The Beneficial Reuse of Biowastes to Improve Contaminated Soils

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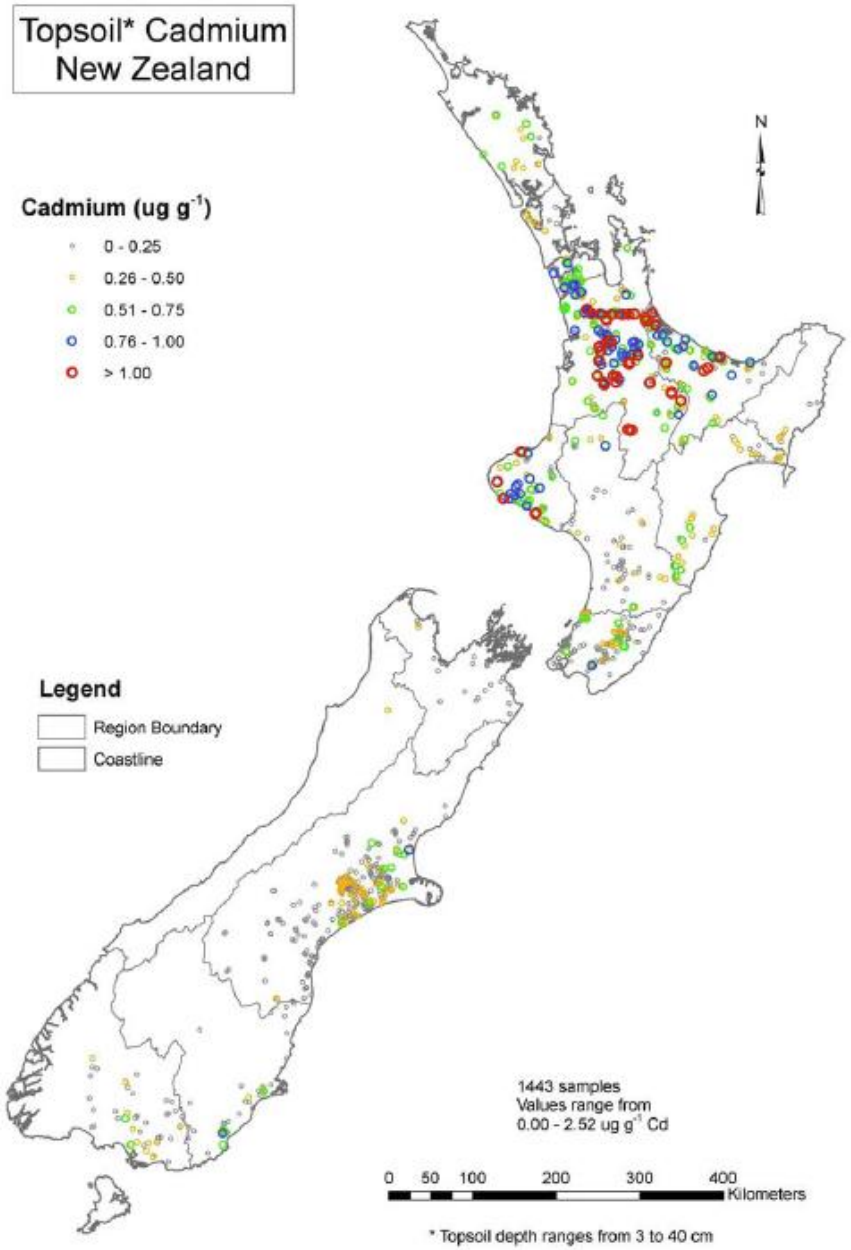
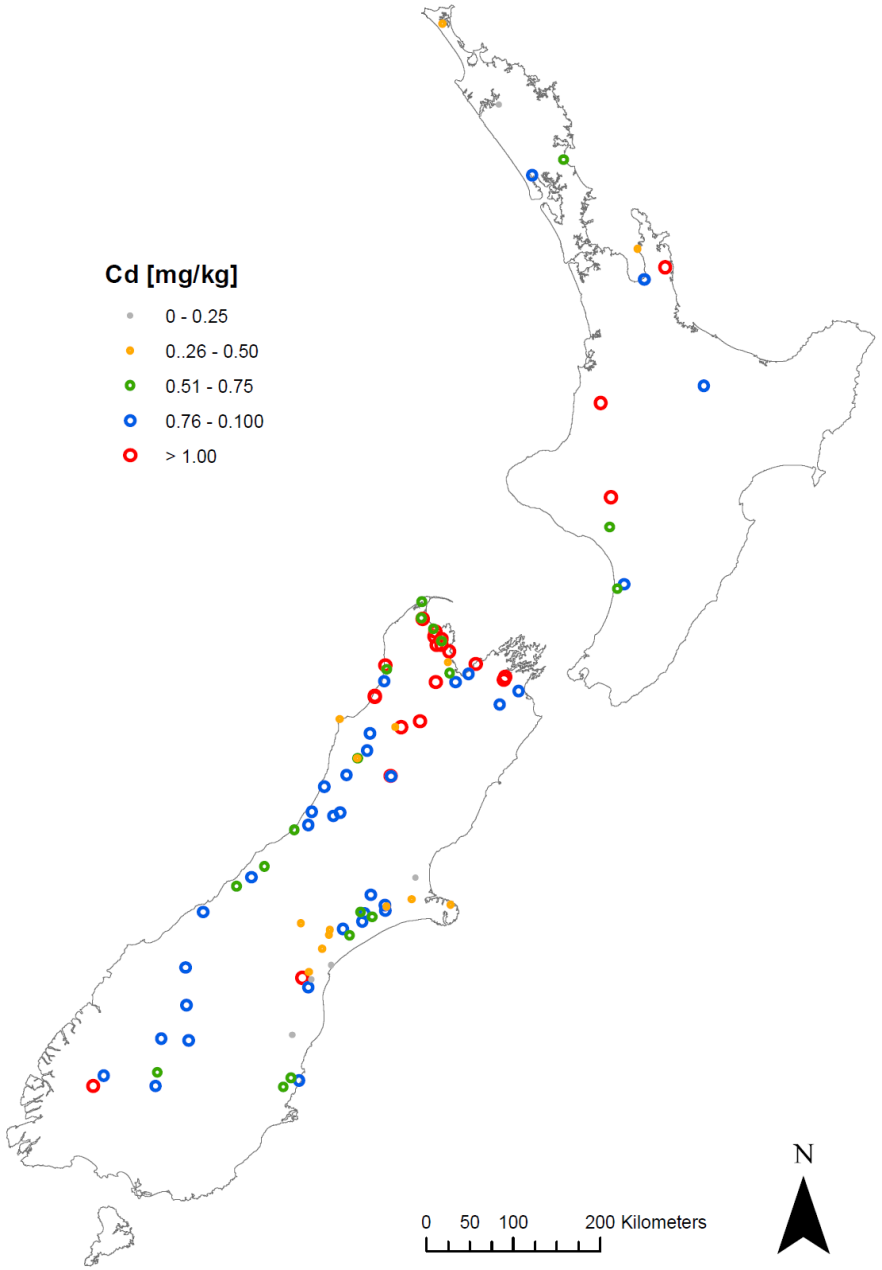
Soil contamination: the presence of an unwanted chemical that reduces soil function

- Healthy food
- Healthy water
- Healthy ecosystems
- Healthy people

Fertilisers can contain unwanted passengers, such as cadmium

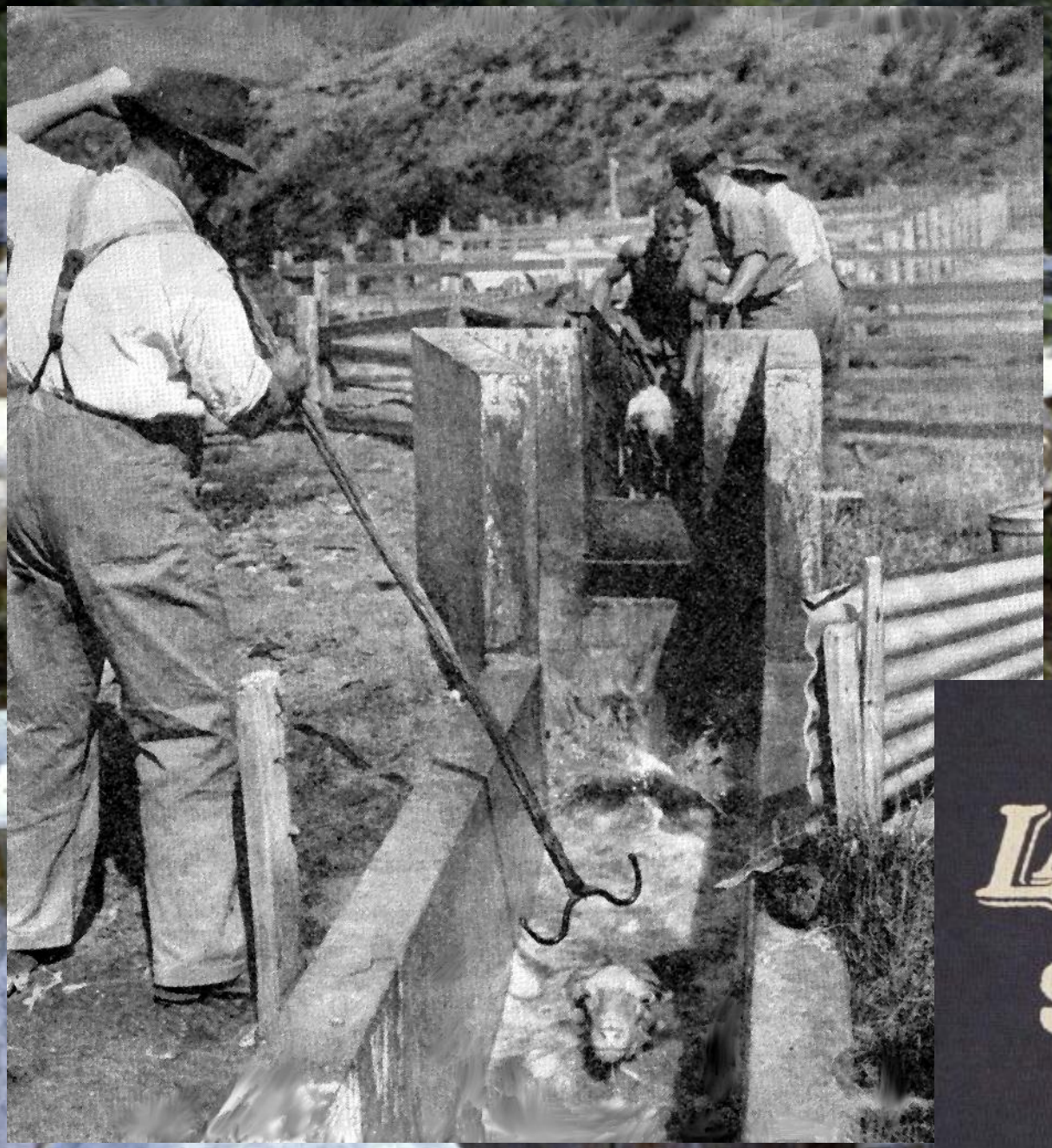


1990-2000



2010

https://www.winespectator.com/articles/is-copper-safe-for-wine

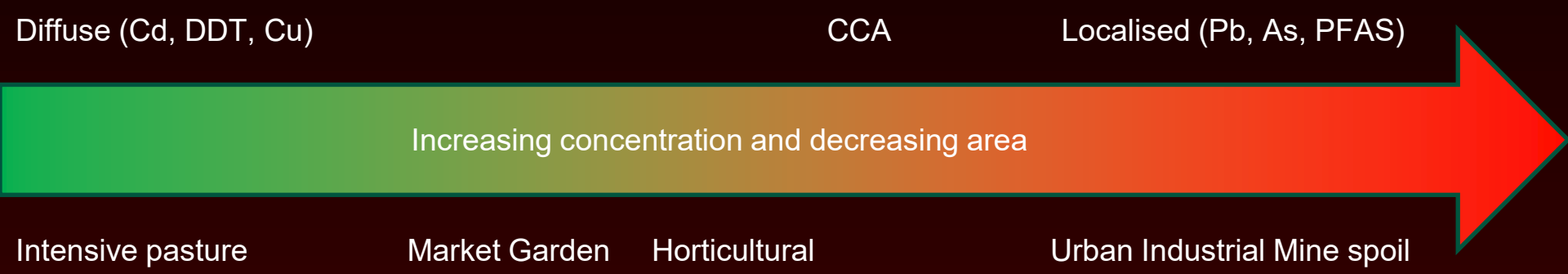


Sunbeam
LAN-O-LEEN
(IMPROVED FORMULA) TRADE MARK

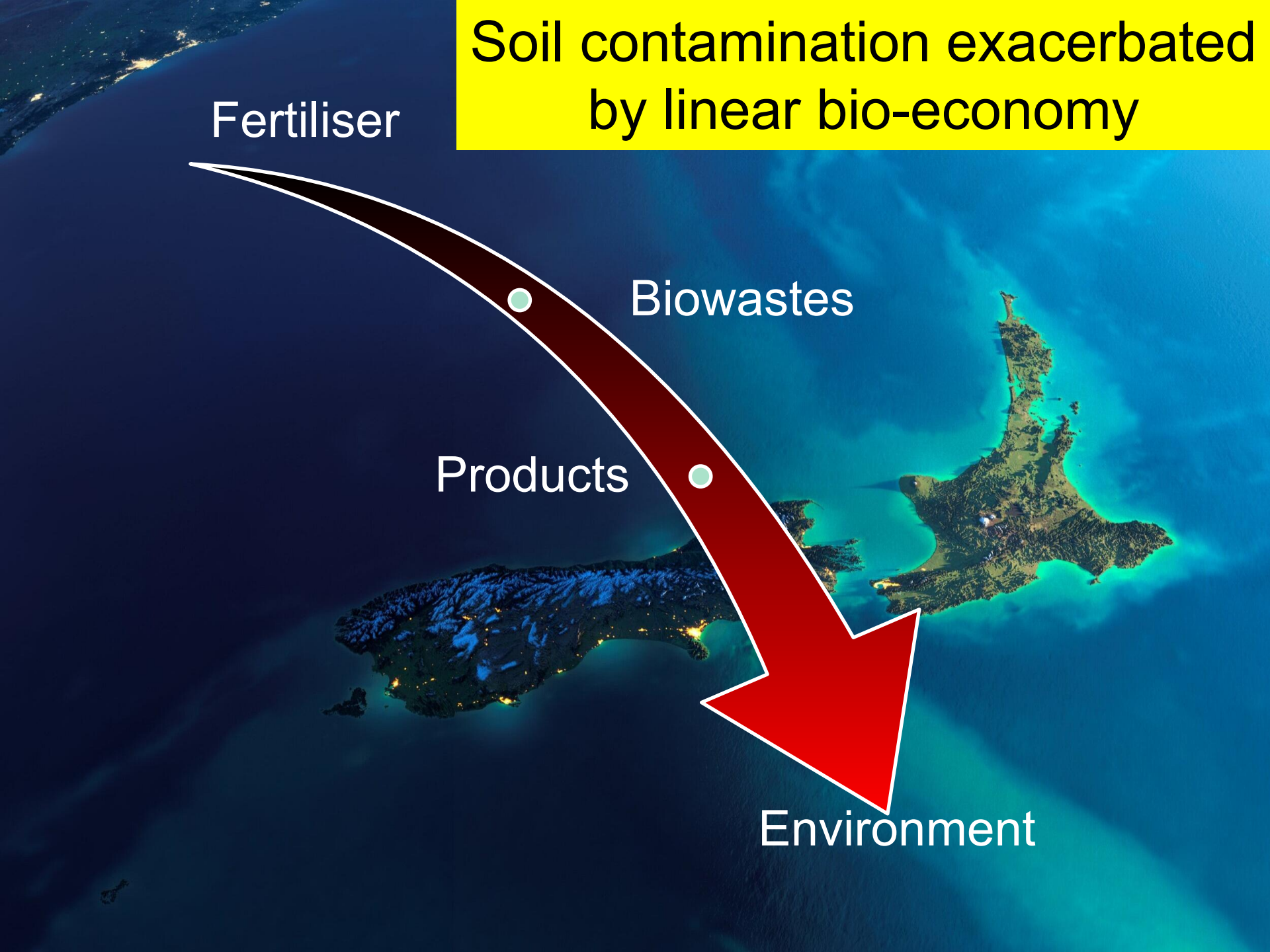
SHEEP DIP

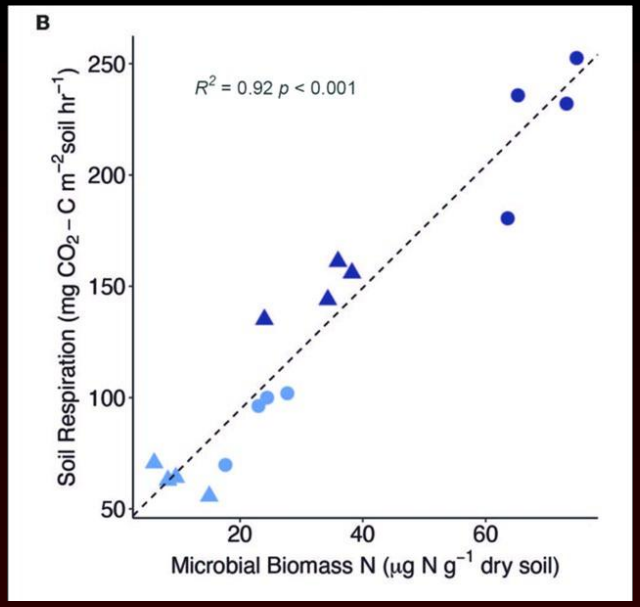
ACTIVE CONSTITUENTS 32.5% w/v
ARSENIC TRIOXIDE $As_2 O_3$
AS SODIUM ARSENITE

Contaminated soil in New Zealand

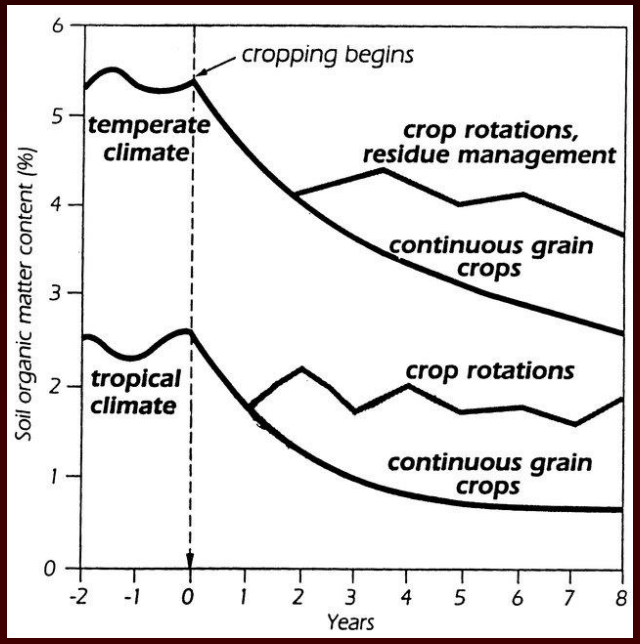


- Often depleted in organic carbon
- May be deficient in essential trace elements


Soil contamination exacerbated by linear bio-economy
Fertiliser
Biowastes
Products
Environment



(Kerdraon et al. 2020 Frontiers in Forests and Global Change DOI: 10.3389/ffgc.2019.00090)



(Ayala & Rao 2002. Current Science 82(7))

Linear bioeconomy: contaminant accumulation, loss of soil carbon

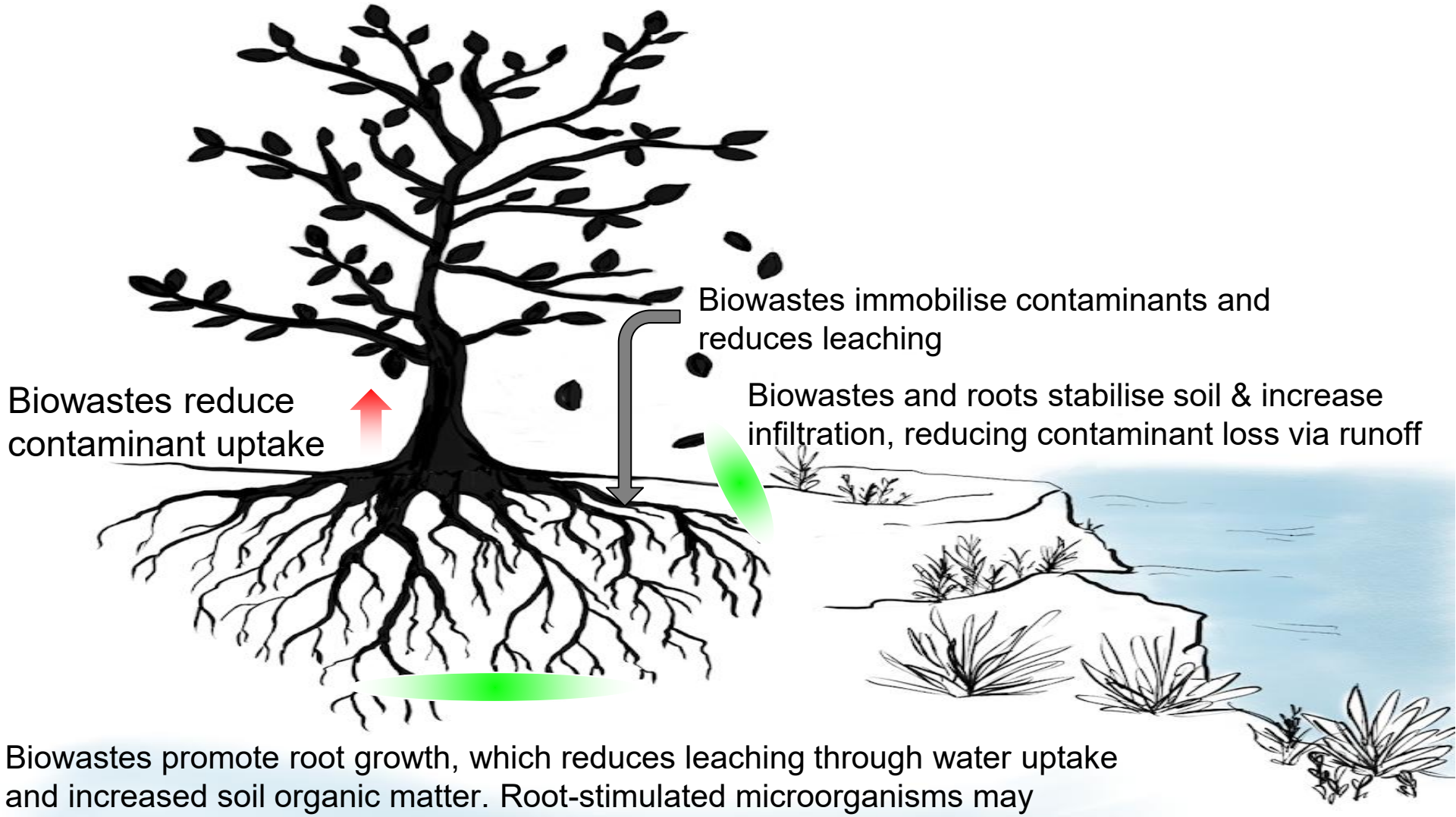
12.6 million tonnes of waste sent to landfill

2.9 million tonnes of organic matter (23%)

Assuming NZ$150 per tonne = NZ$435 million

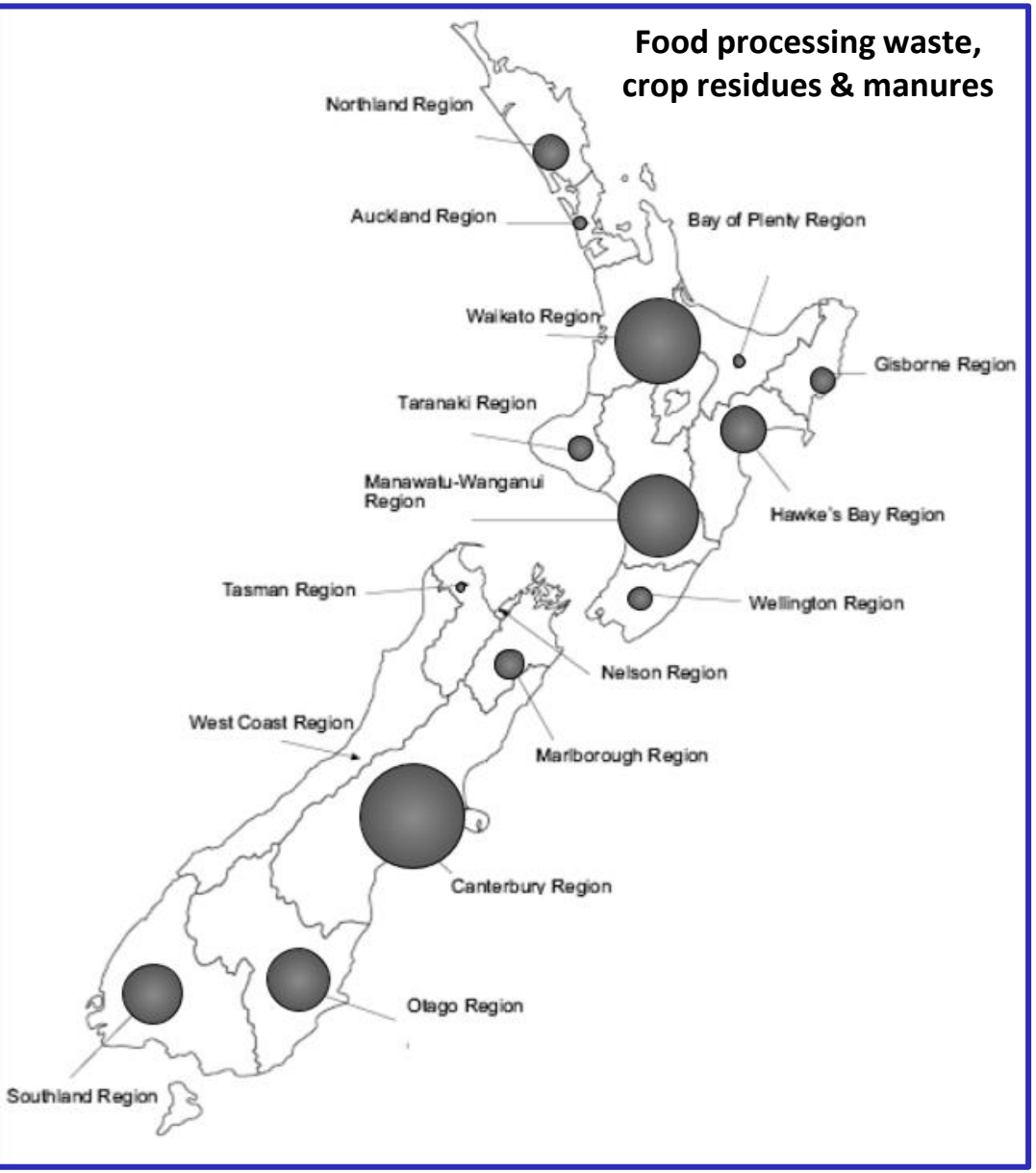
- Expensive
- Environmentally damaging
- Unsustainable
- Squandering value

Improving contaminated soils with biowastes



Biowastes promote root growth, which reduces leaching through water uptake and increased soil organic matter. Root-stimulated microorganisms may degrade or transform contaminants

NZ - biowastes



Wood-waste

>3 million t/yr

Food processing waste

>300,000 t/yr

Crop residues
& manures

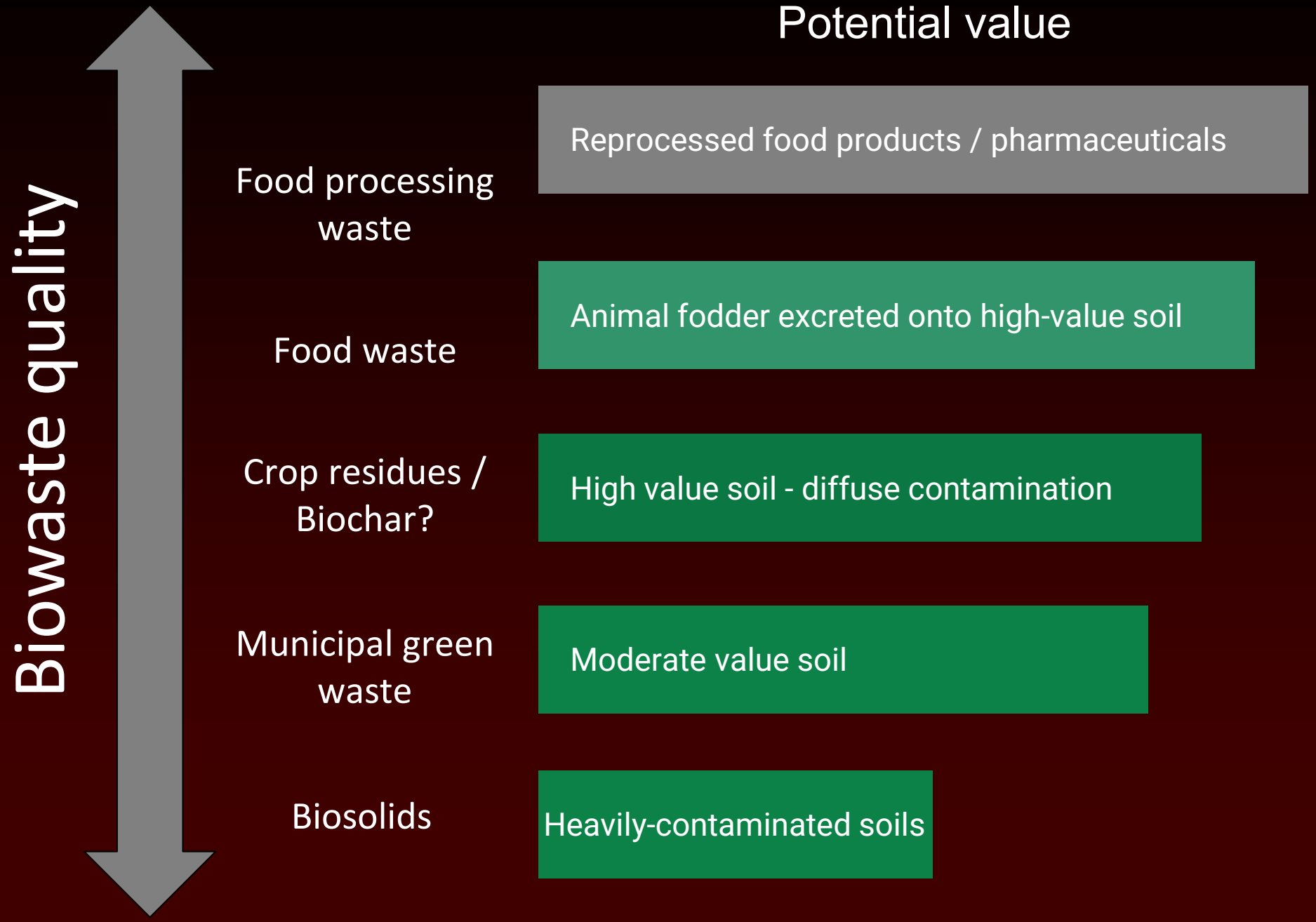
>1 million t/yr

Biosolids

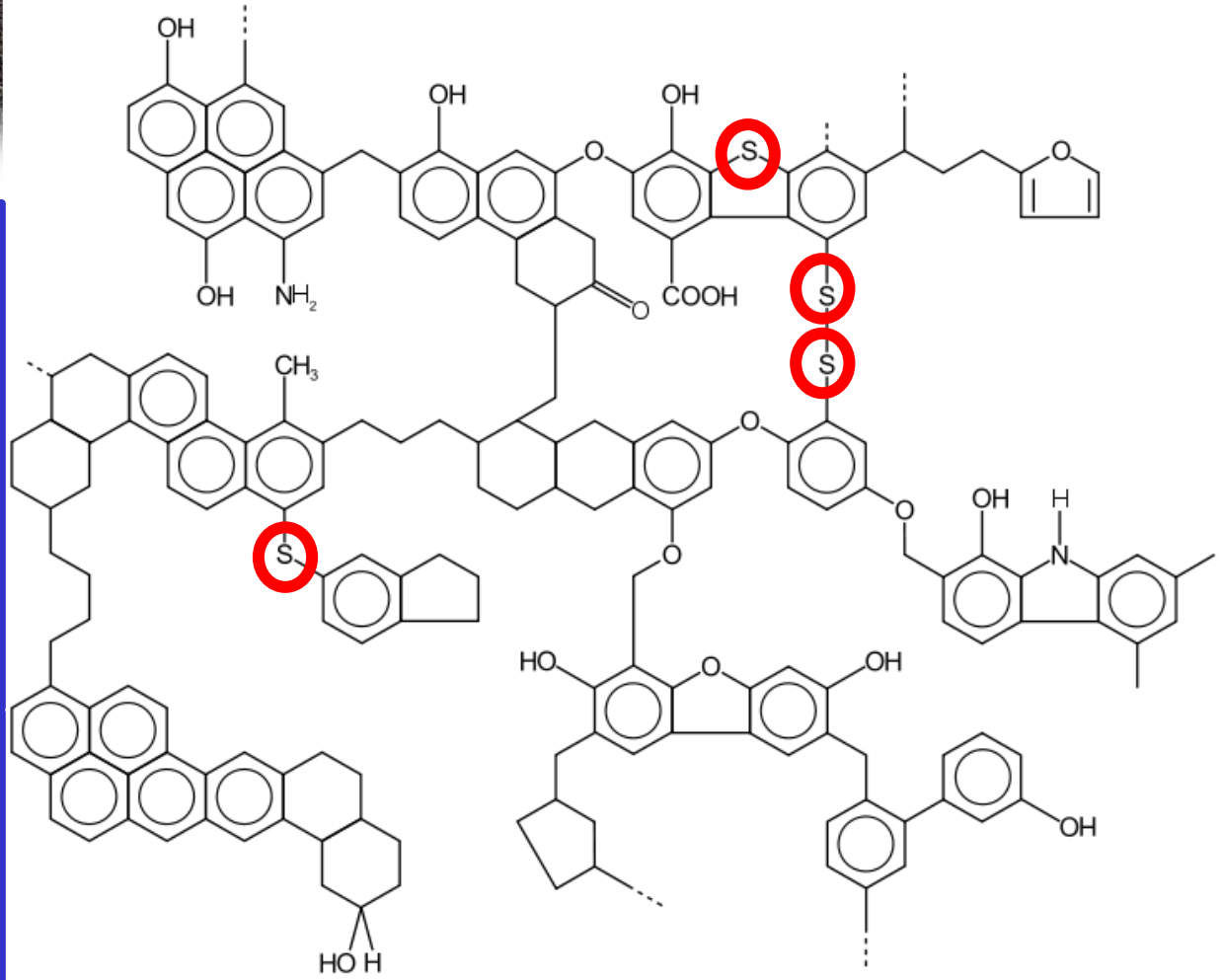
64,000 t/yr

Food waste

157,000 t/yr

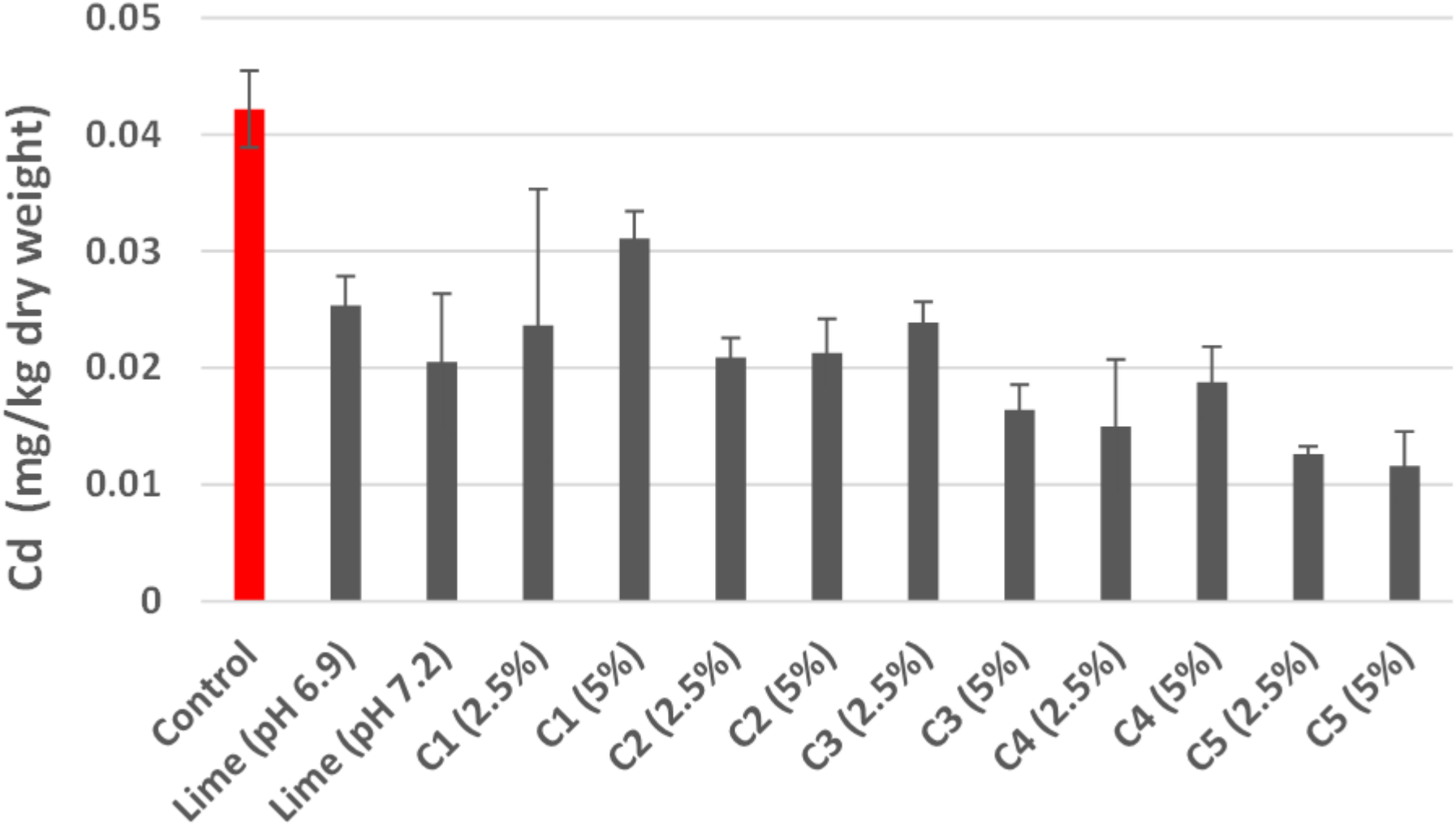

Biowaste quality
Potential value
Food processing waste
Reprocessed food products / pharmaceuticals
Food waste
Animal fodder excreted onto high-value soil
Crop residues / Biochar?
High value soil - diffuse contamination
Municipal green waste
Moderate value soil
Biosolids
Heavily-contaminated soils

+Zn



Reduced soil density

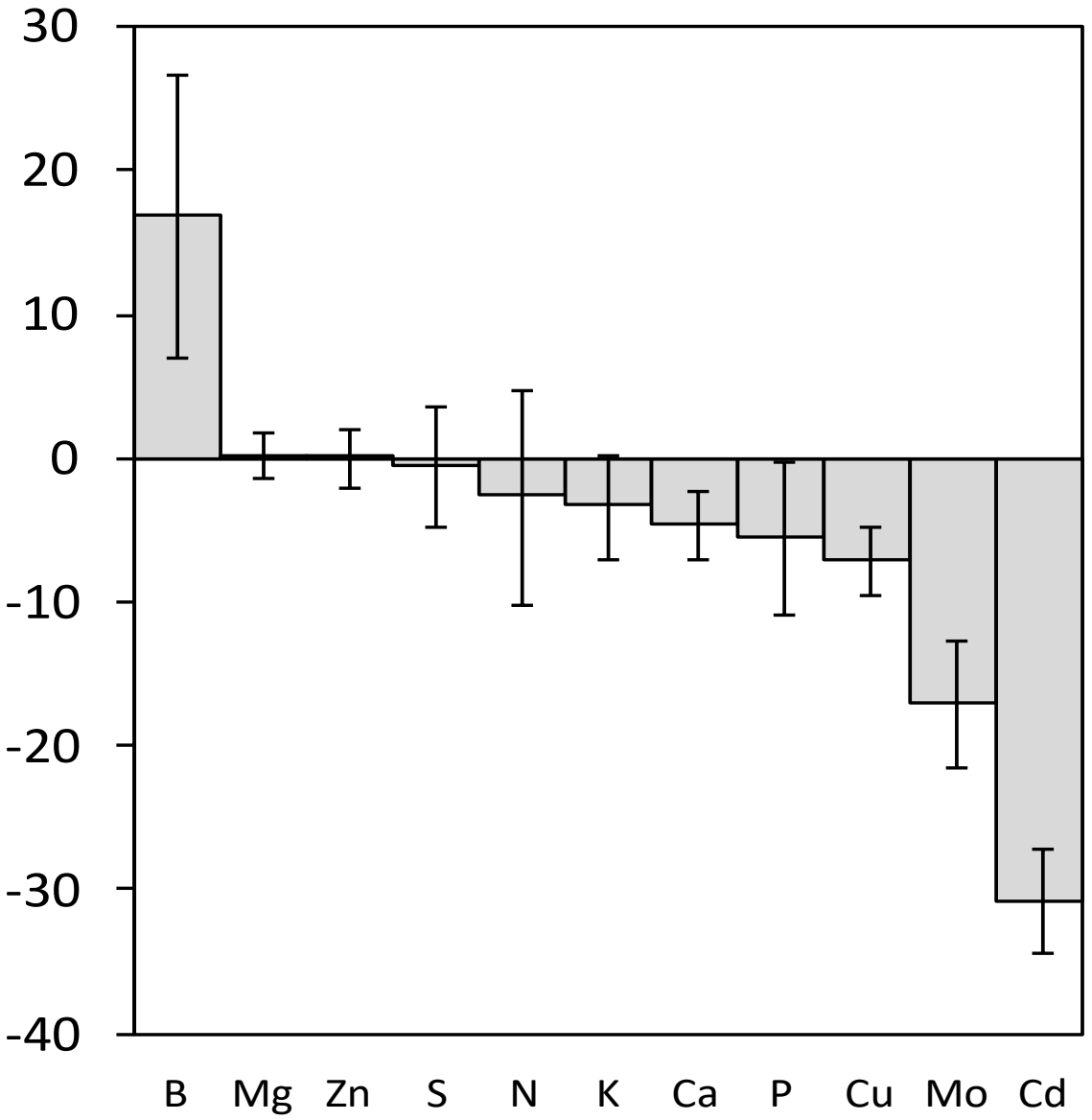
Cd in peeled potatoes (var. Nadine) allophanic loam (1.4 mg Cd/kg pH=6.0)

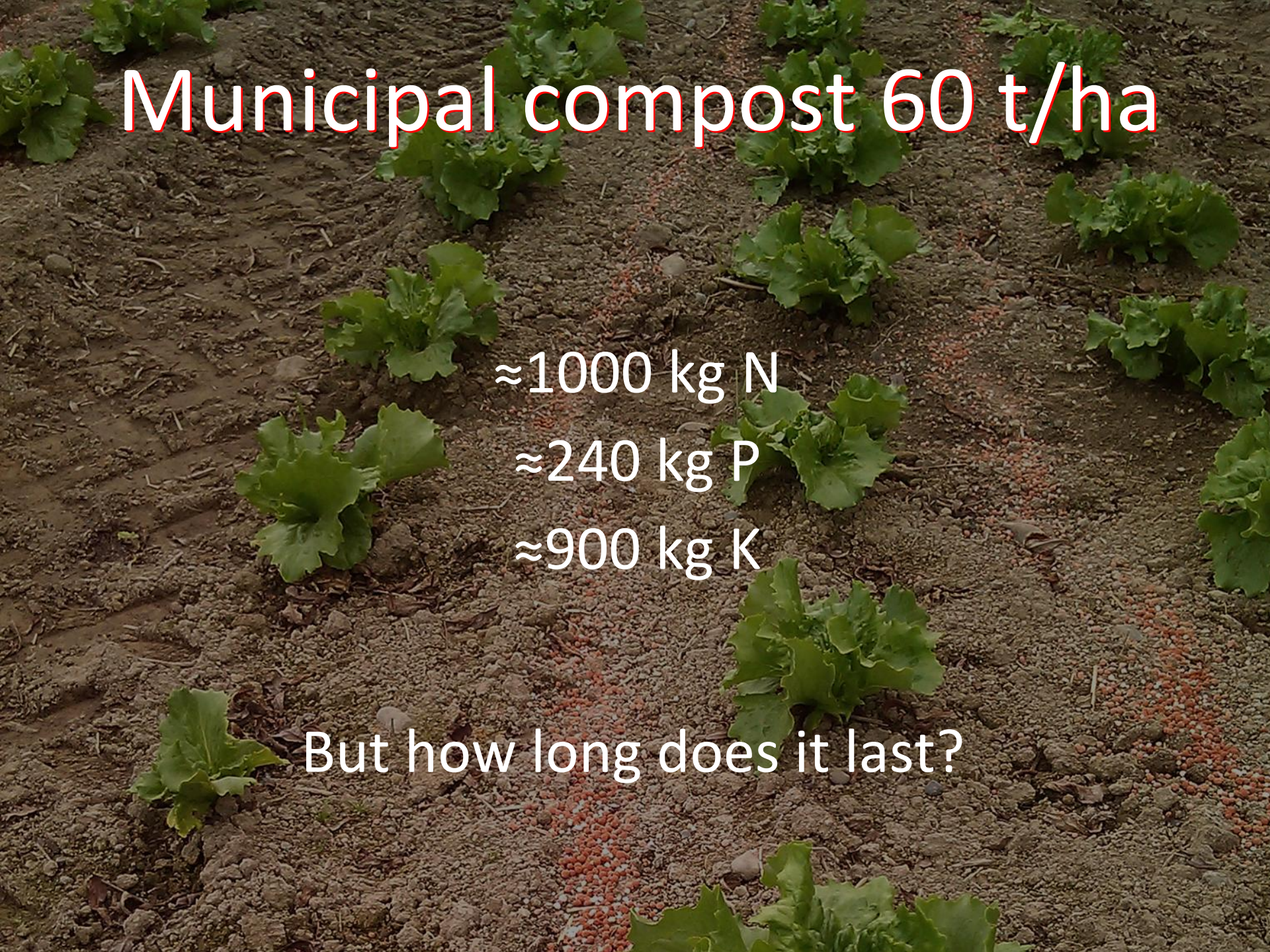


Al Mamun *et al.* (2017). *Journal of Environmental Quality* doi:10.2134/jeq2017.02.0059

Change (%) in *Lolium perenne* following 1% lignite addition

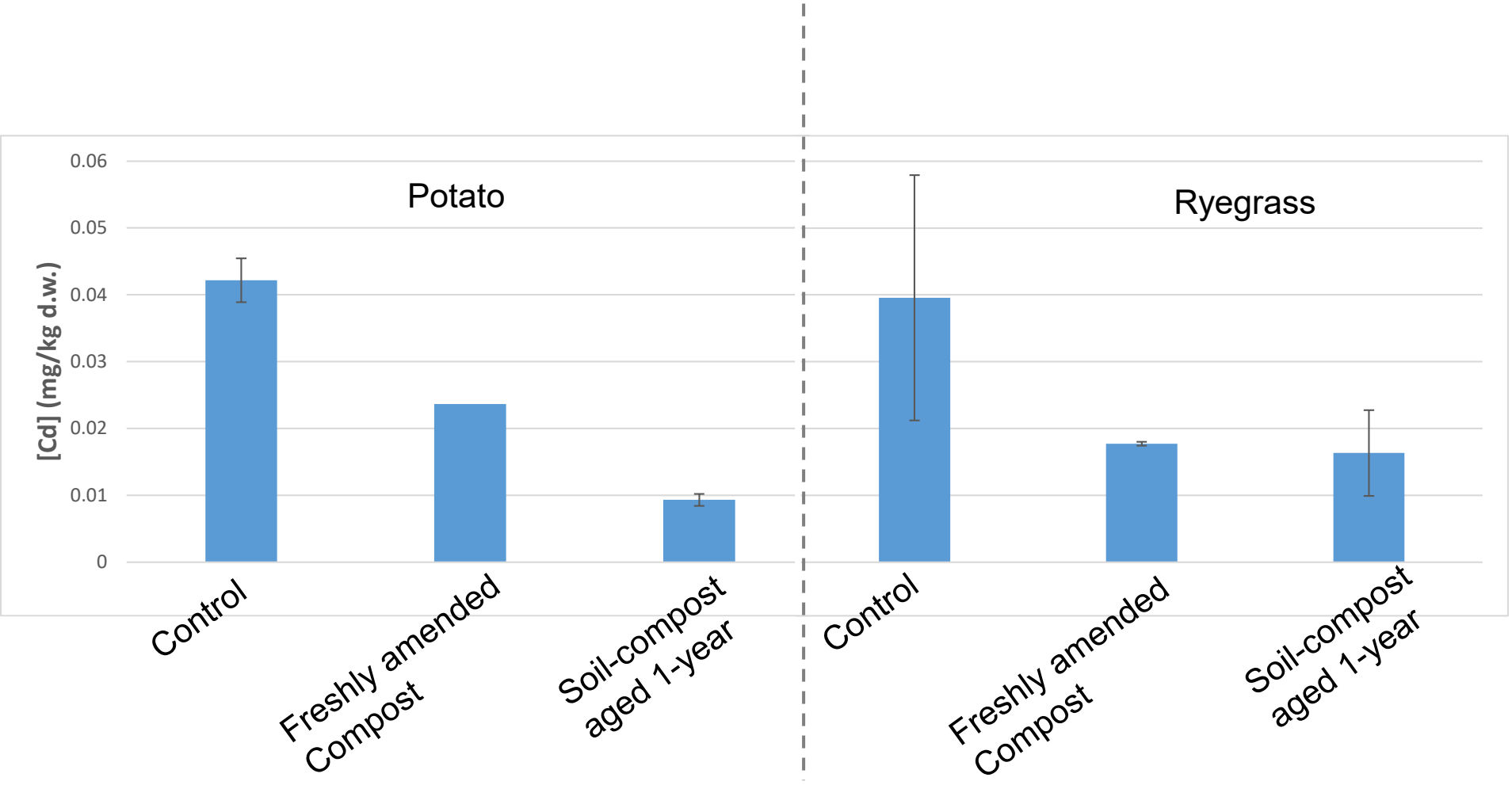
(*Environmental Science & Technology* 47, 719-734,2016)




Municipal compost 60 t/ha
≈1000 kg N
≈240 kg P
≈900 kg K
But how long does it last?

Compost retains Cd for at least 1 year

2.5% compost in allophanic soil (1.4 mg Cd/kg pH=6.0)

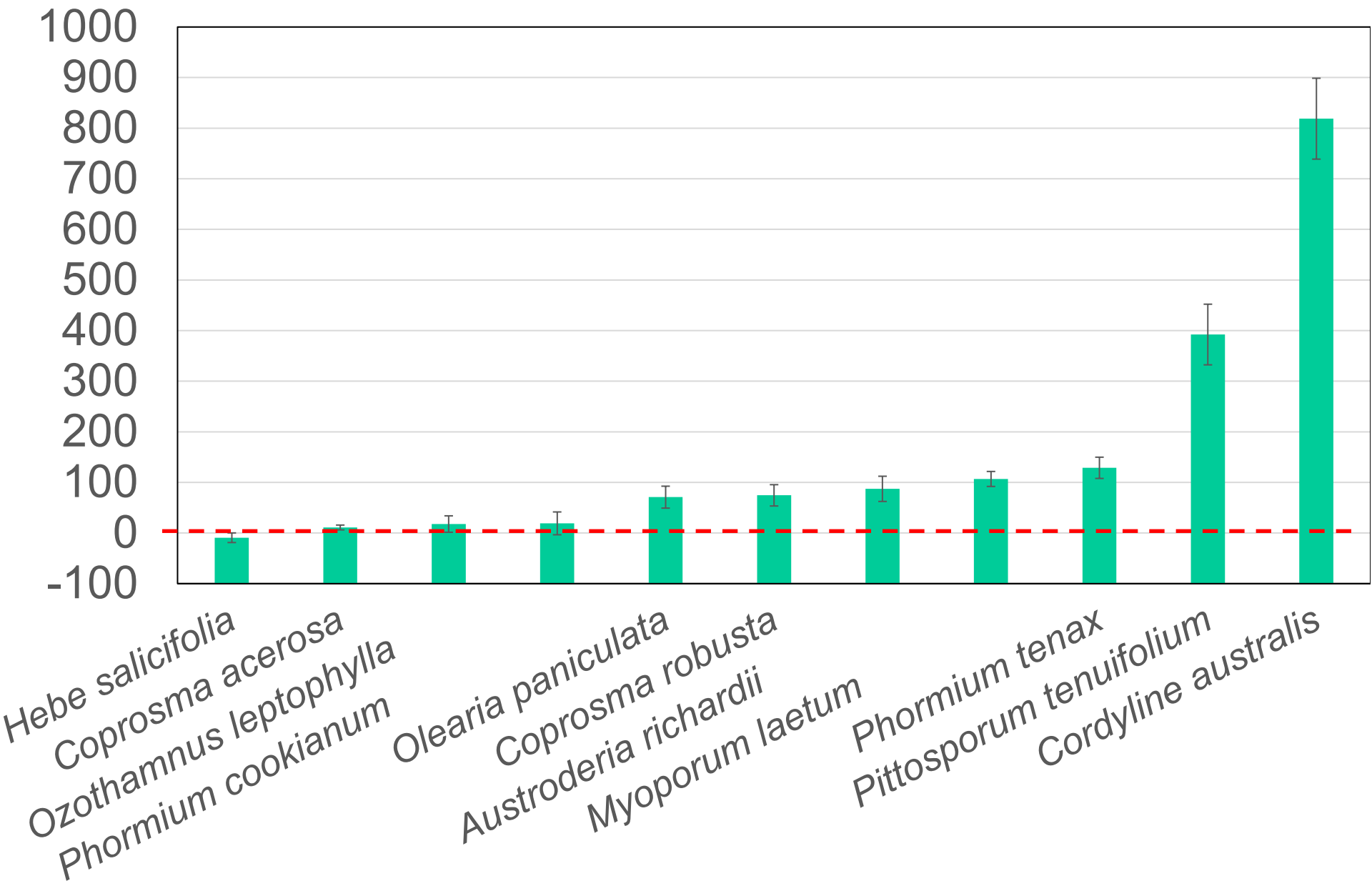


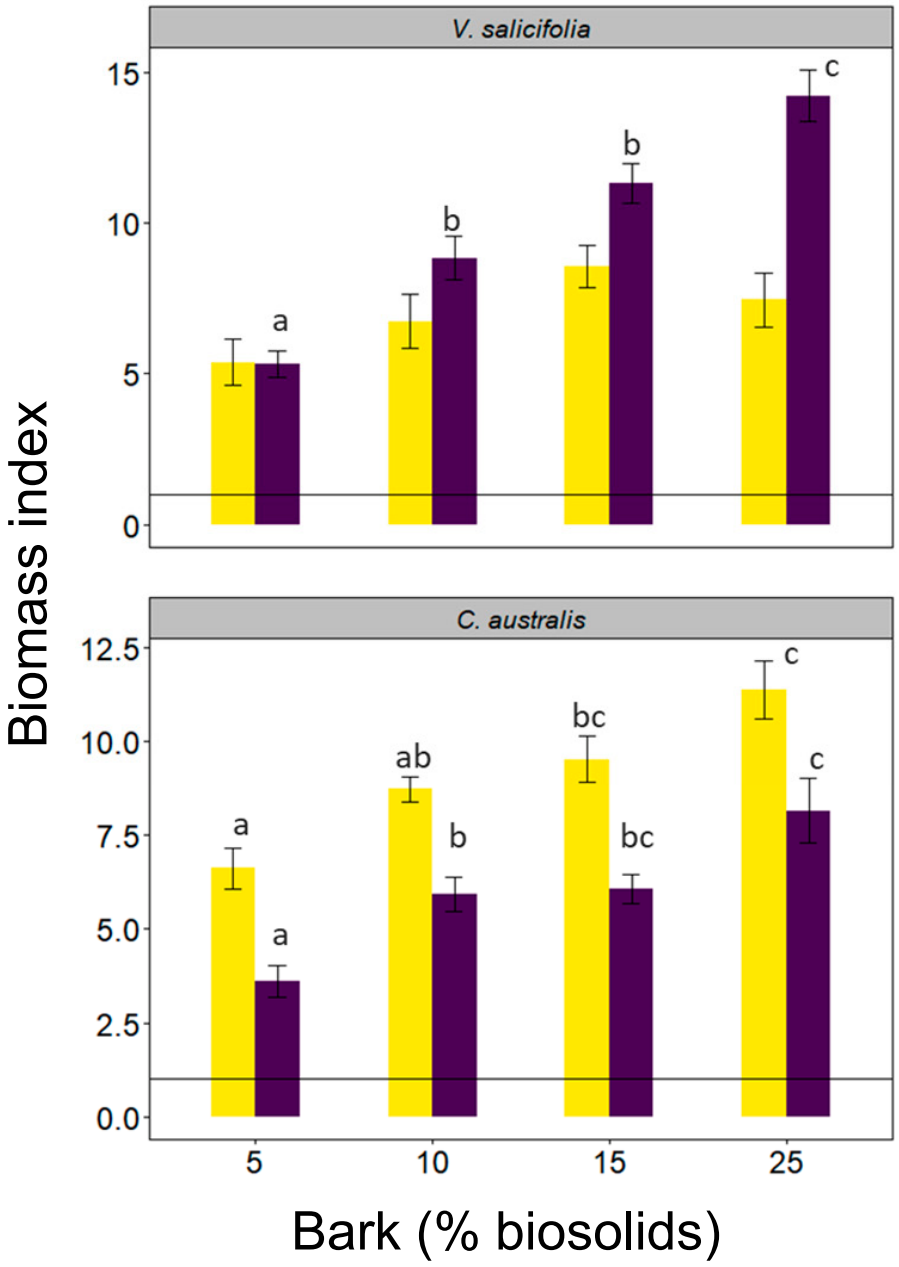
Al Mamun *et al.*, *Soil Systems* 7(4), 107. 2023


Biosolids. Bioterrorism.
Defend Our Food, Water & Air.


• High soil N loading
• High Cu & Zn, xenobiotics, EOCs
• Pathogens

Response of NZ plants to 5% biosolids in degraded soil



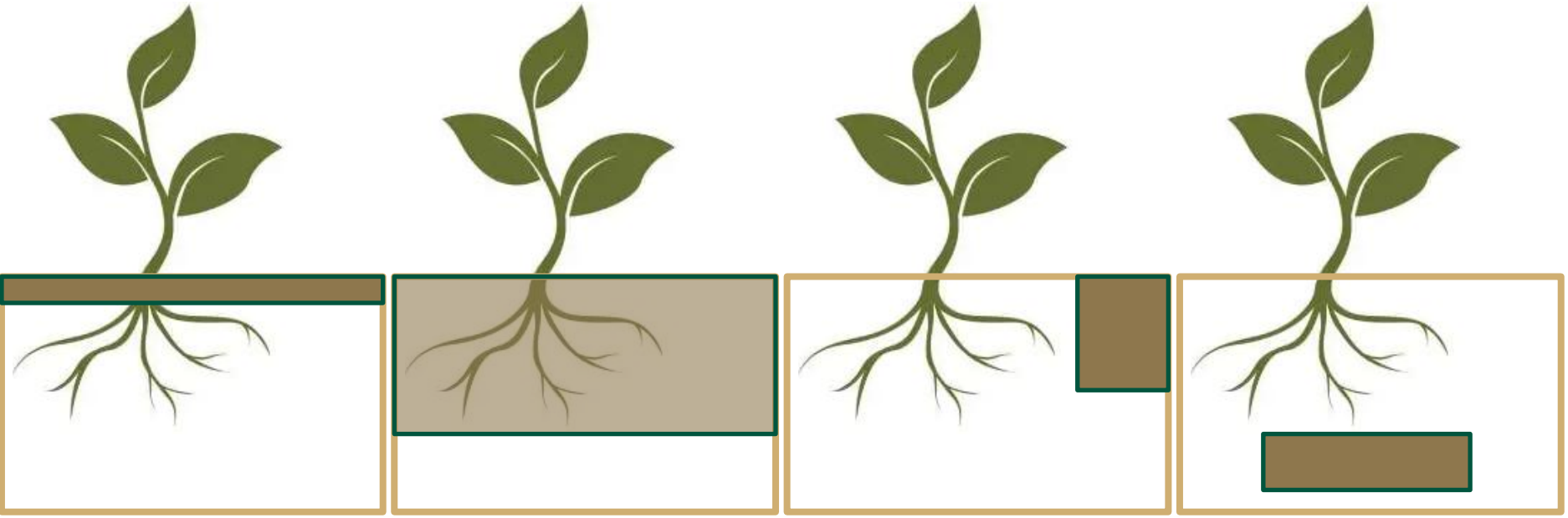


Garcés-Hernández C, *et al*. *Water*. 16(9), 1226, 2024

Effective rates of biosolids addition for contaminated environments results in:

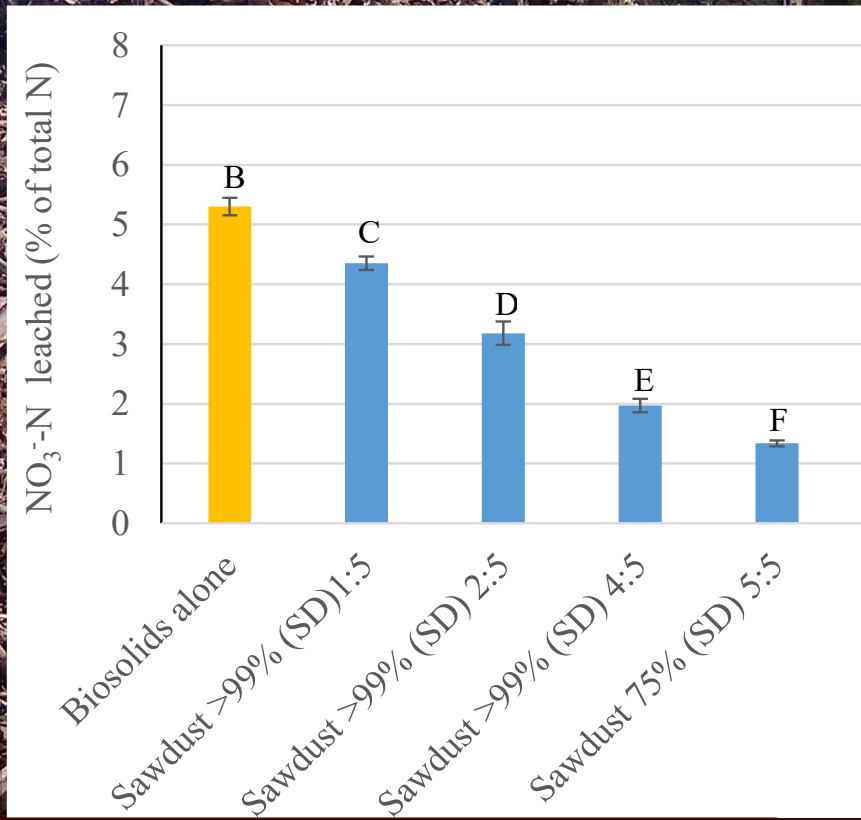
- Excessive nitrate leaching
- Excessive growth of exotic weeds (compared to NZ-native species)

Application configurations



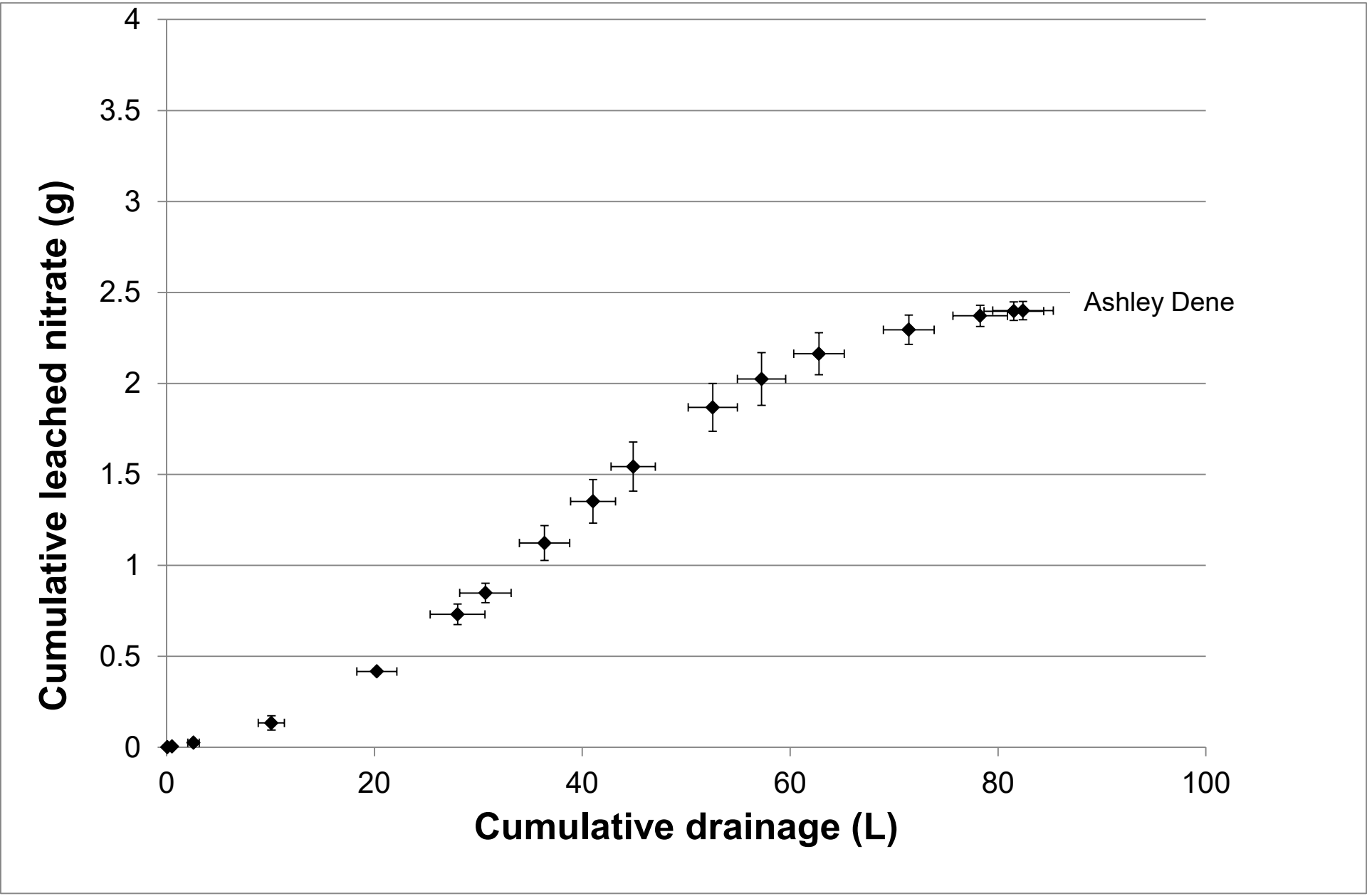
Gutiérrez-Ginés *et al*. *Plant and Soil* 489, 423-428, 2023

Wood-waste mitigates N leaching

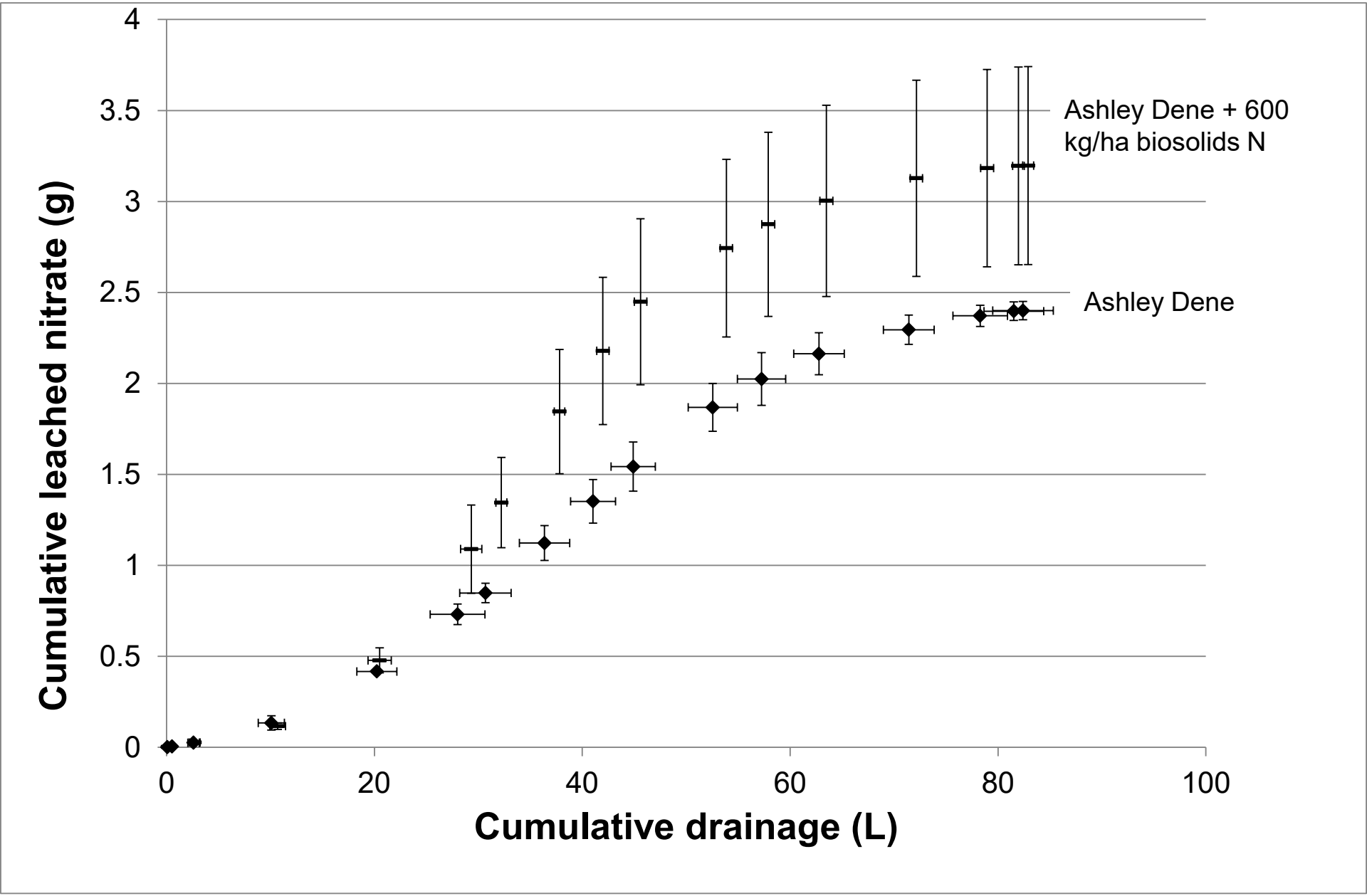


Paramashivam *et al. Journal of Environmental Quality*. 45, 360-367, 2016

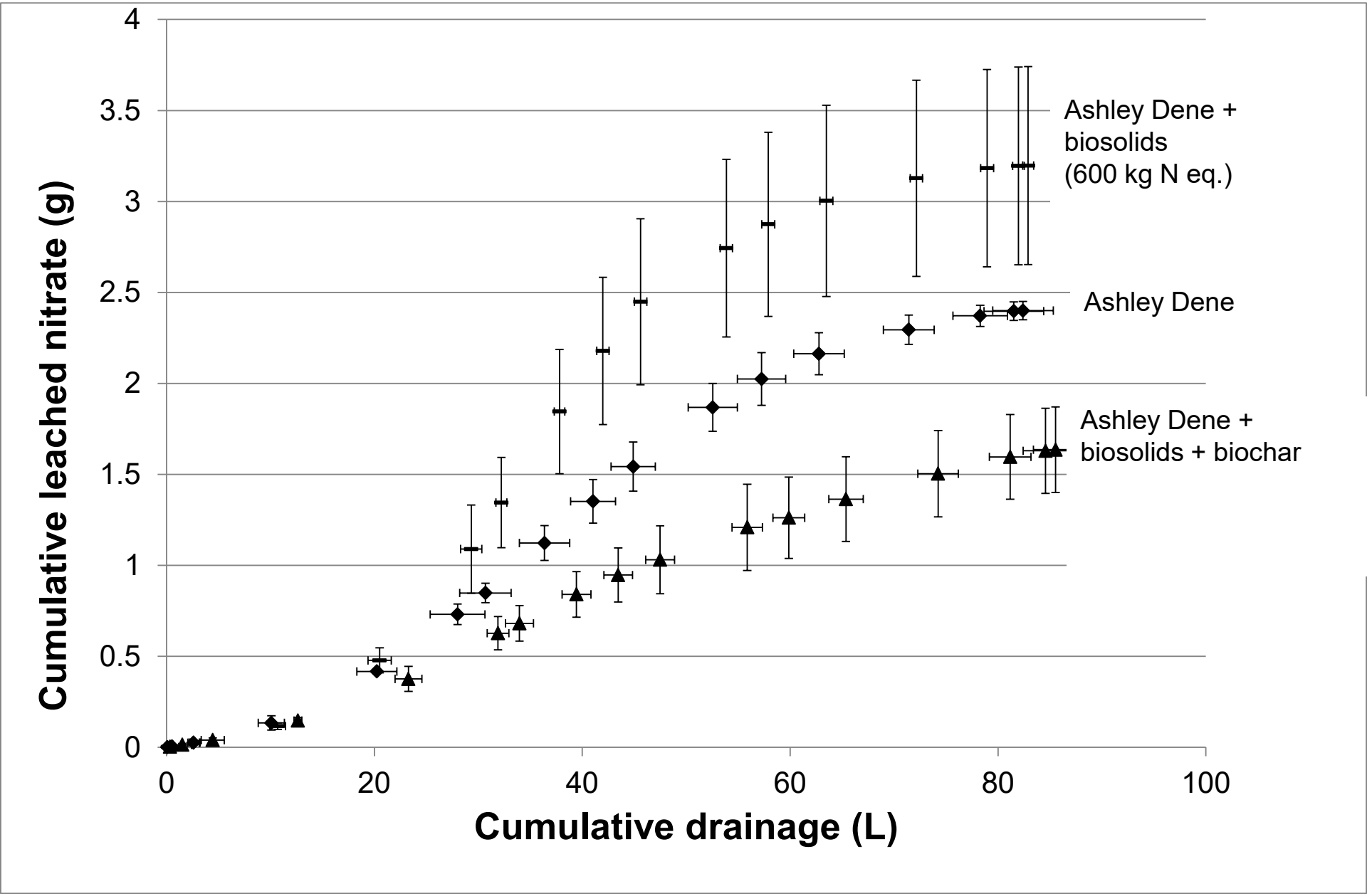
Cumulative nitrate leaching



No surprises: nutrients exacerbate nitrate leaching



Some biochars mitigate nitrate leaching from biosolids…



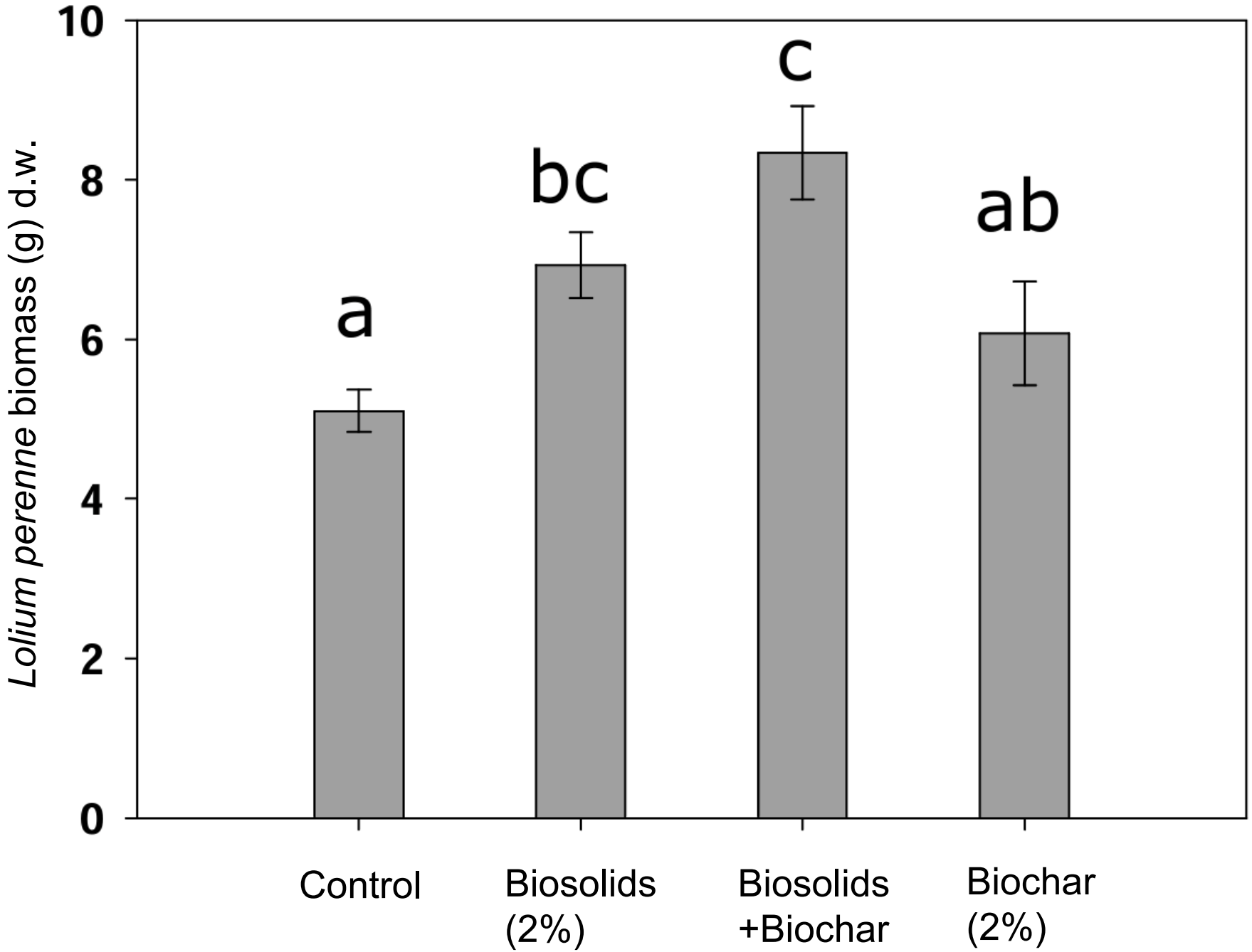
Knowles *et al. Science of the Total Environment* 409, 3206-3210, 2011

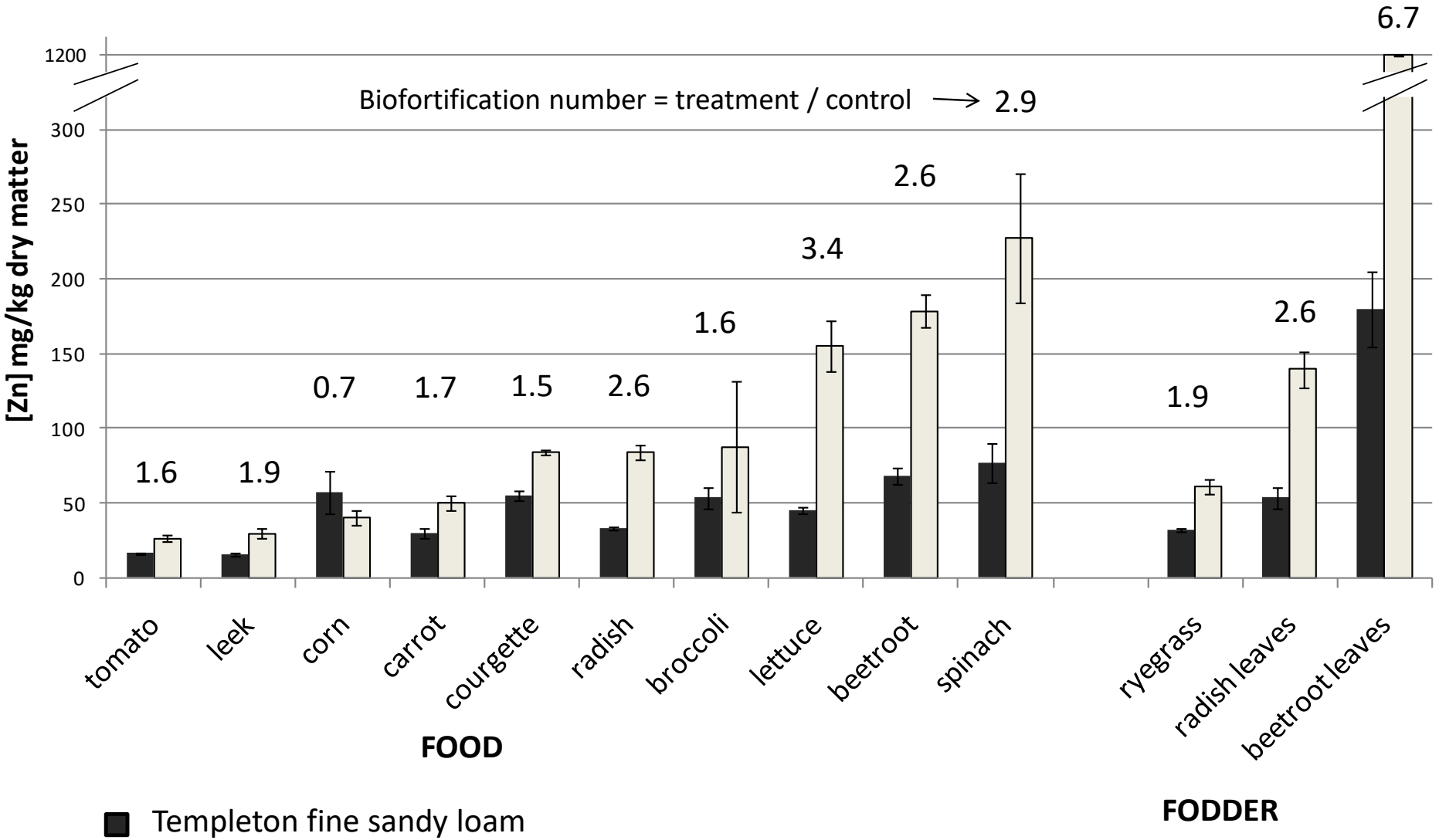
2023 Biochar Market Report US$400 - 1,800 per tonne!

Only useful for high-value contaminated land e.g. Christchurch Red Zone

10µm

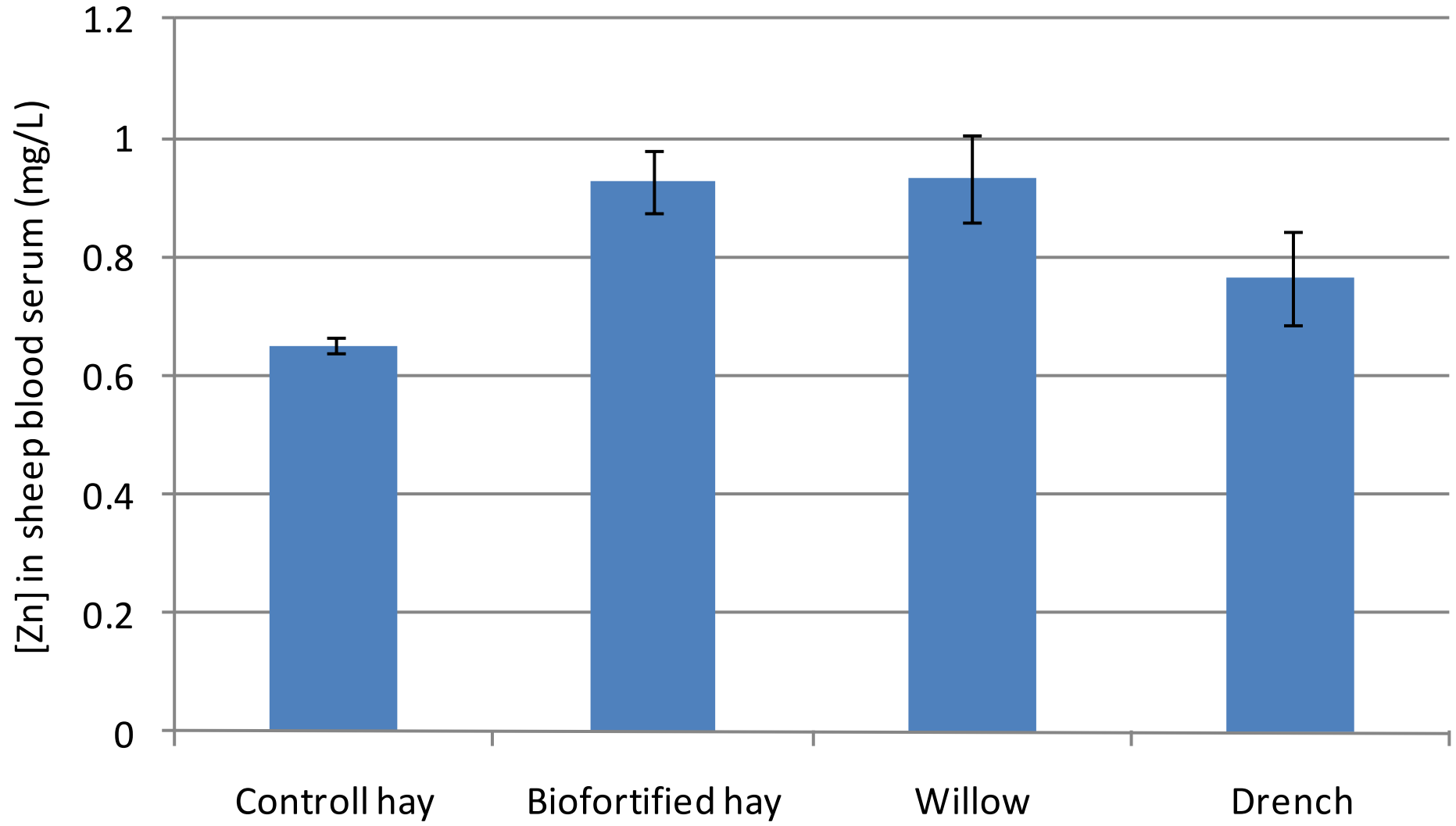
Low-cost charcoal has been produced for millennia





Gartler *et al. Science of the Total Environment* 465, 308-313, 2013.

Sheep blood serum 10 days after treatment (5 replicates)



Anderson *et al. Journal of Geochemical Exploration* 121, 30-35, 2012

Biowastes in the soil – plant system

Unique root zones

Pittosporum tenuifolium

Coprosma robusta

Kunzea robusta

Cordyline australis

Austroderia richardii

Carex secta

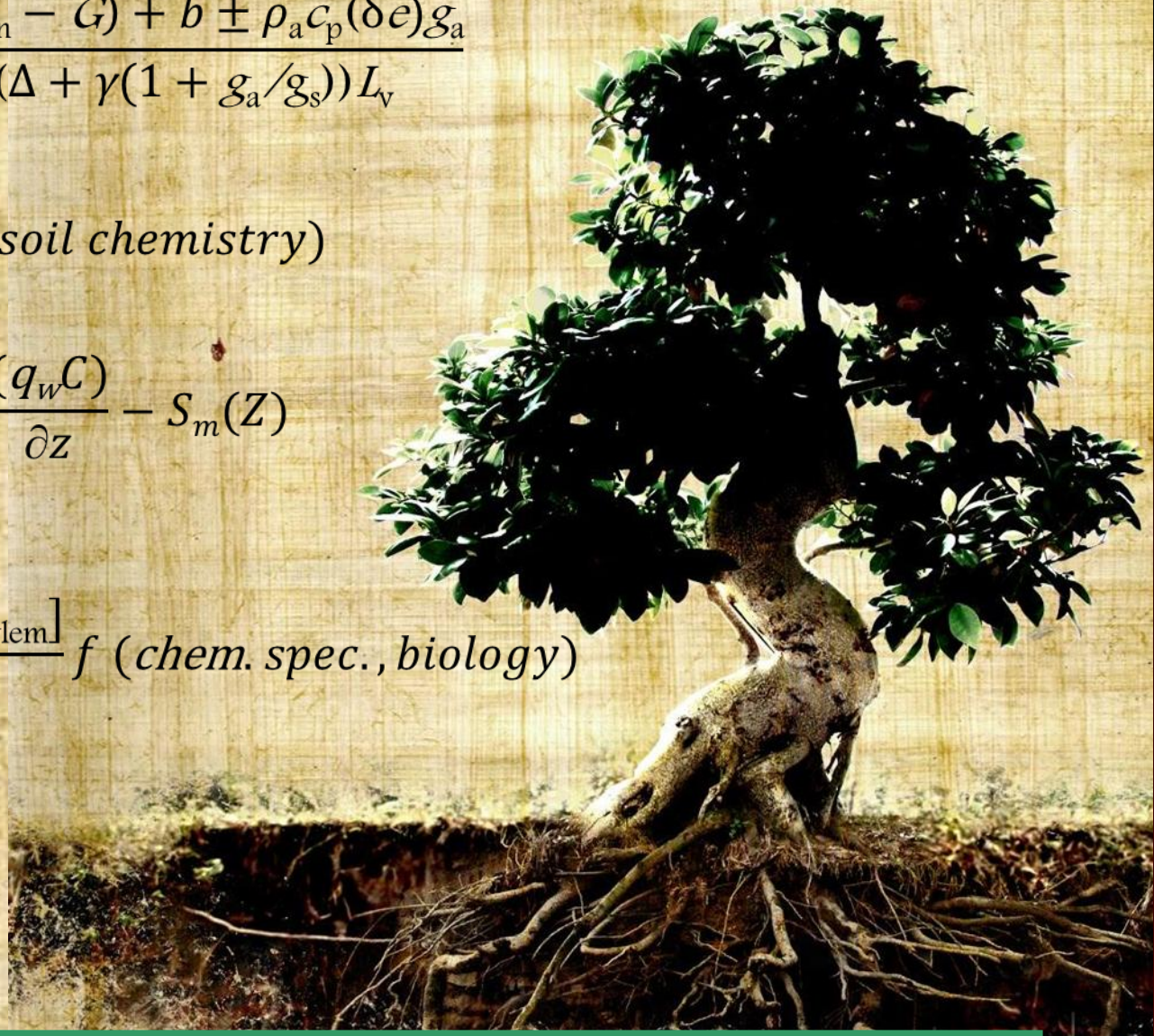
Phormium tenax

$$M \propto T = K_c \frac{\Delta(R_n - G) + b \pm \rho_a c_p (\delta e) g_a}{(\Delta + \gamma(1 + g_a/g_s)) L_v}$$

$$M \propto C = f(M_{soil}, soil\ chemistry)$$

$$\frac{\partial M_{soil}}{\partial t} = \frac{\partial}{\partial z}[(\theta D_s)\frac{\partial C}{\partial z}] - \partial\frac{(q_w C)}{\partial z} - S_m(Z)$$

$$M \propto \phi = \frac{[C_{root\ xylem}]}{[C]} f\ (chem.\ spec., biology)$$



$$M(t) = \int_0^{z_R} \int_0^t R(t`, z)\, T(t`)\, C(t`z)\, \phi\big(C(t`z)\big)\ \ dt\ \ dz$$

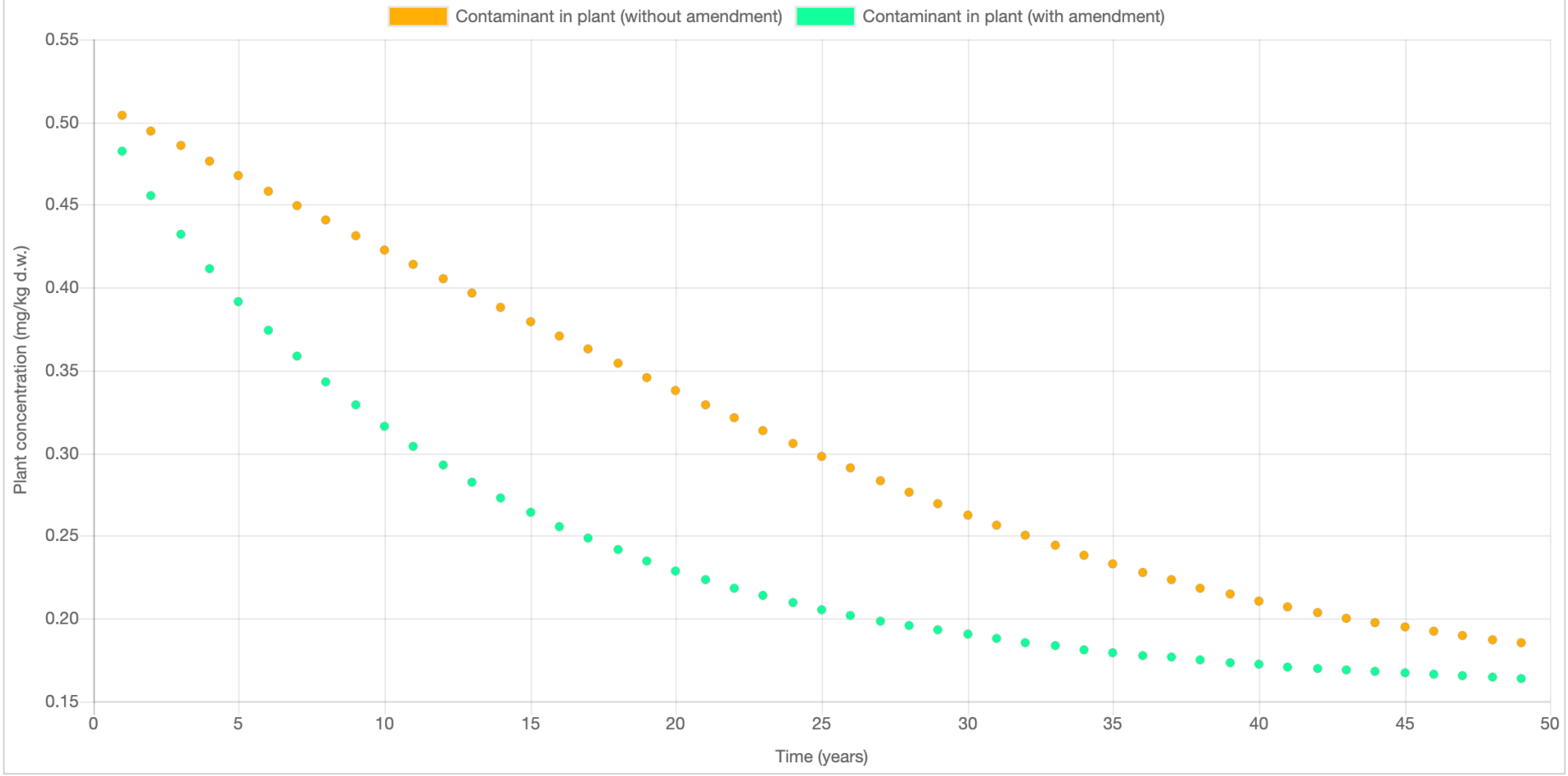
Critical Reviews in Plant Sciences 28(4), 240-266, 2009

KiwiScience - RHIZOFLUX model

Inputs | Outputs | Scenarios

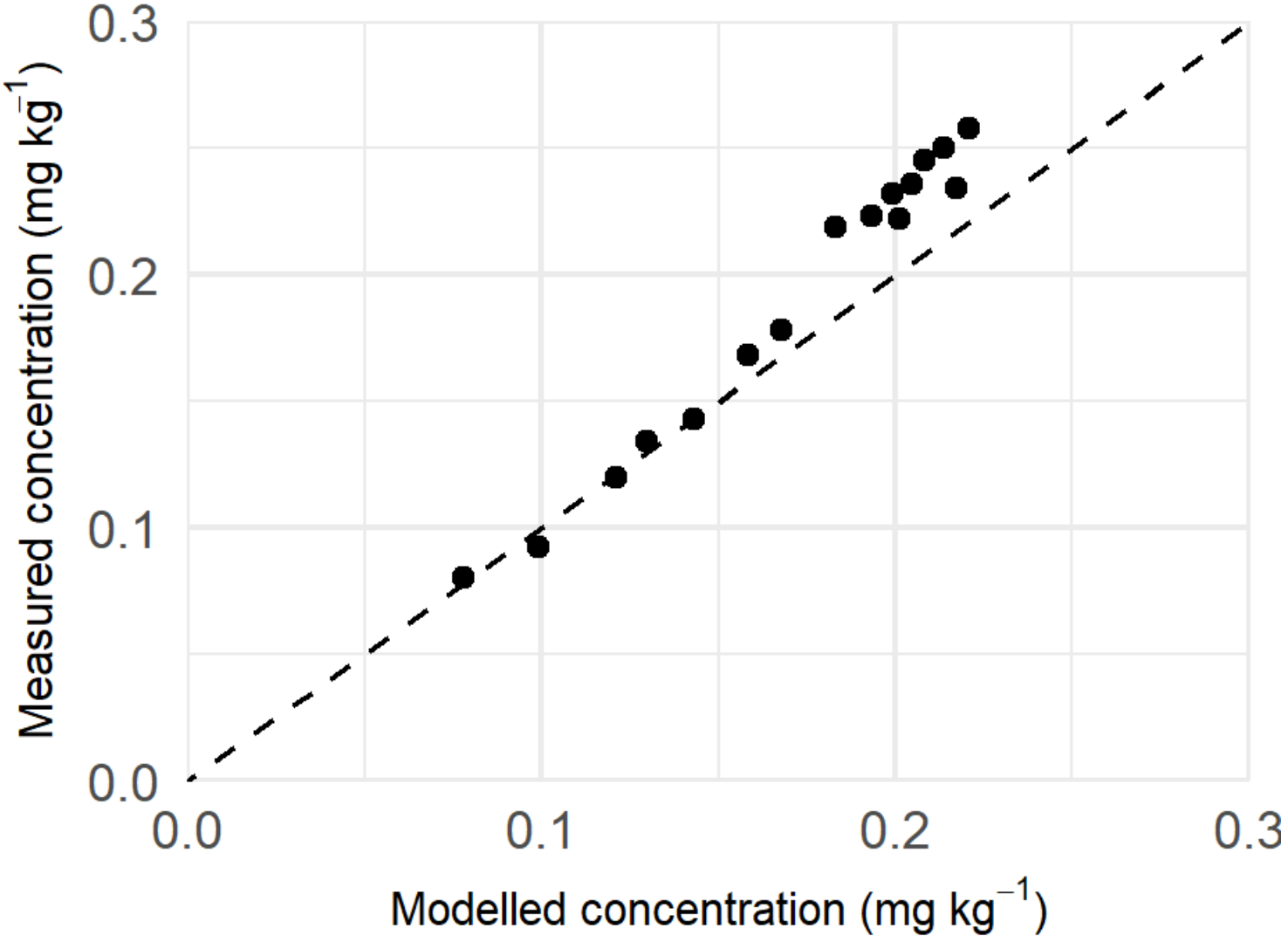
Save Scenario | Calculate

Mass Balance | Plant | Soil | Leaching | Final Profile



Export to XLSX

Validation in field: Cd



Thompson-Morrison *et al. Soil Use and Management* DOI: 10.1111/sum.12935, 2023

Outcomes

- Matching biowastes, particularly biowaste mixtures with contaminated soils can improve food quality, reduce environmental risk, and eliminate disposal costs.
- Mismatch between biosolids safety and biosolids acceptance
- Models are needed to allow the optimisation of biowaste mixtures in complex soil – plant systems

Publications, DSTs and other info:

www.kiwiscience.com