ADVANCE QUEENSLAND INNOVATION PARTNERSHIPS (AQIP) PROJECT

Indigenous Employment, Forestry Livelihoods, Mining 2017 - 2021

University of the Sunshine Coast
Queensland, Australia

The Science Behind Mining

PROJECT PARTNERS

WARNING – ABORIGINAL AND TORRES STRAIT ISLANDER READERS ARE WARNED THAT THIS DOCUMENT MAY CONTAIN THE NAMES AND PHOTOGRAPHS OF DECEASED INDIGENOUS PEOPLE

This document was prepared by the University of the Sunshine Coast's (USC) **Indigenous Forest Livelihoods (IFL) group** (within the **Tropical Forests & People Research Centre - TFAP**). The document is an output of the USC Advance Queensland Innovation Partnerships (AQIP) project '*Indigenous Employment, Forestry Livelihoods, Mining*'. The document provides an overview of the AQIP project's research for development activities and outcomes and was prepared for the benefit of Traditional Owners of the Western Cape York region and beyond that face extractive industry developments on their traditional lands.

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The IFL group within TFAP is part of the Forestry Research Institute at USC and conducts research for development projects that bring together Indigenous people, researchers, industry, governments and non-government organisations to support sustainable Indigenous community development. Our work focuses on resolving challenges associated with forestry, mining and other developments on Indigenous peoples' lands – for informed decision-making for positive economic, social, cultural and environmental outcomes. In partnership with Indigenous peoples, government and the private sector, we work to develop evidence-based policies and programs – collaboration towards 'people-focused, forest-based' livelihood systems, realised through building Indigenous peoples' capacity for meaningful employment and enterprise development throughout the value chain.

Project Partners

Wik Timber. Wik Timber is part of the Wik Development Group and was formed for the benefit of the Wik and Wik-Waya Traditional Owners. Wik Timber's vision includes realising the Wik and Wik-Waya people's expectations for timber to be harvested from mining leases instead of this valuable resource being wasted. The company's objective is to build a sustainable, commercially viable timber industry that will contribute to better mine rehabilitation outcomes and provide opportunities for greater economic participation for local Indigenous people well beyond the life of mining. This includes multiple-use mine rehabilitation on the Wik and Wik-Waya traditional lands. http://www.wiktimber.com.au/

My Pathway. My Pathway is a national education, training, business development and employment services provider. It is the largest Community Development Employment Program (CDEP) provider in the country. My Pathway's vision is to build stronger communities, by working with individuals, families and communities to succeed. https://mypathway.com.au/

The University of Queensland, Centre for Mined Land Rehabilitation (CMLR). The CMLR is a collaborative and multi-disciplinary group of research, teaching and support staff, and postgraduate students. It addresses the environmental challenges of the minerals industry by translating scientific results into practices that continually improve mine rehabilitation outcomes, and is dedicated to delivering excellence in environmental research, education and awareness to the national and international minerals industry, relevant government departments, non-government organisations and local communities. https://smi.uq.edu.au/cmlr

Forest Research Centre (FRC), Southern Cross University. The FRC investigates the ecology and management of forests both in Australia and overseas, and how native forests and plantations can sustainably produce wood products and environmental services including carbon sequestration. Research staff in the FRC have broad and varied forestry and agroforestry interests, including in the development of new products from trees such as bioenergy. https://www.scu.edu.au/research-centres/forest-research-centre/

Private Forestry Services Queensland (PFSQ). PFSQ is an incorporated, 'not for profit' association that is recognised as an industry leader in private native forest management and hardwood plantation development. The PFSQ Team has been working for over 20 years to improve the quality, viability and sustainability of the private forest resource industry in Australia. https://www.pfsq.org.au/

Queensland Government Department of Agriculture & Fisheries (QDAF) – Salisbury Research Facility. QDAF aims to maximise the economic potential for Queensland's primary industries on a sustainable basis through strategic industrial development. The Salisbury Research Facility (Forest Products) works in close partnership with the Forest Products Innovation Team and are equipped to undertake forest products research and development on semi-commercial, pilot and laboratory scales. https://www.daf.qld.gov.au/contact/offices/stations-facilities/salisbury

The Nature Conservancy (TNC). TNC's mission is to conserve the lands and waters on which all life depends. TNC's Northern Australia program supports Indigenous land management across the northern Australian woodland savannas. TNC has the dual objectives of supporting Indigenous groups manage their lands and build an economy that supports long-term management for healthy country and benefits for community. For this AQIP Project, TNC's partnering inputs were limited to interrelated projects that provided support for Traditional Owners through consultation and capacity building.

Green Coast Resources (GCR). GCR is a small Australian-owned mining company that operates the small-scale Hey Point Bauxite Mine near Weipa on which the '*Indigenous Employment, Forestry Livelihoods, Mining*' project was implemented. GCR are committed to sustainable development in all phases of mineral production from exploration and mining lease management, through to operation and mine closure.

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AQIP Project Overview

The *Indigenous Employment, Forestry Livelihoods, Mining* project supports the establishment of a diversified Indigenous forest industry that will maximise Indigenous jobs by harvesting timber and non-timber forest resources ahead of bauxite mining and establishing plantation forestry trials in mine rehabilitation. The project was implemented at the Hey Point Bauxite Mine (on Wik traditional lands) near Weipa in western Cape York Peninsula. Current pre-mining practices in this region include the clearing and burning of valuable native forest resources. These resources can instead be used for Indigenous economic development. Current mine rehabilitation in the region has had mixed environmental outcomes and provided limited benefits for the local Indigenous community. There is potential to improve the mine rehabilitation outcomes through establishment of sustainable land-uses.

The project was supported by the mining sector and the QLD Government. Its aim was to help to reduce waste and environmental impacts, and generate improved Indigenous socio-economic and cultural benefits by establishing mine rehabilitation land-use options that provide jobs and business development. The project has provided provide proof of concept for wide-scale adoption by the mining sector.

The project outputs presented in this publication can inform policymakers, the mining industry and Indigenous communities in the design and implementation of pre- and post-mining management plans and strategies that will lead to acceptable mine-site relinquishment criteria while simultaneously generating improved environmental outcomes and socio-cultural benefits for impacted Indigenous communities.

Foreword

Dr Fiona Solomon – CEO, Aluminium Stewardship Initiative (ASI) https://aluminium-stewardship.org/

The mission of the Aluminium Stewardship Initiative (ASI) is to maximise the contribution of aluminium to a sustainable society. The posters in this publication provide an important contribution to evolving best practice for bauxite mining, and thus the aluminium value chain as a whole.

Critically, Indigenous involvement is at the heart of this work. With bauxite resources all over the world frequently located on the traditional lands of Indigenous Peoples, it is essential that industry take an integrated and participatory approach to sustainable development.

These posters provide evidence-backed and accessible examples of practice improvements that can be made, often taking advantage of local resources and knowledge. The bauxite industry has an opportunity to implement these and lead the way for the extractive industries more generally. We look forward to sharing this publication with the broader ASI community to help catalyse new thinking and change on the ground.

Acknowledgements

Many people have contributed in many ways to this AQIP Project and the research activities and outputs presented in these posters. We especially thank Gina Castelain, Jackie Castelain and Craig Ollington from Wik Timber; Warren Canendo from My Pathway; Associate Professor Peter Erskine, Natasha Ufer, Tracy Menon, Merinda Hall and Professor Longbin Huang from the University of Queensland (Centre for Mined Land Rehabilitation); Associate Professor Graeme Palmer and Sameer Usmani from Southern Cross University (Forest Research Centre); Sean Ryan, Dave Menzies and Duncan Sayer from Private Forestry Services QLD; Luke Preece and David Hinchley from The Nature Conservancy; and Richard Bond from Green Coast Resources. Finally, we acknowledge the contribution made by many Indigenous people in western Cape York Peninsula, through their participation in field work, demonstrating commitment to completion of their Conservation & Land Management (CALM) Certificate training and sharing their practical knowledge, skills and bush experience. We are grateful for the Wik and Wik-Waya Traditional Owners for being so welcoming and supportive of this applied research on their country.

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Traditional Owner Expectations for Pre-Mining Salvage Harvesting of Forest Resources

Mark Annandale[1*] & John Meadows[1]

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BACKGROUND

Bauxite mines are increasingly sited on Indigenous-owned land, particularly in tropical areas including northern Australia. The environmental impacts of bauxite mining are significant. In northern Australia, native vegetation is cleared and typically windrowed and burnt to make way for the mining (Figures 1-4). This wastes a range of forest products and emits significant amounts of greenhouse gases. The pre-mining use of forest products could mitigate these impacts and it is important to Indigenous communities facing bauxite mining developments on their traditional lands that they are engaged in this process. But Indigenous peoples' expectations are rarely considered or adequately addressed in site clearing activities of bauxite mining developments. This has to change. The pre-mining use of forest resources is better for the environment and could also support the livelihoods of the Indigenous communities impacted by bauxite mining developments.

METHOD (What we did)

We did a case-study of the western Cape York Peninsula bauxite mining region in northern Australia. This region is home to Indigenous communities whose traditional lands and livelihoods have been impacted by bauxite mining and exploration for over 60 years. The case-study included an inventory of the pre-mining forest resources and better understanding the expectations of the region's Indigenous communities and Traditional Owners for managing their forest country, including pre-mining salvage harvesting.

The Traditional Owners' expectations were determined through a process of community consultation over the past 20+ years. The lead author conducted the consultation over three related phases of institutional research for development and private consultancy that began in the late 1990s and continued, on and off, until 2020. The consultation was guided by ethical standards for research with Indigenous peoples, and always sought to ensure the right people were speaking for country.

Figures 1-4. The forests around Weipa in western Cape York Peninsula are cleared and burnt prior to bauxite mining, wasting valuable forest resources and emitting greenhouse gases.

"We want to see the timber harvested before the mine. It's good that the timber gets used rather than wasted and burnt. We would like to see a timber mill in Aurukun so that local people have jobs" – Reggie Miller (Wik-Waya Traditional Owner).

FINDINGS

The Indigenous Traditional Owners of western Cape York Peninsula expect full forest resource utilisation ahead of mining on their traditional lands. This fits within their worldview of being custodians of their land and 'caring for country'. The common industry practice of forest clearing and burning to waste is inconsistent with the Traditional Owners' cultural beliefs, knowledge and practices. It is evident that utilising forest resources ahead of mine clearing would support Indigenous livelihoods and have environmental benefits.

We found that some of the salvage harvested forest products have potential economic value for the local Indigenous communities (e.g. sawlogs, timber for local constructions, woodchips for bioenergy), some have high cultural values and applications (e.g. timbers or bark for art and craft, scar trees, 'sugarbag' honey), and some could be used to help improve mine rehabilitation outcomes (e.g. seeds, hollow logs for habitat, woodchips made into mulch/compost or biochar [as a bioenergy by-product] for soil conditioning) (see Figures 5-8). These uses would benefit the Indigenous communities and support new Indigenous businesses. These uses would also help mining companies to reduce waste, greenhouse gas emissions and reliance on non-renewable resources.

Figures 5-8. Some of the applications of salvage harvested forest resources in western Cape York Peninsula – whole log and sawn timbers offered for sale, and woodchipping harvest resides to create mulch/compost to help improve mine rehabilitation soils.

WHERE TO FROM HERE?

Western Cape York Peninsula's forests are still mostly cleared and burnt ahead of mining. But a local Indigenous business – Wik Timber – has begun salvage harvesting from a mining lease and selling sawn timbers. Wik Timber have a vision for integrated salvage harvesting and mine rehabilitation (Figure 9). Our work will continue to support Wik Timber in achieving this vision and its positive environmental and Indigenous livelihood outcomes, while also providing proof of concept to effect government policy change – stopping burning forests to waste and requiring full use of forests cleared for mining.

Figure 9. The Wik Timber vision.

Acknowledgements: This work was funded through the USC Advance QLD Innovation Partnerships (AQIP) project '*Indigenous Employment, Forestry Livelihoods, Mining*'. We acknowledge the Traditional Owners of western Cape York for their participation in the community consultation.

Tropical Forests & People Research Centre – Indigenous Forest Livelihoods

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Indigenous Employment, Forestry Livelihoods, Mining

Traditional Owner Expectations for Multiple-Use Mine Rehabilitation

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BACKGROUND

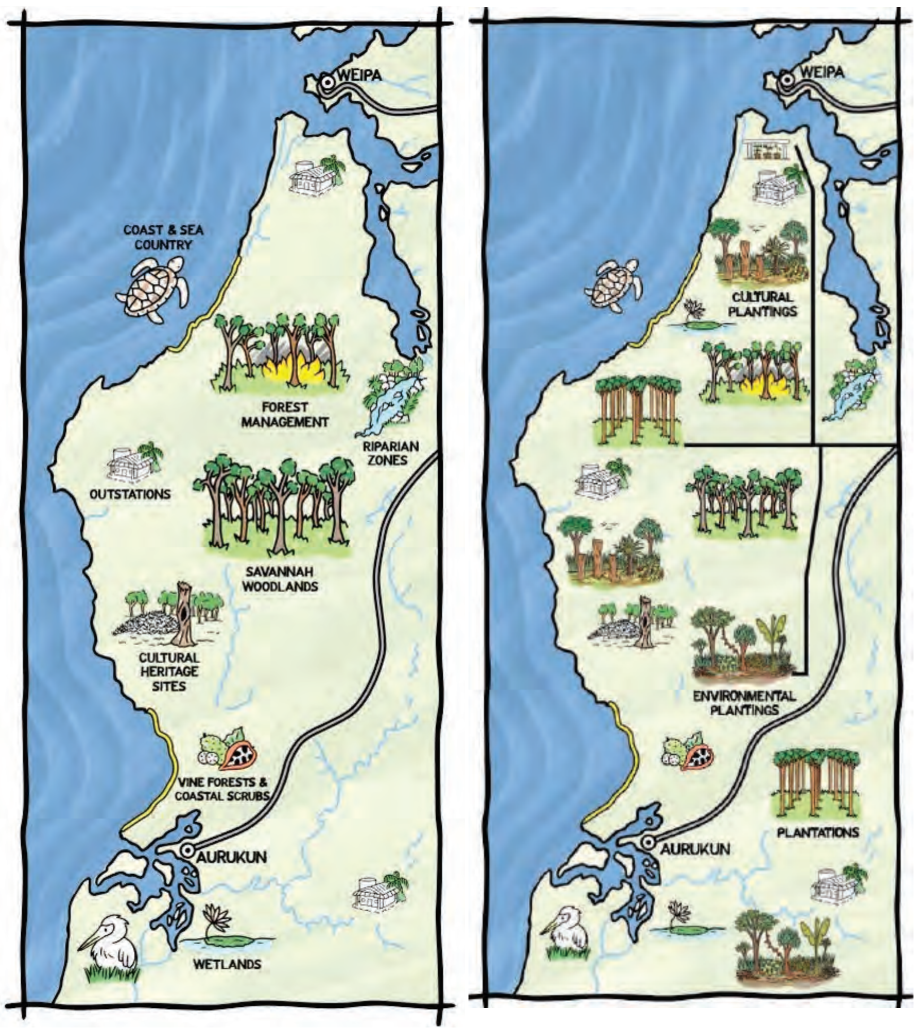
For the Indigenous communities and Traditional Owners of western Cape York Peninsula, bauxite mining creates much concern about biocultural, community health and livelihood impacts associated with the clearing of their traditional lands, the loss of access to these lands and their resources, and the ability to 'care for country'. Effective mine rehabilitation can reduce some of these impacts and it is important to the impacted Indigenous people that they are engaged in this process. But Indigenous peoples' expectations are rarely considered or adequately addressed in mine rehabilitation planning, and mine rehabilitation in western Cape York Peninsula has often had poor environmental outcomes and little to no livelihood benefits for the Indigenous people. This has to change. Mine rehabilitation that meets Traditional Owner expectations could be better for the environment and deliver social, cultural and economic benefits for the impacted Traditional Owners well beyond the life of the mining.

METHOD (What we did)

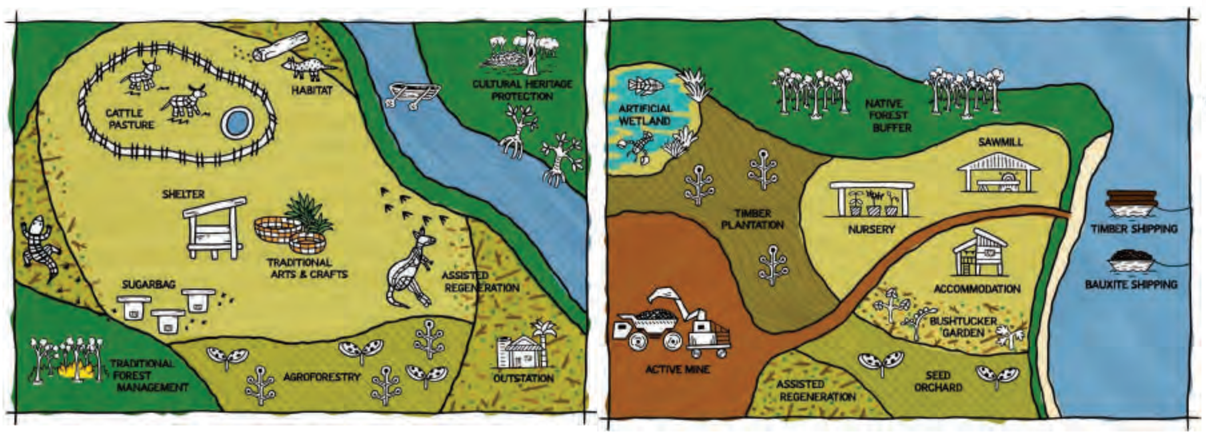
We did a case-study of the western Cape York Peninsula bauxite mining region where the Indigenous people have been impacted by bauxite mining and exploration for over 60 years. The case-study included better understanding the mine rehabilitation expectations of the region's Indigenous Traditional Owners. These expectations were determined through community consultations over the past 20+ years. The lead author conducted the consultations over three related phases of institutional research for development and private consultancy that began in the late 1990s and continued, on and off, until 2020. The consultations were guided by ethical standards for research with Indigenous peoples, and always sought to ensure the right people were speaking for country. The consultations informed the development of conceptual diagrams using stylised art to show the Traditional Owners' key messages and views of what effective mine rehabilitation looks like to them.

FINDINGS

The Traditional Owners' expectations focused on an Indigenous community forestry 'vision' – including the use of all forest resources before mine clearing and multiple-use mine rehabilitation. The mine rehabilitation is expected to be a mosaic of forests, grasslands, wetlands and community-based infrastructure for long-term environmental, cultural and livelihood benefits. Drawings began with visualising a 'big picture' – how the landscape looks before mining and how preferred rehabilitation land uses (e.g. environmental and agroforestry/cultural plantings, commercial timber plantations) fit into the landscape after mining **(Figures 1 & 2)**. 'Finer-scale' pictures were then developed as design concepts to assist on-ground implementation. **Figures 3 & 4** are examples of these pictures.



Figures 1 & 2. The Traditional Owners' 'big picture' of the mining landscape – showing features before mining (left) and how some preferred land uses (different types of rehabilitation plantings) fit into the landscape after mining (right).



Figures 3 & 4. 'Fine-scale' multiple-use mine rehabilitation concept diagrams – showing Traditional Owners' expectations for multiple-use mine rehabilitation, focusing on biocultural landscape restoration (left) and community development outcomes (right), and they could fit with existing land uses (e.g. mining buffers).

Queensland government mine rehabilitation policy and mining company practice in the case-study region currently prioritise the restoration of the pre-mining ecosystem. But this approach has largely failed. Multiple-use mine rehabilitation can create more resilient post-mining landscapes that match Traditional Owner expectations for an integration of conservation, production and community development objectives. As a general guide, Traditional Owners envision ~30% of the rehabilitation landscape designated to environmental (i.e. ecosystem restoration) plantings, ~30% to commercial timber plantations, ~30% to agroforestry/cultural plantings, and ~10% to community infrastructure. Community development through mine rehabilitation is a high priority of the Traditional Owners. **Figure 5** highlights some of the envisioned community development opportunities.

Figure 5. The Traditional Owners' 'vision' for Indigenous community development (including training and employment) opportunities provided by multiple-use mine rehabilitation.

WHERE TO FROM HERE?

There is a need for trials of Traditional Owner-defined multiple-use mine rehabilitation to quantify the costs and benefits of different landscape designs, and test the development and monitoring of locally-appropriate success criteria. The western Cape York Peninsula region presents significant opportunities for such trials and deserves greater focus by government agencies and mining companies to empower and benefit Traditional Owners who will one day be handed back the land for their management of the post-mined landscape.

Acknowledgements: This work was funded through the USC Advance QLD Innovation Partnerships (AQIP) project '*Indigenous Employment, Forestry Livelihoods, Mining*'. We acknowledge the inputs from Traditional Owners including elders from the following groups: Alngith, Anathangayth, Angkamuthi, Atambaya, Dulhunty, Peppan, Taepadhighi, Thanikwithi, Tjungundji, Warranggu, Wathayn, Wik and Wik-Waya, and Yupungathi. We also acknowledge Allan Bragg and Ian Little for inputs to the community consultations and mine rehabilitation concepts. Camila Ribeiro and Daniel Nogueira produced all figures.

Indigenous Employment, Forestry Livelihoods, Mining

Assessing Forestry Values of Cape York's Savanna Woodlands

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BACKGROUND: Significant areas of forest country in Cape York Peninsula are owned by Indigenous people. In the western Cape, these forests are mostly savanna woodlands (Fig. 1) that are some of the healthiest and largest areas of continuous savanna woodland left in the world. Some of these woodlands could be sustainably managed for commercial timber production (Fig. 1). The woodlands also have high biodiversity, cultural and ecosystem service values, including storing carbon. But large areas are being cleared and burnt to make way for mining. Not enough forestry data has been collected from these woodlands. We need to build on Traditional Knowledge, to know more about the timber and carbon values of Cape York's savanna woodlands because these values could then be better managed by Indigenous communities, to support local businesses and livelihoods.

Figure 1. Vast tracts of savanna woodlands in western Cape York Peninsula (left), with some areas having commercial timber values (right).

METHOD (What we did): We used local knowledge and science to assess around 20,000 ha of commercially-viable Indigenous-owned forest between Aurukun and Weipa in western Cape York. We used striplines and plots to measure all trees >10 cm diameter at breast height (DBH) (Fig. 2) to work out average values for each hectare, for total volume, volume by timber product, aboveground biomass (AGB – how much all the trees weigh) and carbon (C) stocks for the region's savanna woodlands. Some plots were permanent growth plots (PGPs) that can be remeasured in the future to determine long-term forest growth and responses to management such as thinning. We also used destructive sampling in ten plots (in forests to be cleared for mining – Fig. 3) to determine average per hectare values for the AGB and C stocks of the understorey. The understorey included all trees <10 cm DBH, shrubs, groundcovers (grasses, herbs and vines) and woody debris.

Figure 2. Measuring trees and establishing plots.

Figure 3. Measuring aboveground biomass.

FINDINGS: Results are summarised in Table 1. Darwin Stringybark, Melville-Island Bloodwood and Cooktown Ironwood are the region's main commercial species. There is high variability in forest quality, with a general trend of reducing productivity from east to west (Fig. 4). Sawlogs are the main commercial product and there typically aren't many higher-value pole or peeler (veneer) logs, except in some high-quality regrowth areas. Most of the volume is chip logs that are small or have poor form or other defects. Mature forest stores around 90 tonnes of C/ha. This includes around 12 t/ha in the understorey, but this amount can change each year due to regular dry season fires.

Table 1. Summary of the forest assessment results (average per hectare values for Indigenous-owned commercially-viable forests in western Cape York)

Stems/ha	Basal Area (m^2/ha)	Total Volume (m^3/ha)	Sawlog (m^3/ha)	Pole & Peeler (m^3/ha)	Chip log (m^3/ha)	AGB (t/ha)	C (t/ha)
217 +/- 13	13 +/- 1	52 +/- 4	16 +/- 2	4 +/- 0.5	32 +/- 3	186 +/- 13	87 +/- 6

Notes: Timber volumes are underbark volumes; +/- values are standard errors; In areas to be cleared for mining, a 1m stump must be retained which would reduce the timber volumes available for harvest.

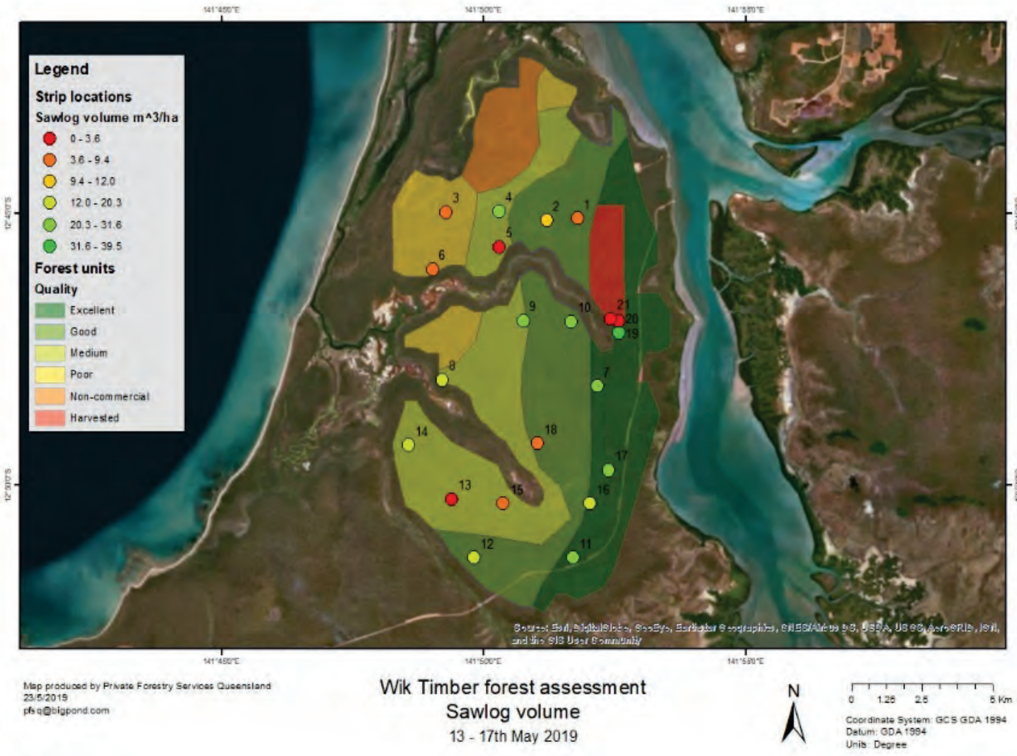

Figure 4. Forest productivity mapping of a mining lease on Wik traditional lands.

WHERE TO FROM HERE? This is the most detailed field-based assessment of forest productivity undertaken in western Cape York. It shows that many areas are more productive than current government mapping suggests. But we need to do more assessments, including in younger regrowth forests, establish more PGPs and teach Traditional Owners how to measure them, and support Traditional Owners to do more good forest management such as thinning and traditional fire because this will help the forests grow more high-value products. We also need to work out the best uses for the lower-value chip logs, which may include bioenergy or biochar and mulch for use in mine rehabilitation. And we need to do more to understand how the aboveground and belowground C stocks change with harvesting and other management because forest C trading can be an important sustainable income stream for local Traditional Owners.

Acknowledgements: This work was funded through the USC Advance QLD Innovation Partnerships (AQIP) project '*Indigenous Employment, Forestry Livelihoods, Mining*'. We acknowledge the fieldwork assistance from Dave Menzies and Duncan Sayers of PFSQ and local Wik Traditional Owners.

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Bauxite Mining & Greenhouse Gas Emissions

Part 1: Tracking emissions from forest clearing – 1958-2018

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BACKGROUND

Around 1/3 of annual global carbon emissions are caused by deforestation. Bauxite mining involves the clearing (and often burning) of forests, wasting valuable timber and non-wood forest resources and generating substantial carbon dioxide (CO_2) emissions. Since the late 1950s, native forest around Weipa in northern Australia has been cleared and burnt for bauxite mining each year (Figure 1). Related greenhouse gas emissions have not yet been documented. Bauxite mining around Weipa is likely to continue for many more decades. It is important to highlight the extent of historical greenhouse gas emissions to mining industry operators and government regulators and encourage changes to current poor practices.

Figure 1. To clear the landscape for bauxite mining, native forest is often burnt to waste. This is common practice around Weipa in northern Australia.

METHOD (What we did)

We estimated historical greenhouse gas emissions from forest clearing associated with the bauxite mining from the granted mining lease area around Weipa (Figure 2). Cleared areas are sometimes rehabilitated. At times, rehabilitated areas are cleared again. We derived temporally and spatially explicit estimations of the greenhouse gas emissions related to the clearing and burning of forest from 1958 to 2018. We also estimated the amount of CO_2 removed from the atmosphere by storing carbon in mine rehabilitation.

We divided the area mined for bauxite into 27 x 27 m squares. For each square, we looked out for events that changed the vegetation cover (Figure 3) between 1958 (just before extensive mine clearing started) to 2018 using satellite images and computer algorithms (FLINTpro software). The biomass of the native forest was measured on the ground through a forest inventory. This inventory information, combined with the observed events on each square and assumptions of how forest rehabilitation grows, allowed us to estimate the changes in forest biomass — and therefore the related emissions or storage of carbon and other greenhouse gases.

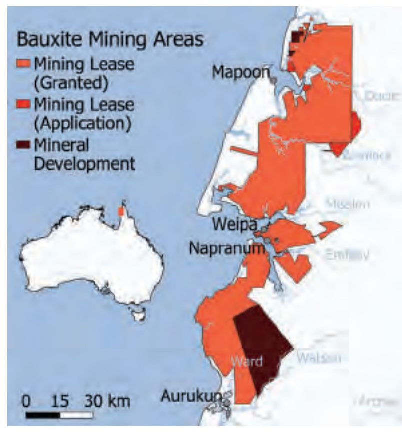

Figure 2. Bauxite Mining areas around Weipa.

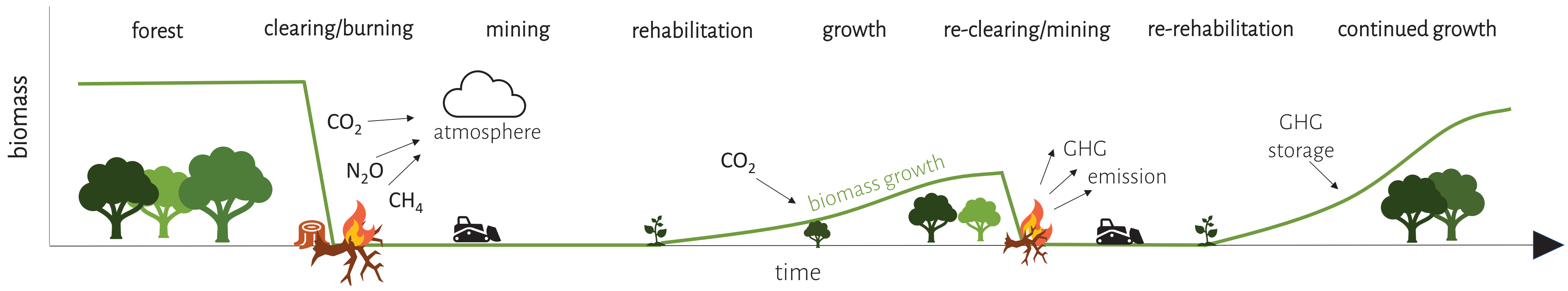

Figure 3. Example of forest clearing and rehabilitation events observed for one 27 m x 27 m square of bauxite mining lease over time.

FINDINGS

- Around **32,450 ha** of forest were **cleared** for bauxite mining around Weipa (1958 to 2018).
- Around **15.6 million tonnes** of CO_2 equivalent* have been **emitted** from the forest clearing (Figure 4).** This includes methane (CH_4) and nitrous oxide (N_2O), which are released in addition to CO_2 when biomass is burned.***
- Carbon equivalent of around **2.6 million tonnes** of CO_2 has been **removed** from the atmosphere and stored in mine rehabilitations.
- Net emissions (emissions minus removals from storage) are shown as cumulated net emissions over the years in Figure 5.

* Both CH_4 and N_2O have a much higher global warming potential than CO_2. To make the effect of these gases comparable, they are multiplied by a factor and expressed as a CO_2 equivalent.
** For the 1958 to 1987 period, no specific forest cover maps were available. For this period and the respective area of forest clearing, an equal annual clearing rate was assumed. Natural biomass reductions from termites have not been taken into account, which would lower the emissions.
*** Here we assumed a burning efficiency factor of 0.95. This means that 5% of the biomass is not released as gas. A high efficiency is justified since trees are purposefully piled up and burnt, and this process is often repeated to maximise disposal.

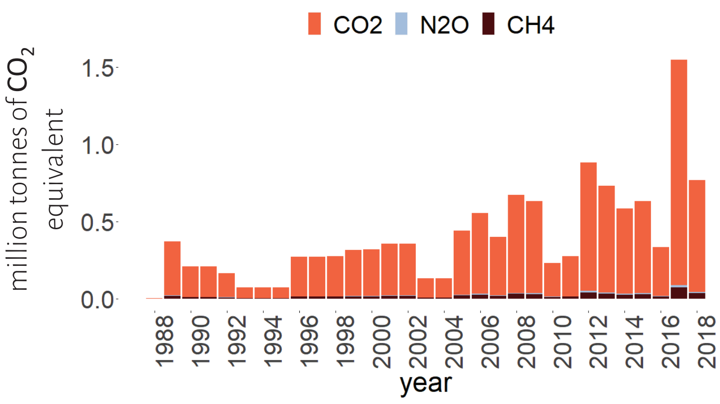

Figure 4. Greenhouse gas emissions from forest clearing for bauxite mining around Weipa.

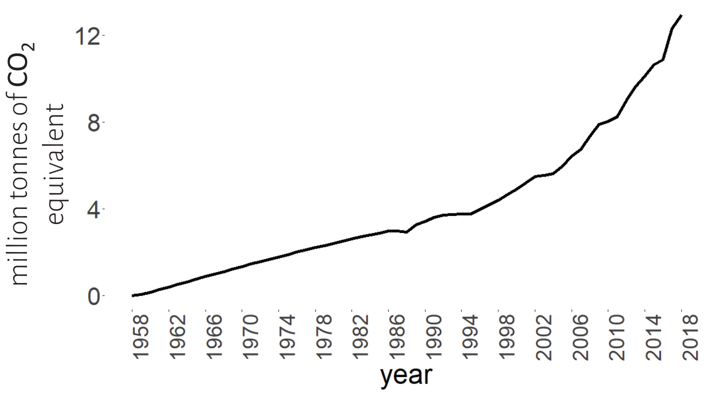

Figure 5. Cumulated net emissions (emissions minus removals from storage in mine rehabilitation) from bauxite mining around Weipa.

WHERE TO FROM HERE?

Our results show that large amounts of greenhouse gases have been emitted through the clearing and burning of forests ahead of mining around Weipa. Current mining rehabilitation practices result in a low proportion of CO_2 removals (storage) from the atmosphere.

The current practices will have to be improved. The results of these simulations can be used as reference to evaluate management alternatives (see Part 2 of the '*Bauxite Mining & GHG Emissions*' poster series). The method can be used to measure, verify and report future mining impacts.

Not all sources of greenhouse gases related to the forest clearing have been integrated in this study. For example, more research is needed to understand the greenhouse gas fluxes from and into the forest soils.

Greenhouse gases are not the only impacts forest clearings and rehabilitations have on the environment. The impacts on biodiversity and ecosystem services should be simultaneously considered and integrated into the simulations.

Acknowledgements
This work was funded by the USC Advance QLD Innovation Partnerships (AQIP) project '*Indigenous Employment, Forestry Livelihoods, Mining*'. The simulations were conducted with the FLINTpro software and supported by the Mullion Group, with special thanks to Dr Rob Waterworth and Mr Geoff Roberts at the Mullion Group.

Tropical Forests and People Research Centre

Bauxite Mining & Greenhouse Gas Emissions

Part 2: Reducing net emissions from forest clearing

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BACKGROUND

Since the late 1950s, around 30,000 ha of native forest around Weipa in northern Australia has been cleared and burnt to make way for bauxite mining. This has wasted around 8.5 million tonnes dry biomass of valuable forest resources and resulted in around 15.6 million tonnes of greenhouse gas emissions. Another 30,000 ha of forest or more will likely be cleared over the next 30 years as bauxite mining expands in the region. The industry's current wasteful and high emissions practices need to change. In addition, mine rehabilitation around Weipa has not yet successfully restored the cleared native forest (savanna woodland), meaning that opportunities to maximise the capture of atmospheric CO_2 as carbon stored in mine rehabilitation have not been taken.

We propose an alternative to the current pre- and post-mining forest management practices of the bauxite mining industry around Weipa. Instead of burning the biomass to waste, valuable timber products can be recovered and utilized to support local Indigenous communities (Figure 1). Mine rehabilitation can be improved to enhance its carbon storage and other ecosystem and community benefits. Here, we demonstrate the impact of this proposed 'better practice' scenario on greenhouse gas emissions and storage over the next 30 years (2020-2050) compared to the practices used around Weipa between 1988 and 2018.

Figure 1. Forests cleared and burnt to make way for bauxite mining could instead provide timber and biofuel for local Indigenous communities.

METHOD (What we did)

A forest inventory was conducted within the mining lease area (Figure 2) to estimate the biomass stored in the forest and the products (timber and biofuel) that could be salvaged instead of being burnt to waste (Table 1).

We used a software program (FullCAM) to simulate the treatment of the mining sites according to the better practice scenario assumptions (see Scenario Assumptions). Parameters predefined in FullCAM were combined with data from the forest inventory, determining that the Above Ground Biomass = 168 t dm/ha and the Dead Organic Matter = 18.1 t dm/ha.

The better practice scenario presented here, and the historic simulation presented in the *Part 1 Bauxite Mining & Greenhouse Gas Emissions* poster, are comparable as they are based on the same models and parameters.

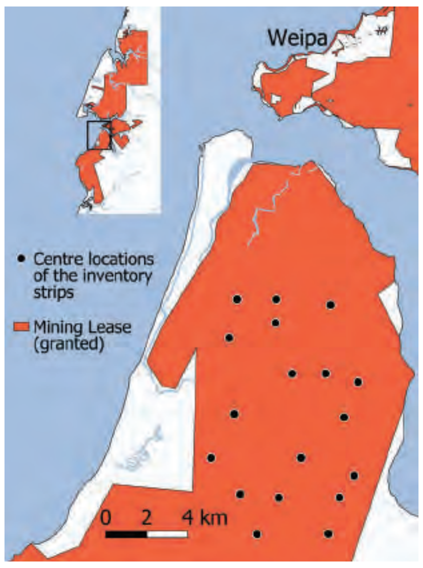

Figure 2. Locations of the forest inventory strips.

SCENARIO ASSUMPTIONS

For the better practice scenario, we assumed that:

- Each year, 1000 ha of forest are cleared for bauxite mining around Weipa for the next 30 years (2020-2050).
- When felled, trees are cut 1 m above the ground so that the roots can be easily pulled out of the ground prior to mining.
- The burning of both biomass in the field and in bioenergy systems includes CO_2, methane and nitrous oxide emissions.
- 10% of the mined area is not rehabilitated, instead being left clear for subsequent community infrastructure uses.
- All other areas are rehabilitated one year after clearing.

We propose 3 different types of mine rehabilitations:

- Commercial timber plantations (30%, thinned twice)
- Environmental plantings (30%)*
- Cultural plantings (30%)*

*Both environmental and cultural plantings are direct-seeded and thinned once in year 5 for maintenance. Removed trees are replaced with seedlings of age 0.

FINDINGS

- The better practice scenario results in both lower emissions and higher removals of greenhouse gases*.
- Net emissions (emissions minus storage) of the better practice scenario are around 38% of the net emissions of the historic scenario (Table 2, Figure 3).
- The higher greenhouse gas emissions of the historic simulations can be explained by:
  a. the frequent re-clearing of mine rehabilitation, and
  b. the longer storage of carbon in timber products in the better practice scenario.
- The lower carbon storage (CO_2 removal) in the historic simulations is due to:
  a. delayed rehabilitation,
  b. frequent re-clearing, and
  c. larger areas not rehabilitated until today.

*Natural biomass reductions from termites have not yet been taken into account.

Table 1. Tree sections with related products (defined from inventory).

Tree Section	Product	Share of the Tree Section turned into the Product
Trunk	Construction	12.41 %
	Furniture	2.46 %
	Biofuel	75.96 %
	Deadwood*	9.16 %
Roots	Deadwood	100.00 %
Others	Biofuel	100.00 %

*Deadwood is materials used for habitat and soil enhancement in mine rehabilitation.

Table 2. Greenhouse gas emissions and storage (million tonnes of CO_2 equivalent) for the better practice versus historic simulations. Historic emissions are calculated with reference to the area cleared for mining between 1988 and 2018 and scaled up to 30,000 ha.

	Better Practice	Historic
Emissions	9.2	14.0
Storage	4.3	1.2
Net	4.9	12.8

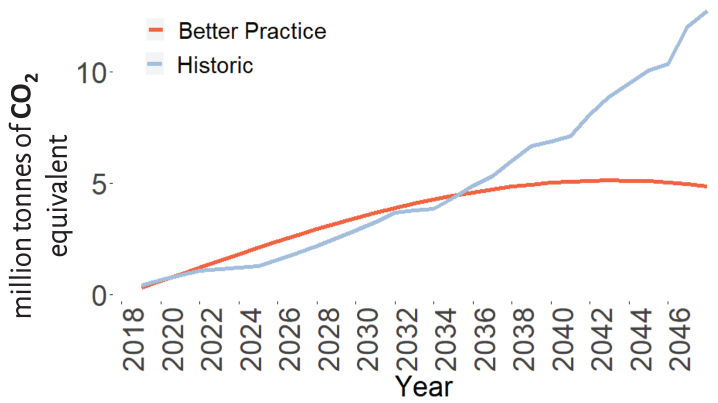

Figure 3. Cumulated net emissions (emissions minus storage) for the better practice versus historic simulations. Historic emissions are calculated with reference to the area cleared for mining between 1988 and 2018 and scaled up to 30,000 ha.

Acknowledgements

This work was funded by the USC Advance QLD Innovation Partnerships (AQIP) project '*Indigenous Employment, Forestry Livelihoods, Mining*'. Historic simulations were conducted with the FLINTpro software and supported by the Mullion Group. Special thanks to Dr Rob Waterworth and Mr Geoff Roberts at the Mullion Group.

WHERE TO FROM HERE?

Our results show the clear greenhouse gas emission benefits of changing the current pre- and post-mining forest management practices of the bauxite mining industry around Weipa to the alternative 'better practice' approach presented here. In addition, harvested biofuel can be used to replace non-renewable energy sources in local communities, thereby having additional greenhouse gas emission benefits.

We encourage mining companies and government regulators to use the outlined methods for exploring alternative pathways that can reduce the mining industry's carbon footprint and negative impacts on the environment while simultaneously providing livelihood options for impacted Indigenous communities.

Tropical Forests & People Research Centre – Indigenous Forest Livelihoods

Indigenous employment, forestry livelihoods, mining
Conservation & Land Management training

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CREATE CHANGE

BACKGROUND: Many local Indigenous people in western Cape York Peninsula, and particularly many of the region's youth, want to do work on country. This includes conservation work to protect the environment and cultural sites, to do traditional land management, to become rangers and for some people work for companies like Wik Timber or mining companies. Our project provided an opportunity to partner with the regional social and economic development organisation MyPathway, to deliver Conservation & Land Management (CALM) Certificate I and II courses for Indigenous people interested in careers working on country. The CALM training helped prepare them for working on country by developing their knowledge, skills, work readiness and experience in many areas of natural and cultural resource management, including safe and sustainable forest management and mine rehabilitation techniques. Importantly, as part of the CALM training we were able to involve the trainees in many of the research activities we were doing at the Hey Point Bauxite Mine.

What we did to build the trainees' knowledge, skills, work readiness and experience

The CALM training involved theory work in the classroom and practical work at the MyPathway nursery at Napranum and on the Hey Point mine site. The trainees got lots of hands-on experience and mentoring to measure trees, collect soil samples, record information and learn how to use specialist forestry tools. Working alongside the university scientists and government forest rangers was of great benefit to the trainees. The training courses taught skills in:

- Safe working practices;
- Numeracy and literacy lessons and support;
- Tree marking and measuring for timber harvesting (Figure 1), including identifying habitat trees;
- Forest inventory recording;
- Soil sampling (Figures 2 & 3);
- Separating leaves and sticks from felled trees to weigh for biomass assessments (Figures 4 & 5);
- Collecting seeds (Figure 6)
- Plant nursery work (Figures 7, 8 & 9);
- Using a GPS and reading maps;
- Doing mine rehabilitation and other revegetation work (Figures 10 & 11);
- Collecting wood samples from trees (Figure 12);
- Installing camera traps; and
- Helping with flying drones.

Some participants also received machine operating, first aid, chainsaw and chemical training.

Figure 1: Marking a tree for forestry inventory at Hey Point.

Figure 2: Collecting soil samples from stockpiled topsoil at Hey Point.

Figure 3: Collecting soil samples from natural forest at Hey Point.

Figure 4: Separating leaves from felled tree to weigh, at Hey Point.

Figure 5: Separating sticks and leaves from felled tree to weigh , at Hey Point.

Figure 6: Collecting Ironwood seeds for planting in mine rehabilitation at Hey Point.

Figure 7: Work in the Napranum My Pathway nursery, propagating plants.

Figure 8: Work in the Napranum nursery.

Figure 9: Ironwood seedlings grown in the nursery.

Outcomes and future plans

The project included Indigenous people in all fieldwork, successfully upskilling them and benefiting the researchers. Of 33 participants in the CALM I course, 25 graduated in December 2018, and of the 24 participants in the CALM II course, 13 graduated in August 2019. Some trainees got jobs and all said they got a lot out of the course and benefited from the real work experience, learnt a lot about science and were more ready and motivated to get work in the western Cape region. The CALM training was a successful model that should be repeated in other research projects in the region.

Figure 10: Clearing vines for the planting in vegetation buffer zones at Hey Point.

Figure 11: Planting seeds in the vegetation buffer zone at Hey Point.

Figure 12: Collecting fresh wood samples under the bark of a felled tree at Hey Point.

Acknowledgements

This work was funded by University of the Sunshine Coast's Advance Queensland Innovation Partnerships (AQIP) project '*Indigenous Employment, Forestry Livelihoods, Mining*'. CALM training was delivered by MyPathway for Training Connections Australia. Special thanks to Warren Cannendo for leading the training, and Kurt von Kleist (USC), Peter Erskine (UQ), Gina Castelain (Wik Timber), Sean Ryan (PFSQ) and all other USC and UQ researchers that worked at the Hey Point site and contributed to the CALM training.

Indigenous employment, forestry livelihoods, mining

Tools and Equipment Used for Fieldwork

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BACKGROUND At the Hey Point bauxite mine, we needed to collect and measure lots of things to learn about the area from a scientific perspective. We had help from Traditional Owners and Napranum community members to measure trees, take photos and collect tree and soil samples over many fieldwork visits. For all of this work before, during and after mine rehabilitation, we needed many different kinds of tools and equipment. Having the right tools and equipment is important for data and samples to be collected and analysed properly. Here, we talk about some of the tools and equipment we used.

Before rehabilitation

We measured lots of trees to find the biomass of all the trees (how much wood, branches, leaves) at Hey Point. We used **spray paint for marking** and a **'DBH' (Diameter at Breast Height) tape** to measure how wide the trees were across the trunk **(Figure 1)**.

We used a **chisel** to remove tree bark and a special **drill** to remove some of the fresh wood underneath the bark **(Figure 2)**. Then we collected wood samples in **glass tubes (Figure 3)**. This was to test the water inside the tree.

We cut down trees and separated all the sticks and leaves, using **secateurs**, **large scales** to weigh them with **tarps** and **rope (Figure 4)**. Then we collected smaller samples to weigh on **small scales**, dried them in an **oven** and weighed them again to see how much water was in the sample **(Figure 5)**. Wooden discs from the same trees were sampled, by cutting a small pie shape with an **axe** and a **chisel**, then weighing the discs before and after drying **(Figure 6)**.

Figure 1: Spray-painted tree, measuring 30 cm DBH.

Figure 2: Drilling into the tree bark.

Figure 3: Collecting samples of wood underneath the tree bark.

Figure 4: Separated sticks and leaves from a felled tree.

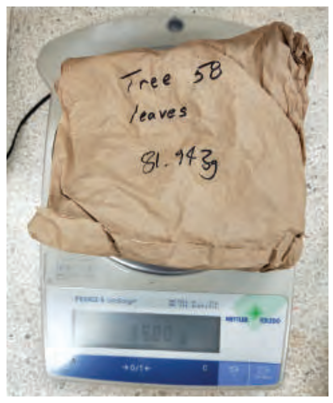

Figure 5: Weighing a small sample of leaves from a tree, after drying.

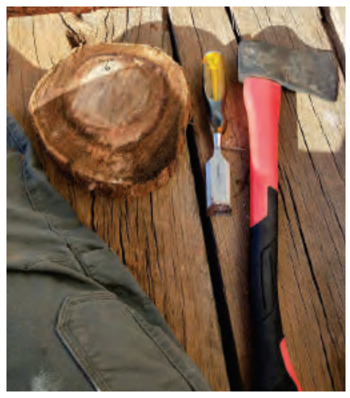

Figure 6: Tools used to cut pie shapes from wooden disc of cut tree.

Soil was collected from different places to see how much nutrients there was. We used **shovels** and a **tarp** to mix samples from different holes **(Figure 7)**.

Figure 7: Collecting soil with shovels.

We flew a **drone** overhead to see the site from a bird's-eye-view **(Figure 8)**. With **photos** from the drone, we could more easily see where the soil had been moved and could identify trees from above.

Figure 8: Drones to collect images from above.

Motion-sensing cameras were set up in an area that was cleared and naturally growing back. This was to see what animals were using the site, even when the forest wasn't grown back yet. The cameras caught pigs, dogs and a bull **(Figure 9)**. Now we've seen that feral animals use the site more than big native animals like kangaroos.

Figure 9: Photos captured by motion-sensing camera, showing a pig (left), a bull (top right) and a dog (bottom right).

During rehabilitation

Seeds were weighed with **small scales** to help us sow them evenly across the rehabilitation **(Figure 10)**. We used **kitchen measuring spoons** to sow the right amounts **(Figure 11)**.

In the rehabilitation area, we used a long **100m measuring tape (Figure 12)** to divide the area and make sure we were sowing each spoon of seeds in the right size area **(Figure 13)**.

Figure 10: Weighing seeds before rehabilitation.

Figure 11: Kitchen spoons used to measure seeds.

Figure 12: 100 meter measuring tape.

Figure 13: Using measuring tape to sow seeds in a line.

To apply fertiliser in the direct seeding area, we used **buckets** to spread this over the surface by hand **(Figure 14)**. We used spray-painted **wooden posts** to see the boundaries of where to fertilise **(Figure 15)**. In the tubestock area, we put a small cup (**cut plastic bottle**) of fertiliser in the holes where some seedlings were planted **(Figure 14)**.

Figure 14: Bucket of fertilizer and small cup used to measure it.

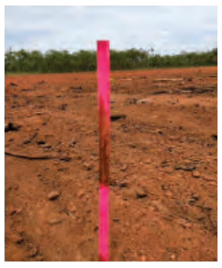

Figure 15: Spray-painted wooden post marking fertilizer blocks.

Figure 16: Trimble GPS to find locations in the rehabilitation.

Figure 17: GPS screen showing map of rehabilitation design.

After rehabilitation

We used **software** on the **computer** to randomly choose where to measure seedlings in the direct seeding area. When we mapped these areas (plots), we put the locations on a **GPS** to find the exact places when we were in the rehabilitation area **(Figures 16 & 17)**. We marked the place of each plot with **posts** and **numbered tags (Figure 18)**.

Plants were measured in the direct seeding rehabilitation with a small **ruler (Figure 19)**. In the tubestock rehabilitation, the seedlings were bigger so we made a **measuring stick** with a **broom handle** and wrote the measurements on the stick **(Figure 20)**. Then we needed to write down all of the measurements on **paper to record** it and analyse it back at the university **(Figure 21)**.

Figure 18: Post with tag showing plot 1 in direct seeding rehabilitation.

Figure 19: Measuring Nonda plum seedling with small ruler.

Figure 20: measuring bloodwood seedling with measuring stick.

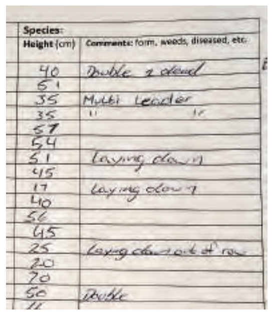

Figure 21: Recorded plant heights in the tubestock rehabilitation.

Acknowledgements

This work was funded by the University of the Sunshine Coast's Advance Queensland Innovation Partnerships (AQIP) project '*Indigenous Employment, Forestry Livelihoods, Mining*'. Wik Timber, Wik Traditional Owners and other Indigenous community members helped with the data collection as part of CALM training and work experience. Thanks also to Robyn Boldy, Kurt von Kleist and Adriana Vega for help with many tasks.

Indigenous employment, forestry livelihoods, mining
Finding, identifying & measuring trees using drone technology

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CREATE CHANGE

BACKGROUND

The three main trees at Weipa and at the Hey Point Bauxite Mine are Darwin Stringybark (Figure 1), Melville Island Bloodwood (Figure 2) and Cooktown Ironwood (Figure 3). Before mining, the forest is cleared, and many valuable timber trees can be wasted. It is important to know how many of these trees are in an area, and how big they are, so they can be harvested, or seed collected from them, before they are removed for mining.
Drones might be able to help make it quicker and easier to find, identify and measure these trees, so that people don't have to spend as much time in the forest measuring the trees by hand. If this can be done quickly by drone, we can more quickly know how much timber is in a forest before harvesting the trees.

Figure 1: Darwin Stringybark (*Eucalyptus tetrodonta*).

Figure 2: Melville Island Bloodwood (*Corymbia nesophila*).

Figure 3: Cooktown Ironwood (*Erythrophleum chlorostachys*).

METHOD (what we did)

At Hey Point, we used a drone to identify tree canopies from above (Figure 4) and a GPS to map more than 120 tree canopies from the ground (Figure 5). The heights of the trees were recorded as well as their width, measured with a DBH (Diameter at Breast Height) tape (Figure 6). The drone was flown over a large area to get lots of images of many trees and the images were combined to create a map of the whole area (Figure 7). This process also uses mathematics to see how measuring trees from the ground compares with measuring them with drones from above (see point elevation and digital surface model in Figures 8c and 8d). We wanted to see:
- which trees could be identified from drone imagery, and
- if the tree width (DBH) could predict how big their canopies were.

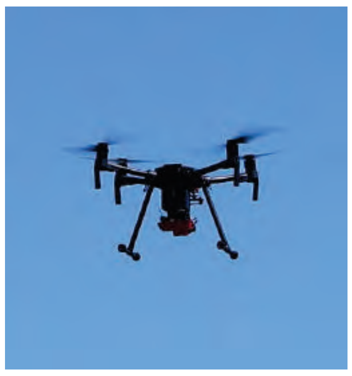

Figure 4: Drone being used to identify trees from above.

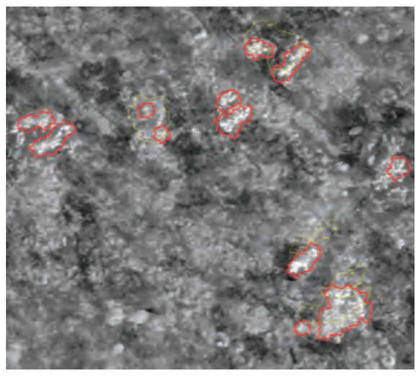

Figure 5: Mapped canopy areas from the GPS on-ground.

Figure 6: Tree measuring from the ground.

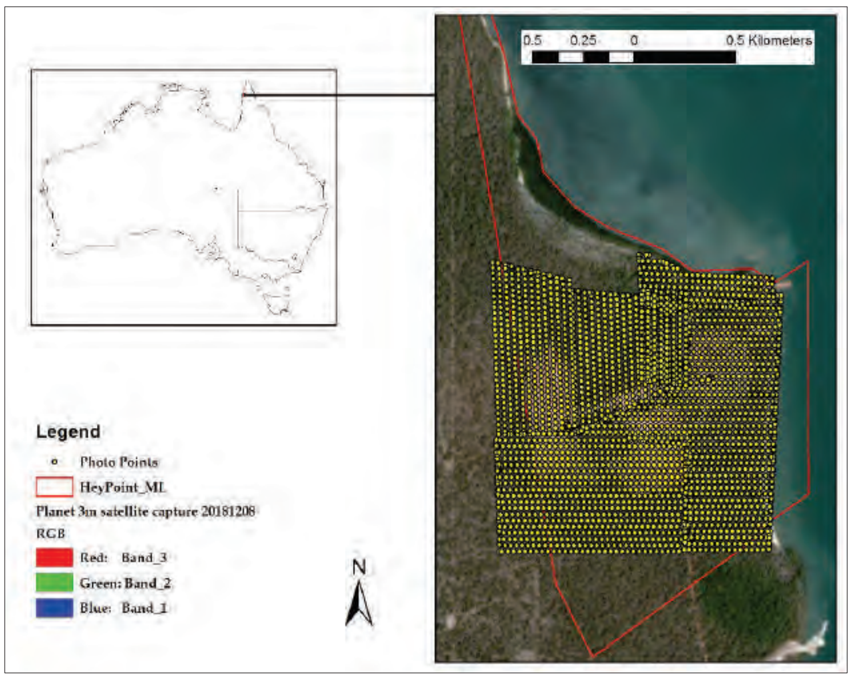

Figure 7: Map of images taken by drone over the Hey Point Bauxite Mine.

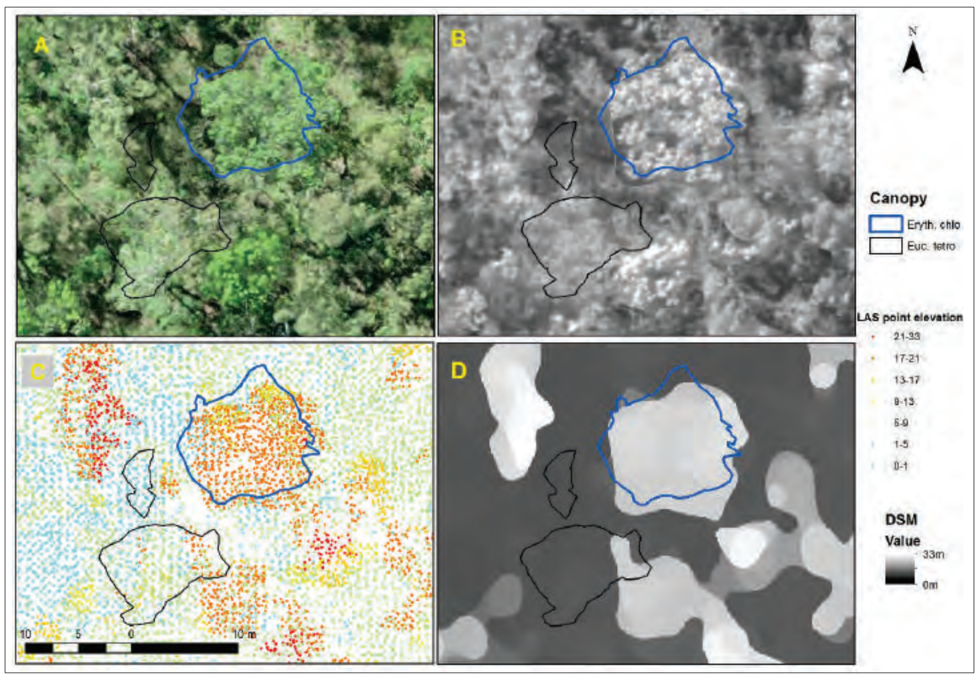

Figure 8: Mapped canopies from drone images show that Ironwood canopy (blue outline) is more visible from all kinds of data imagery than Stringybark (black outline).

FINDINGS

- Stringybark and Bloodwood are hard for a drone to see from above because their canopies are patchy and their leaves are thin and pointing down. Bloodwood is especially difficult, as it has even smaller and thinner leaves than Stringybark.
- Ironwood was easier to identify from above because the canopy was thicker and greener, and the leaves wider (Figure 8). Most of the Ironwood trees could be identified by the drone (Figure 9).
- Stringybark and Bloodwood DBH ground data predicted the canopy area of these trees quite well.
- Ironwood DBH did not predict canopy area very well. This might be because Ironwood can grow underneath Stringybark and Bloodwood canopies, making the Ironwood canopy a bit hidden. Additionally, Stringybark and Bloodwood will drop branches if shaded, as they need to be at the top of the canopy for light.

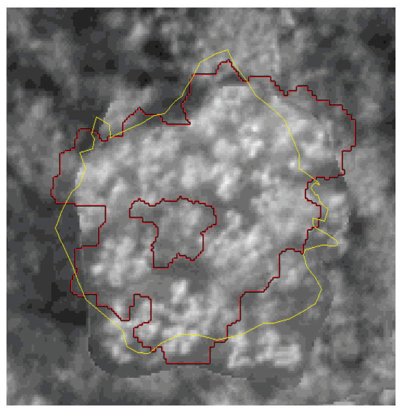

Figure 9: Ironwood canopy mapped with GPS (yellow outline) and identified with the drone (red outline).

Where to from here?

- It would be useful to do more drones studies of Cape York's woodlands because this work could help with many forest and land management activities.
- Locating and identifying trees using a drone could help us measure the biomass and carbon of the trees in a forest, and what timber is available to harvest before mining.
- The study also shows how new drone technology can help with the conservation of the large old Ironwoods that are becoming less common in western Cape York because of mining.

Acknowledgements
This work was funded by University of the Sunshine Coast's Advance Queensland Innovation Partnerships (AQIP) project '*Indigenous Employment, Forestry Livelihoods, Mining*'. Wik Timber, Wik Traditional Owners and other Indigenous community members helped with mapping and measuring trees, as well as observing drone flying for CALM training and work experience.

Tropical Forests & People Research Centre

Indigenous employment, forestry livelihoods, mining

Mine Rehabilitation

University of the Sunshine Coast
Queensland, Australia

The University of Queensland
Australia
CREATE CHANGE

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BACKGROUND: At the Hey Point bauxite mine near Weipa, bauxite has been mined since 2017. For mining of the 'middle pit' (Figure 1), forest was cleared, and soil around 50 centimetres deep pushed aside into stockpiles in 2017 and 2018 (Figures 2a and 3), to reach the bauxite underneath. Some of the soil was mixed and left in the middle of the pit during mining (Figure 2a). For rehabilitation preparation in 2019, the topsoil stockpiles were re-spread over the pit (Figure 2b).

The aim of the mine rehabilitation at Hey Point is to put back native plants that the local Traditional Owners know and that may support their livelihoods. After consultation, the important plants were:

- Trees that can be harvested for timber – Stringybark, Bloodwood and Ironwood,
- Plants for bushfood – Nonda plum and long yam,
- Plants for art and craft materials – bloodroot and coral tree, and
- Other plants for producing seeds for future mine rehabilitation.

Figure 1: Hey Point Mining Lease boundary, showing the 'middle pit' in the center.

Figure 2: a) Topsoil stockpiles pushed aside for mining, and b) The same stockpiles after re-spreading for rehabilitation. Arrows show direction of soil spreading.

Figure 3: Bauxite mining, with soil stockpiles.

Figure 4: Ripping the re-spread topsoil before rehabilitation.

Figure 5: Seedlings to be planted on left and direct seeding on right.

METHOD (what we did): Seeds were collected on site and around the Weipa area. Some tree seeds were sent to Gove in Arnhem Land to be grown into seedlings by an Indigenous-owned nursery, and the seedlings were then sent back to Weipa for mine rehabilitation.

Before planting, the re-spread soil needed to be ripped to open up the soil, to help rainwater soak in and let the tree roots go deep into the soil (Figure 4). We had 2 rehabilitation areas, one for direct seeding onto the ground and one for planting straight rows using the seedlings grown in the nursery (Figures 5-8). We also put on some fertiliser and charcoal called biochar (Figure 9) to see if and how they could help the plants grow.

The direct seeding was done in November 2019, before the wet season. The seedlings were planted in February 2020, during the wet season.

Figure 6: Part of the seed mix for direct seeding onto the ground.

Figure 7: Seedlings for planting, grown at Gove, Arnhem Land.

Figure 8: Seedlings planted in rows.

Figure 9: Fertiliser and biochar added to the rehabilitation.

Where to from here?: We want to know which way of planting works best, which plants survive and grow better after mining, which re-spread topsoil type is better for the plants, and if the fertiliser and biochar helps the plants grow more. To do this we need to:

- Measure how many direct-seeded plants grow after the first wet season, if they survive and grow in the first dry season, and if there are differences in the different topsoils, and with and without the fertiliser,
- Measure the survival and growth of the planted seedlings after the first dry season, and if this differs with the fertiliser and biochar, and
- Collect soil in the rehabilitation areas to see if there are any differences in the soil nutrients, chemicals and good bacteria and fungi, and see if this helped the plants grow better.

Acknowledgements

This work was funded by the University of the Sunshine Coast's Advance Queensland Innovation Partnerships (AQIP) project '*Indigenous Employment, Forestry Livelihoods, Mining*'. Wik Timber, Wik Traditional Owners and other Indigenous community members helped with the data collection as part of CALM training and work experience. Thanks also to Robyn Boldy, for help with this fieldwork.

Indigenous employment, forestry livelihoods, mining

Assessing Soil Health

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BACKGROUND

Mining removes the top layers of soils to get to the bauxite (Figure 1), disturbing the natural state of the soils. When the disturbed soil is put back after mining for the rehabilitation, it may not be as healthy as before and the rehabilitation won't be as good as the natural forest. It is important to understand the soil health in the natural forests, and see how the soil health changes in stockpiled topsoil and then respread topsoils. Then we can work out the best time of the year to disturb or move soil, the best way to manage the soils and to look after soils so they eventually return to the quality of the natural soil, which will help successful rehabilitation.

Figure 1: Mining pit cleared of soils.

Figure 2: Stockpiled topsoil moved aside for mining, which will be re-spread for rehabilitation.

METHOD (what we did)

We collected soil samples at many different locations at the Hey Point bauxite mine. To understand the soil health, we sampled soils in the natural forest, from disturbed areas and in soil stockpiles (Figures 3 & 4). After the mining pit had been rehabilitated, we sampled soils from many locations in the rehabilitation areas, from all the different ages of soil stockpiles that were re-spread (Figure 5) and from where we had added fertiliser, to test the soil from many different areas (Figure 6). To get the soil, we mixed samples together, called 'bulk sampling' (Figures 7 & 8), at each location. The soils were tested for nutrients (what food was available for plants), carbon, organic matter and water in the laboratory at the University of Queensland.

Figure 3: Soil samples collected before rehabilitation in the natural forest and from stockpiled topsoil.

Figure 4: Soil sampling in stockpiled topsoil (old topsoil from Figure 3).

Figure 6: Soil samples collected in the rehabilitation areas, and some from the natural forest.

FINDINGS

- Soil carbon and nutrients available for plants changed across the site.
- In the rehabilitation soils, there was much less nutrients and water than the natural forest.
- Topsoil that was mixed and disturbed more had less nutrients and water, showing that soil health is lost with disturbance and mixing.
- Freshly disturbed soil still had more water and was healthier than stockpiled topsoil.
- Soil compaction from heavy machines, uneven respreading and uneven deep ripping of the mine floor might have removed some nutrients and water in some parts of the rehabilitation soil.

Figure 5: Re-spread topsoil in rehabilitation area.

OUTCOMES (what we learnt)

- Soil handling for mining needs to be carefully managed and at the right time to keep enough nutrients in the soil.
- Soil needs to be spread evenly across the rehabilitation to keep the soil healthy.
- Rehabilitation soil health could be improved to help mine rehabilitation by adding mulch from the trees and plants cleared before mining, or adding fertilisers that are shown to improve the soil health and available nutrients.
- Best practice soil handling and management needs to be practiced during and after mining for mine rehabilitation to be healthy and successful.

Figure 7: Digging for soil samples in natural forest.

Figure 8: Mixing soils for 'bulk sampling'.

Acknowledgements This work was funded by the USC Advance Queensland Innovation Partnerships (AQIP) project '*Indigenous Employment, Forestry Livelihoods, Mining*'. Thanks to Traditional Owners and participants undertaking their CALM certificate who helped collect the soils. Thanks also to Robyn Boldy for assistance with field sampling, and Professor Longbin Huang for prescribing soil sampling methods.

Indigenous employment, forestry livelihoods, mining

Bauxite mine rehabilitation using direct seeding

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The University of Queensland Australia

CREATE CHANGE

BACKGROUND

Most mine rehabilitation in Weipa uses the direct seeding method. This method spreads native seeds over bare soil and is a quick way to put plants back into a mining pit. At the Hey Point bauxite mine near Weipa, stockpiled topsoil was pushed back over the mining pit (Figure 1). These topsoils were made up of 2 years old and a mixture of 2-3 years old soil (some of this soil was moved in the wet season). This is a common approach for mine rehabilitation in this area, but is not the best way to handle soil for mine rehabilitation. Best practice is to put topsoils directly back into a mine pit and not handle the soil during the wet season.

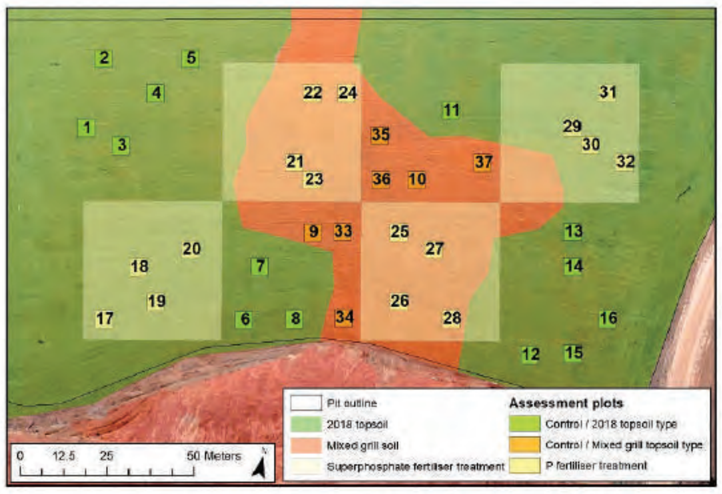

Figure 1: Measuring plots in the direct seeding area

METHOD (what we did)

We conducted a direct seeding trial at the Hey Point bauxite mine to test the establishment and growth of important native plants. These plants included the long yam, giddee-giddee, love-vine, bloodroot, and the trees Darwin Stringybark, Melville Island Bloodwood, Cooktown Ironwood, *Acacia rothii*, nonda plum and coral tree.

Seeds were spread by hand (direct seeded), in a section of the mining pit before the wet season in November 2019. In February 2020, during the wet-season, fertiliser (Phosphorus) was spread over some of the rehabilitation area (Figure 1).

To measure the growth of seedlings, plots were randomly chosen (Figure 1) and marked with wooden pegs (Figure 2). In these plots, we wanted to see if some plants established and grew better on the different topsoil types or if the fertiliser helped them grow. We measured the plants during the wet season (2 months after the seeds were sown) and in the dry season (9 months after sowing). The height of each seedling and the number of each species were recorded (Figure 3).

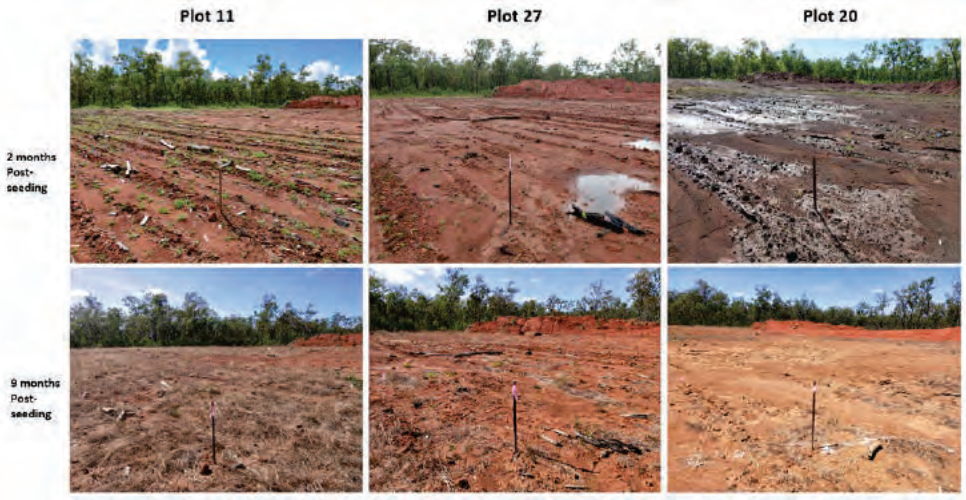

Figure 2: Measuring plots in the wet season (top row) and dry season (bottom row).

Figure 3: Measuring plants (nonda plum)

FINDINGS

We found that the seedlings established and grew at similar rates with and without fertiliser and in the different aged soils.

- Fertiliser did not appear to help the seedlings grow faster or help them survive more - they were just as good without it.
- The mixed topsoil resulted in seedling growth that was similar to the unmixed topsoil.

The coral tree seedlings were drying out and had stopped growing (Figure 4) and some had died over the dry season. Some stringybark seedlings (Figure 5) also died over the dry season, but not as much as the coral tree.

Bloodwood seedlings had the most growth from the wet season to the dry season (Figure 6), followed by nonda plum (Figure 7), then the wattle tree *Acacia rothii* (Figure 8), stringybark and ironwood (Figure 9).

The trees with hard seeds (nonda plum, wattle and ironwood) also grew back naturally from the soil. Trees with soft, small seeds (stringybark and bloodwood) didn't grow back naturally from the soil much because the seeds can get lost when the topsoil is removed and replaced.

Figure 4: Coral tree (*Adenanthera pavonina*) was dried out.

Figure 5: Stringybark (*Eucalyptus tetrodonta*)

Figure 6: Bloodwood (*Corymbia nesophila*)

Figure 7: Nonda plum (*Parinari nonda*)

Figure 8: *Acacia rothii*

Figure 9: Ironwood (*Erythrophleum chlorostachys*)

OUTCOMES (what we learnt)

- The trial was compromised by the soil handling, which was not best practice.
- Direct seeding for mine rehabilitation can be used to establish many different plant species, even with very poor soil conditions.
- Some plants establish naturally because they are brought into the area by wind or birds.
- Trees that can grow back naturally from the soil do not need to be seeded as much as the other trees in mine rehabilitation areas. This means that stringybark and bloodwood need more seeds to be sown than ironwood, wattles and nonda plum.
- Coral tree is not a good species to seed in early mine rehabilitation.
- Bloodwood grows faster than stringybark and may be a good canopy tree species to grow early in mine rehabilitation areas.
- How much seed is used in direct seeding is important and each species is different.
- These are still early results – it is too early to know the full effects of the soil handling and fertiliser in the field on seedling establishment.

Acknowledgements

This work was funded by the USC Advance Queensland Innovation Partnerships (AQIP) project '*Indigenous Employment, Forestry Livelihoods, Mining*'. Thanks to Tayla Cardelli for helping with measurements.

Indigenous employment, forestry livelihoods, mining

Bauxite mine rehabilitation using tubestock planting

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The University of Queensland Australia

CREATE CHANGE

BACKGROUND

Direct seeding is the most common mine rehabilitation method in Weipa. Planting tubestock is an alternative method, but it takes more time to set up and may be more expensive. It depends on the land use plan after mining. Tubestock can be a good way to grow plants for plantations for timber or orchards for fruit, or for plants that do not establish well from direct seeding.

For the Hey Point bauxite mine (HPBM) rehabilitation, topsoil was pushed back over the mine pit in December 2018 and January 2019. The northern section of the pit was for tubestock planting (Figure 1). When tubestock was planted in February 2020, the area was flooded near the middle of the pit so this area was not used (Figure 2). In the dry season, this flooded area had dried up (Figure 3), grass grew and fire burnt both sides of the rehabilitation (Figure 1).

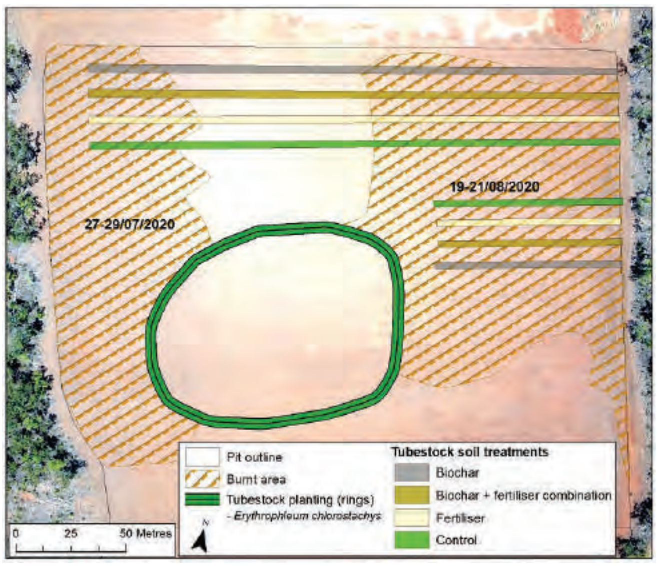

Figure 1: Map of tubestock rehabilitation area showing soil treatments and areas affected by fire on 27-29th July and 19-21st August 2020.

METHOD (what we did)

We planted the tubestock trial at the HPBM to test the survival and growth of three important local trees suitable for timber production and environmental benefits – Darwin Stringybark, Melville Island Bloodwood and Cooktown Ironwood. Seedlings were grown at the Gulkula mine in Arnhem Land (Northern Territory), and flown back to Weipa for planting in the wet season, in February 2020.

We planted the seedlings in rows across the rehabilitation area. Some rows were planted with fertiliser, with biochar (like charcoal) or a combination of biochar + fertiliser (Figure 1). We wanted to see if these helped the tree seedlings survive and grow in the rehabilitation area.

After 7 months (in the dry season) we came back to measure the survival and growth of the trees. Because of COVID-19 we could not go to site for grass control, so native grasses covered some areas, which later burnt. At each plant, we recorded if they were alive, how tall they were (Figure 4), gave them a health score, considering if they were sick or growing well, and recorded other information such as if they had multiple stems or were leaning over or they had been burnt in the grass fire.

Figure 2: Flooded area of tubestock rehabilitation in wet-season, February 2020.

Figure 3: Flooded area had dried over the dry-season, September 2020.

FINDINGS

The fire affected half of the tubestock planting area by burning through the dry grass (Figure 1). It burnt one third of planted seedlings, however, some burnt plants survived and grew back (Figure 5). None of the Ironwood were burnt by the fire as they were planted around the wet area where there was not much grass (Figure 6).

From our measurements, we found that:

- Bloodwood grew taller with biochar and the biochar + fertiliser combination, and grew less with fertiliser alone. They had the best health with biochar alone.
- Stringybark grew taller with fertiliser and grew less with biochar. They had better health with the fertiliser or no soil additions.
- Bloodwood seedlings were the tallest overall (45 cm average, Figure 7), Stringybark was in-between (36 cm, Figure 8) and Ironwood were the shortest (16 cm).
- Bloodwood and Ironwood had better health than Stringybark overall.
- Seedlings heights might be affected by the depth of the topsoil.

Figure 4: Measuring bloodwood seedling (*Corymbia nesophila*)

Figure 5: Burnt bloodwood seedling resprouting after fire

Figure 6: Ironwood seedling (*Erythrophleum chlorostachys*)

Figure 7: Bloodwood seedling with adult leaves

Figure 8: Stringybark seedling, leaning over

Where to from here?

Our findings are still very early findings, but they do suggest:

- Soil needs to be spread level across the rehabilitation so that the ground doesn't flood or isn't too hard to plant.
- Uncontrolled fire will affect many seedlings. Fire risk should be reduced by controlling grass cover.
- Biochar should be used in mine rehabilitation at Weipa as it might help other plants grow too.
- More soil additions like mulch and composted mulch should be tested to work out how much of them will help the seedlings grow more and survive best, and how best to apply them.
- Bloodwood might be easier to grow than Stringybark, but we need to know more about the different soil additions these trees might prefer.
- Ironwood might need tubestock planting as it grows slow. Ironwood should be grown closer to very wet areas.
- Tubestock should be used in mine rehabilitation where the goal is to provide trees for timber or fruit, or plants that don't grow well from seed.
- The tubestock trial at the HPBM should be monitored for years to come to see the longer-term results, and more tubestock trials should be established in the Weipa region.

Acknowledgements

This work was funded by University of the Sunshine Coast's Advance Queensland Innovation Partnerships (AQIP) project '*Indigenous Employment, Forestry Livelihoods, Mining*'. Wik Timber, Wik Traditional Owners and other Indigenous community members helped with the planting as part of CALM training and work experience. Thanks to Robyn Boldy for preparations and help with planting, and Tayla Cardelli and Joshua Martin for helping with measurements.

Indigenous Employment, Forestry Livelihoods, Mining

Can mulch improve soil quality and mine rehabilitation success?

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BACKGROUND

Before bauxite mining, the forest is cleared and burnt, and the natural topsoil is stripped and stored in piles, sometimes for years. The soil is spread back out to re-grow the forest. Stockpiled soil becomes less able to grow strong healthy plants the longer it is stored. But this soil can be improved with the right amendments. We wanted to know if woodchipping the trees, turning it to mulch and adding it to the soil improves soil quality and plant growth. This is the first study to look at how to improve the soil with the forest resources instead of burning it.

Figure 1. Three ages of soil was collected from the Hey Point bauxite mine near Weipa (northern QLD): Fresh, 1.5 years stockpiled, and 3 years stockpiled.

Figure 2. Stockpiled soils at the Hey Point bauxite mine.

Figure 3. Native tree seedling growing in mulch-fertiliser amended soil.

METHOD (What we did)

We tested what happens to Stringybark (*Eucalyptus tetrodonta*) seedlings grown in fresh soil, 1.5 year and 3 year stockpiled soil (Figs 1 & 2), when adding mulch and fertiliser.

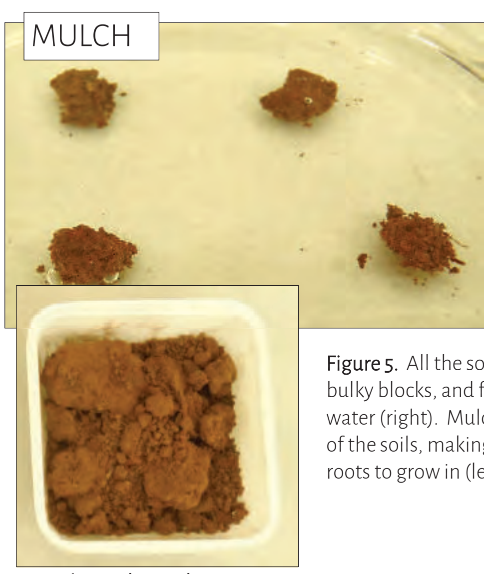
We also measured changes in soil quality to understand how the mulch and fertiliser worked to effect the plants' growth (Fig 3).

Figure 4. Eight month-old Stringybark seedlings after growing in stockpiled soils with or without mulch and fertiliser

FINDINGS

At every soil age, Stringybark seedlings grew best with fertiliser amendment (Fig 4, row 3). Mulch caused soil nitrogen to be consumed by microbes, leaving much less for plants, so Stringybark seedlings did not grow as well in these pots (Fig 4, rows 2 and 4). Over time, this nitrogen will eventually become available to the plants, rather than being washed out of the soil with heavy rainfall, if no mulch was added.

Adding mulch to stockpiled soils made them less hard and bulky when dry (Fig 5), because the small crumbs of soil held together better when wet. This means mulch makes re-spread stockpiled soils less susceptible to erosion. Mulch also increased the amount of water that the soil could hold for plants to use, and the activity of soil microorganisms that can help keep soils healthy.



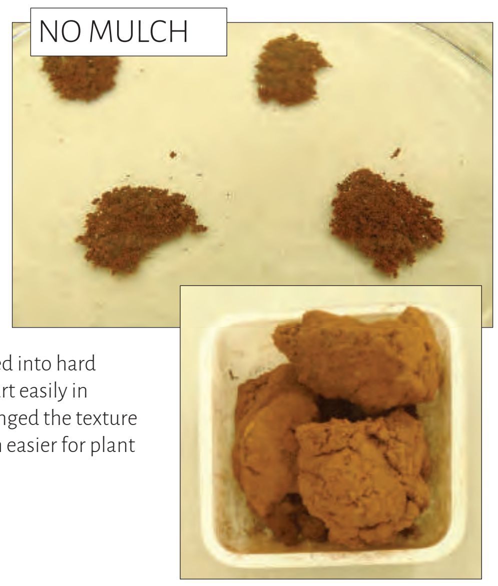


Figure 5. All the soils dried into hard bulky blocks, and fell apart easily in water (right). Mulch changed the texture of the soils, making them easier for plant roots to grow in (left).

WHERE TO FROM HERE?

If mulch is created from more green plant material and small branches (which contains more nitrogen) rather than the woody trunks of the trees , seedling growth would likely be much better. Composting the mulch before adding it to the soils might also help the plants get access to nutrients like nitrogen that are 'locked-up' in the woody mulch materials.

Acknowledgements: This work was funded through the Advance QLD Innovation Partnerships (AQIP) project '*Indigenous Employment, Forestry Livelihoods, Mining*'. We acknowledge inputs from John Meadows and Mark Annandale of the Tropical Forests and People Research Centre, University of the Sunshine Coast; and Peter Erskine and Natasha Ufer of the Sustainable Minerals Institute, University of Queensland.

Tropical Forests and People Research Centre

Indigenous Employment, Forestry Livelihoods, Mining

An Investigation of Indigenous Yam Propagation: Utilizing *Dioscorea transversa* seeds in mined land rehabilitation.

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BACKGROUND: Yams are a highly valued, culturally significant bushfood of many Traditional Owner groups in northern Australia. Establishment of yam species should therefore be an important component of mine rehabilitation in such regions. This experiment aimed at identifying treatments and temperature/light conditions that are ideal for establishment of the long yam (*Dioscorea transversa*). Soils of varying stockpile age (3-year old, 1-year old, and freshly removed topsoil) were used to study whether stockpiling times influenced germination success/failure.

Fig. 1 – Long yam seeds used in the experiment.

METHOD (What we did): To simulate the fire-prone environment of the savanna woodlands of northern Australia, we applied 4 seed treatments prior to planting:

- Soaking in hot water for 10 minutes followed by slow cooling;
- Soaking in smoke solution for 24 hours;
- Soaking in a weak potassium nitrate solution for 24 hours; and
- Sowing in an ash bed derived from burnt wood chips and logs.

The treated seeds were sown in three bauxite-mined soils of varying ages i.e. 3-year old and 1-year old stockpiled soil, and freshly removed topsoil. Growth was compared to untreated seed sown in potting mix. The trials were placed in a regular glasshouse and one with alternating day/night temperatures of 30/20°C. The experiment lasted 44 days from the day of sowing.

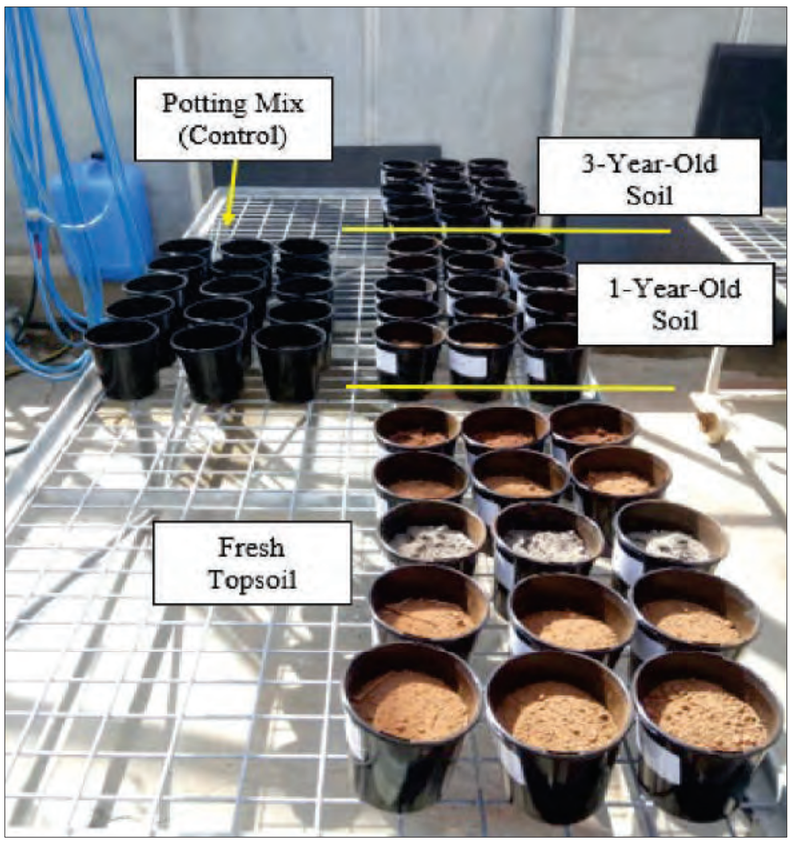

Fig. 2 – Experimental set up in each glasshouse.

FINDINGS: The seeds did not show any response to hot water and ash bed treatments. The smoke/nitrate treatments, soil age or any combination of these did not significantly affect germination success. Maximum germination was triggered with alternating day/night temperatures of 30/20°C.

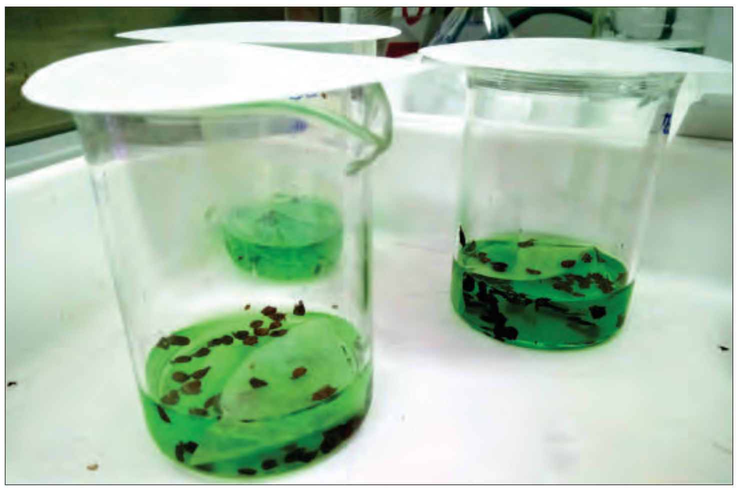

Fig. 3 – Soaking seeds in a smoke solution.

Fig. 4 – Seedlings emerging at 22 days.

Fig. 5 – Seedlings at 44 days.

WHERE TO FROM HERE?

Results from this experiment demonstrate that long yams can be propagated on mined soils and could therefore be grown in mine rehabilitation for traditional uses. Economic assessment of cultivating yams for commercial use may be worthwhile for the emerging niche market for bushfoods. This may allow communities to sustain long yam plantations independently post mining.

Acknowledgements: We would like to acknowledge the Wik-Waya, Wathayan and Alngith Traditional Owners of the land. This work was funded through the Advance Queensland Innovation Partnerships (AQIP) project '*Indigenous Employment, Forestry Livelihoods, Mining*'. We also acknowledge Mark Annandale, Dr. John Meadows, Natasha Ufer, Merinda Hall, and UQ glasshouse services for the provision of support and facilities throughout the experiment.

Indigenous employment, forestry livelihoods, mining

Assessing ecosystem services and the benefits from Country

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University of the Sunshine Coast Queensland, Australia

The University of Queensland Australia

CREATE CHANGE

BACKGROUND

Caring for Country and making sure it is healthy can lead to benefits for you and your family. These benefits from healthy Country are often called 'ecosystem services'. Examples of ecosystem services are outlined in Figures 1-4. We all value the land in different ways, and it is important to understand connections to Country and how these connections support wellbeing. Understanding these connections is important when planning the rehabilitation of Country that has been degraded or disturbed. For example, when Country is mined, many ecosystem services will be lost. So we need to know what is special about Country, both culturally and physically, to understand how to return these values after mining.

Figure 1. Regulating services (such as mangrove areas that regulate water and protect coastlines).

Figure 2. Provisioning services – those that provide physical benefits (such as bush tucker from plants such as Sandpaper Fig).

Figure 3. Supporting services – such as soil formation and nutrient cycling provided by intact ecosystems such as *Eucalyptus* forests.

Figure 4. Cultural services – these include benefits from activities such as camping, fishing, ceremonial, spiritual and cultural practices on Country.

METHOD (What we did)

We developed a method to talk about ecosystem services with Traditional Owners (TOs). We used ecosystem services 'cards' (example Figure 5) to discuss what ecosystem services are and understand what is most valuable to TOs.

We held group discussions on Country to talk about how Country makes people feel good and what contributes most to overall wellbeing.

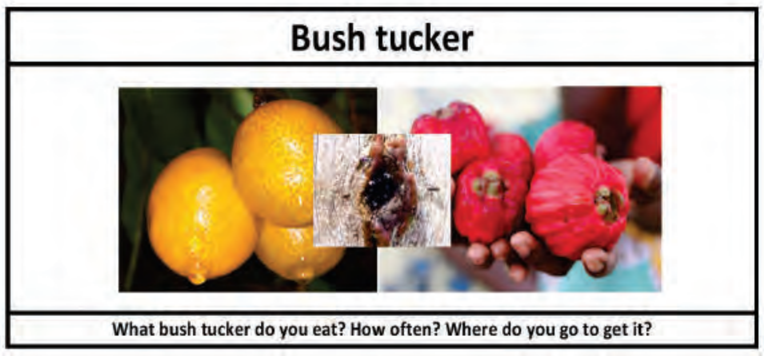

Figure 5. Example of ecosystem services cards used in discussions.

FINDINGS

While all ecosystem services are important, we found that culturally, sharing of knowledge on Country and recreation/fun outdoors, and physically, having fresh water and food (hunting for food and bush tucker) was most important to the wellbeing of people (as seen in Figure 6). This is what TOs said they would like to be able to do and see on Country.

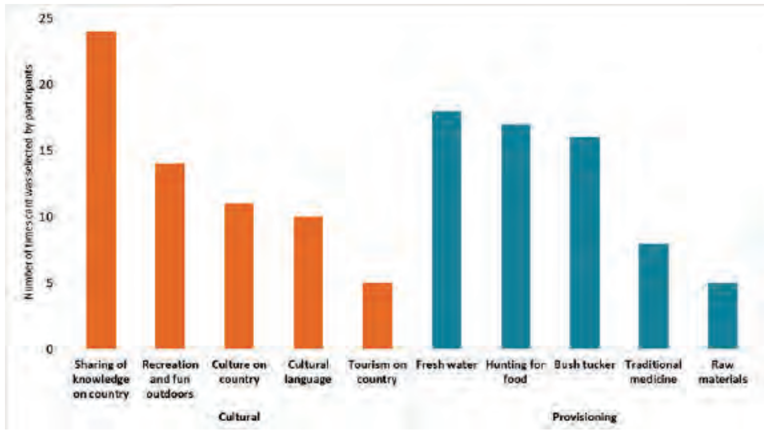

Figure 6. Results from discussions.

WHERE TO FROM HERE?

The information from this study can be used to plan the rehabilitation of mine sites and what the landscape could look like after mining. Figure 7 shows how the land changes with mining, with an example of a post-mining mix of land uses that includes the cultural and physical ecosystem services that are important to TOs.

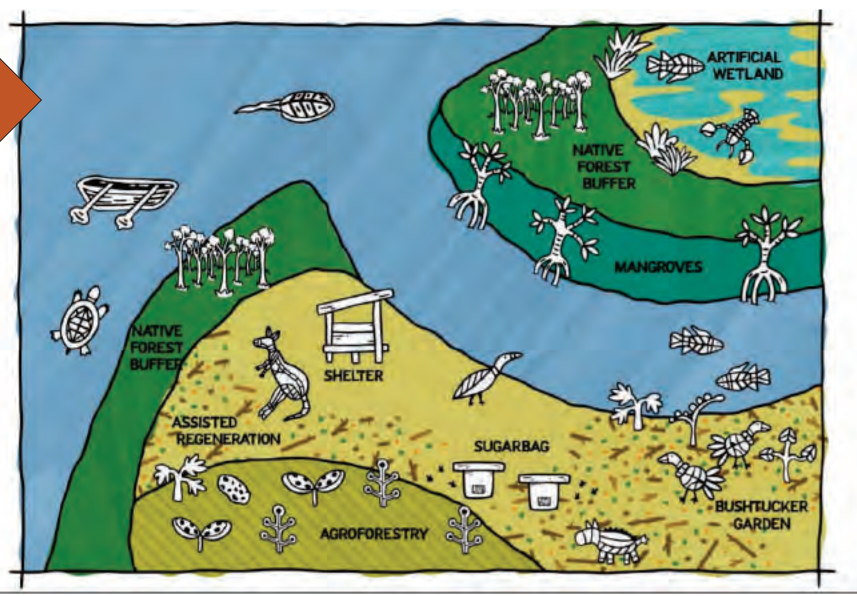

Figure 7. When mining occurs, the landscape changes from open woodland forests to a bare open landscape. The last image in this timeline is an example of how TOs want to see important values and ecosystem services returned to Country after mining.

Acknowledgements

This work was funded by a UQ RTP Scholarship and the USC Advance QLD Innovation Partnerships (AQIP) project '*Indigenous Employment, Forestry Livelihoods, Mining*'. Thanks to the Traditional Owners who helped with the discussions as part of training and work experience through the AQIP Project, Wik Timber, Natasha Ufer and Dr John Meadows, and Camila Ribeiro and Daniel Nogueira for the illustration in Figure 7.

Tropical Forests and People Research Centre

Tree soil water use in Cape York savanna woodlands: implications for mine rehabilitation

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THE UNIVERSITY OF QUEENSLAND AUSTRALIA

University of the Sunshine Coast Queensland, Australia

Background

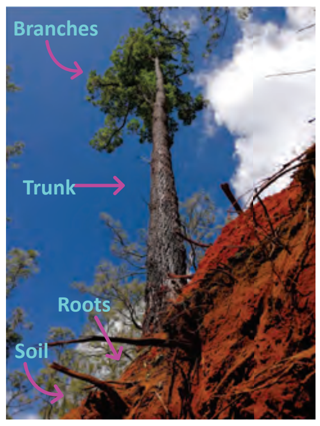
Savanna woodland forests are important in northern Australia, but large areas are being cleared for bauxite mining. After mining, landscape-scale mine rehabilitation is needed, but the main tree species – Darwin stringybark and Melville Island bloodwood – can be difficult to establish. After mining, the soil profile has a different water storage capacity, sometimes more waterlogged in the wet season and harder and dryer in the dry season. We need to understand how the two main tree species use water in the soil to help their successful rehabilitation.

What we did

We dug out the roots of 12 large Darwin stringybark and Melville Island bloodwood trees at a bauxite mine near Weipa on Cape York in northern Queensland. Then, we sampled water from the:

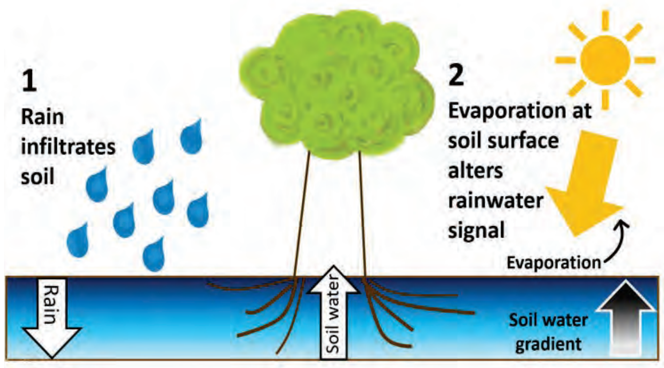
- Roots
- Trunk and branches
- Soil around the roots, and
- Groundwater

We used these samples to understand where in the soil these trees get their water from.



How to find out which water the tree is using

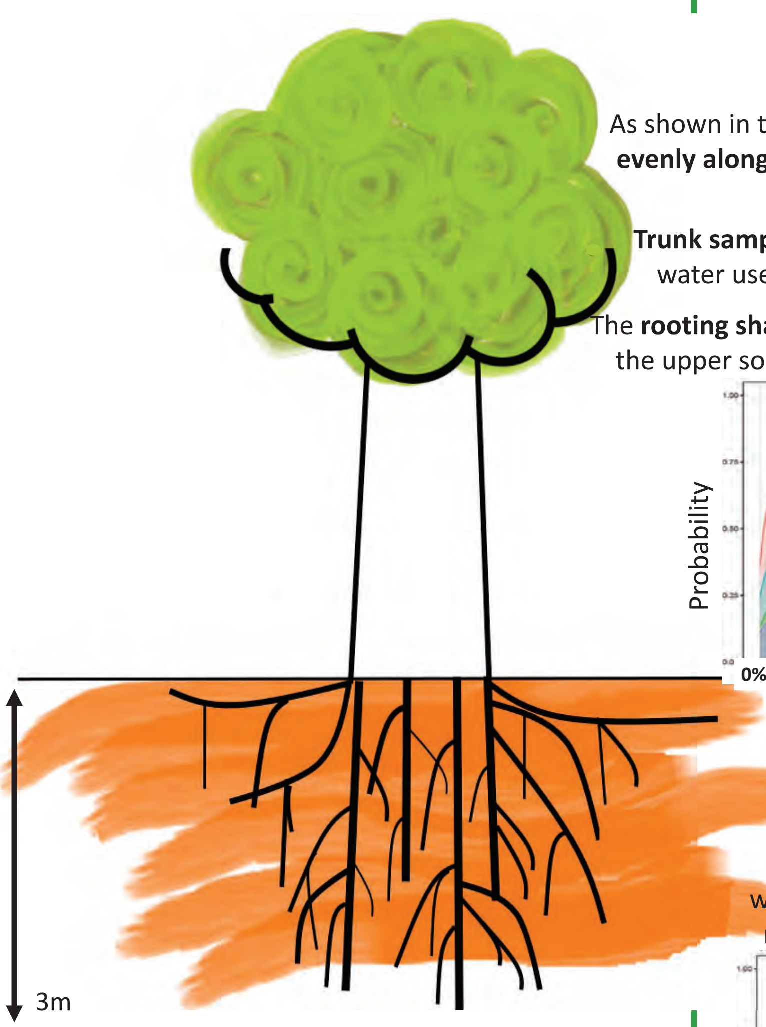
- After rain flows through soil, evaporation at the soil surface changes the original rainwater signal.
- This results in a "signal gradient" along the soil profile, with each depth having its own signal.
- Tree water is compared to this signal gradient to identify where in the soil the tree gets its water from.



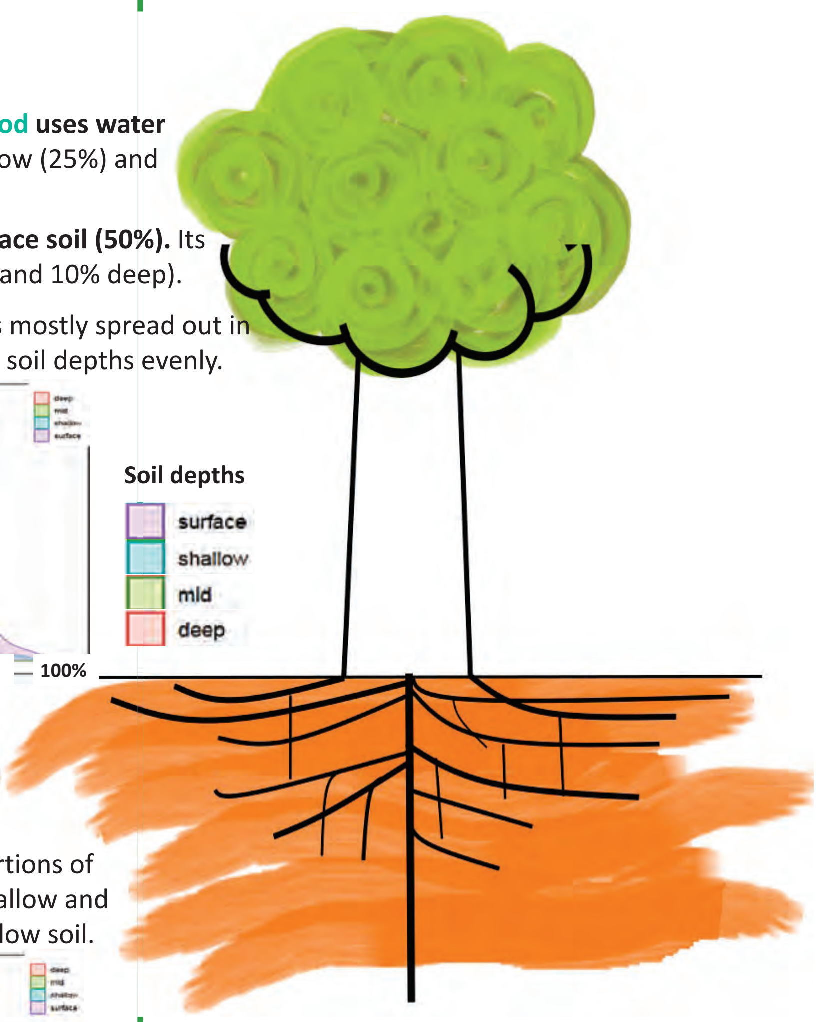
Findings

The stringybark and bloodwood tree roots reach 3m deep. They use the same soil water sources. But the amounts of water sources used are different between the two species. This is probably due to the very different rooting shapes, as shown in the photos here.

Melville Island bloodwood



Darwin stringybark



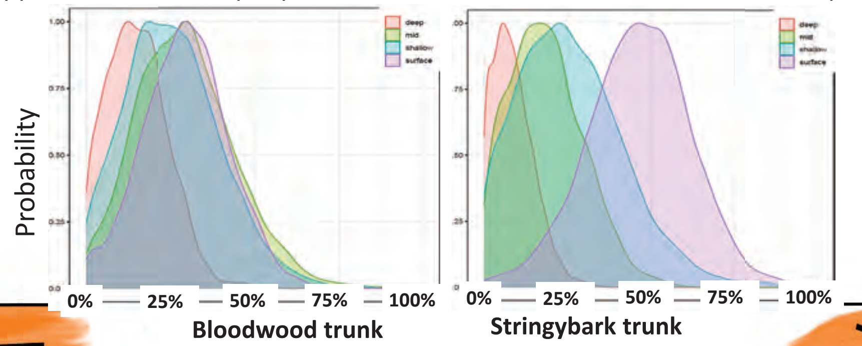
How do stringybark and bloodwood use water in the soil profile?

Trunk

As shown in the graphs below, **trunk samples showed that bloodwood uses water evenly along the soil profile.** It uses water from surface (30%), shallow (25%) and mid depths (30%), but less water in deep soil (15%).

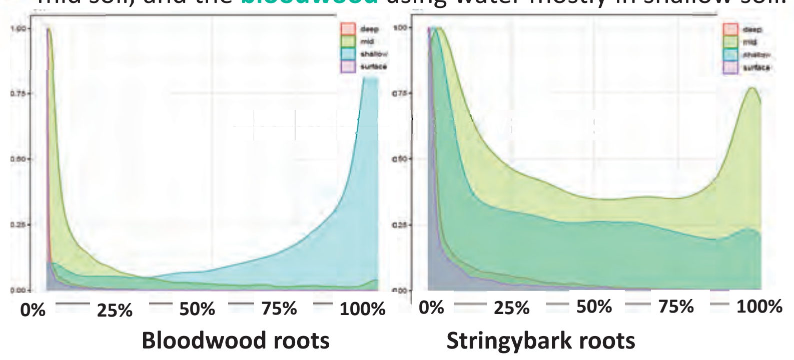
Trunk samples showed that stringybark mostly uses water in surface soil (50%). Its water use gets less as the roots go down (25% shallow, 20% mid and 10% deep).

The **rooting shape** confirms how the trees get water. Stringybark roots mostly spread out in the upper soil with a deep tap root, while bloodwood roots cover all soil depths evenly.



Roots

In the graphs below, roots showed very different proportions of water use, with the stringybark using water mostly in shallow and mid soil, and the bloodwood using water mostly in shallow soil.



Where to from here?

- Both stringybark and bloodwood trees can reach the same water in the soil, but how they use that water is different, probably due to their different rooting shapes.
- These root shapes should be considered in mine rehabilitation. It is possible that stringybark roots spread more widely than bloodwood roots to get water from the shallow to mid depth soil.

Both species relied on water mainly down to mid soil depths, but still used important amounts of deep soil water. Rehabilitation efforts should make sure to deep-rip the hard pan under the bauxite to help seedlings of both species get the soil water they need to survive the first dry season and possible severe droughts in the future.

Acknowledgements

Thanks to MyPathway (Napranum) and to the Traditional Owners for their important help with the data collection as part of their Conservation & Land Management (CALM) Certificate training. Thanks to Kurt von Kleist and Grahame Applegate for their help with fieldwork, and to Green Coast Resources for providing access to the study site. This work was funded by the Advance QLD Innovation Partnerships (AQIP) project '*Indigenous Employment, Forestry Livelihoods, Mining*' and a UQ RTP Scholarship.

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USC

Developing Indigenous commercial forestry in northern Australia

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BACKGROUND: Indigenous communities in northern Australia own, manage or have special rights to around 46 million hectares of forest (Table 1, Figure 1). Some of these forests support a small but important Indigenous commercial forestry and forest products industry. There is a lot of opportunity for further sustainable forestry development to support Indigenous jobs, and cultural and livelihood benefits for remote northern Australian Indigenous communities.

Table 1. Area of forest in the northern Australian Indigenous estate, by Indigenous land ownership and management categories, and by jurisdiction ('000 hectares).

Category	NT	Nthn QLD	Nthn WA	Total NA
Indigenous owned & managed	11,490	4,747	1,226	17,464
Indigenous managed	1,726	2,528	317	4,571
Indigenous co-managed	55	740	57	852
Other Special Rights	5,421	16,224	1,590	23,235
Total Indigenous Forest Estate	**18,693**	**24,238**	**3,191**	**46,122**
Total Forest in Jurisdiction	**23,735**	**35,783**	**3,662**	**63,180**
Proportion of total forest that is forest on the Indigenous estate	**79%**	**68%**	**87%**	**73%**

Source: ABARES (2019, data provided for this project, derived from the National Forest Inventory *Australia's Indigenous forest estate (2018)* spatial dataset as at 2016: agriculture.gov.au/abares/forestsaustralia/forest-data-maps-and-tools/spatial-data/indigenous-forest.

METHOD (What we did):

We looked at the forestry information and talked to as many people as we could across the north to better understand the growth potential of Indigenous commercial forestry in northern Australia. This included three regional meetings (held in Cairns, Nhulunbuy and Darwin) and we visited three Indigenous commercial forestry businesses to prepare case studies of them – Wik Timber in western Cape York Peninsula (QLD), Gumatj Sawmill in east Arnhem Land (NT) and Tiwi Plantations Corporation (NT) (see Figures 2 – 4).

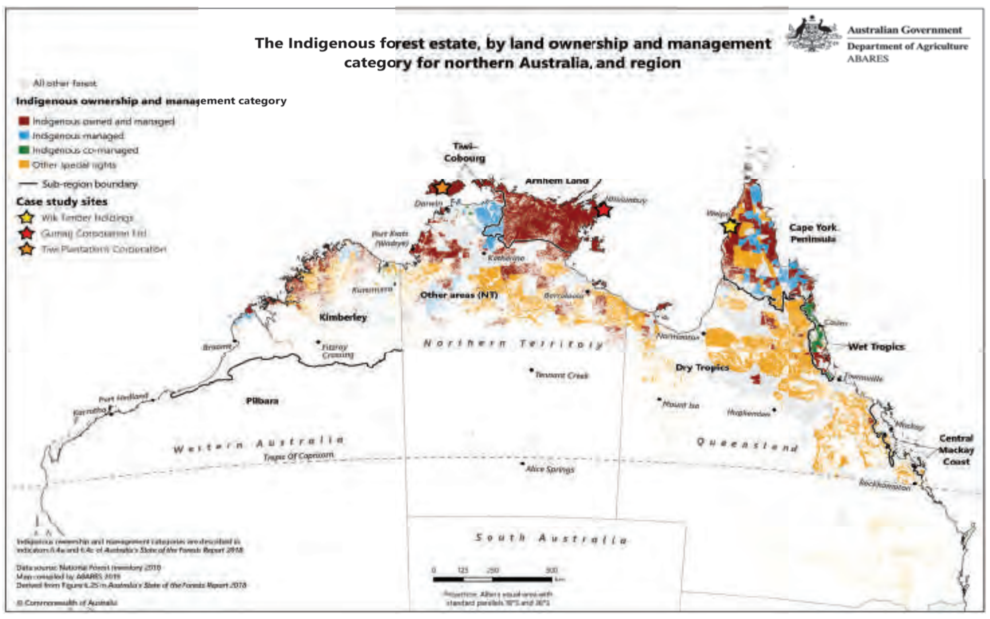

Fig. 1. The Indigenous forest in northern Australia, by jurisdiction and region.
Source: ABARES (2019, data provided for this project)

FINDINGS:

Key opportunities, challenges and needs for further development of Indigenous commercial forestry in northern Australia were identified around four major themes – **commercial native forests**, **plantation forestry**, **mine rehabilitation**, and **capacity building**.

Fig 2. Wik Timber logs sent to market in 2018

Fig. 3. Gumatj Sawmill in operation

Fig. 4. Tiwi Islander forestry employees on Melville Island

WHERE TO FROM HERE?

Policy, investment and other priority research for development needs include:

Commercial Native Forests: native forest inventory, forest management trials and long-term monitoring; community sawmills processing local timbers for local applications. **Plantation Forestry:** new plantation forestry trials. **Mine Rehabilitation:** pre-mining forest salvage harvesting and integrated product utilisation; multiple-use community forestry in mine rehabilitation. **Capacity Building:** locally-designed, field-based 'forest ranger' training programs; technical and tertiary professional forestry education pathways for Indigenous people; business development support including mentoring.

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Indigenous Employment, Forestry Livelihoods, Mining

Bioenergy in remote Indigenous communities

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AIM

To understand how much woody biomass (i.e. low-grade logs and sawmill residues) is available from salvage harvesting of the Amrun bauxite mining lease in western Cape York Peninsula to generate energy for nearby Indigenous communities and biochar for mine rehabilitation.

BACKGROUND

The clearing and burning to waste of Indigenous-owned forests is the usual practice before mining in northern Australia. Pre-mining salvage harvesting, involving local processing of high-value sawlogs and chipping of lower-grade logs for local bioenergy applications, would better utilize the forest resources and benefit the local Indigenous communities. Over coming decades, bauxite mining is set to expand around some remote Indigenous communities in northern Australia. Large volumes of currently wasted low-grade logs and sawmill residues will be available to generate bioenergy and biochar. Small-scale, community-based bioenergy industries could provide environmental and social benefits for these remote Indigenous communities. For example, bioenergy generated through gasification or pyrolysis, a thermal conversion process exposing woody biomass to high temperatures in the absence of oxygen, could reduce community reliance on diesel-generated power. Biochar, as a by-product of gasification and pyrolysis, can be used in mine rehabilitation to benefit soils and promote plant growth, including future bioenergy crops established in the post-mining landscape.

METHOD

Based on:

- 20.94 m^3 per hectare (ha) of low-grade logs from forest thinning,
- 27.60 m^3 per ha of low-grade logs at final harvest,
- 19,500 green tonnes per year of sawmill residues from processing sawlogs at Hey Point,
- Geometry of the Amrun Lease mining areas (**Figure 1**),
- 1079 kg/m^3 average air-dry density (12% moisture) of the three dominant tree species in the region,
- 19.30 MJ/kg average energy content of woody biomass,
- 300 kg char/dry tonne woody biomass,
- 300 GJ per person per year average energy demand in Queensland, and
- A population of 1200 people in Aurukun, an equivalent population of 1000 people in the Boyd Point mine camp and an equivalent population of 500 people at Hey Point,

we estimated the total forest area within the Amrun Lease mining areas and their respective volumes of recoverable low-grade logs through forest thinning and final harvest operations (**Table 1**). Three potential locations are considered for energy production – **Hey Point**, **Boyd Point** and **Aurukun**, with energy demands of **4.8 MW**, **9.5 MW** and **11.4 MW**, respectively. Based on proximity, the Amrun Lease mining areas were allocated to the three potential energy facilities (**Figure 1 & Table 1**). The Boyd Point area will be largely harvested within the next 13 years. The remaining areas will undergo thinning over the next 13 years to increase forest productivity, before a final pre-mining harvest 14 to 40 years from the start of 2021.

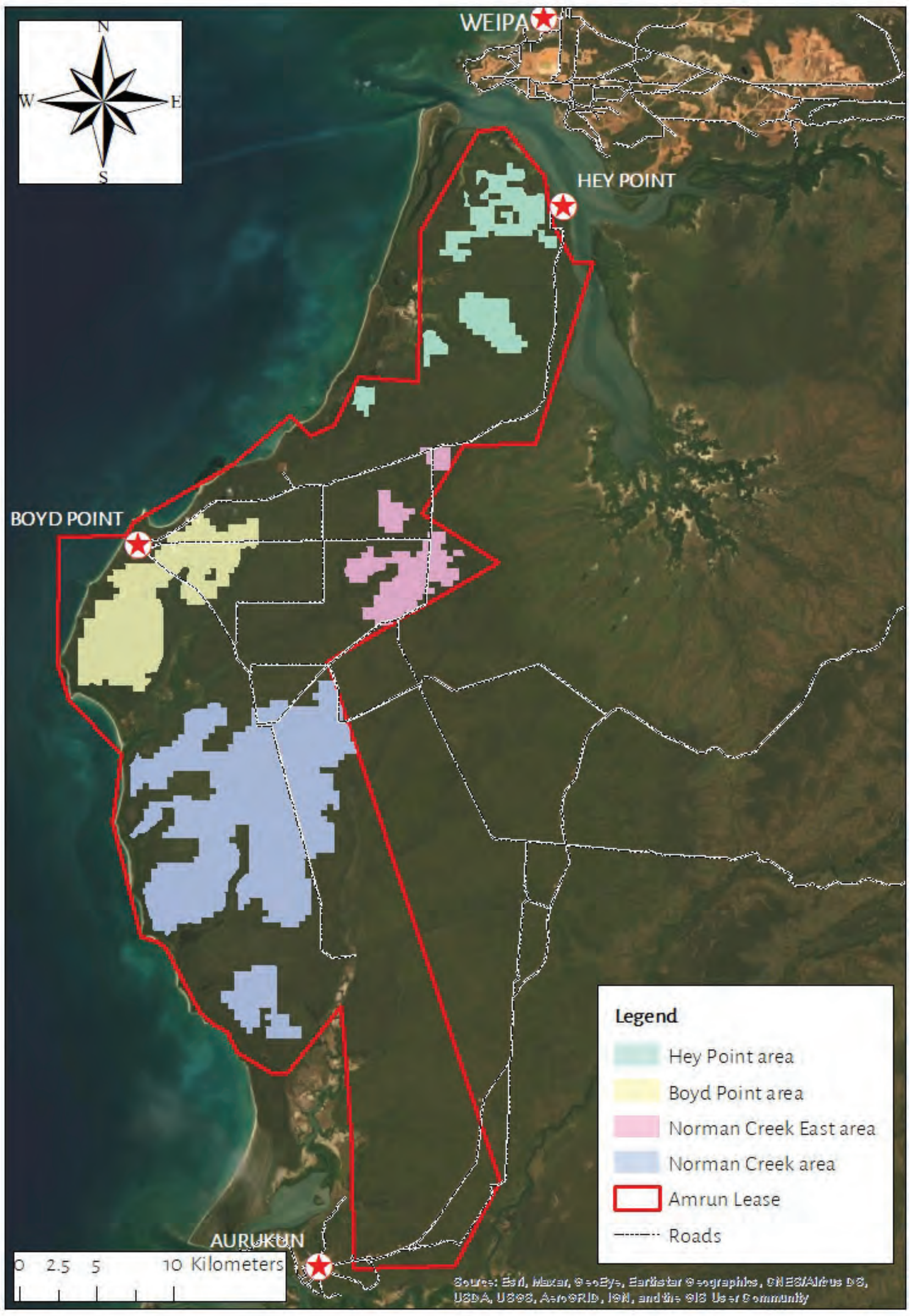

Figure 1. The Amrun Lease and mining areas for woody biomass supply in the western Cape York Peninsula region in northern Australia.

Table 1. Available low-grade log volume, potential biochar and energy (heat and power) production from the Amrun Lease mining areas. The potential annual energy production is presented for the three potential energy facilities – Hey Point, Boyd Point and Aurukun.

		Hey Point		Boyd Point	Aurukun
		Hey Point area	Norman Creek East area	Boyd Point area	Norman Creek area
Years 1-13	Total area (ha)	3,255	2,807	5,701	15,333
	Total low-grade log (m^3)	68,166	58,790	154,139	321,115
	Dry tonnes low-grade log (12% moisture)	73,620	63,494	166,470	346,805
	Char (tonnes)	22,086	19,048	49,941	104,041
	Heat and power (MW @ 80% efficiency)	36	31	101	170
	Average energy (MW) per year	**5.16**		**7.73**	**13.06**
Years 14-40	Total area (ha)	3,255	2,807	480	15,333
	Total low-grade log (m^3)	89,832	77,476	13,249	423,179
	Dry tonnes low-grade log (12% moisture)	97,019	83,674	14,309	457,033
	Char (tonnes)	29,106	25,102	4,293	37,110
	Heat and power (MW @ 80% efficiency)	48	41	7	224
	Average energy (MW) per year	**3.28**		**0.26**	**8.29**

FINDINGS & DIRECTION

Over the next 40 years, a total of **657 MW** of heat and power can be created using **low-grade logs** that otherwise go to waste. An **additional 346 MW** of heat and power can be generated from **sawmill residues**.

Other options using pyrolysis have the potential to produce both energy and up to **390 thousand tonnes of biochar** to improve mine rehabilitation.

The energy demands of Aurukun and Hey Point can easily be supplied. This is especially so with the addition of sawmill residues. The demand of Boyd Point is harder to meet, therefor, this location might be more suited to biochar production. The produced char could be redistributed over the Amrun Lease during mine rehabilitation.

Acknowledgements
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Tropical Forests and People Research Centre

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Indigenous Employment, Forestry Livelihoods, Mining

Analysis of char and energy production from the combustion of woody biomass from different hardwood species

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BACKGROUND. Unconnected to the national energy grid, supply of electricity to remote Indigenous communities in the region of Cape York is provided by diesel generators. This supply is approximately 20 times the retail price paid by consumers in grid-connected, populated areas of Australia. In a region that is rich with biomass and has potential supplies from forest clearing for bauxite mining, an opportunity exists to substitute expensive diesel fuel with carbon neutral biomass. Standard steam turbine electricity generation technology is very expensive at the small scales required by Indigenous communities in the Cape York region. An alternative is provided by thermal gasification of biomass to produce fuel gasses that may supply gas turbines or low cost internal combustion engines that in turn drive electricity generators. This opportunity however is challenged by the need to "clean" fuel gasses produced by gasification to remove corrosive and fouling tars and other heavier products of thermal decomposition. The research described here presents results of work aimed at solving this problem.

METHOD. A novel solution to the gas cleaning problem is to do gasification in two stages (Figure 1).

1. Use a furnace to combust biomass at controlled air flow to produce carbon (char), heat and exhausting tars, then
2. Move the carbon and char to a separate chamber and react this with water to produce high energy hydrogen and carbon monoxide.

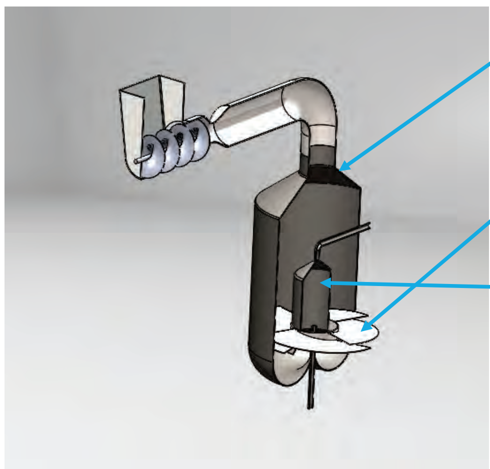

Figure 1. Schematic diagram of a proposed two stage gasifier showing fuel feed, outer biomass furnace, and screw auger transfer to second stage reaction vessel.

The research questions studied asked:

- Could carbon be produced along with sufficient energy to produce the fuel gasses from the carbon produced? and
- What combustion air flow produced this balance of heat and carbon?

A series of trials were conducted using a laboratory furnace (Figures 2 & 3) to measure carbon and heat production at three rates of combustion air flow to answer these questions. Woodchips of three tree species common to the region were examined – *Eucalyptus tetrodonta* (Darwin stringybark), *Erythrophleum chlorostachys* (Cooktown ironwood) (Figure 4) and *Corymbia nesophila* (Melville Island bloodwood).

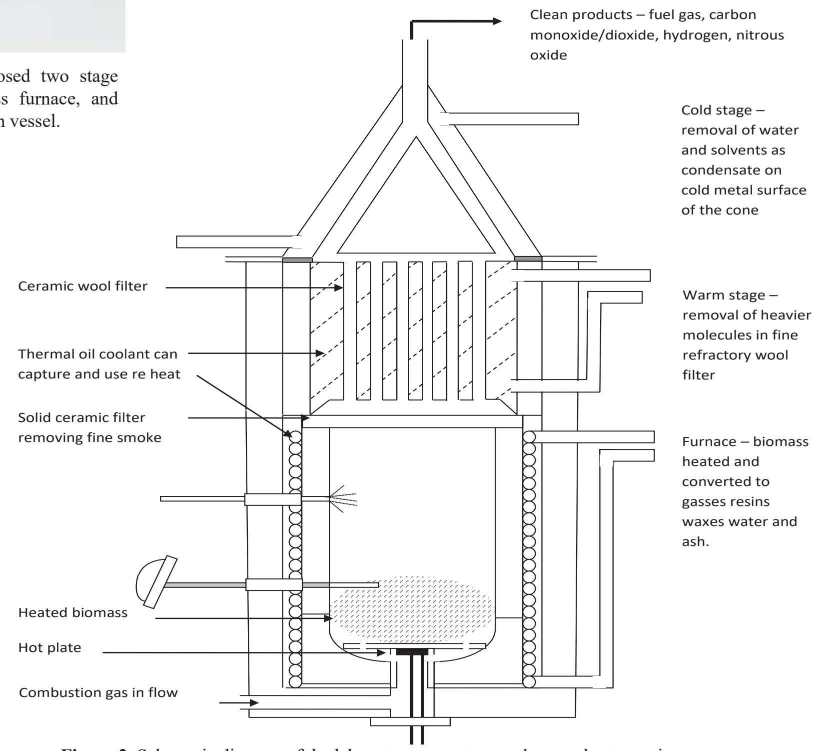

Figure 2. Schematic diagram of the laboratory apparatus used to conduct experiments.

FINDINGS. The results indicate a two-stage approach to gasification may provide an effective method of producing a clean hydrogen and carbon monoxide gas mixture as fuel for electricity generation (Figures 5-7). The experiments have also shown a potential advantage of mixing plant species to get the best production of carbon and heat to enable gasification, that consistent fuel particle size will bring better control of the process, and that efficiency will be improved and emissions reduced if tar products of the furnace can be condensed in the fuel supply to be re-burned.

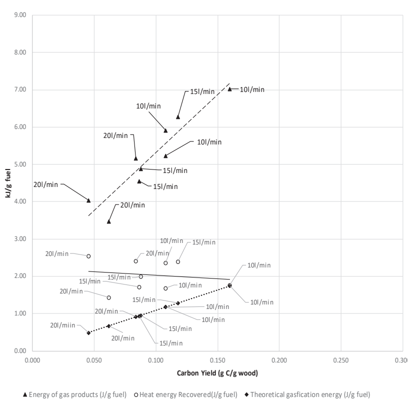

Figure 5. Results for Cooktown ironwood. Solid triangles = energy of gas products (H2, CO), open circles = heat energy recovered during combustion, solid diamonds = energy required to gasify carbon yield. The point of intersection of "heat energy recovered during combustion" and "energy required to gasify carbon yield", represents the optimum for these variables. For Cooktown ironwood, this airflow is 10l/min or slightly less.

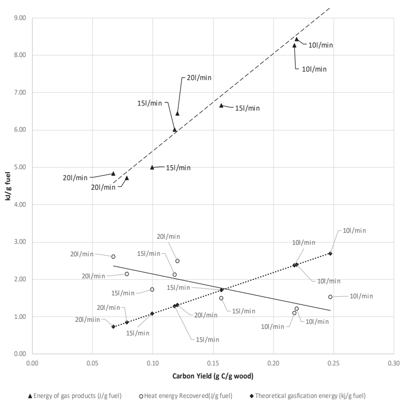

Figure 6. Results for Melville Island bloodwood. Solid triangles = energy of gas products (H2, CO), open circles = heat energy recovered during combustion, solid diamonds = energy required to gasify carbon yield. The point of intersection of "heat energy recovered during combustion" and "energy required to gasify carbon yield", represents the optimum for these variables. For Melville Island bloodwood this was approximately 15 l/min or slightly less.

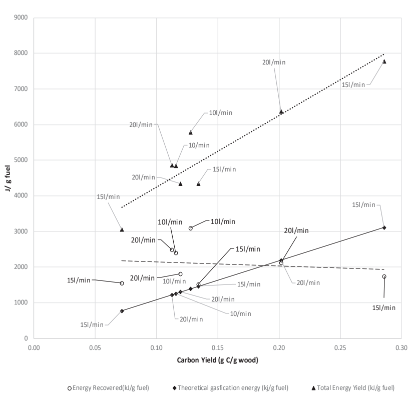

Figure 7. Results for Darwin stringybark. Solid triangles = energy of gas products (H2, CO), open circles = heat energy recovered during combustion, solid diamonds = energy required to gasify carbon yield. The point of intersection of "heat energy recovered during combustion" and "energy required to gasify carbon yield", represents the optimum for these variables. For Darwin stringybark this was not determined due to difficulty burning at these air flows, and likely requires 20l/min of more.

Figure 3. Laboratory facility. Cooling system centre and furnace under hood on the right.

Figure 4. Cooktown ironwood before and after combustion.

WHERE TO FROM HERE? Commencing in 2021, a small-scale two-stage gasifier converting biomass to fuel gasses will be constructed to further assess the costs and efficiency of this novel design. A small group of private investors have agreed to fund this work with the aim to use wood waste to supply renewable energy to wood processing operations. There is potential application of this small-scale bioenergy system for remote Indigenous communities and timber processing facilities in Cape York.

Acknowledgements. This work was funded by collaboration with the University of the Sunshine Coast supported by the Advance QLD Innovation Partnerships (AQIP) project '*Indigenous Employment, Forestry Livelihoods, Mining*'. The authors would like to acknowledge the valuable contribution of Professor Brian Towler of The University of Qld, who provided the initial direction to the two stage gasification approach. This work is under review for publication on the journal *Renewable Energy*.

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Indigenous Employment, Forestry Livelihoods, Mining

Adhesive systems development for Darwin stringybark engineered wood products

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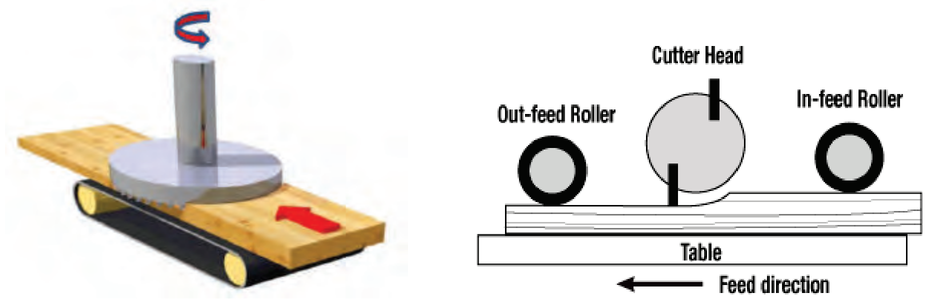
BACKGROUND

Changes in forest resources, coupled with shifts in markets towards more sustainable materials, has increased the demand for and use of engineered wood products (EWPs). Increasing the production of glue-laminated timber (glulam) is one way for the timber industry to respond. Darwin stringybark (*Eucalyptus tetrodonta*) is an important commercial forest resource in northern Australia and the production of EWPs such as glulam from this resource represents a significant commercial opportunity for the timber industry. However, bonding Darwin stringybark timber with durable, structural adhesives has proven difficult because of its high density and particular wood chemistry. Solutions are necessary to access high-value EWP markets.



(a) (b)

Figure 1. Machining preparation method comparison between (a) Rotoles face milling approach and (b) Conventional planing approach.

METHOD (What we did)

This study evaluated, at the laboratory scale, the effect of different timber surface machining preparation methods on timber wettability, roughness, permeability and the tensile shear strength of adhesive bonds of Darwin stringybark timber. Three machining methods were selected – conventional planing, sanding post-planing and face milling. Additionally, two adhesive types were tested – fast-curing modern polyurethane (PUR) and more traditional resorcinol formaldehyde (RF). Also tested was the effect of ambient versus elevated temperature curing for the RF adhesive.

At the semi-industrial scale, the study screened over thirty different manufacturing protocols (including chemical surface preparations, adhesive additives, pressing parameters) to identify optimization opportunities. Its primary aim was to contribute to the development of optimal adhesion protocols. Trials were conducted on short length glulam beams comprising of 5 laminates.

Figure 2. Glulam samples being prepared.

Figure 3. Manufactured glulam samples.

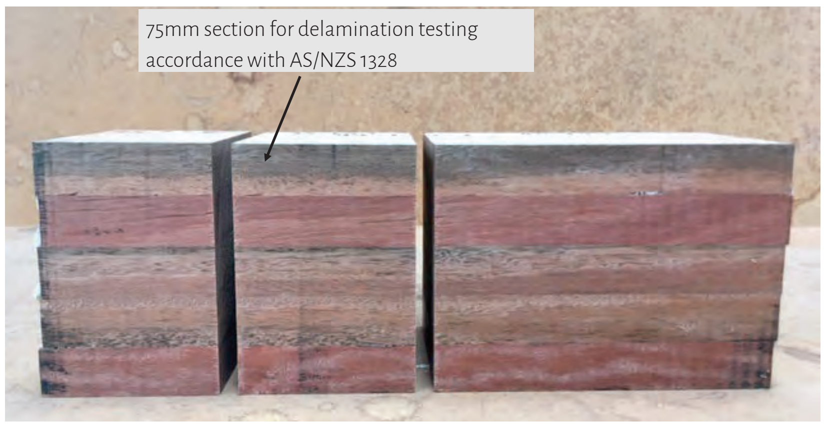


Figure 4. Glue line assessment section removed from the middle of the glulam sample.

FINDINGS

- The pre-gluing surface machining method significantly influenced the roughness, wettability and permeability of Darwin stringybark timber, and the tensile shear strength of bonded samples. Where trials compared planing, sanding post-planning and face milling, face milling performed better than sanding post-planing, and planing resulted in the poorest delamination result.
- Modern polyurethane adhesives provided comparable and in some cases better performance than the more traditional resorcinol formaldehyde combinations.
- Chemical surface treatments were shown in some cases to assist in improving the bond performance. Further studies are required to determine the effectiveness of these chemical treatments with varying manufacturing conditions.

Figure 5. Glulam can be used in a wide range of structural and architectural applications.

WHERE TO FROM HERE?

The results demonstrated that glue-laminated timber products can be developed from Darwin stringybark. Several combinations of board surface preparation method, adhesive type and manufacturing protocols resulted in acceptable bond performance of the glue-laminated timber products.

While the study included an extensive number of trials, a wide range of different treatments were included with low replication. Additional trials of the better performing configurations are necessary to assess repeatability. These trials should also include a program of testing at larger scales to confirm their commercial suitability.

Acknowledgements

This work was funded by the USC Advance QLD Innovation Partnerships (AQIP) project '*Indigenous Employment, Forestry Livelihoods, Mining*'. DTM Timber supplied the timber used in the trials. Adhesives and technical advice was provided by Jowat Universal Adhesives Australia Pty Ltd, and Hexion Pty Ltd. The support provided by the Queensland Government, Department of Agriculture and Fisheries (DAF) through the provision of the unique facilities located at the Salisbury Research Facility is acknowledged as critical to facilitate studies of this nature.

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