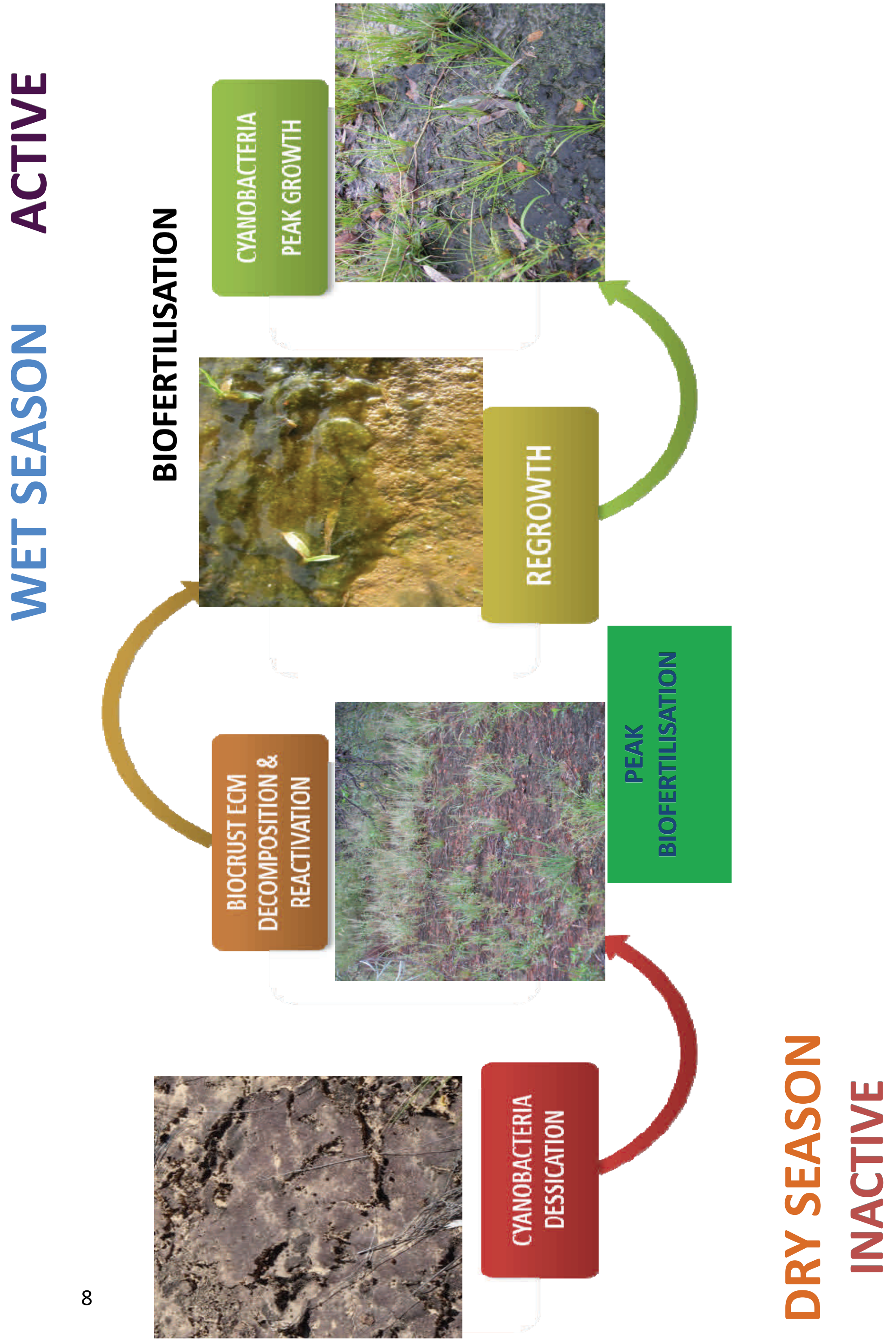


THE VALUE OF CYANOBACTERIAL SOIL CRUSTS IN NORTHERN AGRICULTURAL SYSTEMS

Interim Report

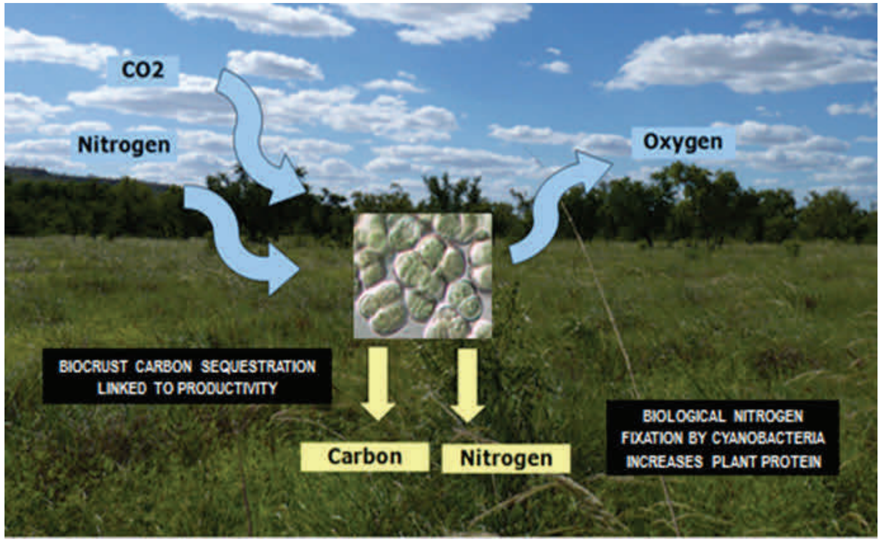
Dr Wendy Williams and Prof Burkhard Büdel

The University of Queensland Australia, The University of Kaiserslautern Germany

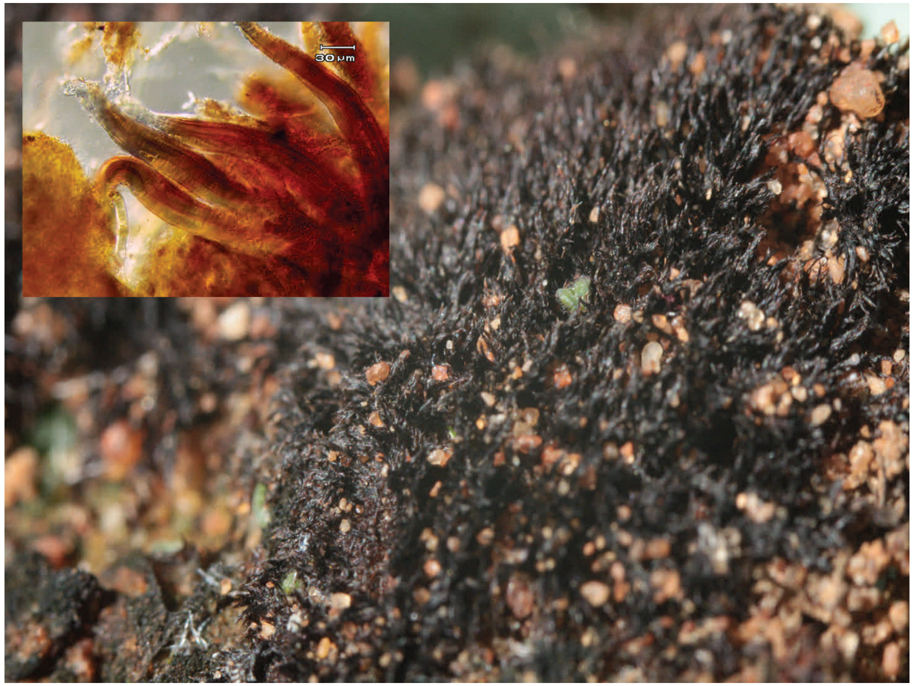
CYANOBACTERIAL BIOFERTILISATION SHAPES PRODUCTIVITY

Biocrusts form across soil surfaces and are home to a large range of biologically important microorganisms that are critical to soil function and plant nutrition. Across the rangelands of Australia cyanobacteria often dominate the biocrusts covering the soil surface. Cyanobacteria photosynthesise (use carbon dioxide) and many fix atmospheric nitrogen (like legumes), so in many ways they are similar to plants. During the wet season cyanobacteria grow vigorously to the extent that they act as a cover crop, protecting and fertilising the soil.

Soil cyanobacteria are strongly influenced by water and light availability and vary within their habitat. To protect against harmful ultraviolet irradiation many cyano-bacteria develop highly pigmented outer sheaths that gives them a typical black-ish, dark green or reddish-brown colour on the soil or rocks. They can readily use the resources from their environment, fixing atmospheric nitrogen and scavenging for nutrients, often storing resources ready for the next growth opportunity.



On soil, biocrusts can be physically different, dependent on the micro-organisms that make up the crust. Biocrusts generally contain several different cyanobacteria as well as micro-lichens, algae, liverworts, mosses, micro-fungi and bacteria. Nevertheless, cyanobacterial crusts can be thin biofilms (less than 1 mm thick) consisting of only one or two species whereas, well-developed biocrusts can be highly complex containing many microorganisms and be more than 1 cm thick.

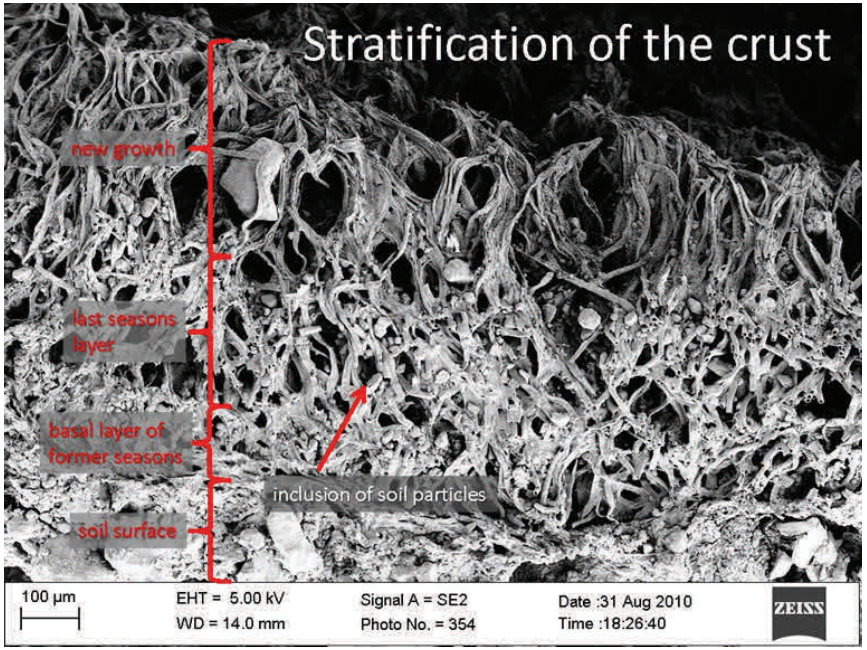


Close up image of a living cyanobacterial biocrust illustrating black pigmentation UV sunscreen and the inclusion of soil particles into the cyanobacterial filaments, inset of same cyanobacterial filaments at 200 x magnification, image © WJ Williams

This project has been supported by AgForce North, Queensland Parks and Wildlife, MMG Century Mine, Primary Industries Longreach, the Australian Geographical Society, The University of Queensland, the University of Kaiserslautern (Germany) and, the University of New South Wales

contact email: wendy.williams@uq.edu

web: www.cyano-online.org

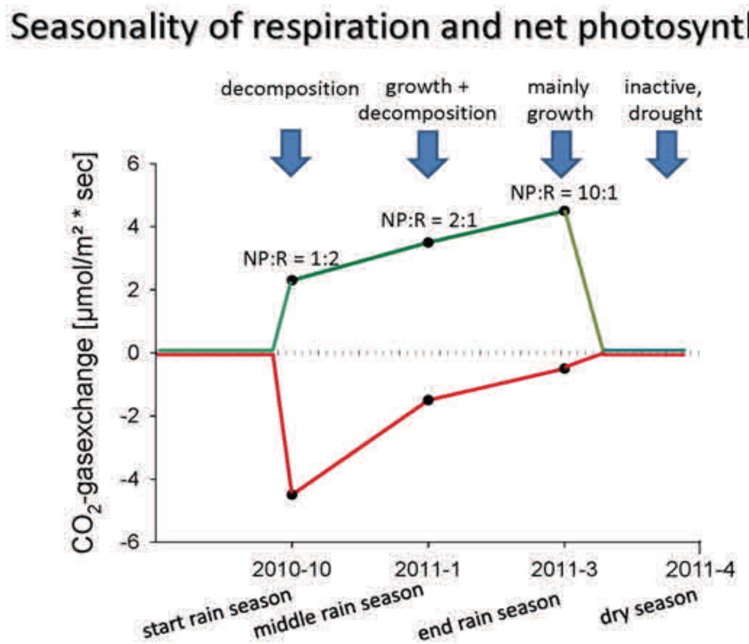


High resolution cross section of the cyanobacterial biocrust illustrating its stratification i.e. different layers with the inclusion of soil particles into the cyanobacterial filaments, last years growth that breaks down into organic matter and this seasons new growth, image by © B. Büdel

Annually, the crusts net primary productivity (NPP) supported the breakdown of the ECM (crust structure) and, a certain level of cell lysis (death) during the first significant rain events of the wet season. At the commencement of the wet season a gradual increase in NPP reflected the decomposition of the ECM, followed by a regrowth phase then, accelerated growth at the height of the wet season. Towards the end of the season NPP gradually declined. Plant-available nitrogen fluctuated throughout the wet season and peaked mid to late season.

Cyanobacterial crusts were also tested for photosynthetic activity during the dry season (2012) at a further four sites over a 1500 km east-west latitudinal transect across northern Australia, and there was no yield. At Pungalina-Seven Emu (Northern Territory) sampling was carried out in the dry season although five days prior there had been an unseasonal two day rain event (14 mm). Nevertheless, the cyanobacterial crusts were found to be in a desiccated state with little or no yield from PSII following two hours of rewetting (*in situ*). These findings support those from the Boodjamulla National Park project that have shown that cyanobacteria do not respond to rainfall events during the dry season.

Recent research that has been focused on the function and productivity of biocrusts in the northern savannah has provided important information regarding the role of cyanobacteria in soil nutrient cycling and carbon sequestration. Seasonal data acquired from measurements taken over two years (graph below) has revealed that cyanobacterial generated organic matter breaks down in the early stages of the wet season. This is followed by a high growth phase before cyanobacterial crusts dry out at the end of wet season and then remain inactive during the dry season (or drought). The graph below illustrates the relationship between biocrust decomposition (R: red line) and growth (NP: green line) over the 2010 –2011 wet season derived from *in situ* data.



Graph illustrates carbon sequestration and respiration of cyanobacterial crust on a seasonal basis © B. Büdel

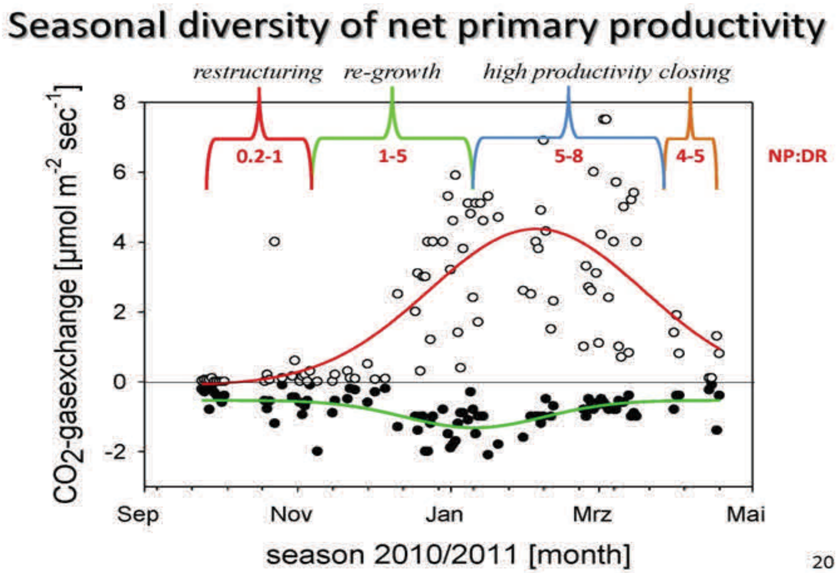
Globally, on an annual basis, biocrusts have been shown to contribute to at least 7% of soil carbon and 45% of biologically fixed nitrogen, and the results from this northern research project support this. Cyclical growth and breakdown of cyano-bacterial crusts that are rich in organic matter suggests that in regions where these biocrusts are prominent, pasture nutrition and soil carbon will be influenced.

MEASURING CARBON SEQUESTRATION BY CYANOBACTERIAL SOIL CRUSTS

Measuring the net amount of carbon dioxide (CO_2) taken up by cyanobacterial soil crusts requires equipment that can measure the change in atmospheric CO_2 concentration to an accuracy of 0.1 ppm. As this is also mixed up with what the trees and grass use we must isolate a small piece of soil crust while keeping it functioning under normal conditions in its natural environment.

The cuvette (left) that measures the carbon sequestration by cyanobacteria and the analytical equipment (right) required for data collection with Prof Burkhard Büdel and Dr Wendy Williams

The cuvette then "captures" the air for 3 minutes taking multiple measurements of the changes in the air concentrations of CO_2.



Measurements from the cuvette were analysed to demonstrate the net carbon sequestration or primary productivity that occurred during the 2010 and 2011 wet season © B. Büdel

SEASONAL TRANSFORMATION OF BIOCRUST REGULATES SOIL FUNCTION

At Boodjamulla National Park in north-western Queensland, perennial soil crusts dominated by cyanobacteria (*Scytonema* and *Symploca*) and liverworts (*Riccia*) grow extensively in between the tussock grasses of the dry savannah and the flood plain expanses. Seasonal carbon sequestration, plant-available nitrogen, crust desiccation (dry and inactive) and resurrection (reactivation) were studied in detail over two years (2009–2011). For several months during the winter dry season there was little or no rain followed by frequent and substantial storm rains throughout the summer wet season. The total annual rainfall was 1082 and 1128 mm over consecutive wet seasons.

Cyanobacterial biocrusts remained in a desiccated state for around half of the year. During this time the resurrection or recovery of Photosystem II (PSII) following periodic watering were tested using an Imaging PAM (Walz). PSII in cyanobacteria showed no signs of resurrection until new *Nostoc* colonies emerged on the eighth day. In the following dry season, biocrust samples were dry-preserved. These were then reintroduced into their natural environment one month into the wet season that was now high in humidity and subject to periodic rains. After the first rain event resurrection of PSII commenced within two hours and was fully functional within 24 hours at which time existing cyanobacterial cells rapidly re-hydrated and the extra-cellular matrix (ECM) appeared hydrophilic (absorbs water). Extra-cellular polysaccharide (EPS) production, initially as non-consolidated mucilage followed by cohesive gel, was observed several times throughout the wet season. Eventually, as the humidity drops and sunny conditions prevail, soil surface temperatures remain high (45-60°C), the EPS hardens and dries forming thick polymeric surfaces that appear hydrophobic (repel water). During the dry season temperatures fluctuate and the crusts crack and curl. After the first rains of the upcoming wet season the ECM starts to break down and the crust disintegrates before new perennial crusts start to regrow. These field studies demonstrated the environmental conditions governing the function of cyanobacterial ECM and the resurrection of PSII in the dry savannah.