and ash contribute more sensor observed signal, leading to the overestimation for NSV burnt level without the constrain of tree cover. By integrating the tree coverage in inversion process, the overall classification accuracy improved from 60% to 80%, and the kappa coefficient improved from 0.27 to 0.58 (Table 2). Model performances were similar in study site 2, the overall accuracy and the kappa coefficient increased from 73% to 83% and 0.25 to 0.38, respectively (Table 1). The improvement in accuracy at study site 2 was less than that of study site 1 demonstrated a potential to reduce the burn severity estimation errors for areas with low TCC, and thus site 1, with lower tree canopy cover than site 2, has experienced greater improvement in the accuracy. The results pooling the data for both sites together show that the estimation accuracy significantly improved by the proposed method to integrate tree coverage (RTM+TC) (Table 1). The overall accuracy and kappa coefficient improved from 65% to 81%, and 0.35 to 0.55, respectively.

Table 1.
Error matrix comparing burn severity observed on the field and estimated at study sites 1 and 2, and the two study sites together. Estimations were done using the FRT RTM alone and a global optimal search (without consider tree cover, RTM) and integrating information on tree cover (RTM+TC).

			RTM				RTM+TC			
			NSV	SV	Totals	Commission accuracy	NSV	SV	Totals	Commission accuracy
Study site 1	Field data	NSV	**69**	113	182	38%	**154**	28	182	85%
		SV	8	**113**	121	93%	33	**88**	121	73%
		Totals	77	226	**303**		187	116	**303**	
		Omission accuracy	90%	50%		**60%**	82%	76%		**80%**
	Kappa		**0.27**				**0.58**			
Study site 2	Field data	NSV	**118**	45	163	72%	**135**	28	163	83%
		SV	3	**13**	16	81%	3	**13**	16	81%
		Totals	121	58	**179**		138	41	**179**	
		Omission accuracy	98%	22%		**73%**	98%	32%		**83%**
	Kappa		**0.25**				**0.38**			
Two study sites	Field data	NSV	**187**	158	345	54%	**289**	56	345	84%
		SV	11	**126**	137	92%	36	**101**	137	74%
		Totals	198	284	**482**		325	157	**482**	
		Omission accuracy	94%	44%		**65%**	89%	64%		**81%**
	Kappa		**0.35**				**0.55**			

4. CONCLUSION

Burn severity is a critical factor for fire-related management and vegetation recovery. Previous burn severity estimation studies based on RTM simulation methods generally suggest that the burn severity index and spectral reflectance response should be corresponded to each other. However, the background of char and ash will have different contributions to the spectral signal achieved by remote sensing sensors with the tree coverage variation, causing that the same burn severity can correspond to different spectral reflectance and the same spectral reflectance could correspond to different burn severity. In this study, the overestimation errors of low burn severity in sparse tree covered area were significantly modified by integrating tree coverage in RTM inversion. Future work will focus on extending the methodology to other ecosystems.

5. REFERENCES

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