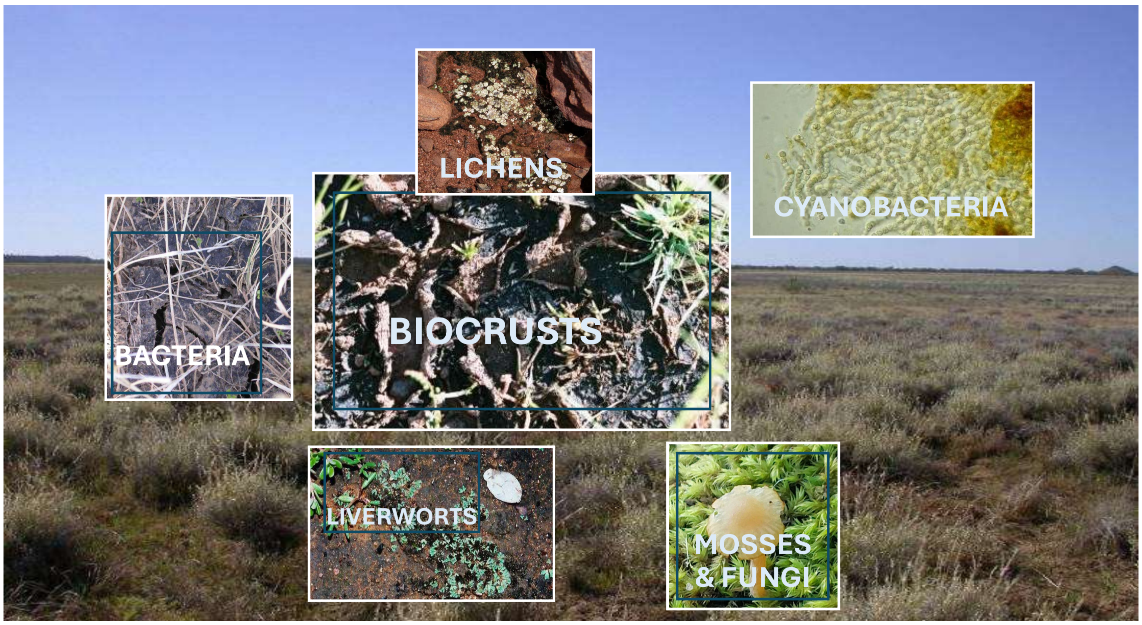
Farm Business Resilience Program

Biocrusts in the Australian Rangelands

A guide to understanding biocrusts and the latest research on their function in grazing ecosystems



Biocrusts are a community of living organisms (illustrated above) – containing a wide variety of species that can include all or some lichens, mosses, liverworts, bacteria including cyanobacteria, and fungi. Biocrust communities occupy the surface of the soil and subsoil to a depth of just a few millimetres (Fig. 1). They perform important ecological roles to protect the soil and cycle nutrients. These organisms can be grouped into several categories that help to describe them and their function. Biocrusts include many bacterial species that are capable of living in a range of habitats called generalists, and specialists that are specifically adapted to certain conditions such as rainfall, temperature, soil type and microsite (e.g. open spaces or under grass plants). Some bacteria are extremophiles that can survive very high temperatures and drought.

Non-vascular plants: Mosses, Liverworts and Hornworts

Mosses and liverworts do not have a vascular system (xylem and phloem) rather they contain simple tissues with functions that allow for the internal transport of water.

Symbiotic organisms: Lichens

Lichens form a symbiotic (two way) relationship between a cyanobacteria and fungi or an algae and fungi where both organisms benefit from each other, trading resources.

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Autotrophs, Photoautotrophs, Chemotrophs: Plants, Cyanobacteria, Algae, Bacteria

Autotrophs can make their own food, but photoautotrophs use light to capture photons that provide energy to produce complex organic compounds and acquire energy. Some autotrophs are also chemotrophs that have the capacity to use chemical reactions to produce food.

Heterotrophs: Bacteria, Fungi

Heterotrophs do not produce their own food but live through the consumption of other non-living biomass; they do not produce organic compounds for use as an energy source but take them from their environment and are important in decomposition processes.

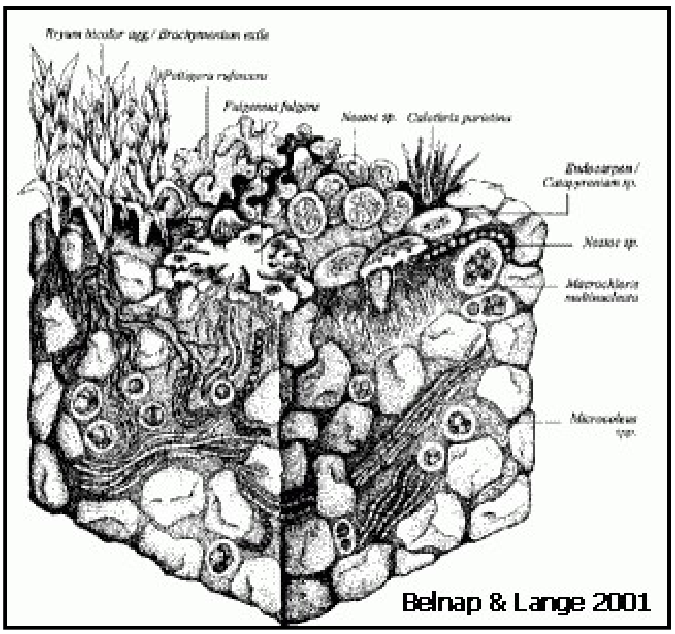


Figure 1. *3D illustration of microorganisms in a biocrust that includes surface dwellers (lichens, mosses, liverworts, cyanobacteria, algae) and subsurface dwellers (cyanobacteria, bacteria, micro fungi). (Belnap and Lange, 2003).*

(a)

(b)

Figure 2. *Cyanobacteria live both under the surface (a) and on the surface and have the capacity to move up and down the soil profile to gain light and moisture. (b) Cyanobacteria filaments are made up of many cells with a granular appearance that illustrates the storage of nutrients such as carbon, nitrogen and micronutrients.*

Biocrust Function

Biocrusts are a critical part of both soil health and landscape function across the Australian rangelands. Through DNA analysis we now know that more than 57 genes in cyanobacteria and bacteria function to take part in the whole of the nitrogen cycle (M. Vega pers. comm.). This example of the bacterial communities within a biocrust illustrates how important they are. In rangeland soils we do not know what many bacteria do. These bacteria are all present for a purpose, they are well adapted to the climate and rely on one another for resources. In semi-arid, arid and savannah rangelands, if the top centimetre is lost through drought or excessive trampling, much of this function will be lost and takes time to replace.

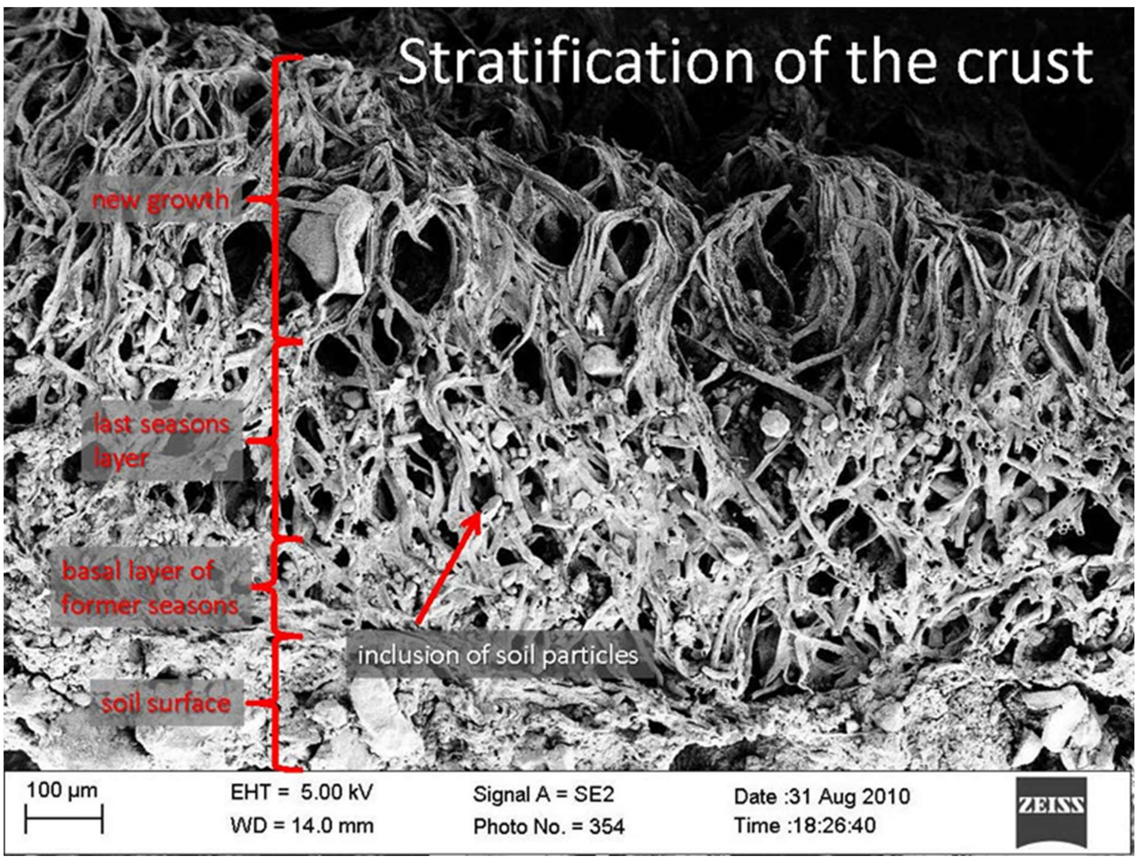


Figure 3. *Cyanobacteria often dominate biocrusts in the rangelands. This Scanning Electron Micrograph (100 um) illustrates the layers formed each season with the previous seasons biocrust gradually being integrated into the soil with new biocrust above (Büdel et al., 2018).*

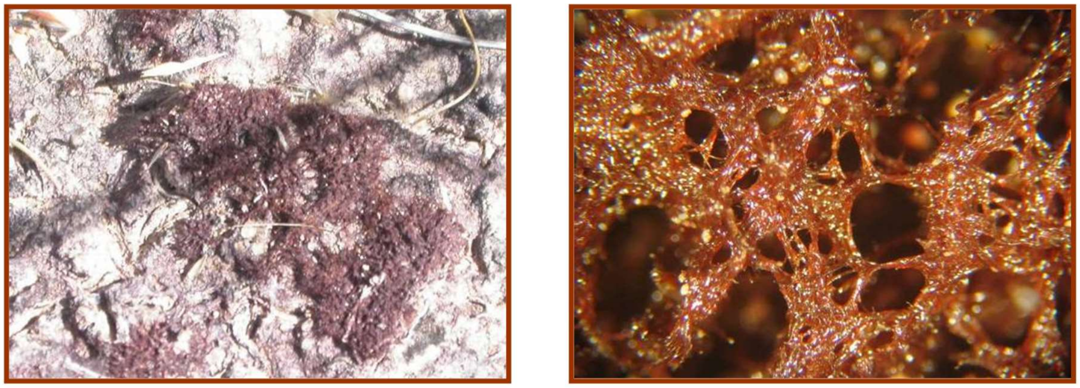


Figure 4. *Cyanobacteria can form a web of filaments that entrap soil particles and manage water infiltration. Cyanobacteria also produce a coloured pigment that acts as a sunscreen protecting their photosynthetic cells from harmful ultraviolet rays.*

In a detailed study of biocrusts and bacterial composition and function we found that bacteria formed >90% of the biocrust and over 80% of cyanobacteria had the capacity to fix N. In summary, biocrust bacteria were primed to form critical functions and both specialists and generalists in their role. For example, some bacteria, including cyanobacteria are adapted to extreme temperatures while others are adapted to decomposition and nutrient cycling. Key genera and their roles are summarised in Figure 5. Yet, we also found that about a third of bacteria were unknown therefore their functional purpose is poorly understood.

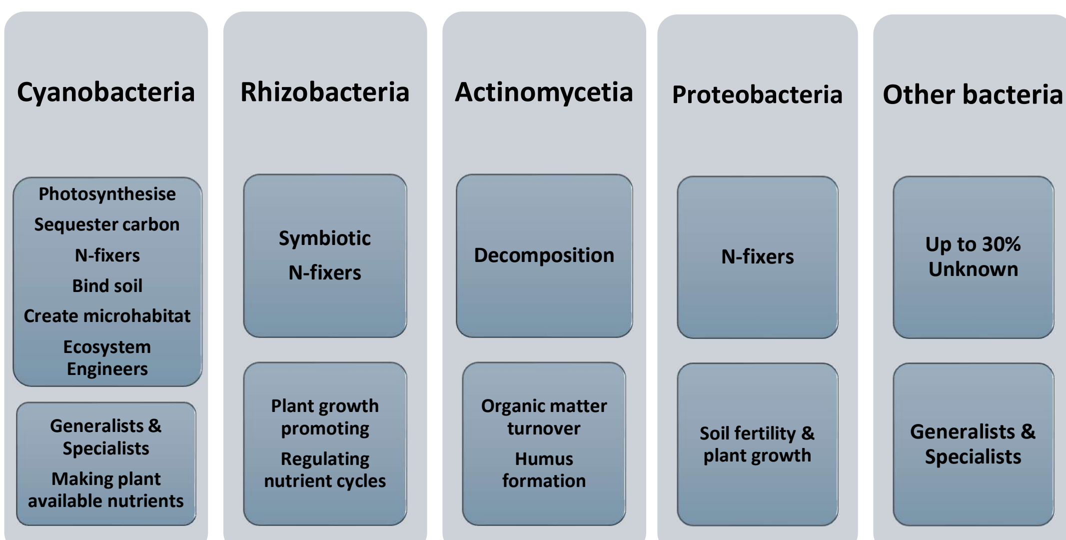


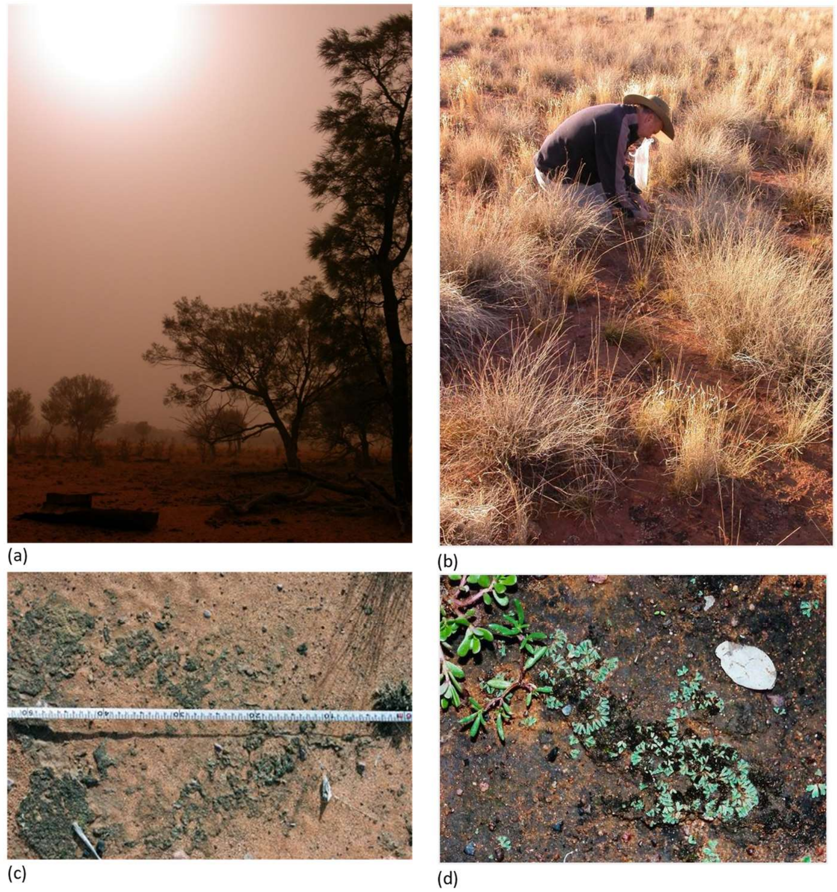
Figure 5. *Example of bacterial composition and roles in biocrust function taken from research in a rangeland soil. It was shown that bacteria formed >90% biocrust.*

Biocrusts in drought

During drought most biocrusts remain intact on the soil surface even if they are covered by a layer of sand brought in by willy willies (Fig. 6,7). This protects the soil surface and the underling profile from being blown or washed away by rain. However, if livestock are left in the paddock during drought or prolonged dry periods, the ground will be broken up, including the biocrust which then often disintegrates into its fragments blown away. If the soil surface is still protected with biocrusts they will recover when it rains and before the grass starts to regrow (Fig. 7). This provides a nutrient rich top layer on soil surfaces that acts as a nursery for seeds to germinate.

Figure 6. *(left) Millennial Drought, Western Queensland, (2003) followed by floods (2004).*

Figure 7. *(right) (a) Dust storms during drought relocate topsoil and biocrust organisms. (b) Typical perennial grassland where biocrusts live. (c) biocrust recovering after drought and rain with new patches growing. (d) biocrust with liverworts and cyanobacteria (dark colour) recovering after drought to occupy the soil surface between grass plants.*



Porphyrosiphon notarisii *Scytonema hofman- bangii* *Schizothrix sp.*

Figure 8. *Typical cyanobacteria found in Western Queensland rangeland soils (400x magnification).*

Why are cyanobacteria so important?

Cyanobacteria often form the scaffolding of the biocrust community as they create the greatest biomass in terms of size and integrate the biocrust community into a skin-like structure on the soil surface. Even though individual filaments are very small and detailed physiology is only visible under the microscope (Fig. 8), the magnitude of their effect when grouped together underpins their importance (Fig. 3,4). For this reason cyanobacteria are referred to as ecosystem engineers (Eldridge et al., 2010). Cyanobacteria improve soil organic content with nitrogen enrichment, including the formation of extracellular polysaccharides (EPS), which facilitate soil aggregation through the mucilaginous EPS binding agent that results in increasing humus content (Pandey et al., 2020).

Cyanobacteria photosynthesise like plants and many species fix nitrogen straight from the air into a plant available form. In research carried out in northern Queensland we found that cyanobacterial biocrusts had a net positive effect on carbon uptake over the course of the wet season (Büdel et al., 2018). This is an important outcome that features net zero emissions where biocrusts occupy soil surfaces. Nevertheless, livestock trampling, vehicle disturbance as well as other natural influences will diminish this benefit. Resting paddocks during times of biocrust growth will allow time for biocrusts to regrow and recolonise soil surfaces (Fig. 9).

Nitrogen fixation is carried out by heterotrophic and chemolithotrophic bacteria and many cyanobacteria who have specialised cells called heterocysts that have a thickened cell wall (to exclude oxygen) but take up nitrogen from the air. This process likely evolved during the oxygen devoid Precambrian period some 2+ billion years ago. Of the N_2 fixing microbial taxa, the cyanobacteria are of particular biogeochemical and ecological interest because they were also the first O_2 evolving photosynthetic organisms on Earth (Paerl, 2017).

In northern Queensland, cyanobacterial crusts dominated by N-fixing cyanobacteria Scytonema (Fig. 8), Stigonema and Nostoc, contributed over 5 kg plant available N per hectare over the course of a wet season (Williams et al., 2018). Peak N-fixation occurred during the height of the wet season when the cyanobacterial diversity in the biocrust was at its highest. Furthermore, just before the biocrust became inactive (during the dry season) a higher amount of plant available N was measured (Williams et al., 2018). New research suggests that the increased input of biocrust mediated N into the grass would result in improved pasture quality.

Seasonal growth of biocrusts

Biocrusts only function and photosynthesise when they are moist or wet. When they are dry, they remain dormant but do not lose their cell integrity. When it rains or with heavy dewfall biocrust organisms start to function again. Biocrusts in the Australian rangelands react differently to summer and winter rainfall. Biocrusts in northern and central Australia are primed to reactivate and grow in the wet season (Williams et al., 2014), whereas In southern Australia, biocrusts will react and grow in winter or summer. Thus, the function and activity of biocrusts can vary depending on seasonal effects (Fig. 9) along rainfall gradients, and timing of rainfall can determine their productivity (Büdel et al., 2018; Chilton et al., 2022; Williams et al., 2014).

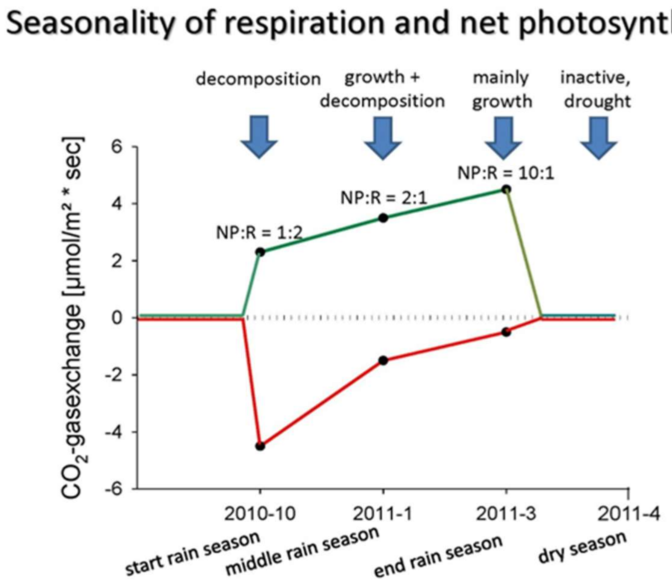


Figure 9. *Where there is a distinctive seasonal rainfall biocrusts reactivate once humidity rises. The green line represents growth (positive uptake of* CO_2*) and the red line represents decomposition (release of* CO_2*). The biocrust structure often decomposes before regrowth (also see Fig. 3) with peak growth at the height of the wet season (Büdel et al., 2018).*

Protecting biocrusts

Some key recommendations for the protection of biocrusts include:

- Moderate stocking rates
- Wet season spelling (where applicable)
- Seasonal spelling according to climate
- Resting paddocks during drought
- Including biocrusts in your monitoring program.

Further reading discussing the effects of grazing and fire (Vega-Cofre et al., 2023) and excessive trampling on biocrusts and the care of biocrusts include a range of publications (Eldridge and Delgado-Baquerizo, 2017; Williams et al., 2021, 2008)

Monitoring biocrusts

Recent research has demonstrated that biocrusts can be measured using mobile phone images, UAV and satellite imagery. Some methods are more technically advanced than others however online training is often available. Of most interest is the use of mobile phone photos to monitor ground cover including biocrusts. A detailed report is published in the Australian Rangelands Journal (Swe et al., 2023).

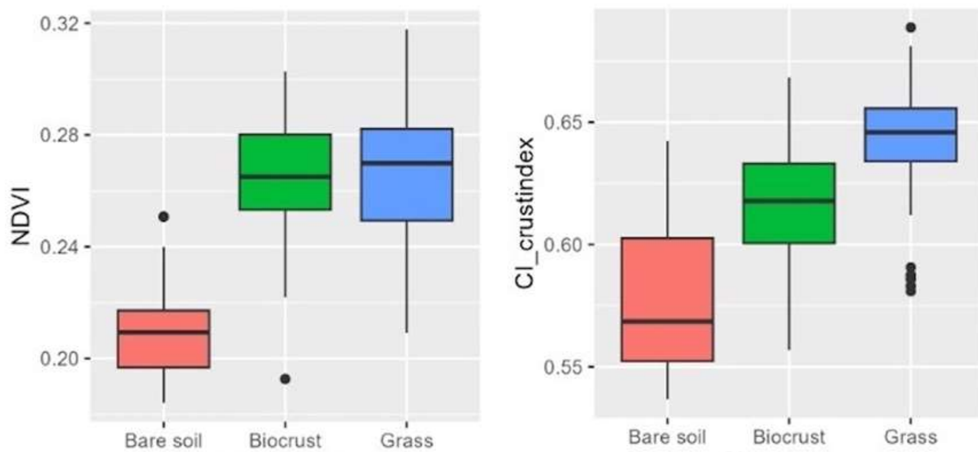


Figure 10. *Comparative analysis of spectral values for Bare Soil, Biocrust, and Grass using Normalized Difference Vegetation Index (NDVI) and Crust Index (CI_Crust Index) in the dry season.*

High resolution satellite imagery can now be used to accurately differentiate between basic ground cover attributes including biocrusts as they also reflect the chlorophyll spectrum. In Figure 10 we demonstrated the application of the Crust Index algorithm to differentiate between biocrust and grass using PlanetScope (3 m multi-spectral resolution). The Crust Index was originally developed in Israel and tested globally with success (Karnieli, 1997; Rieser et al., 2021). These are the first tests in Australia illustrating the capacity to select out the spectral bands that represent the biocrust. Future research and testing will include applications across different land types and with multi-spectral UAV's.

Further research will be published in 2025 to improve our knowledge on measuring the positive outcomes of biocrust presence.

For additional information: https://futurebeef.com.au/biocrusts-the-living-skin-of-rangeland-soils/

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