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Impacts of biochar on boosting biological nitrogen fixation and remediating heavy metal uptake in ex-tin mining areas

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ASEA UNINET ASEAN-European Academic University Network

Kabupaten Bangka

Tut Wuri Handayani

oead

Erasmus+

Timah

FOOD INSECURITY

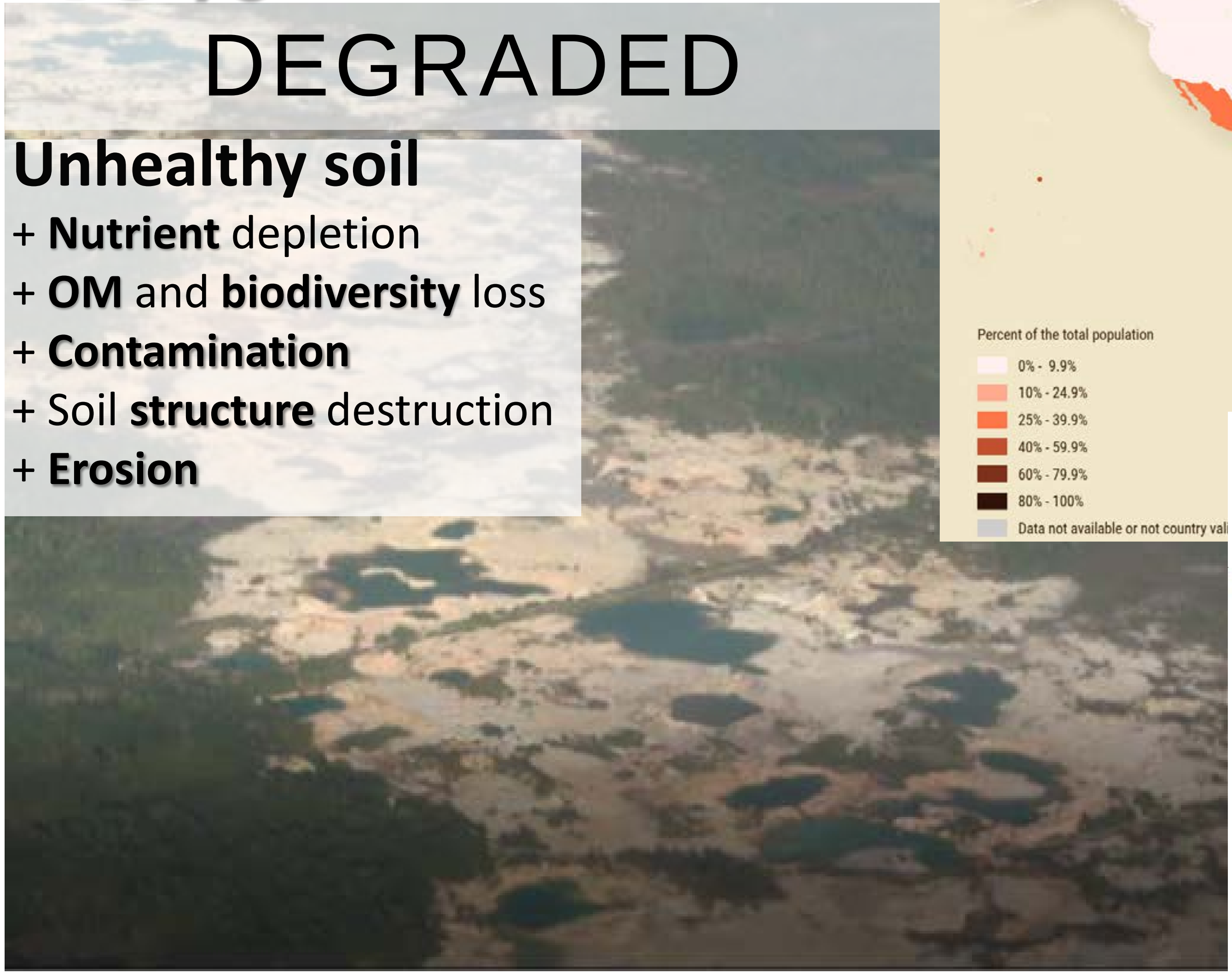
Up to

40% of land =

DEGRADED

Unhealthy soil

+ **Nutrient** depletion
+ **OM** and **biodiversity** loss
+ **Contamination**
+ Soil **structure** destruction
+ **Erosion**



Aerial photo of ex-tin mining on Bangka Island, Indonesia

Soil reclamation with **BIOCHAR** and **LEGUMES**

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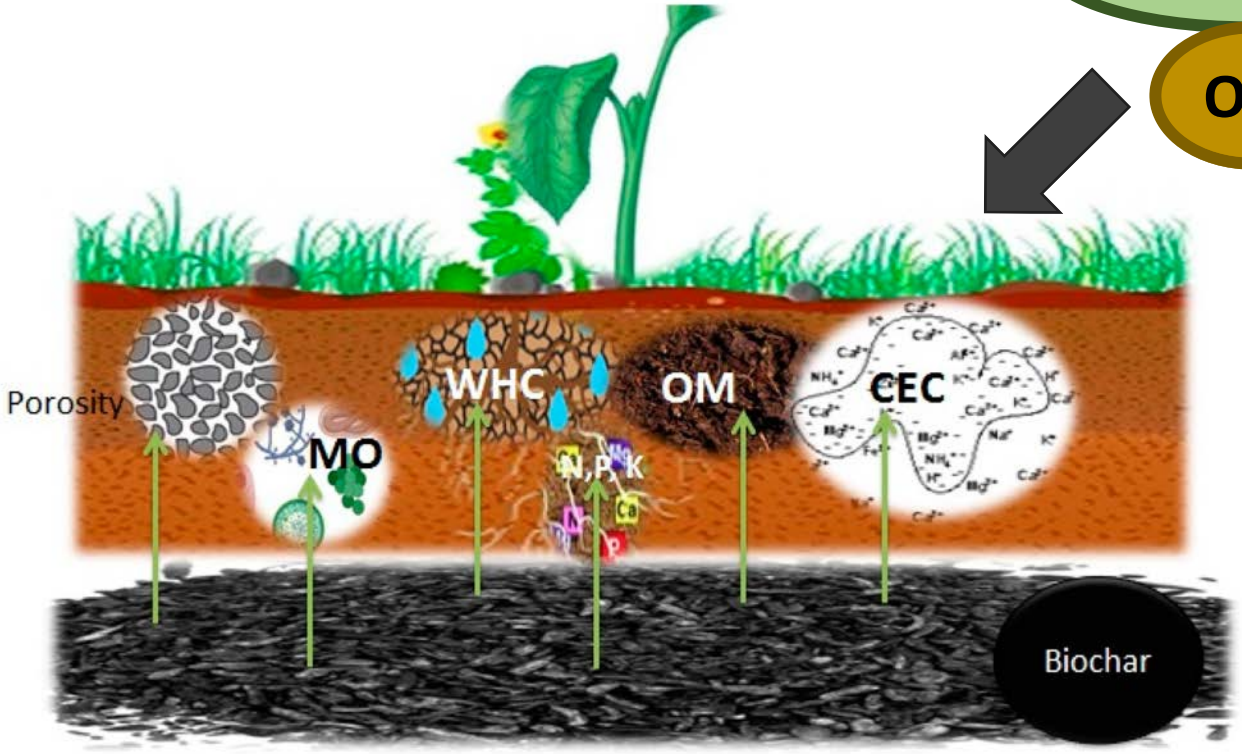
Improve soil properties → Plant growth
Absorb pollutants → Safety soil

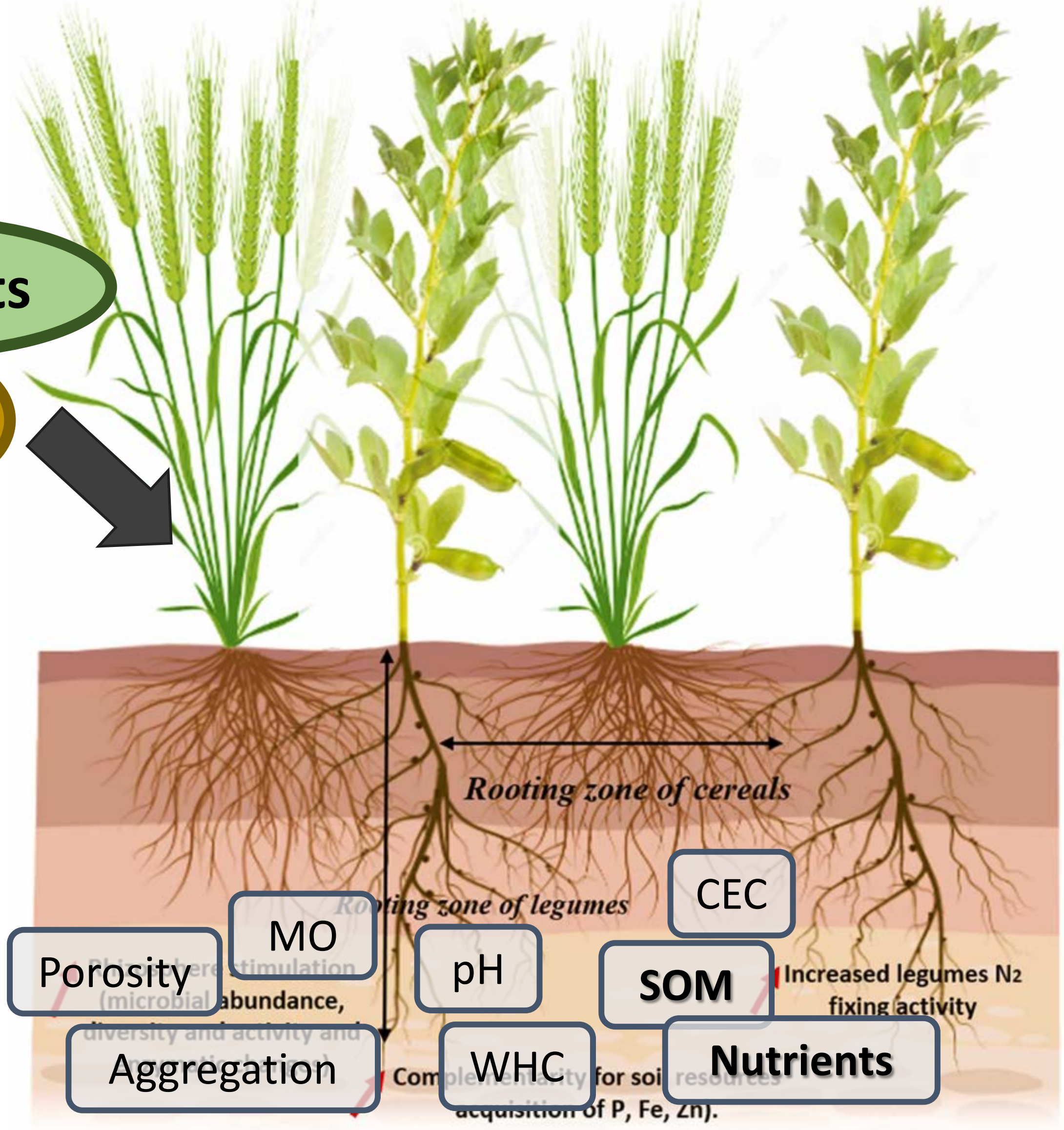
Nutrients

OM



Biochar increases porosity, microorganisms (MO), water holding capacity, organic matter, nutrients and CEC of soil

Alkharabsheh et al. (2021)



Adapted from Chamki et al. (2022)

Study site and experimental design

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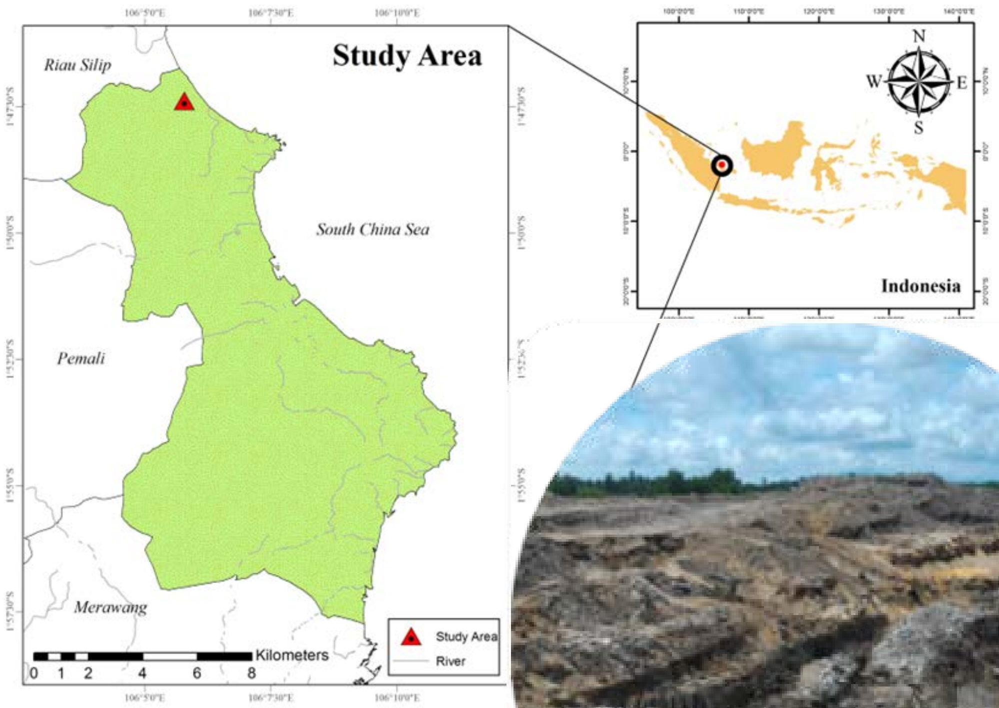

Sand 75%
pH 5.7
TOC 0.6%
Low nutrient

4	5	2	3	6	1	A
3	6	1	5	4	2	B
1	4	5	6	2	3	C
6	2	3	1	4	5	D

11 m

17 m

- 1 control soil
- 2 dolomite
- 3 compost
- 4 charcoal
- 5 charcoal + compost
- 6 charcoal + sawdust

Maftukhah et al. (2023), Agronomy

Hypotheses

H1: Biochar will **promote biological N-fixation** in amended soil.

Legume, ^{15}N

H2: Biochar will improve **crop yields**.

H2.1: Biochar will *increase* crop yields.

H2.2: Biochar will *lessen heavy metal uptake* by crops grown.

Crop yields
Heavy metal accumulation
Soil properties

Cropping and Sampling

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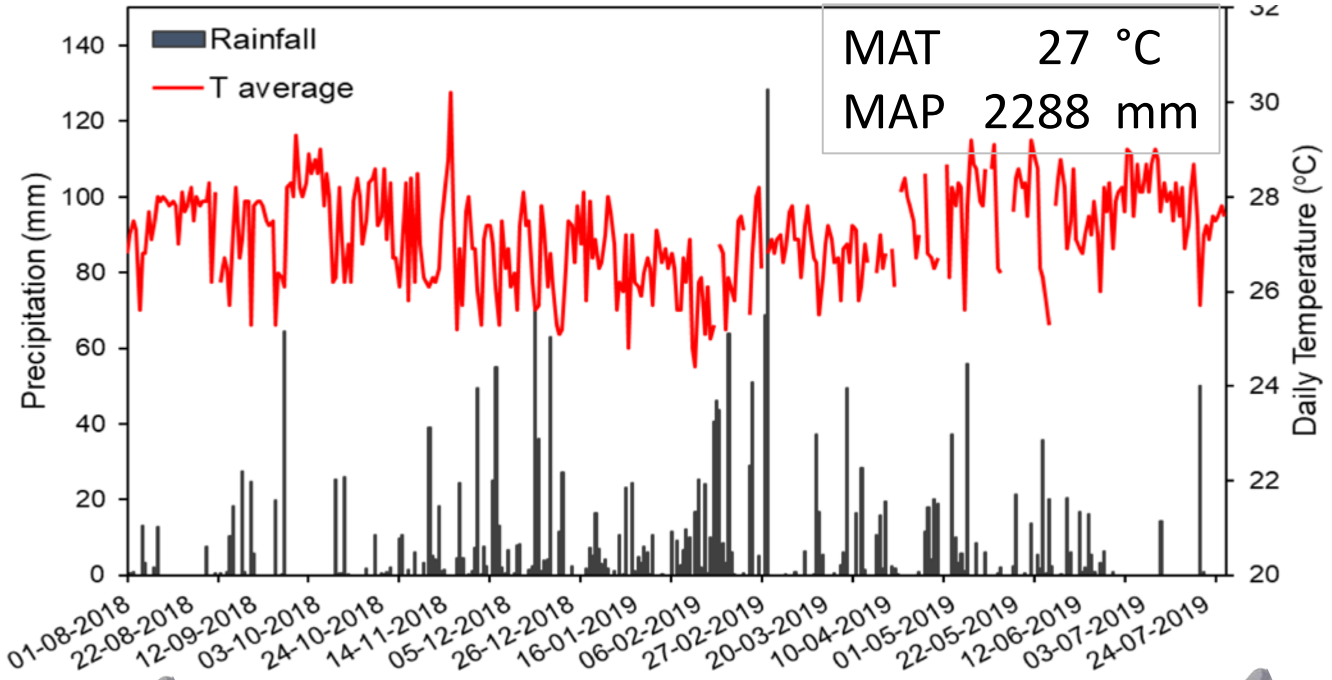
Centrosema 1	Centrosema 2
Cassava	



Cassava
(*Manihot esculenta*)

Centrosema
(*Centrosema pubescens*)

Soil (0-20 cm)	Plant
pH, EC, CEC, WHC	Yield
TOC	(TC)
TN	TN, $\delta^{15}N$
AP, AK	
Pb, As, Cd	Pb, As, Cd

Characteristics of biochar and soil amendments

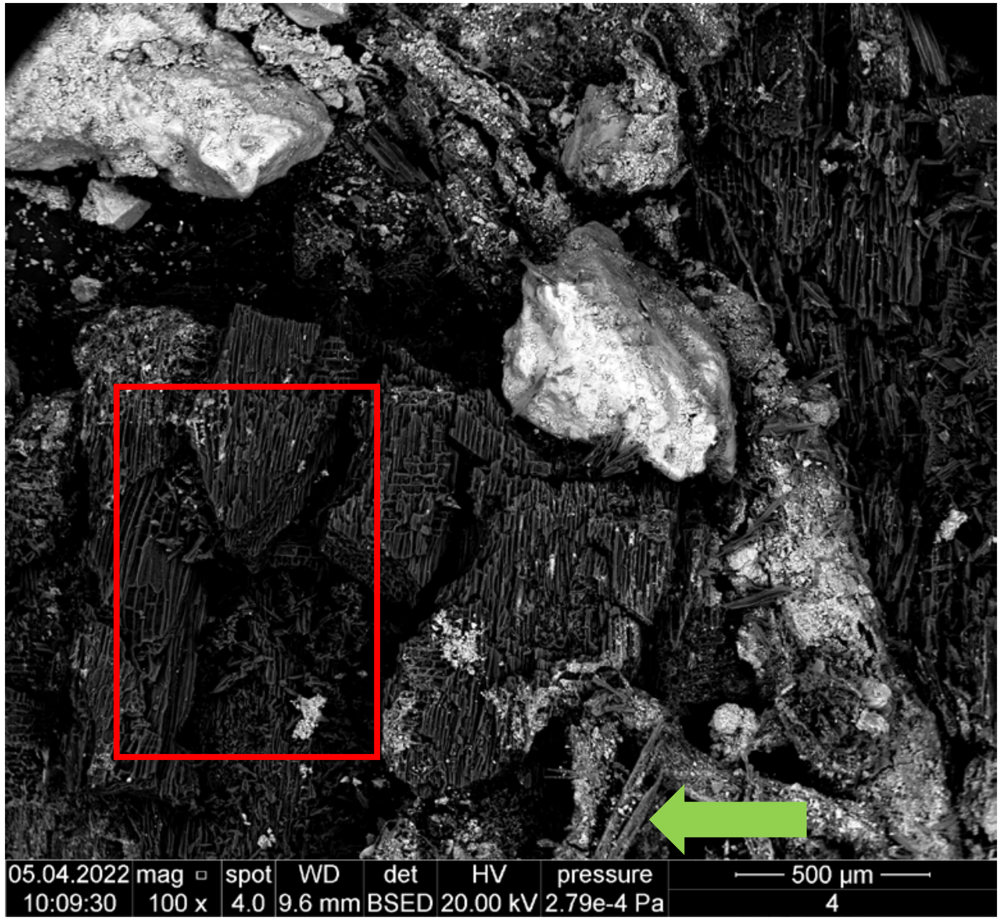


Table 3. Physicochemical properties of the soil amendments used in the experimental site. Cation exchange capacity, CEC; total nitrogen, TN; total organic carbon, TOC; dissolved organic carbon, DOC; total phosphate, TP; available phosphate, AP; total potassium, TK; available potassium, AK; and electrical conductivity, EC. Given are mean (n = 2).

Parameters	Sawdust	Dolomite	Charcoal	Compost
pH	6.3	6.0	7.6	7.2
CEC (mmol·kg^{-1})	55	277	345	1254
TN (%)	0.04	n.d	0.38	1.65
TOC (%)	45.96	0.54	74.35	22.67
Carbonate (%)	n.d	12.29	n.d	n.d
CN Ratio	1173	-	196	14
DOC (mg·L^{-1})	302	1.69	206	749
TP (mg·kg^{-1})	n.d	272	3603	23701
AP (mg·kg^{-1})	n.d	89	2494	21631
TK (mg·kg^{-1})	3097	81	15483	23102
AK (mg·kg^{-1})	771	40	9155	17117
EC (S·m^{-1})	0.03	0.01	0.31	0.67

n.d means not detected, as values are below the limit of detection

Maftukhah et al. (2023), Agronomy

Results – N fixation

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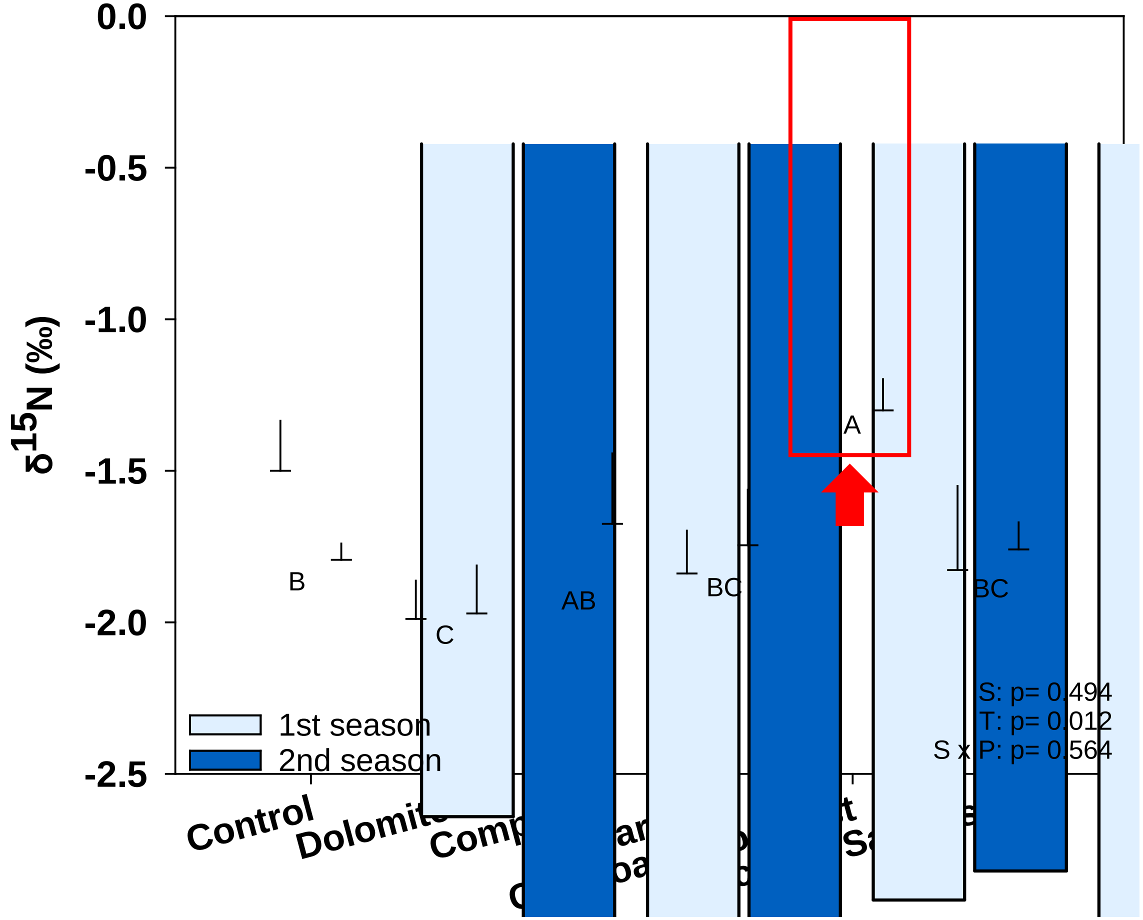
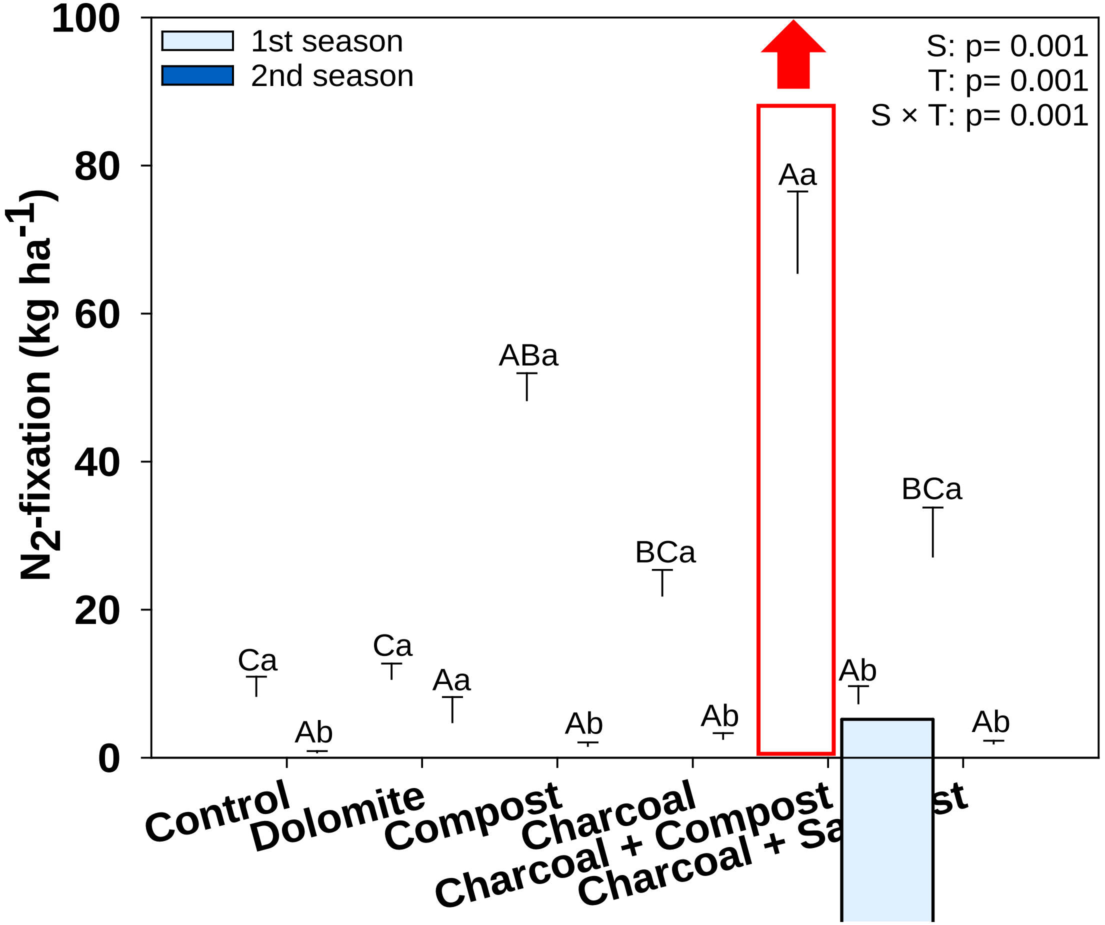
N isotope ratio in shoot

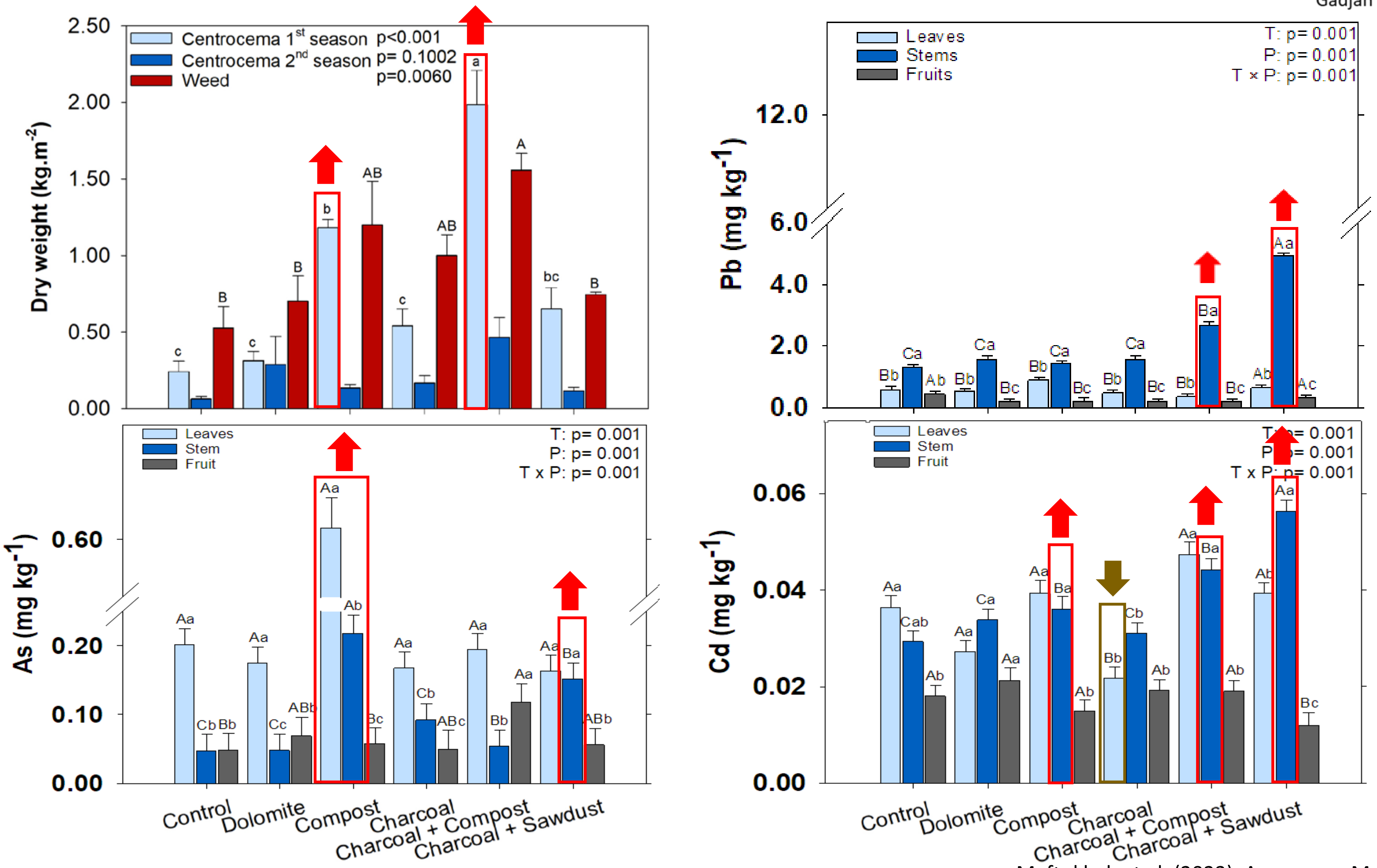


Amount of N-fixation



Maftukhah et al (2023), Land

Results -- Centrosema



Maftukhah et al. (2023), Agronomy; Maftukhah et al. (in revision)

Results – Cassava

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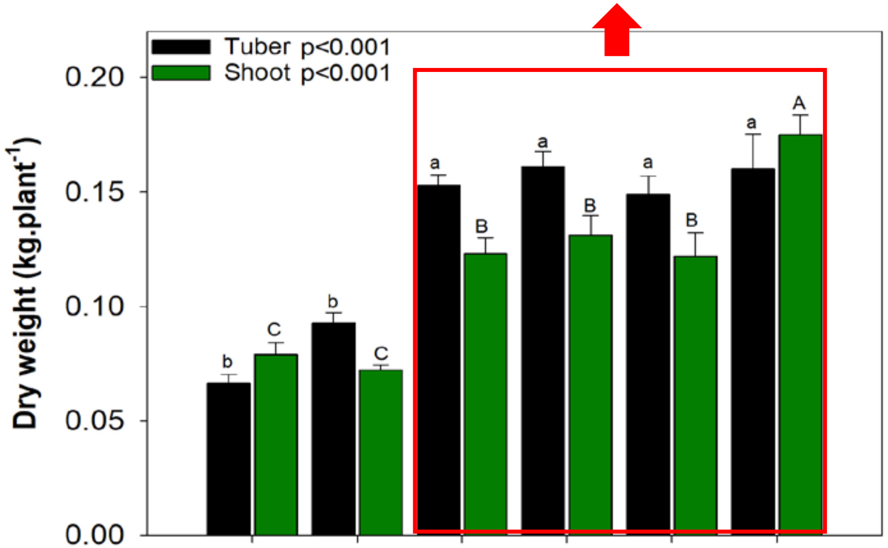

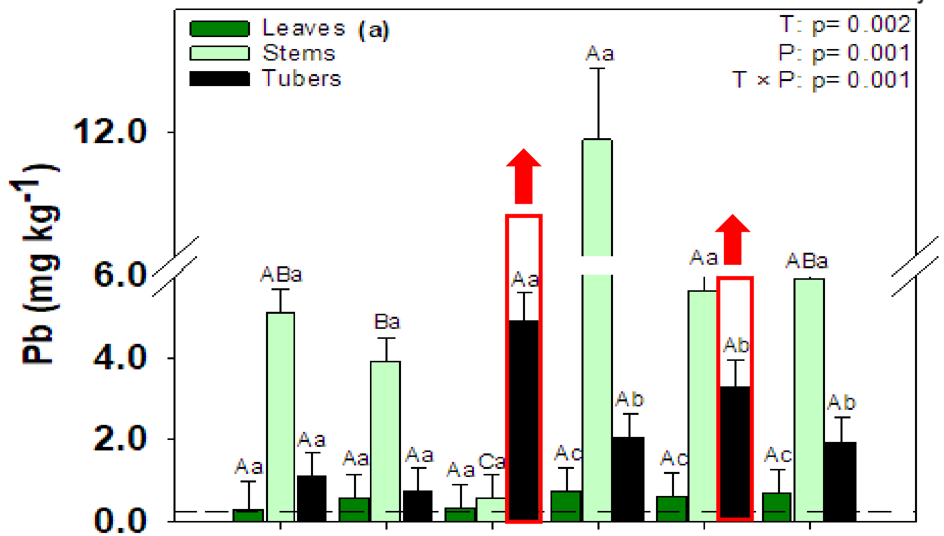

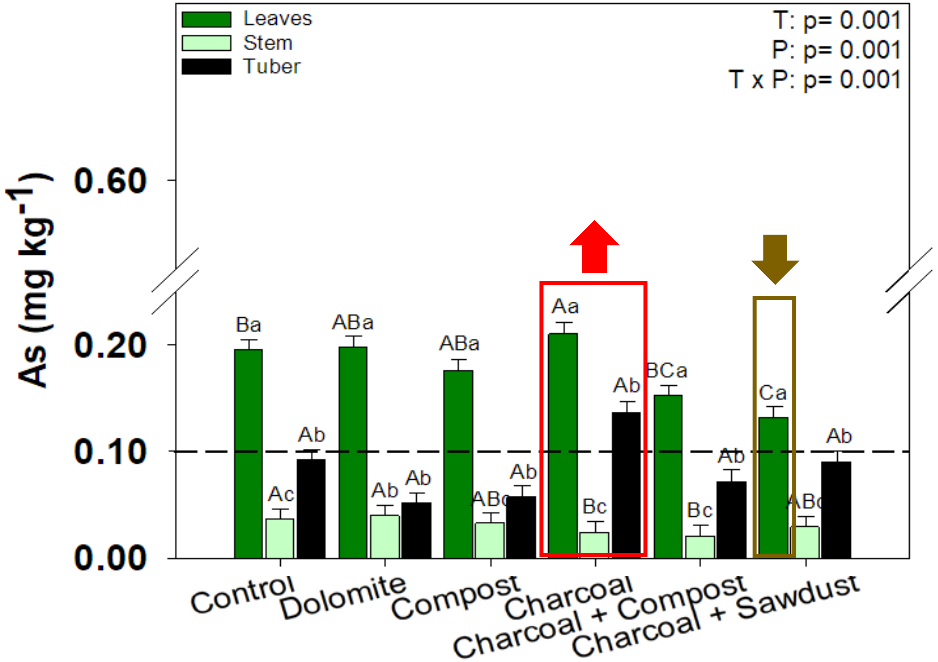

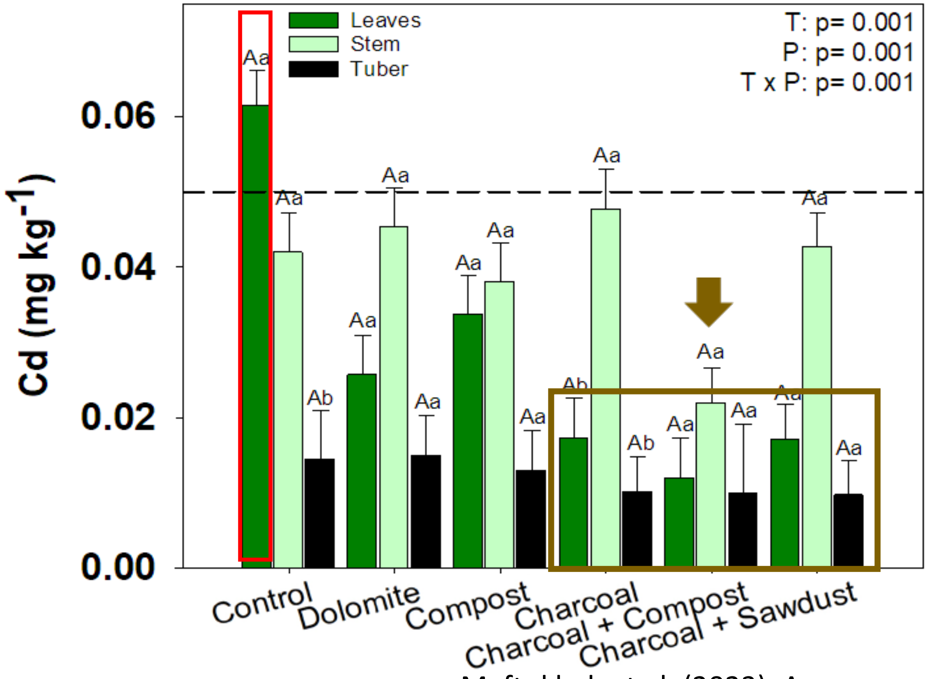

Maftukhah et al. (2023), Agronomy; Maftukhah et al. (in revision)

Results – Soil properties

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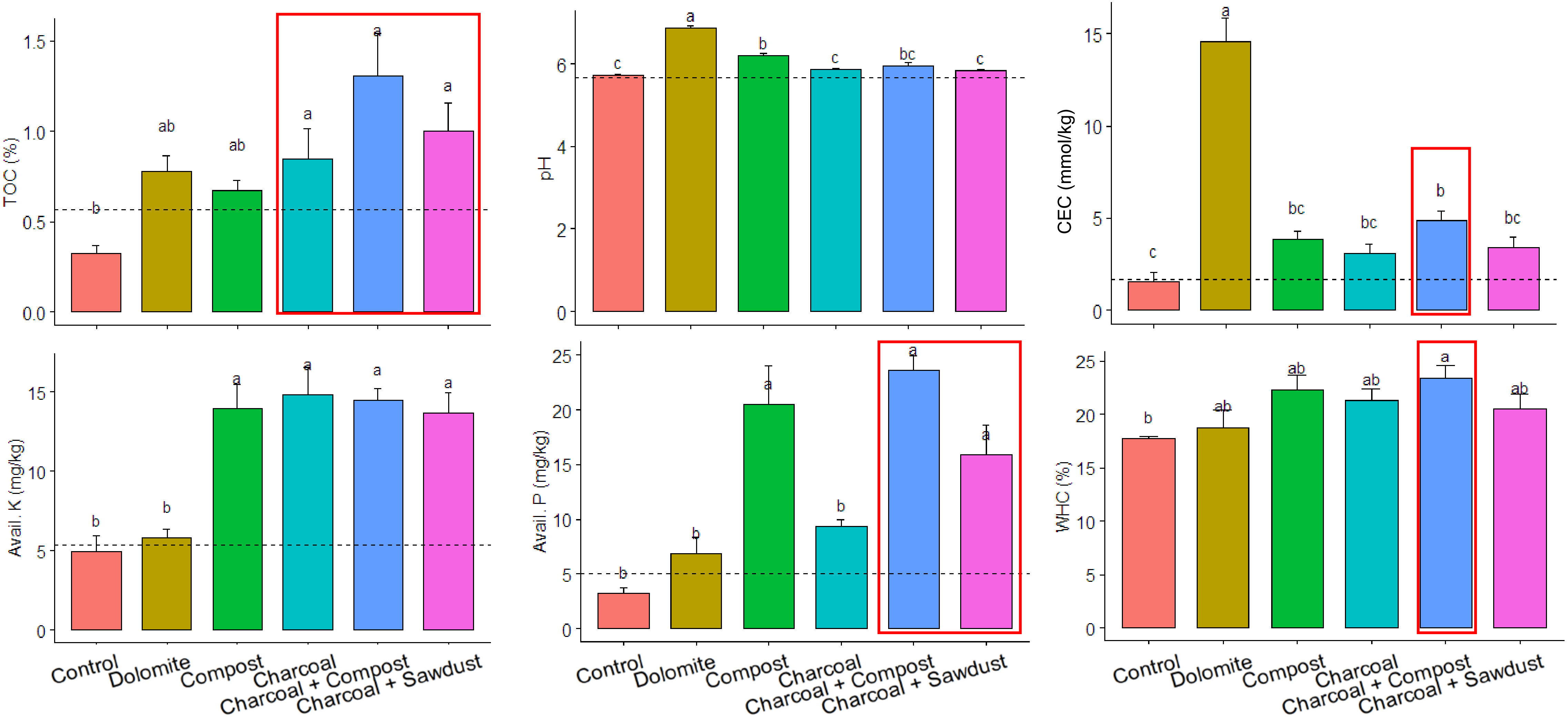

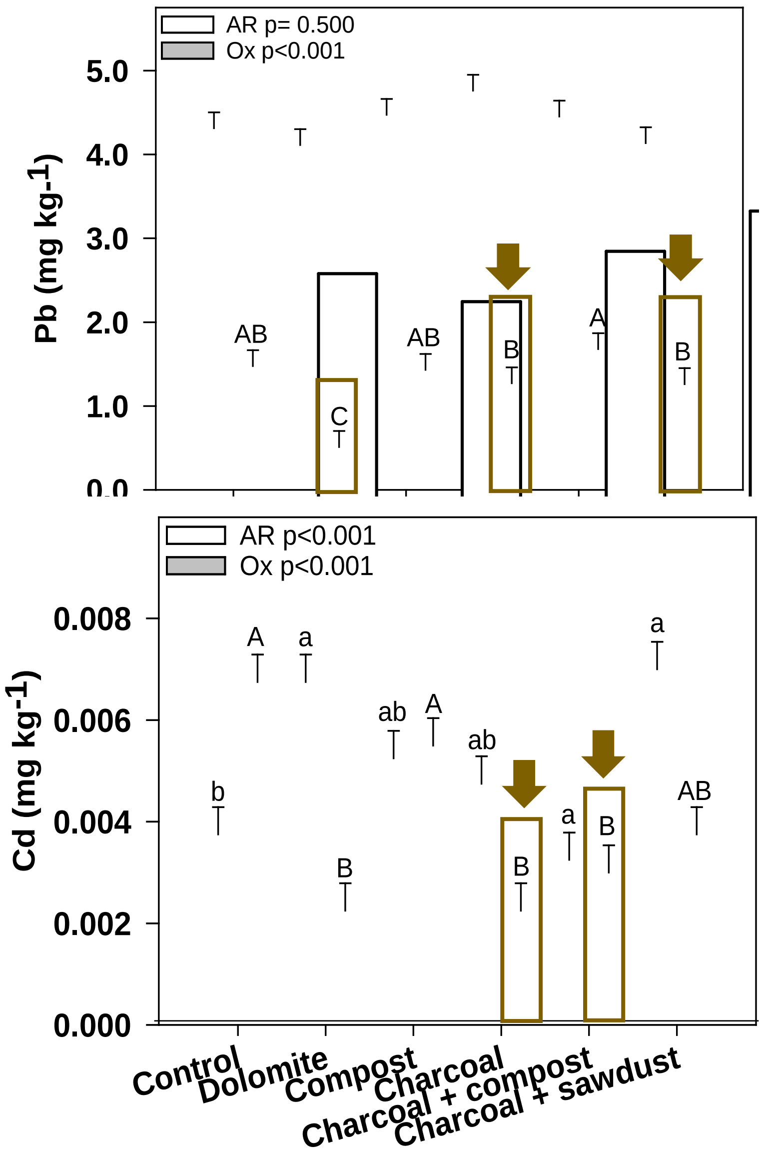

Bioaccumulation factor

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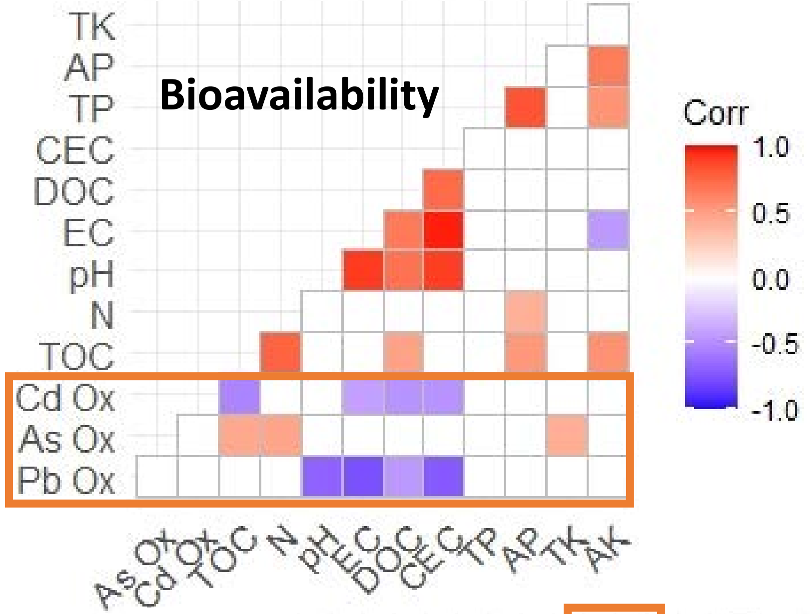
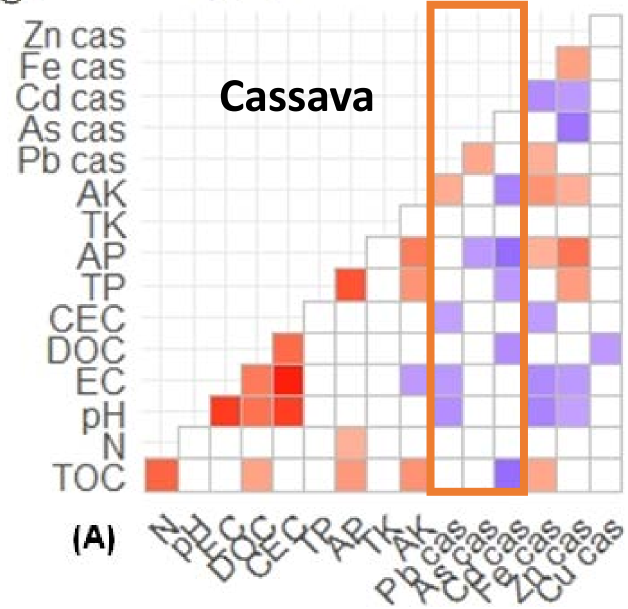
- **Cd** – Hyperaccumulator
- Different response between **crop species** and **heavy metals**

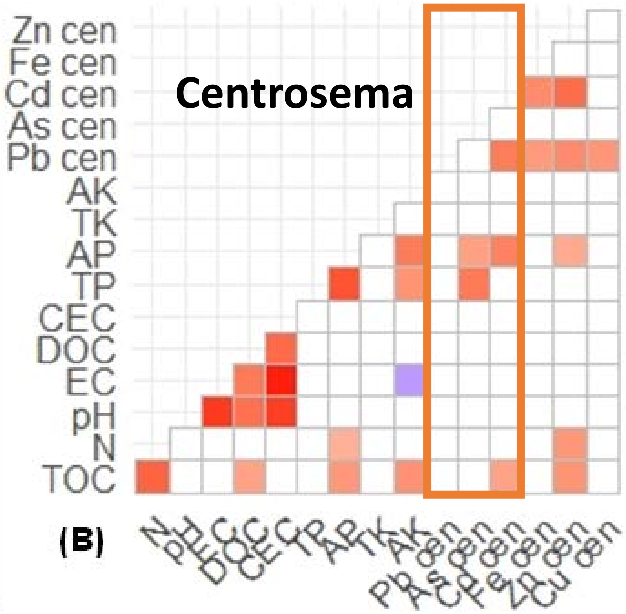
BCF	Plant parts	Control	Dolomite	Compost	Charcoal	Charcoal +compost	Charcoal +sawdust
Cassava							
Pb	Leaves	0.09±0.00	0.14±0.02	0.09±0.02	0.19±0.02	0.14±0.04	0.17±0.02
	Stems	1.60±0.27^{b}	0.97±0.25^{b}	0.14±0.03^{c}	2.99±0.28^{a}	1.28±0.05^{b}	1.51±0.12^{b}
	Tubers	0.29±0.05	0.18±0.03	1.21±0.25	0.52±0.11	0.74±0.09	0.50±0.08
As	Leaves	0.24±0.03^{ab}	0.28±0.01^{a}	0.22±0.02^{ab}	0.29±0.01^{a}	0.17±0.02^{b}	0.18±0.03^{b}
	Stems	0.05±0.00^{a}	0.06±0.00^{a}	0.04±0.00^{a}	0.03±0.00^{ab}	0.02±0.00^{b}	0.04±0.00^{a}
	Tubers	0.12±0.00^{b}	0.08±0.00^{b}	0.08±0.00^{b}	0.19±0.02^{a}	0.08±0.00^{b}	0.12±0.01^{b}
Cd	Leaves	18.27±3.86	4.00±0.64	6.88±0.80	3.98±0.61	3.64±0.36	2.64±0.63
	Stems	12.07±1.86	6.95±0.90	7.71±0.75	11.49±2.10	6.46±1.07	6.58±1.91
	Tubers	3.87±0.78	2.27±0.33	2.68±0.22	2.25±0.17	2.98±0.29	1.47±0.31
Centrosema							
Pb	Leaves	0.16±0.02	0.13±0.00^{a}	0.22±0.00	0.12±0.01	0.08±0.00^{b}	0.17±0.01
	Stems	0.35±0.03^{c}	0.39±0.04^{c}	0.35±0.03^{c}	0.39±0.00^{c}	0.61±0.03^{b}	1.25±0.02^{a}
	Fruits	0.12±0.01	0.05±0.00^{b}	0.05±0.00	0.05±0.00	0.04±0.00^{b}	0.08±0.00^{a}
As	Leaves	0.25±0.03	0.25±0.01	0.77±0.09	0.23±0.00	0.23±0.08	0.23±0.03
	Stems	0.06±0.00^{c}	0.07±0.00^{c}	0.27±0.01^{a}	0.12±0.01^{b}	0.06±0.02^{c}	0.22±0.07^{a}
	Fruits	0.06±0.01^{b}	0.10±0.00^{ab}	0.08±0.01^{b}	0.07±0.01^{b}	0.13±0.01^{a}	0.08±0.01^{b}
Cd	Leaves	10.47±1.83^{ab}	4.14±0.41^{b}	7.98±0.29^{b}	5.27±1.21^{b}	14.16±1.53^{a}	5.81±0.78^{b}
	Stems	8.79±2.21^{ab}	5.34±1.07^{b}	7.20±0.65^{ab}	7.73±1.74^{ab}	13.44±1.45^{a}	8.36±0.88^{ab}
	Fruits	5.06±0.95^{a}	3.23±0.41^{ab}	3.08±0.05^{ab}	4.62±0.75^{ab}	5.97±0.98^{a}	1.76±0.16^{b}

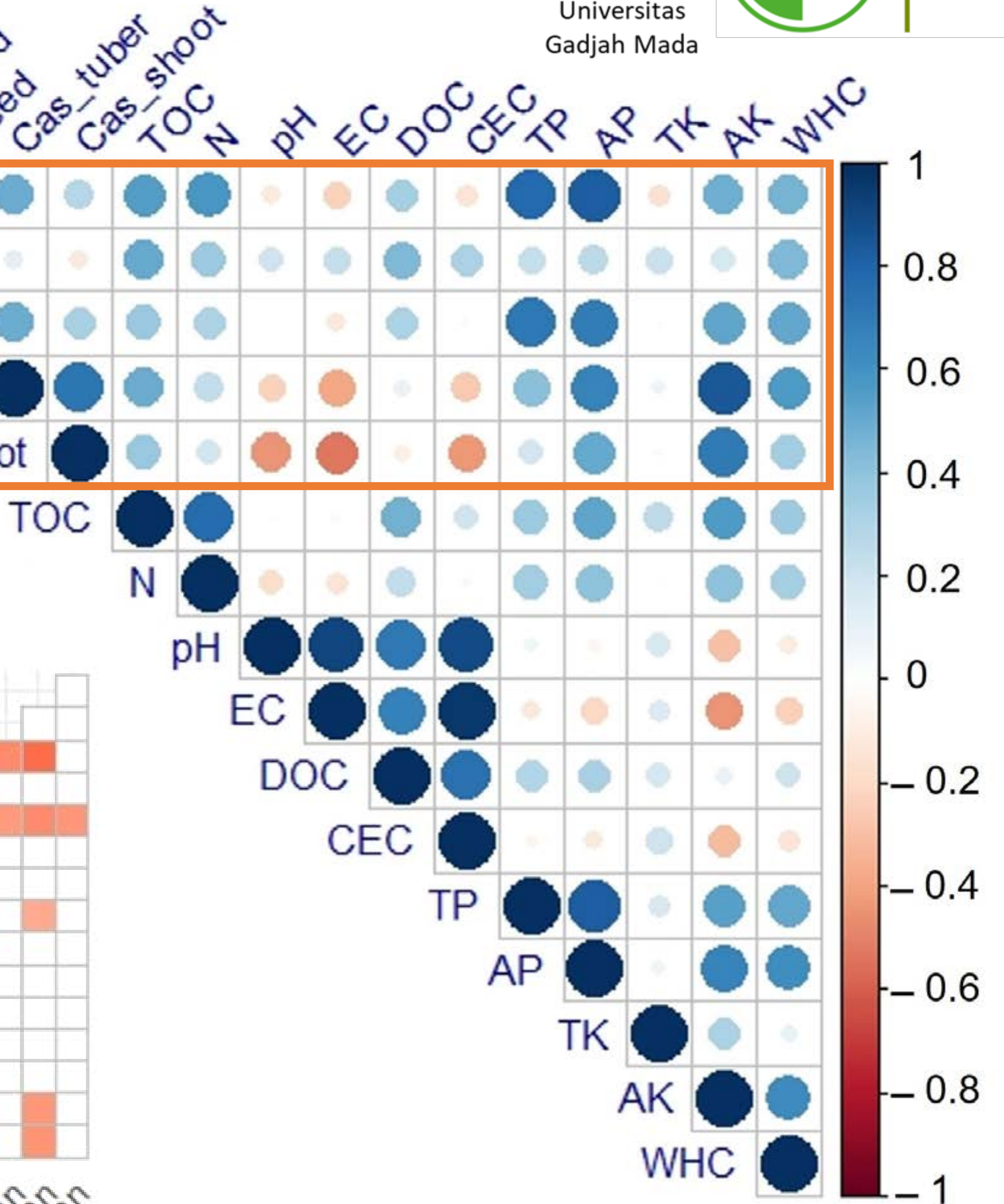
Maftukhah et al (in revision), Ecotoxicology and environmental safety

Correlations









Maftukhah et al. (2023), Agronomy; Maftukhah et al. (in revision)

Conclusions

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- H1: Biochar **promoted biological N-fixation** in amended soil.

Highest in
Charcoal + Compost

- H2: Biochar **improved crop yields**.
  - H2.1: Biochar ***increased*** crop yields.
  - ? H2.2: Biochar ***lessen*** *heavy metal uptake* by crops grown.

depended on
crop species, heavy metals

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Take-Home messages/future study

- Application biochar with other local available soil amendments/fertilizers
- Crop species alteration
- Long-term study

Thank You

Please visit us…

YouTube links:

Video: **Rehabilitating Soil on Bangka Island** https://youtu.be/3nH356Ldxxk

References

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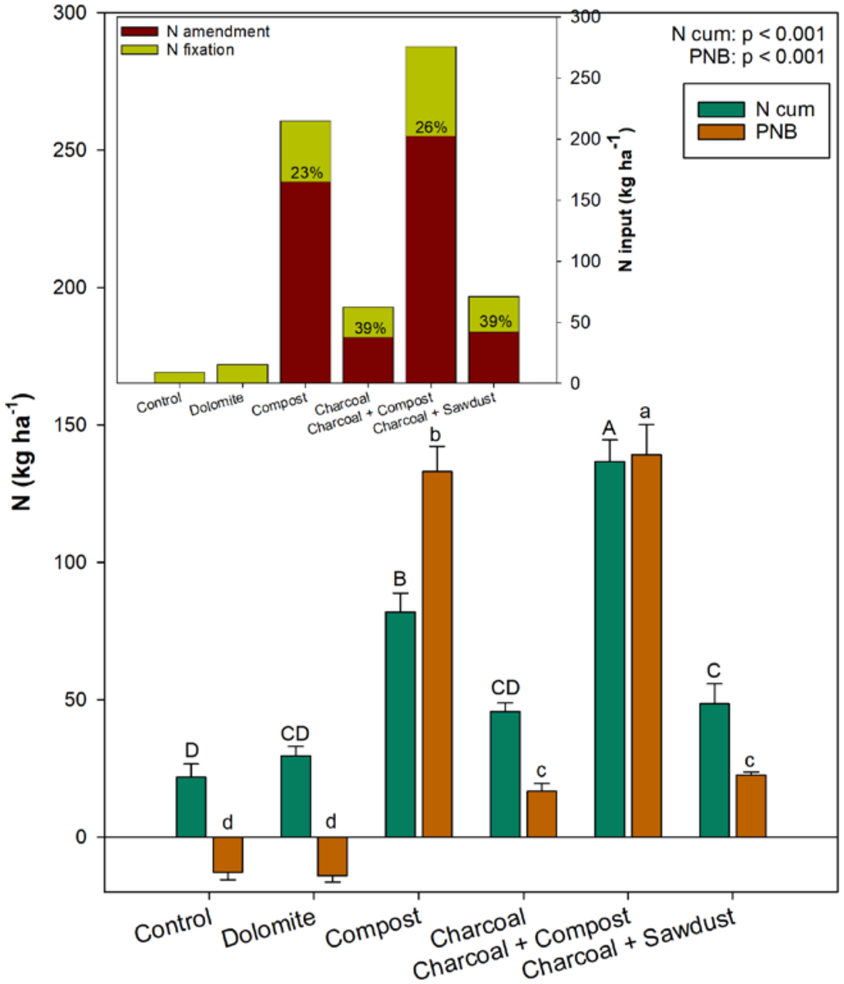

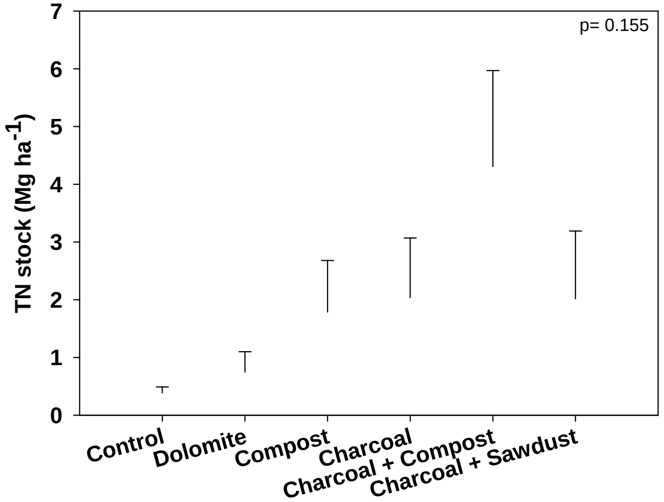

Treatments	N applied (kg ha^{-1})
Control	0
Dolomite	0
Compost	165
Charcoal	38
Charcoal + compost	203
Charcoal + sawdust	42

Maftukhah et al (2023), Land

Table S4. Heavy metal(loid)s concentrations of post-tin mining soils and soil amendments used in the study site. Mean ± standard error were determined for ex-tin mining soils (n= 6) and soil amendments (n= 3).

Heavy metal(loid)s ($mg\ kg^{-1}$)	Soils	Dolomite	Compost	Sawdust	Charcoal
Pb	3.41 ± 0.12	0.80 ± 0.04	3.50 ± 0.42	0.16 ± 0.01	0.51 ± 0.07
As	0.63 ± 0.01	0.11 ± 0.01	2.50 ± 0.02	0.07 ± 0.00	0.34 ± 0.00
Cd	n.d.	0.12 ± 0.00	0.15 ± 0.00	n.d.	0.02 ± 0.00
Fe	538 ± 28.65	698 ± 6.45	2179 ± 8.64	13.99 ± 0.90	3840 ± 10.16
Zn	0.72 ± 0.12	8.80 ± 0.08	108 ± 0.69	1.06 ± 0.08	17.56 ± 0.06
Cu	0.29 ± 0.04	1.86 ± 0.24	15.58 ± 0.12	1.14 ± 0.08	5.78 ± 0.23

Notes: n.d. represents concentration values were lower than the detection limit.