Treating Fe-rich acid mine drainage with Tasmanian plants as a metal removal mechanism

April 25th, 2024

Morgantown, West Virginia

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Supervisory team:

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Dr Brandon Winfrey

Dr Adam Kessler

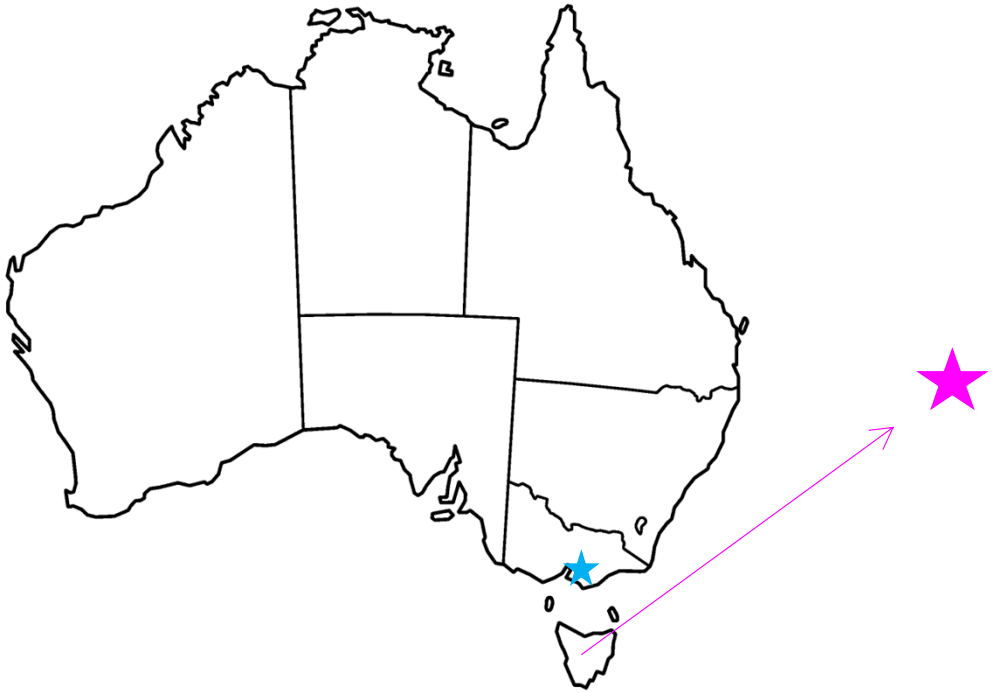
I would like to begin by acknowledging the Traditional Custodians of the land on which Monash University sits, the Bunurong People, the Traditional Custodians of my study site, the Palawa people, and the Traditional Custodians of the land we are meeting on, the Seneca and Mohawk Peoples, and pay my respects to their Elders past, present, and emerging.

Introduction – My study site

My study site – Haulage Creek, Queenstown, Tasmania, Australia

Australia has over 95000 mines, and 89% of them are classified as inactive

Less than 4% of these inactive mines have been rehabilitated



Werner, T. T., et al. (2020). "A Geospatial Database for Effective Mine Rehabilitation in Australia." Minerals **10**(9).

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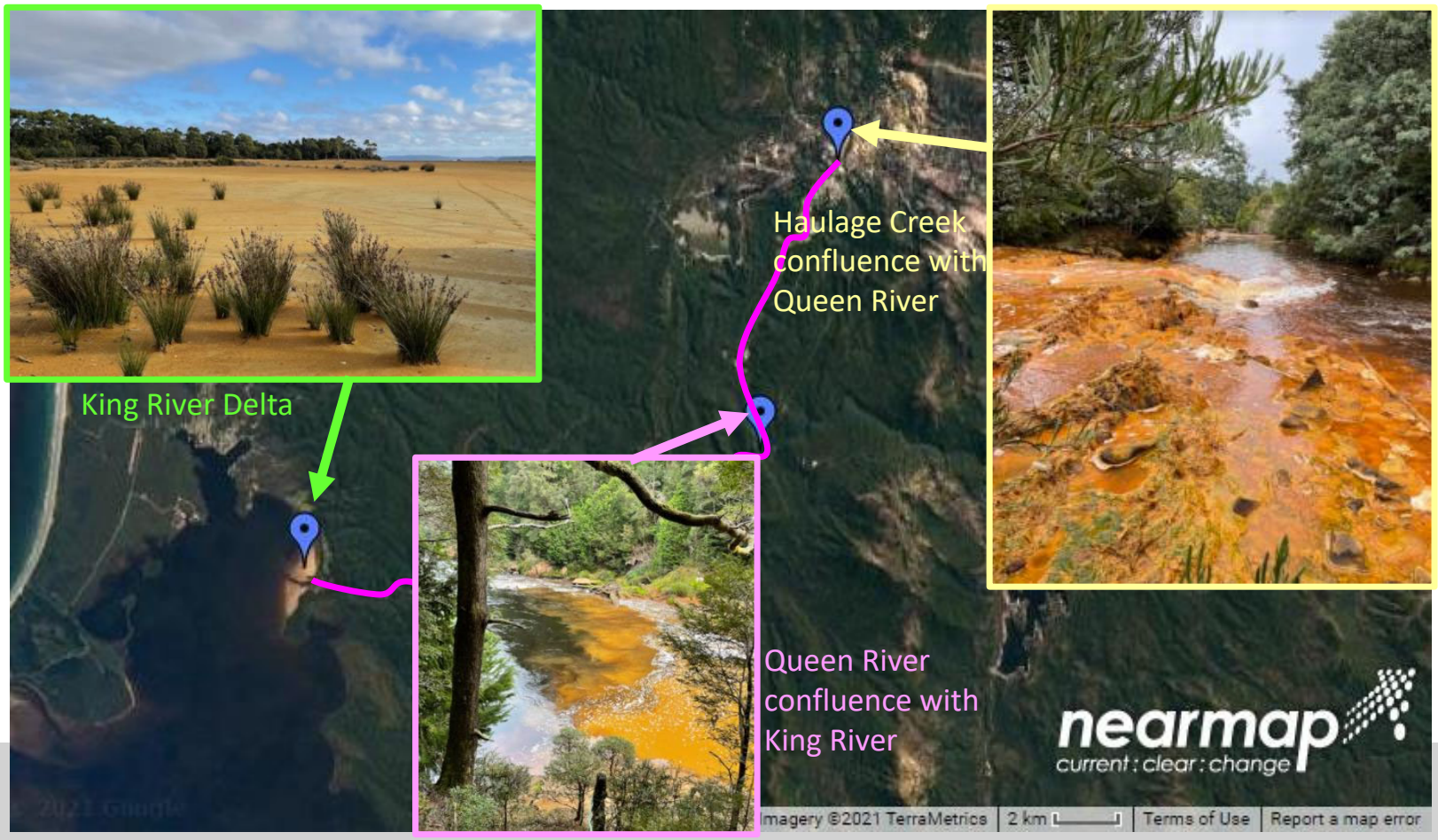

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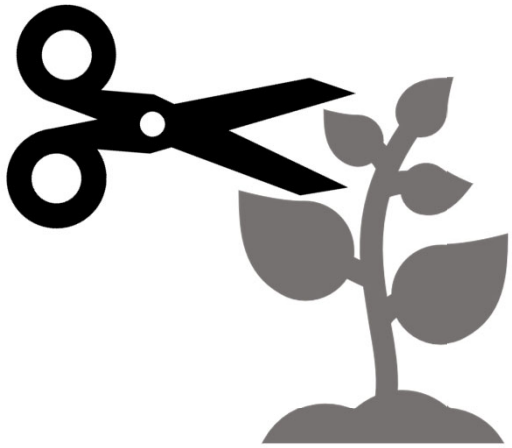
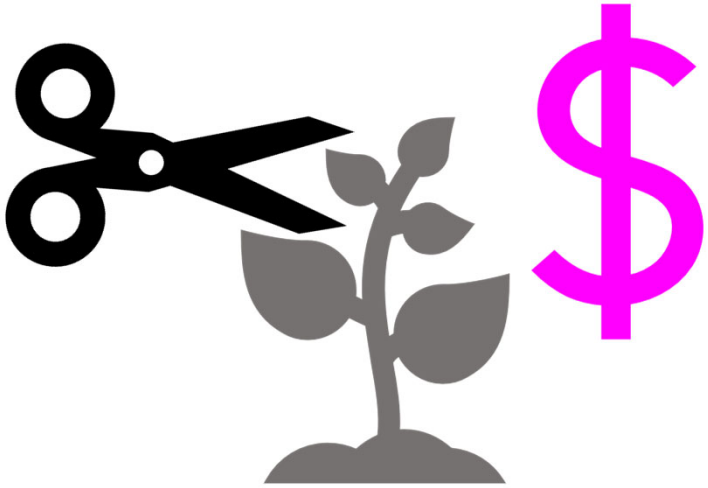
Element	Target AMD concentration (mg/L)
Al	100
Ca	6
Co	.5
u	2
	0.4
	5
Mg	00
Mn	00
Ni	
Pb	0.06
SO_4^{2+}	3400
Sr	0.6
Zn	5

Potential for over 2500 tonnes of iron and 300 tonnes of aluminium to flow down Haulage Creek per year

Phytomining





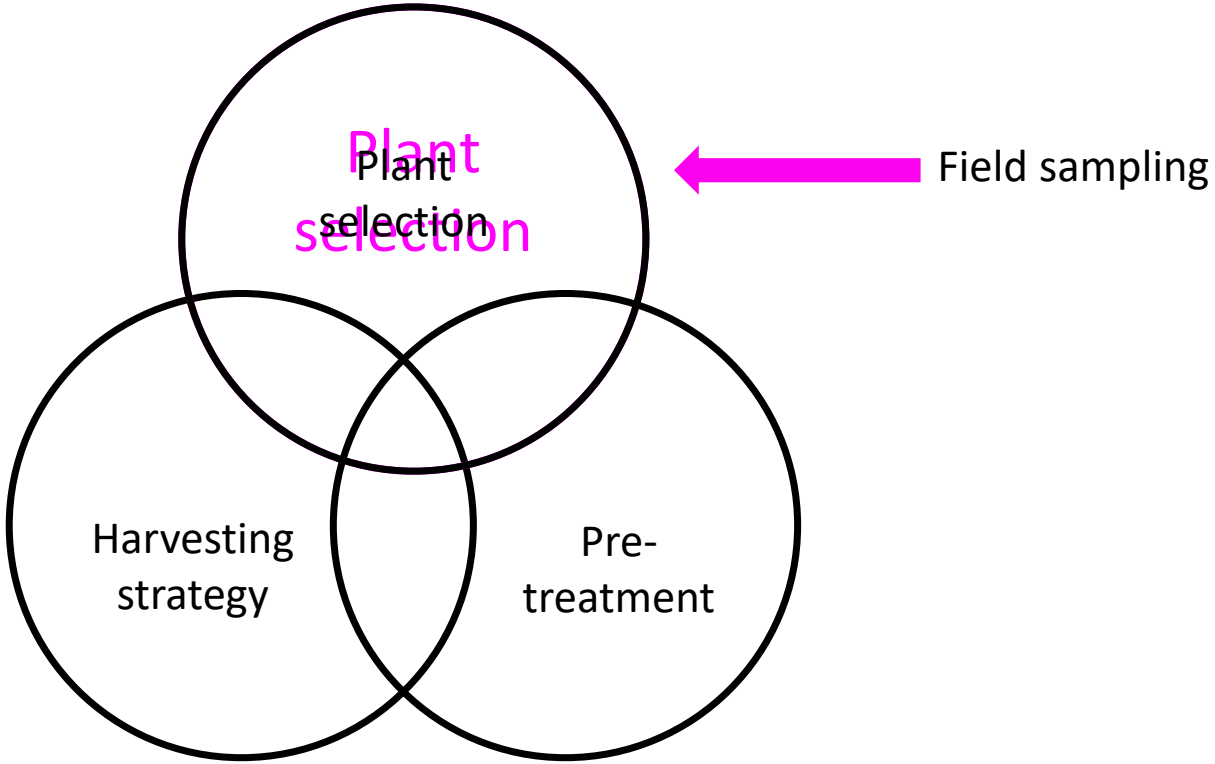
Phytoremediation – using plants to remediate contaminated media

Phytoextraction – removing contaminated plants for remediation

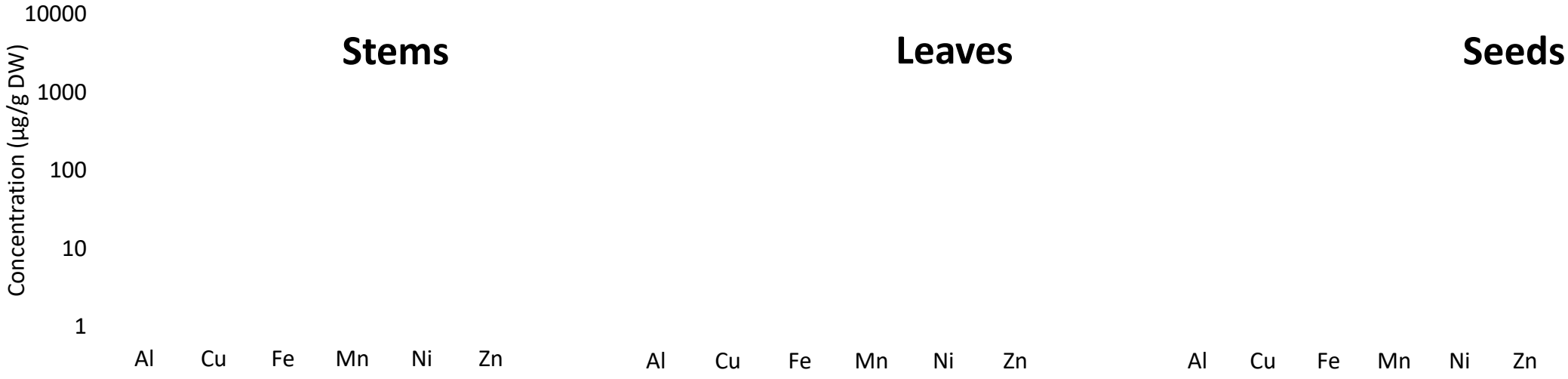
Phytomining – harvesting contaminated plants for remediation and profit

How are the plants to be harvested?

Phytomining considerations for use with AMD



Implications of Tasmanian plant samples



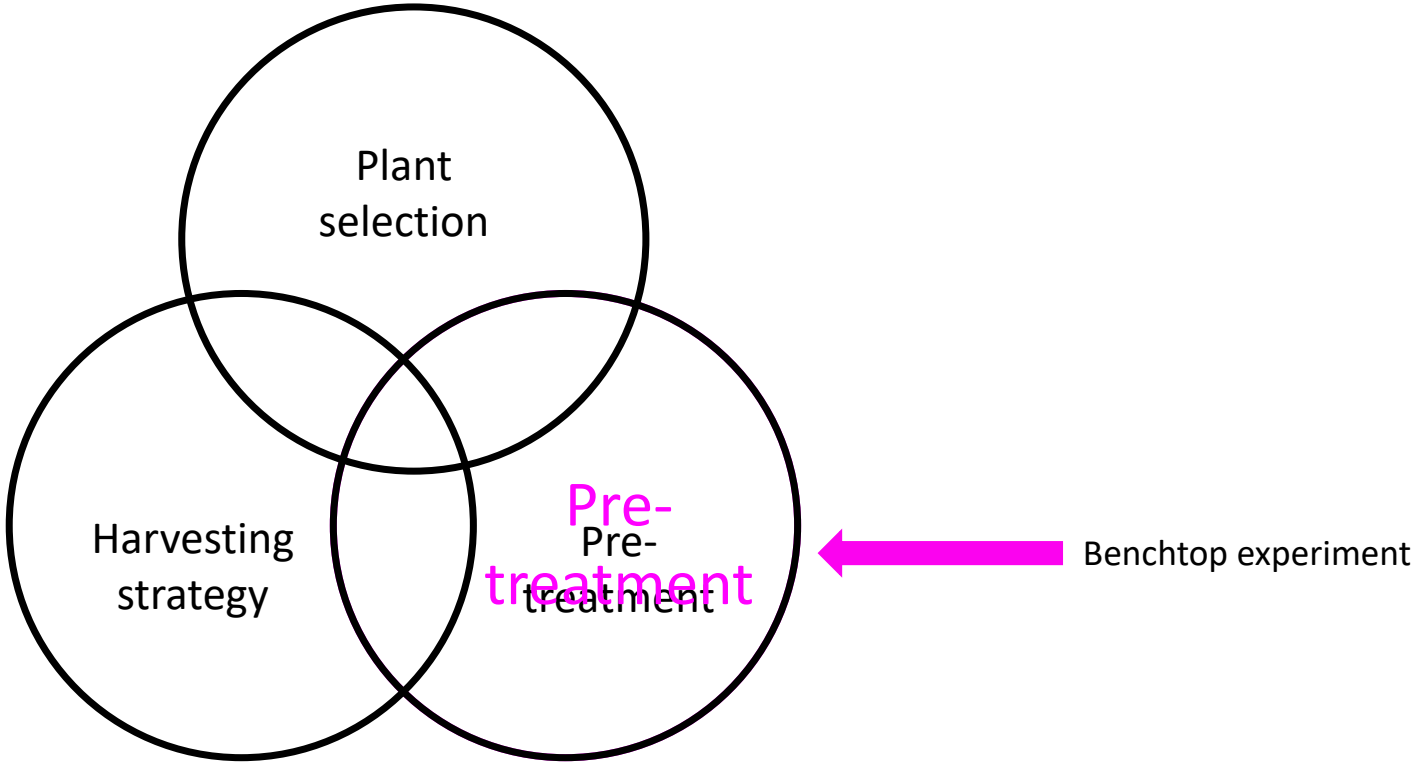
‘Cleaner’

‘Contaminated’

‘Heavily ~~c~~ aminated’

Do we need to pre-treat the AMD to increase plant metal uptake?

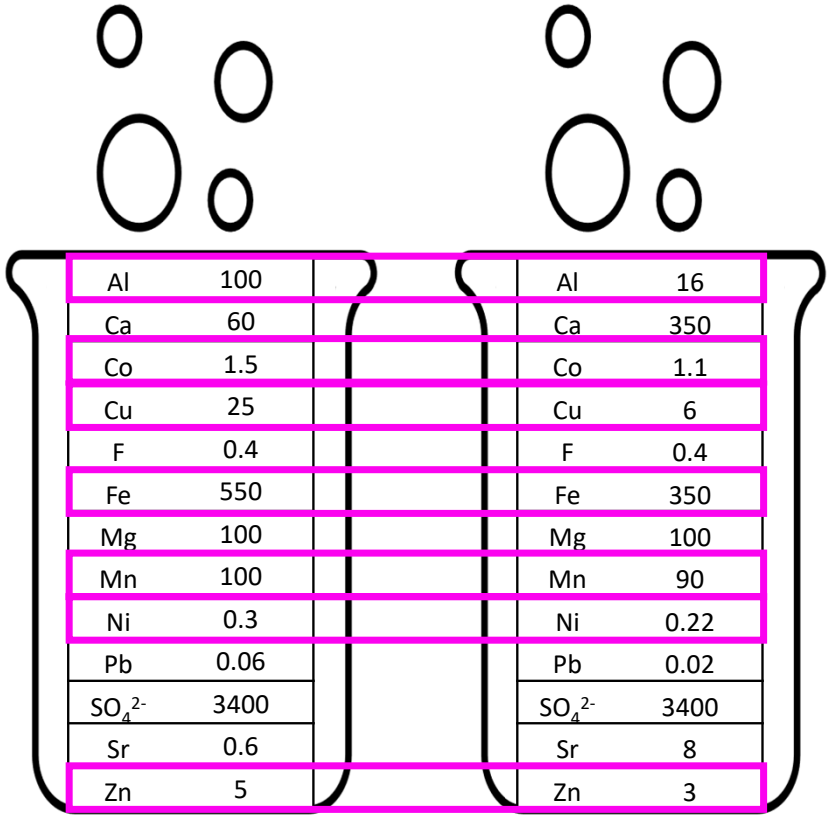
Phytomining considerations for use with AMD



‘Pre-treatment’ using alkaline materials

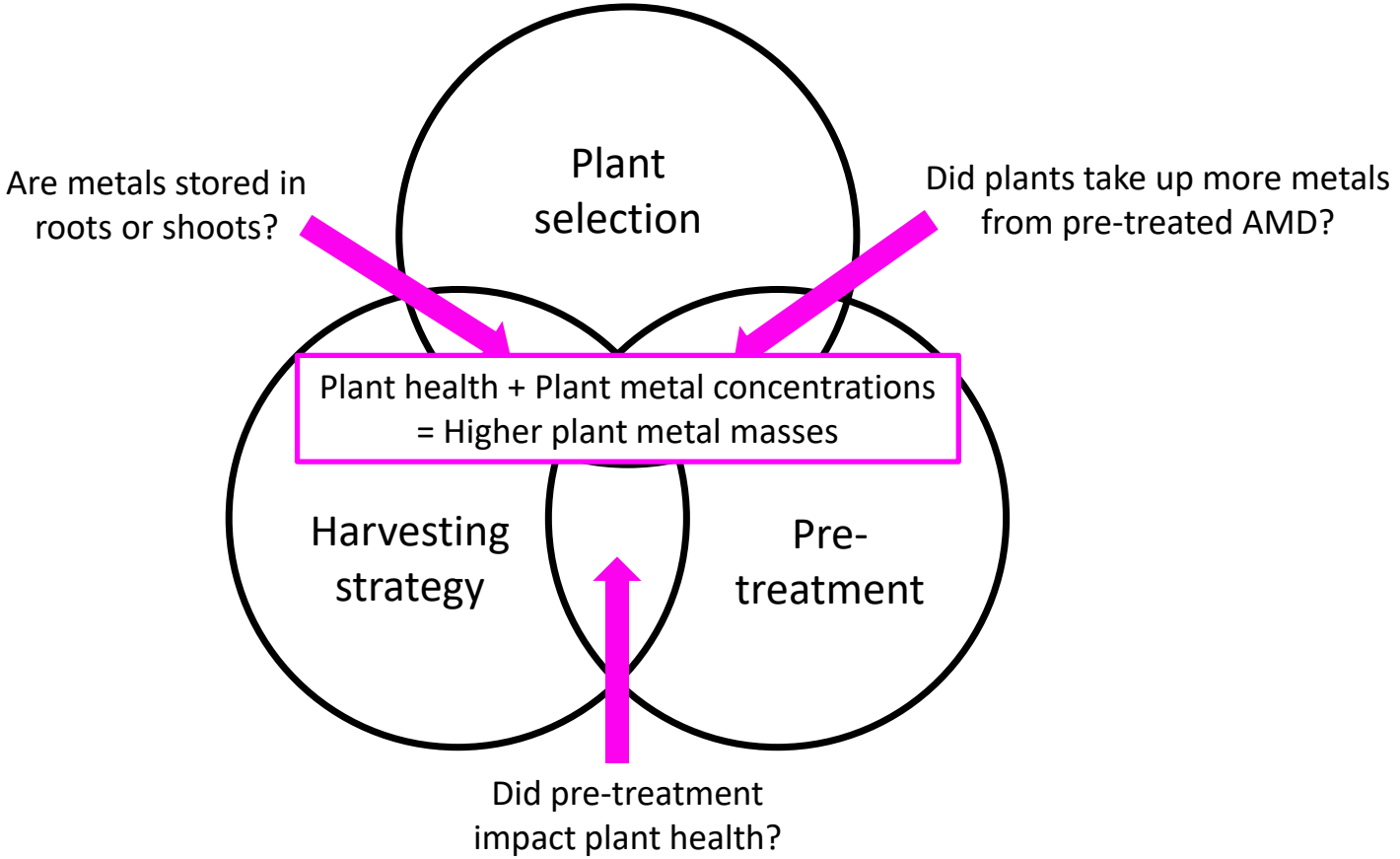
Control (aeration) | Dolomite Lime | Limestone sand | Serpentinite | Oxic limestone | Anoxic limestone

4 hours contact time



	Full-strength AMD solution (mg/L)	‘Pre-treated’ AMD solution (mg/L)
Al	100	16
Ca	60	350
Co	1.5	1.1
Cu	25	6
F	0.4	0.4
Fe	550	350
Mg	100	100
Mn	100	90
Ni	0.3	0.22
Pb	0.06	0.02
SO_4^{2-}	3400	3400
Sr	0.6	8
Zn	5	3

Phytomining considerations for use with AMD



Plant studies

Plant study 1 – Pot-plant survivor!

Add AMD to plants daily → see which survive!

- Which plants will survive in AMD?

Plant study 2 – 'No mow' column study

Sacrifice initial pot plants → dose for six weeks → harvest roots and shoots

- What metals do the plants take up in their roots and shoots?

Plant study 3 – 'Mow' column study

Dose for one week → harvest shoots → continue dosing → harvest roots and shoots

- Do the plants survive and take up similar amounts of metals with lower biomass?

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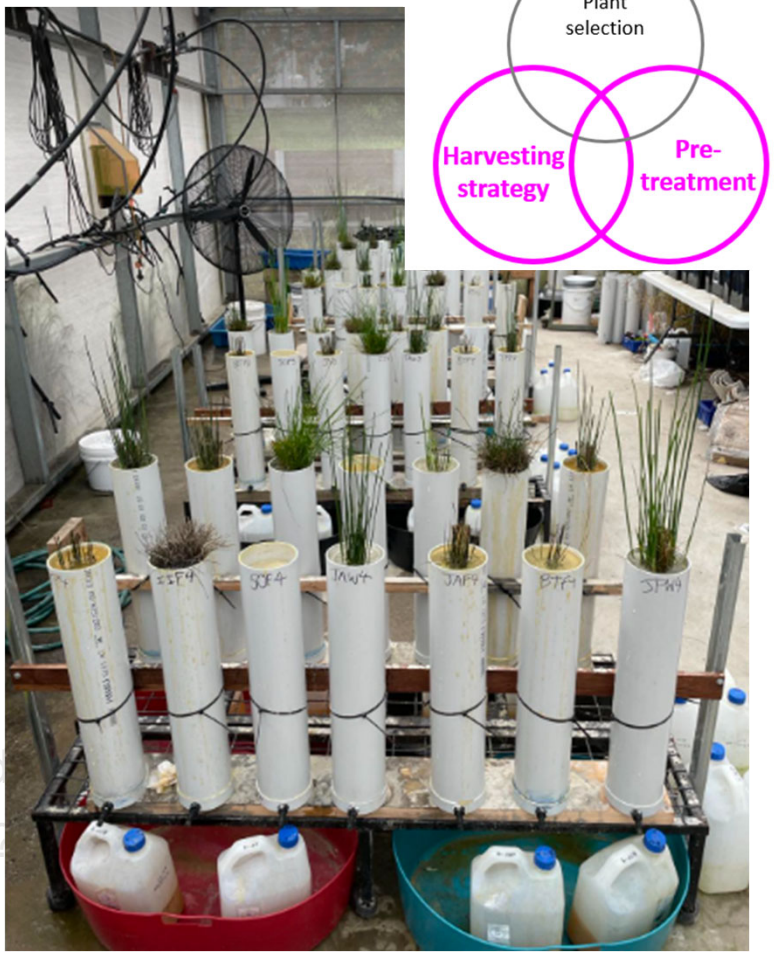

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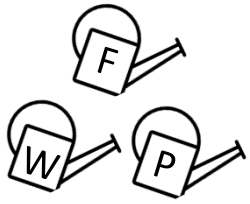

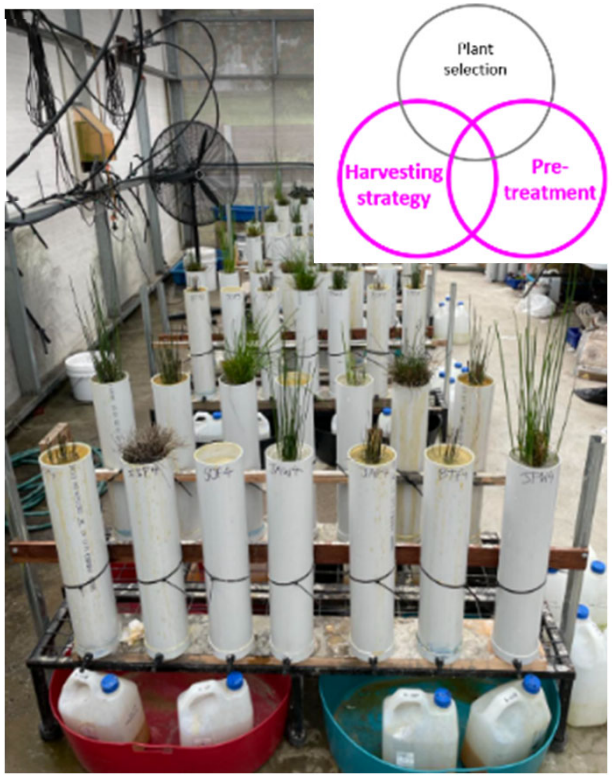

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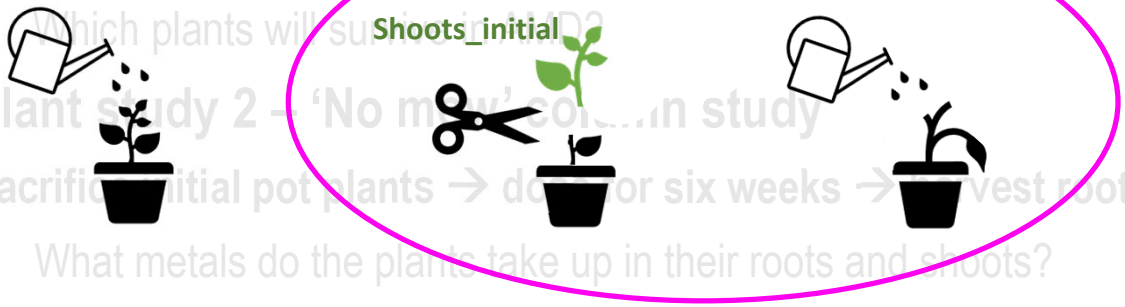
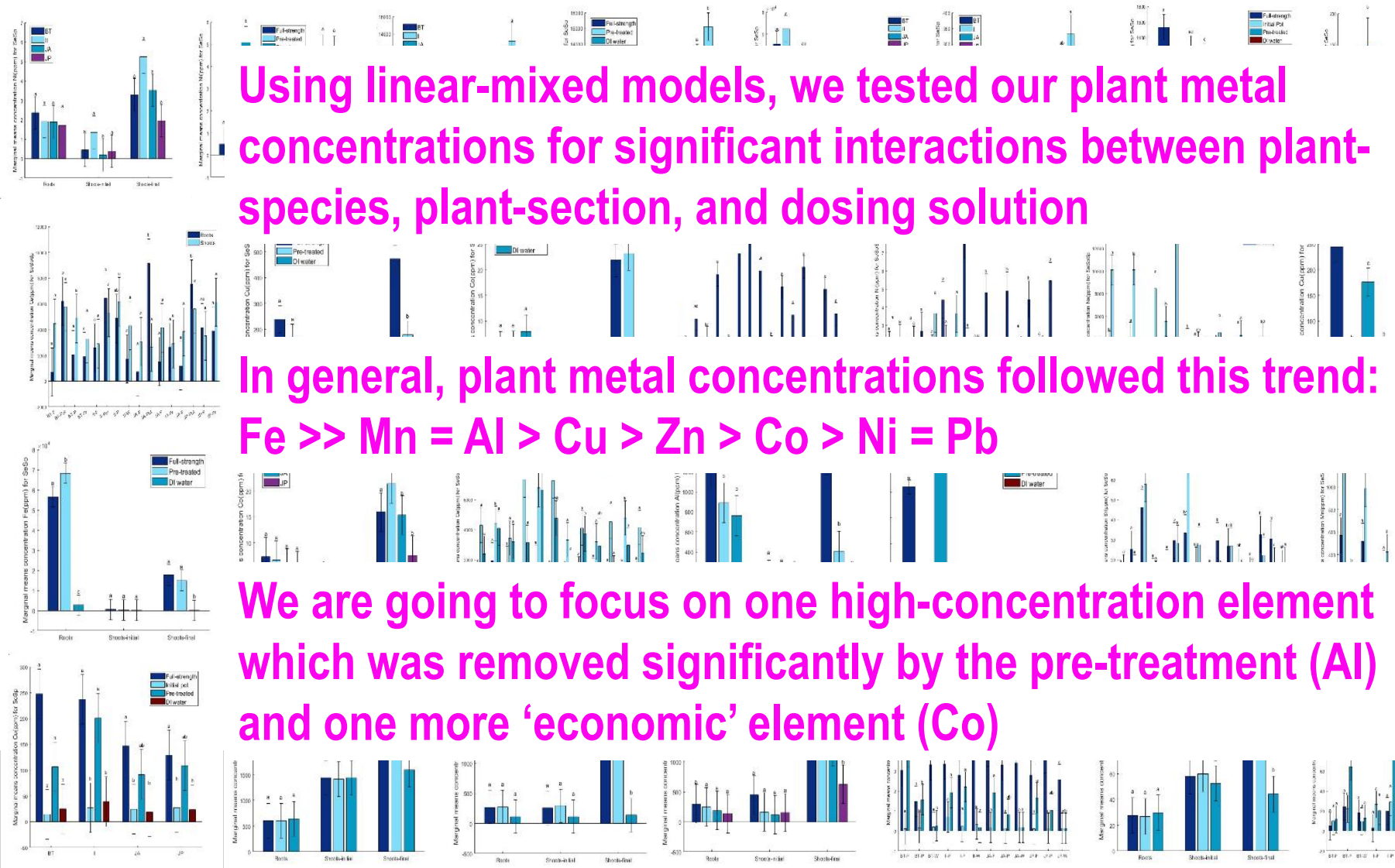


Plant study 3 – 'Mow' column study

Dose for one week → harvest shoots → continue dosing → harvest roots and shoots

- Do the plants survive and take up similar amounts of metals with lower biomass?

A year's worth of linear mixed model results!



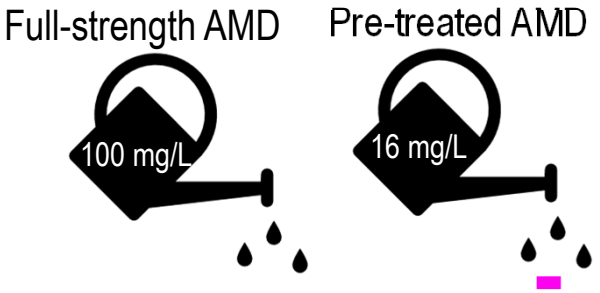
Using linear-mixed models, we tested our plant metal concentrations for significant interactions between plant-species, plant-section, and dosing solution

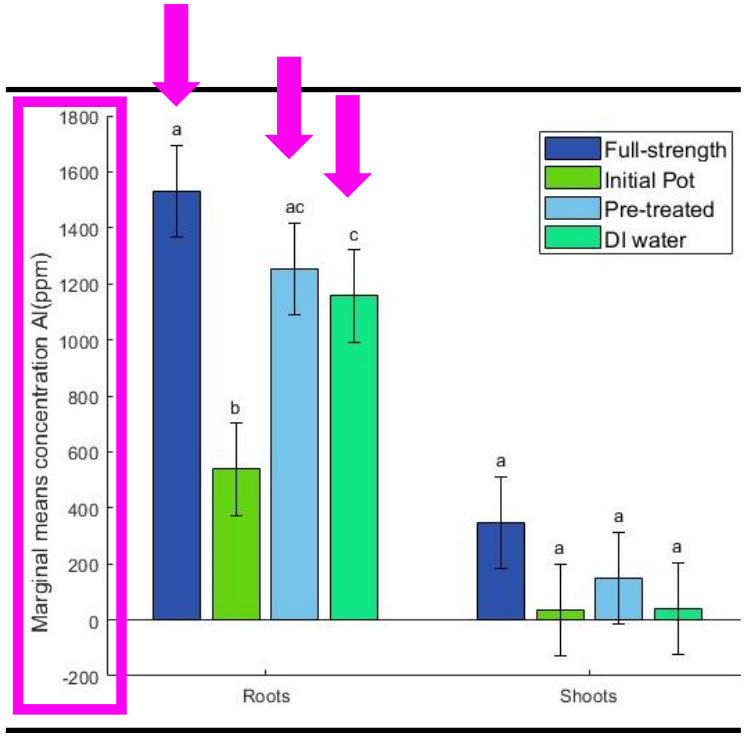
In general, plant metal concentrations followed this trend:
Fe >> Mn = Al > Cu > Zn > Co > Ni = Pb

We are going to focus on one high-concentration element which was removed significantly by the pre-treatment (Al) and one more 'economic' element (Co)

Aluminium

Marginal means for both the ‘No mow’ study and ‘Mow’ study. Figures shown for significant interactions in the linear mixed model





‘No mow’ study

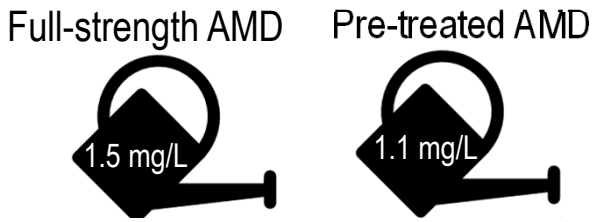
‘Mow’ study

*error bars show the 95% confidence interval

**bars with different colours within the same x-axis grouping (i.e. roots/shoots) with different letters are significantly different to each other at an α=0.05 level.

Cobalt

Marginal means for both the ‘No mow’ and ‘Mow’ study. Figures shown for significant interactions in the linear mixed model



‘No mow’ study

‘Mow’ study

*error bars show the 95% confidence interval

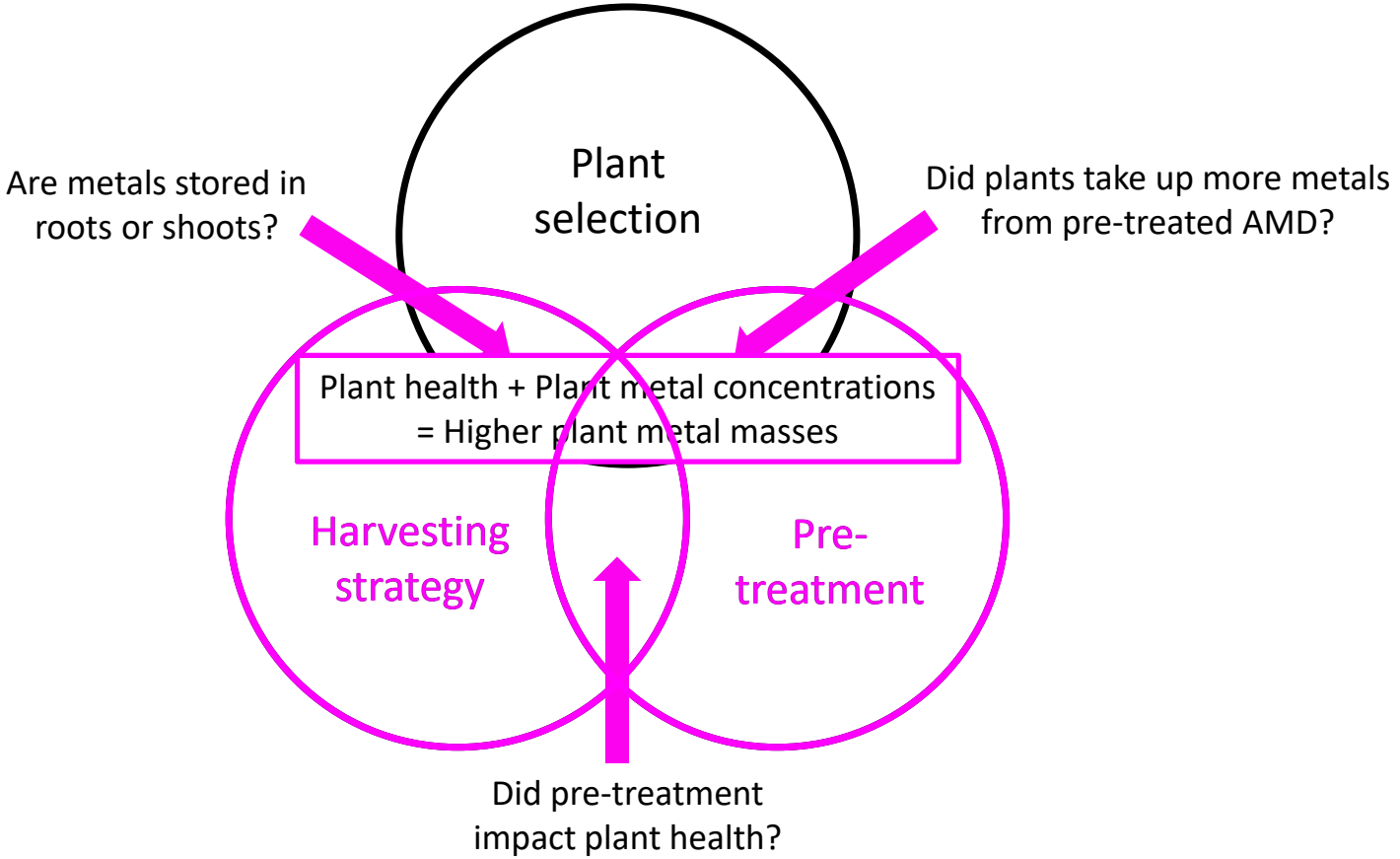
**for the ‘Mow’ study, bars with different colours within the same x-axis grouping with different letters are significantly different to each other at an α=0.05 level.

***for the ‘No mow’ study, bars with the same colour within the same species (all conditions) with different letters are significantly different to each other at an α=0.05 level.

Plant metal summary

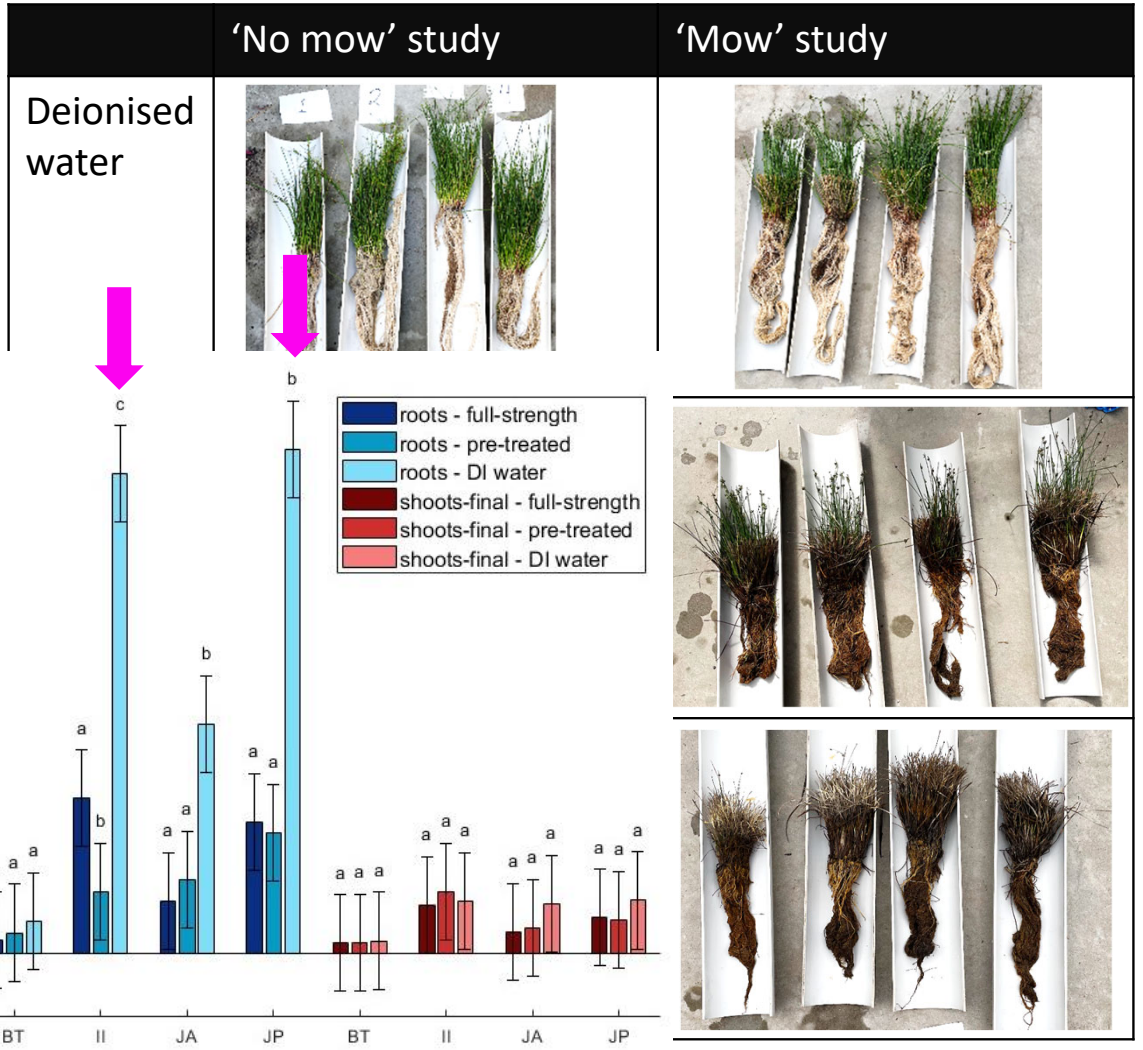
	Plant Section			
	 Roots	Final shoots	Initial shoots	Either!
'No mow' study	Al, Cu, Fe, Ni, Pb	Na	Ca	Ca, Co, Mg, Mn, Sr, Zn
'Mow' study	Al, Fe, Pb	Co, Cu, Mg, Mn, Ni, Sr, Zn	-	

Phytomining considerations for use with AMD



Isolepis inundata end of study 'portraits'

- Metal accretions on the roots of treated plants
- More dieback in the full-strength AM plants
- Plants choose to grow new shoots after being cut rather than regrow th shoot



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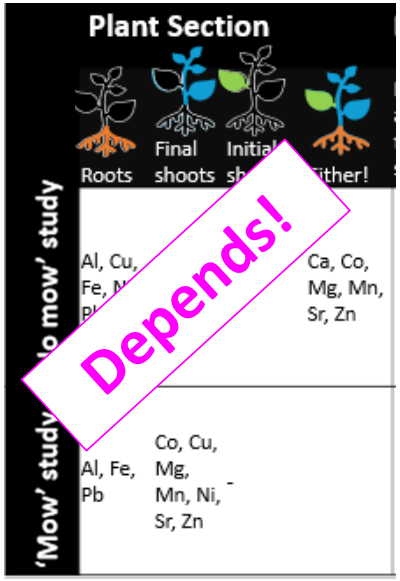
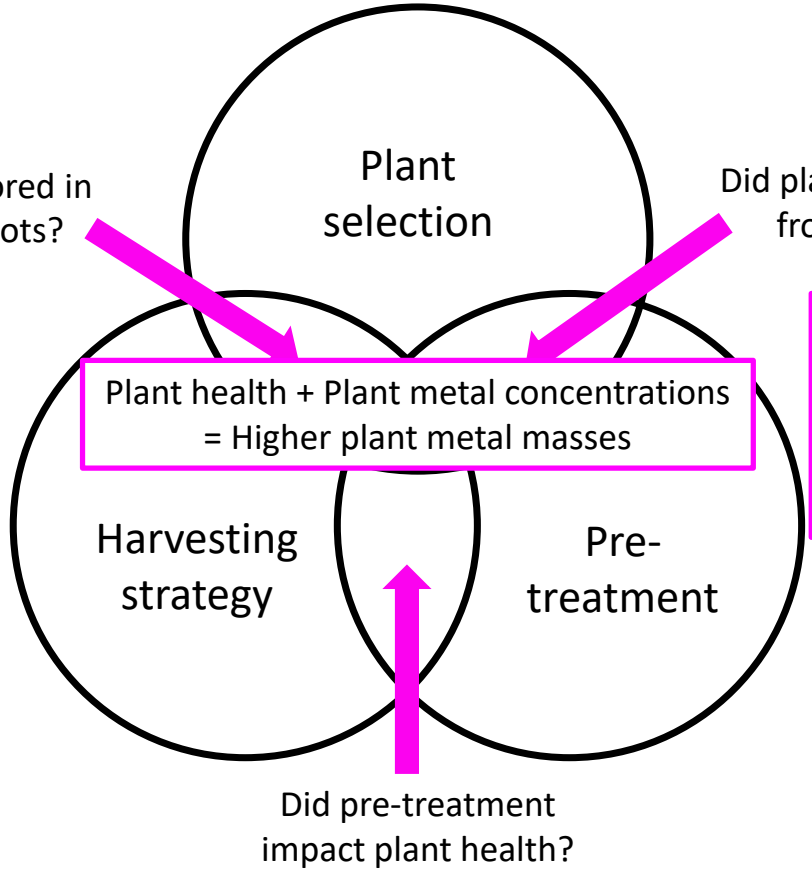
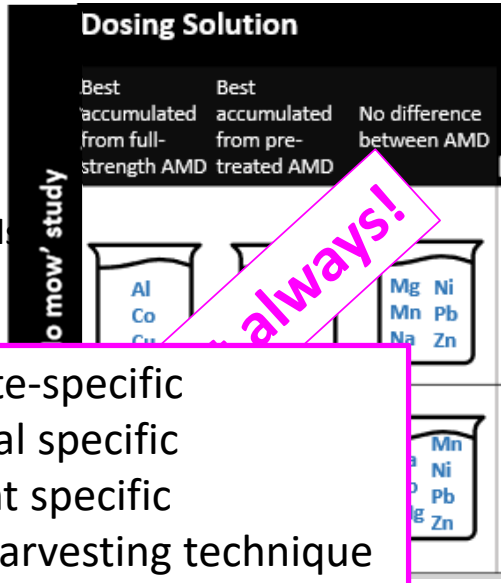
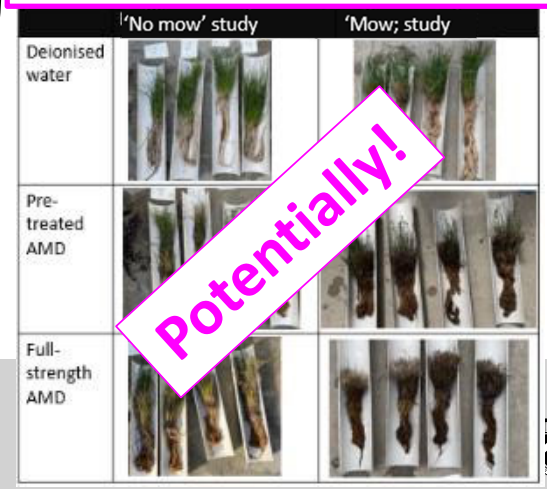






Very site-specific
→Metal specific
→Plant specific
Will depend on harvesting technique



Final conclusions – the big picture?

Plant concentrations from experiment	Ore grades being mined from rock
	2021)
0.06% Cu in some plants	>0.43% Cu ore grade in new mines (Alvear et al., 2020)

Not too bad for a waste product!

Plant concentrations only one magnitude smaller than normal mining operations

mental concentrations often at least one magnitude higher in than the plants growing in the field

?? More research…

Dehaine, Q., et al. (2021). "Geometallurgy of cobalt ores: A review." Minerals engineering **160: 106656.**
ALVEAR, G., RISOPATRON, C. & PEASE, J. 2020. Processing of Complex Materials in the Copper Industry: Challenges and Opportunities Ahead. *JOM,* 72.

Acknowledgements

Thank you to WTF and IMWA for the opportunity to present today

My supervisors Dr Anna Lintern, Dr Brandon Winfrey, and Dr Adam Kessler for their unending support

Carol Steyn, Jessica Renaud, Clint Siggins and MRT from the Department of State Growth, Tasmania for funding this project

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My incredible undergrads Brigitte, Emma, Jeff, Kartik, Luke, Puxuan, and Ywin for all of their help with these experiments – I couldn't have done it without you!

Monash EAE and Monash Civil Engineering lab staff

Dr Bob Nairn at the University of Oklahoma

Wildseed Tasmania

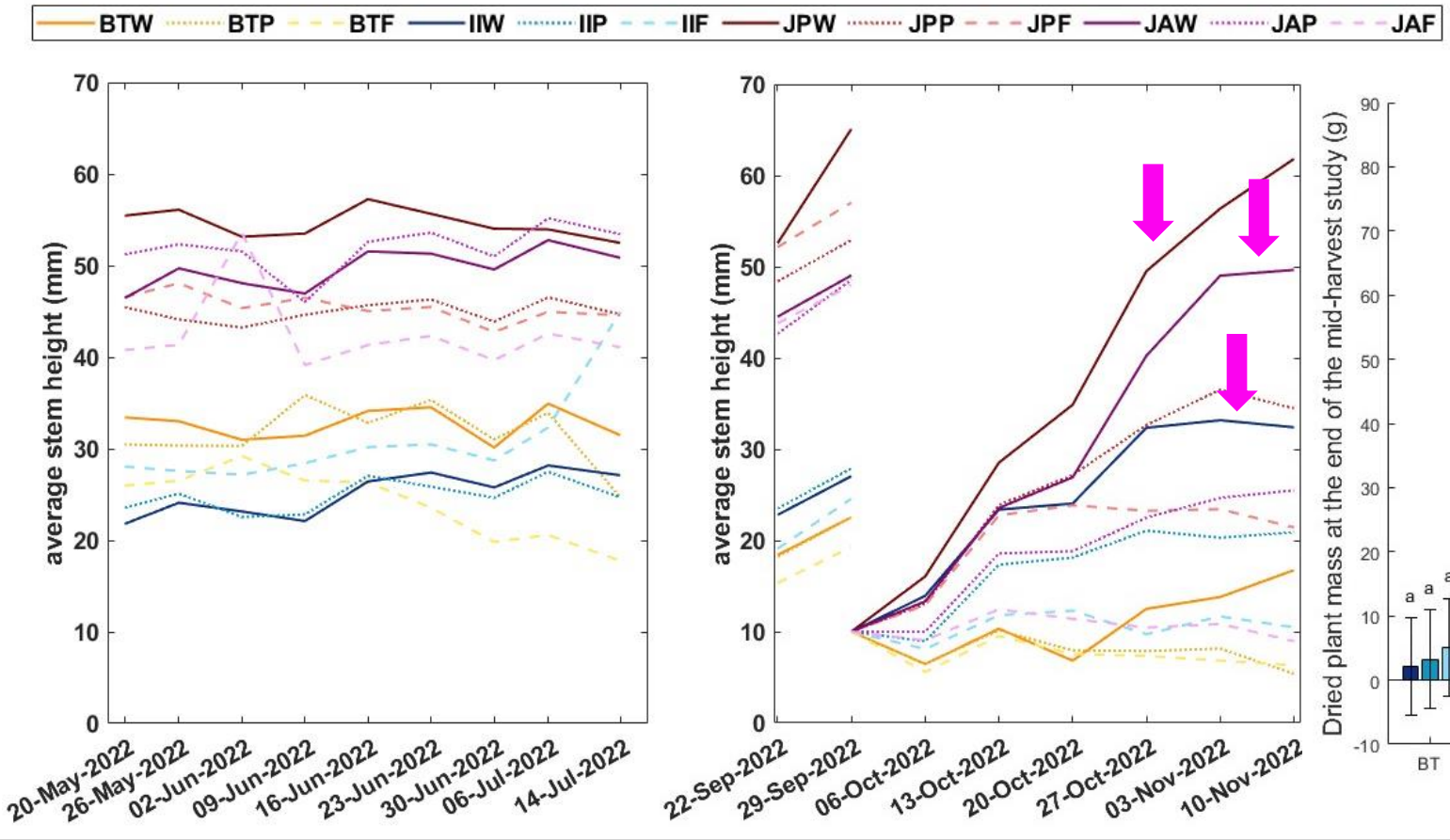
Dr Clare Miller and students at the University of Tasmania

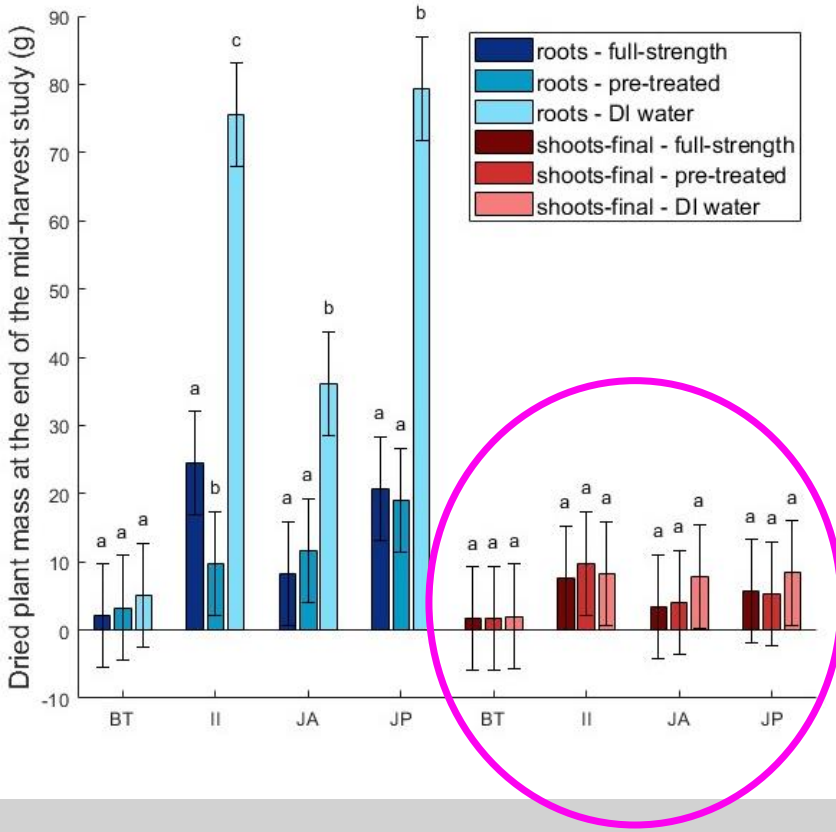
Thank you!

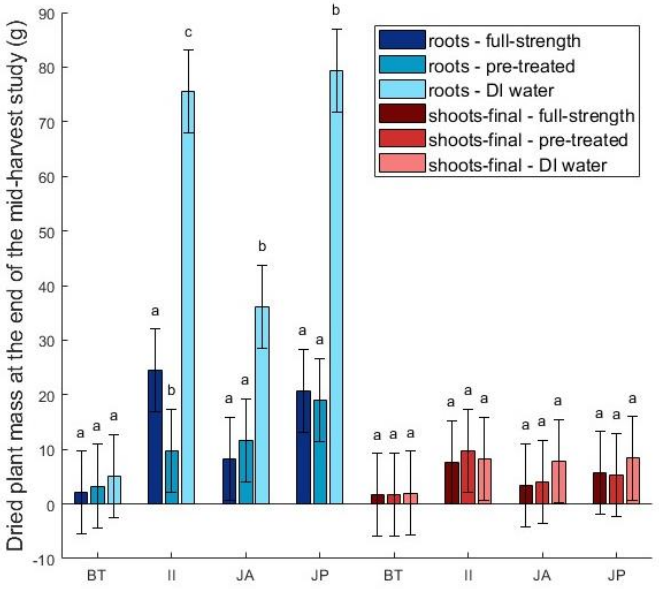
Any questions?

Follow on slides for questions

Plant growth trends







Concentrations (mg/kg)	Masses per plant section (mg)