



Monitoring pre- and post-fire changes in land cover including biocrusts using high resolution satellite imagery in a grazed tropical savanna

Myint Swe, T¹; Williams, WJ¹; Zhao, Y²; Potgieter, A²; Eastaughffe, J³; Cowley, R³; Schmidt, S¹

¹NUE Lab, School of Agriculture and Food Sustainability, The University of Queensland, St Lucia, QLD, 4074, Australia. Email: t.myintswe@uq.edu.au

²The University of Queensland Alliance for Agriculture and Food Innovation, The University of Queensland, Gatton, QLD, 4343, Australia.

³Department of Agriculture and Fisheries, Berrimah Farm, 29 Makagon Road, Berrimah NT, 0828, Australia.

Key words: Monitoring ground cover, biocrusts, rangelands, savanna

Abstract

Biocrusts play a pivotal role as ecosystem engineers, mitigating soil erosion, enhancing soil stability, and enriching nitrogen availability in rangelands. In northern Australian savannas, prescribed fires are a common land management strategy. However, fire impacts biocrust function, making it important to monitor biocrust cover to assess ecosystem health and guide sustainable land management practices. In this study, we investigated land cover with a focus on biocrusts, before and after prescribed fire events at Victoria River Research Station in the Northern Territory.

A 2.6 km² patch situated more than 2 km from water in the north-west corner of a 14.7 km² paddock was burnt in October 2022. Cattle were left in the paddock both during and after the fire. High-resolution PlanetScope imagery was used to track changes in land cover between July 2022 and June 2023. Reference sites that included bare soil, biocrusts (95% coverage) and vegetative cover (grass, shrubs and trees), were collected in the field. Crust Index was employed to discriminate between land cover classes. Using supervised classification with a random tree classifier, we achieved 90% accuracy in identifying these land cover classes across multiple time points.

Post-fire, early wet season, biocrust cover decreased by 10.8%, from 67 ha pre-burn to 39 ha, partially due to an increase of 10% in vegetation cover (189 ha to 215 ha). Grass canopies had obscured the biocrusts underneath them. Bare soil areas expanded by 20%, from 7.9 ha to 9.7 ha, likely due to cattle preferentially utilising the burnt areas post fire during the following wet season. These findings underscore the importance of monitoring and adaptive strategies such as spelling paddocks from grazing post fire, essential for sustainable and resilient ecosystems.

Introduction

Australian rangelands cover vast areas across the country and are essential components of the nation's environmental, societal, and industrial dynamics. However, these landscapes are under increasing pressure from climate change and degradation, which threaten native vegetation, diminish landscape functionality, and cause local extinctions of various biota, including shifts in fungal and bacterial community structures (Hodgkinson & Wang, 2020). Biocrusts are unique and diverse communities of microorganisms, including bacteria, cyanobacteria, fungi, algae, lichens, mosses, and liverworts, that inhabit the soil surface and its upper layers. These biocrusts are predominantly found in regions with limited water availability and sparse vegetation cover (Weber et al., 2022). Occupying much of the soil surface in rangelands, biocrusts play a critical role as ecosystem engineers by mitigating soil erosion, enhancing soil stability, and enriching nitrogen availability. Disturbance factors such as fire and grazing significantly influence these biocrusts (Belnap & Eldridge, 2001).

In the Australian rangelands, prescribed fire is commonly used as a tool to manage vegetation density and regeneration (Nielsen et al., 2020). However, fire impacts biodiversity, including biocrusts, which provide several ecosystem services, such as reducing soil erosion and replenishing nutrients. Therefore, monitoring land cover changes, including biocrust distribution during prescribed fire events, is crucial for assessing ecosystem health and informing decision-making for sustainable rangeland management practices.

Remote sensing is essential tool for monitoring land cover and land use changes, and is a popular tool among agriculturalists and rangeland ecologists (Wabnitz et al., 2008). Detection and mapping for regional distribution of biocrust can be implemented using remote sensing with different platforms, spaceborne, Airborne, and Unmanned Aerial Vehicles (UAVs) (Rieser et al., 2021). Utilising satellite imagery offers a variety of benefits, primarily in its ability to generate a comprehensive temporal range of data. This capability allows for the quantification of both spatial and temporal changes within specific regions.

Multispectral satellite with high spatial resolution is considered to detect biocrust for large scale areas. Several studies have revealed that numerous species face limitations in producing detectable spectral signatures (Baxter et al., 2021). Biocrust's spectral signature resembles both soil and vegetation due to the dynamic states of microphytes that only actively photosynthesise when moist. This results in biocrusts appearing soil-like when dry and exhibiting a vegetation appearance when wet, and engaged in photosynthesis (Rozenstein & Adamowski, 2017).

To address this complexity, specialised methodologies have been developed, including the Crust Index, which utilises the normalised difference between red and blue spectral bands to detect cyanobacteria-dominated biocrusts (Karnieli, 1997). This approach leverages the unique reflectance properties of cyanobacteria, distinguished by the presence of the phycobilin pigment, which strongly reflects in the blue spectral region compared to sandy substrates (Karnieli & Sarafis, 1996).

In northern Australian rangelands, research on biocrust distribution and its response to prescribed fire remains limited. In this study we investigated land cover changes, including biocrust dynamics, before and after prescribed fire events, using high-spatial-resolution imagery from PlanetScope (3 m resolution). Cyanobacteria-dominated biocrusts, known to be prevalent in northern Australian rangelands (Williams et al., 2014), were analysed using the Crust Index to elucidate their spatial distribution and response to fire-driven disturbances. This research contributes to bridging knowledge gaps in biocrust area distribution and informs sustainable land management practices in the rangelands.

Methods

The study was conducted over a 2.6 km² area located at the Victoria River Research Station, Northern Territory, Australia. A prescribed fire event was carried out in October 2022, with cattle remaining in the paddock both

during and after the fire. Reference data were collected in the field to establish baseline conditions for land cover classes, including bare soil, biocrusts (95% coverage), and vegetation (comprising grass, shrubs, and trees). High-resolution imagery from PlanetScope (3 m spatial resolution) was employed to monitor land cover dynamics over the study period, spanning from July 2022 to June 2023.

The Crust Index was applied to differentiate land cover classes, particularly for detecting cyanobacteria-dominated biocrusts (Karnieli, 1997). A supervised classification approach using a random tree classifier was implemented to categorize the land cover into predefined classes. This method achieved an overall classification accuracy of 90%, effectively capturing temporal changes across multiple observation points.

Results

In this research, the spectral analysis is crucial in evaluating land cover changes employing crust index (Fig 1). The fire event significantly altered land cover dynamics within the study site, which included four primary classes: vegetation, bare soil, and biocrusts. The vegetation cover expanded from 189.27 hectares before the fire event during the dry season (July–September 2022) to 215 hectares after the fire event in the post-wet season (April–June 2023). Biocrusts exhibited a pronounced seasonal pattern, with coverage peaking at 67.18 hectares pre-fire and declining to 39.07 hectares post-fire. Conversely, bare soil areas increased from 7.9 hectares before the fire to 9.7 hectares following the fire in the post-wet season.

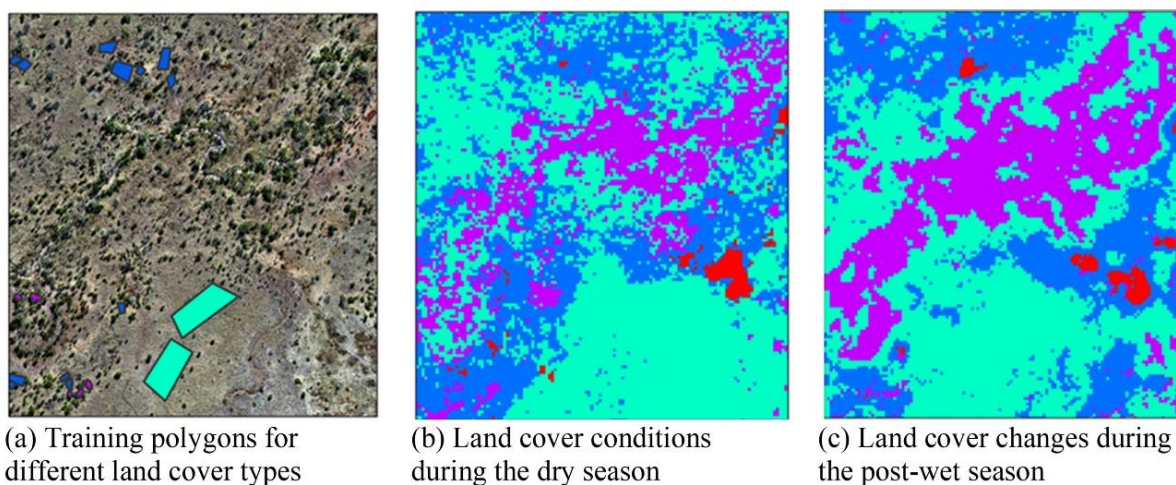


Figure 1. Seasonal land cover changes: (a) Training polygons for different land cover types: blue represents biocrusts, light green indicates grass, purple denotes trees and shrubs, and red corresponds to bare, degraded soil. The Crust Index effectively discriminated biocrusts from vegetation and bare soil during (b) the dry season (pre-fire) and (c) the post-wet season (post-fire).

Discussion

Post-fire rainfall introduced challenges in accurately capturing the spectral signatures of biocrusts, as increased vegetation cover overshadowed biocrust reflectance (Swe et al., 2023). Our findings underscored the discriminative capabilities of the Crust Index in capturing the spectral response differences among individual classes in every season. The pronounced recovery of vegetation—particularly grasses, trees, and shrubs—after the fire was driven by consistent rainfall, highlighting the resilience of rangeland flora to disturbance events. Bare soil areas expanded by 20%, likely due to livestock preferentially grazing in burned regions during the subsequent wet season. These findings highlight the complex interactions between fire, rainfall, and land cover dynamics in rangeland ecosystems. They also underscore the importance of post-fire management strategies, such as resting paddocks from grazing, to allow the recovery of vegetation and biocrust communities.

Acknowledgements

We gratefully acknowledge Meat & Livestock Australia for funding the research program Boosting Natural Regeneration of the Nitrogen Capital in Grazing Lands (B.PAS.0502), undertaken in collaboration with The University of Queensland, the Northern Territory Department of Agriculture and Fisheries, Department of Primary Industries, Queensland, and the team from Victoria River Research Station. Than Myint Swe extends gratitude to the University of Queensland Graduate School and SMARTSAT-CRC for their generous support and funding these studies.

References:

- Baxter, C., Mallen-Cooper, M., Lyons, M. B., & Cornwell, W. K. (2021). Measuring reflectance of tiny organisms: The promise of species level biocrust remote sensing. *Methods in Ecology and Evolution*, *12*(11), 2174–2183. <https://doi.org/10.1111/2041-210X.13690>
- Belnap, J., & Eldridge, D. (2001). Disturbance and recovery of biological soil crusts. In *Biological soil crusts: Structure, function, and management* (pp. 363–383). Springer.
- Hodgkinson, K. C., & Wang, D. (2020). Preventing rangeland degradation: A shared problem for Australia and China. *The Rangeland Journal*, *42*(5), 323. <https://doi.org/10.1071/RJ20068>
- Karnieli, A. (1997). Development and implementation of spectral crust index over dune sands. *International Journal of Remote Sensing*, *18*(6), 1207–1220. <https://doi.org/10.1080/014311697218368>
- Karnieli, A., & Sarafis, V. (1996). Reflectance spectrophotometry of cyanobacteria within soil crusts—A diagnostic tool. *International Journal of Remote Sensing*, *17*(8), 1609–1615. <https://doi.org/10.1080/01431169608948726>
- Nielsen, U. N., Stafford-Smith, M., Metternicht, G. I., Ash, A., Baumber, A., Boer, M. M., Booth, S., Burnside, D., Churchill, A. C., El Hassan, M., Friedel, M. H., Godde, C. M., Kelly, D., Kelly, M., Leys, J. F., McDonald, S. E., Maru, Y. T., Phelps, D. G., Ridges, M., ... Whyte, A. W. (2020). Challenges, solutions and research priorities for sustainable rangelands. *The Rangeland Journal*, *42*(5), 359. <https://doi.org/10.1071/RJ20059>
- Rieser, J., Veste, M., Thiel, M., & Schönbrodt-Stitt, S. (2021). Coverage and Rainfall Response of Biological Soil Crusts Using Multi-Temporal Sentinel-2 Data in a Central European Temperate Dry Acid Grassland. *Remote Sensing*, *13*(16), Article 16. <https://doi.org/10.3390/rs13163093>
- Rozenstein, O., & Adamowski, J. (2017). A review of progress in identifying and characterizing biocrusts using proximal and remote sensing. *International Journal of Applied Earth Observation and Geoinformation*, *57*, 245–255. <https://doi.org/10.1016/j.jag.2017.01.002>
- Swe, T. M., Williams, W. J., Schmidt, S., Potgieter, A., Cowley, R., Mellor, V., Driscoll, C., & Zhao, Y. (2023). Using digital photography to monitor changes in biocrusts and ground cover in a savanna rangeland. *The Rangeland Journal*. <https://www.publish.csiro.au/RJ/RJ22019>
- Wabnitz, C. C., Andréfouët, S., Torres-Pulliza, D., Müller-Karger, F. E., & Kramer, P. A. (2008). Regional-scale seagrass habitat mapping in the Wider Caribbean region using Landsat sensors: Applications to conservation and ecology. *Remote Sensing of Environment*, *112*(8), 3455–3467. <https://doi.org/10.1016/j.rse.2008.01.020>
- Weber, B., Belnap, J., Büdel, B., Antoninka, A. J., Barger, N. N., Chaudhary, V. B., Darrouzet-Nardi, A., Eldridge, D. J., Faist, A. M., Ferrenberg, S., Havrilla, C. A., Huber-Sannwald, E., Malam Issa, O., Maestre, F. T., Reed, S. C., Rodriguez-Caballero, E., Tucker, C., Young, K. E., Zhang, Y., ... Bowker, M. A. (2022). What is a biocrust? A refined, contemporary definition for a broadening research community. *Biological Reviews*, *97*(5), 1768–1785. <https://doi.org/10.1111/brv.12862>
- Williams, W. J., Büdel, B., Reichenberger, H., & Rose, N. (2014). Cyanobacteria in the Australian northern savannah detect the difference between intermittent dry season and wet season rain. *Biodiversity and Conservation*, *23*(7), 1827–1844. <https://doi.org/10.1007/s10531-014-0713-7>