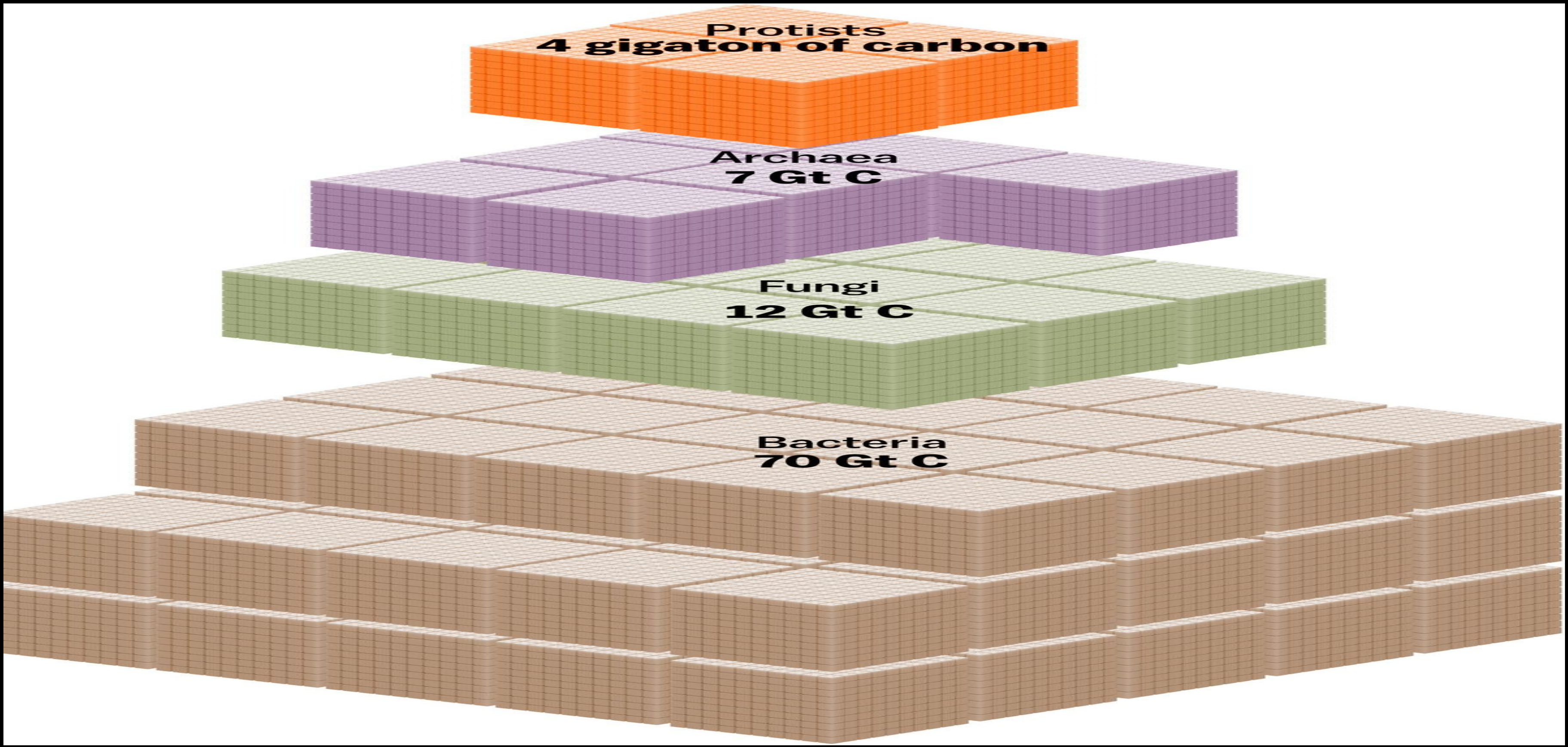
Biological pathways to carbon rich soil

Dr Christine Jones



Mitigation of climate change will require detailed knowledge of how ecosystems function

There is no single factor 'cause'
(eg CO_2)

There is no single factor 'solution'
(eg *Pinus radiata*)

Monocultures of *Pinus radiata*

i) significantly reduce biodiversity
ii) high risk of erosion during establishment and harvest
iii) compacted soils, low in carbon
iii) negative impact on ecosystem processes and water quality

This is an additional slide

There is <u>ZERO</u> net carbon sequestration benefit from harvested timber

(see explanatory notes)

This is an additional slide

The area of land allocated to short-rotation forestry would need to be continually expanded in order to maintain an initial level of carbon sequestration

(see explanatory notes)

This is an additional slide

Non-harvested trees reach ‘steady state’ carbon content, then release the carbon back to the atmosphere when they die

(see explanatory notes)

This is an additional slide

Actively growing *Pinus radiata* trees emit monoterpenes that deactivate the hydroxyl radicals necessary for the photo-oxidation of methane

(see explanatory notes)

Plants are responsible for the production of 10 - 30% of the world's methane

The lungs of the planet are belching methane
http://www.newscientist.com/article/mg18925343.900-the-lungs-of-the-planet-are-belching-methane.html

- Methane escaping from a cottonwood tree. Fred Pearce 24 June 2019. https://e360.yale.edu/features/scientists-probe-the-surprising-role-of-trees-in-methane-emissions

Biodiversity: a key factor

i) effective functioning of all living systems

ii) mitigation of GHGs

Appropriately managed ruminant livestock

i) enhance biodiversity
ii) improve soil function
iii) restore soil carbon at depth
iii) positive impact on ecosystem processes and water quality

The emphasis is on APPROPRIATE management

Appropriately managed soil is a net sink for …

- ~ carbon dioxide (CO_2)
- ~ methane (CH_4)
- ~ nitrous oxide (N_2O)

Managing soil as a
GHG sink

What do we need to know?

‘Appropriate’ management is

~ holistic

~ enhances biodiversity

~ puts microbes front & centre

A recent census of life on earth, measured in gigatonnes of carbon, estimated there are 550 Gt of carbon-based life forms

The biomass distribution on Earth: Yinon M. Bar-On, Rob Phillips, and Ron Milo (PNAS, May 2018)

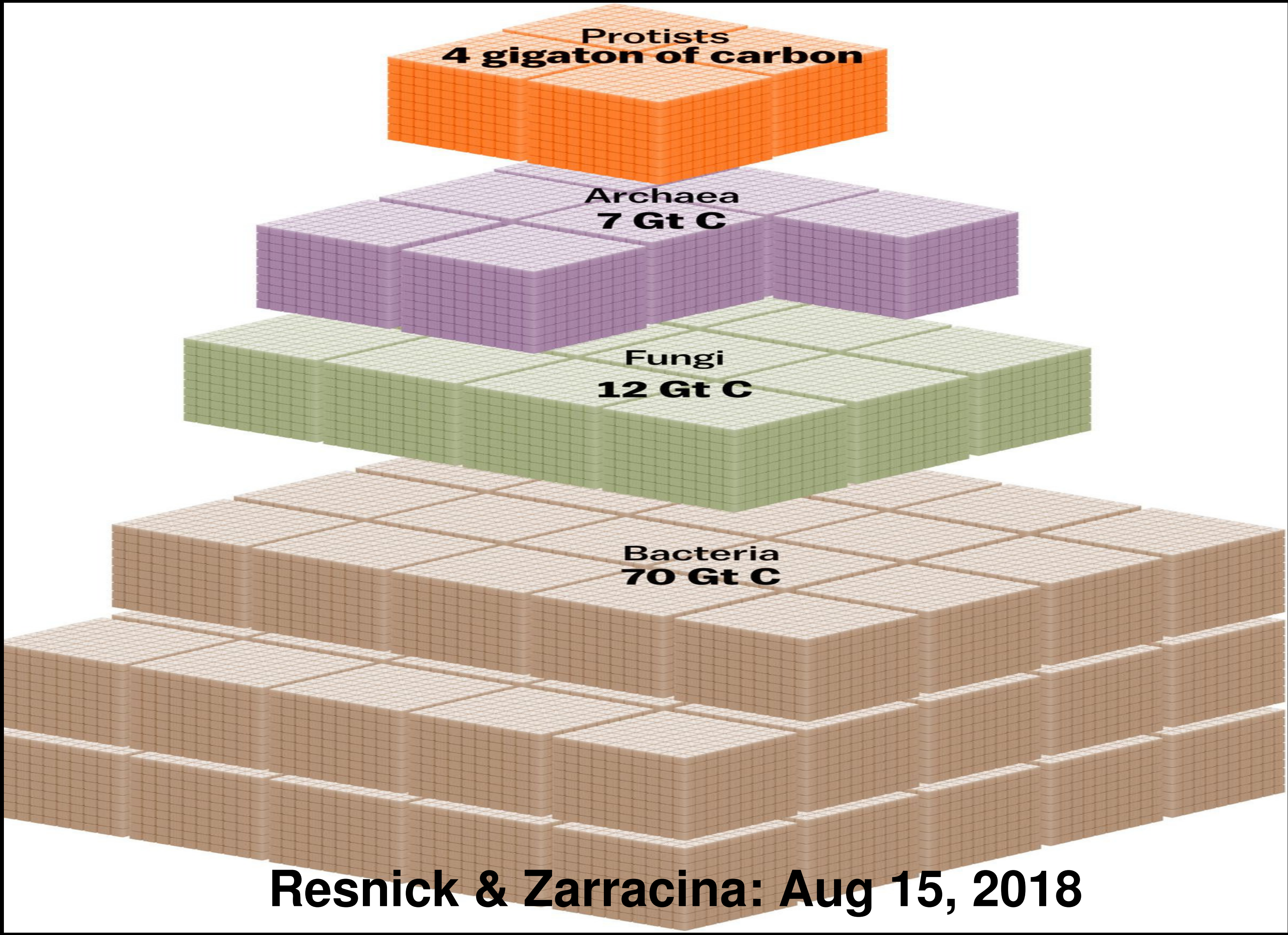
450 Gt of the 550 Gt of carbon is in plants

All other living things make up the remaining 100 Gt

And here's where it gets interesting.

Protists, archaea, fungi and bacteria comprise 93% of the remaining 100 Gt

Weight of microbes in Gt C



Insects, molluscs, fish, nematodes, animals and humans make up the final 7%

All plants and animals are embedded in a microbial world

And also
have a microbial world
embedded <u>within</u>
them

All living things (including plants) are holobionts

In simple terms, a holobiont is the host + microbiome, which together make the ‘whole’

Human holobiont

23 pairs of chromosomes

Thousands of species of microbes

We inherit genes (DNA) from our parents and obtain our microbiome from our mothers

Our genes determine skin colour, hair colour, sex etc

Our microbiome has a large influence on our <u>health</u>

Human health

Many current health issues have been linked to a failure to support a diversity of microbes in the human gut

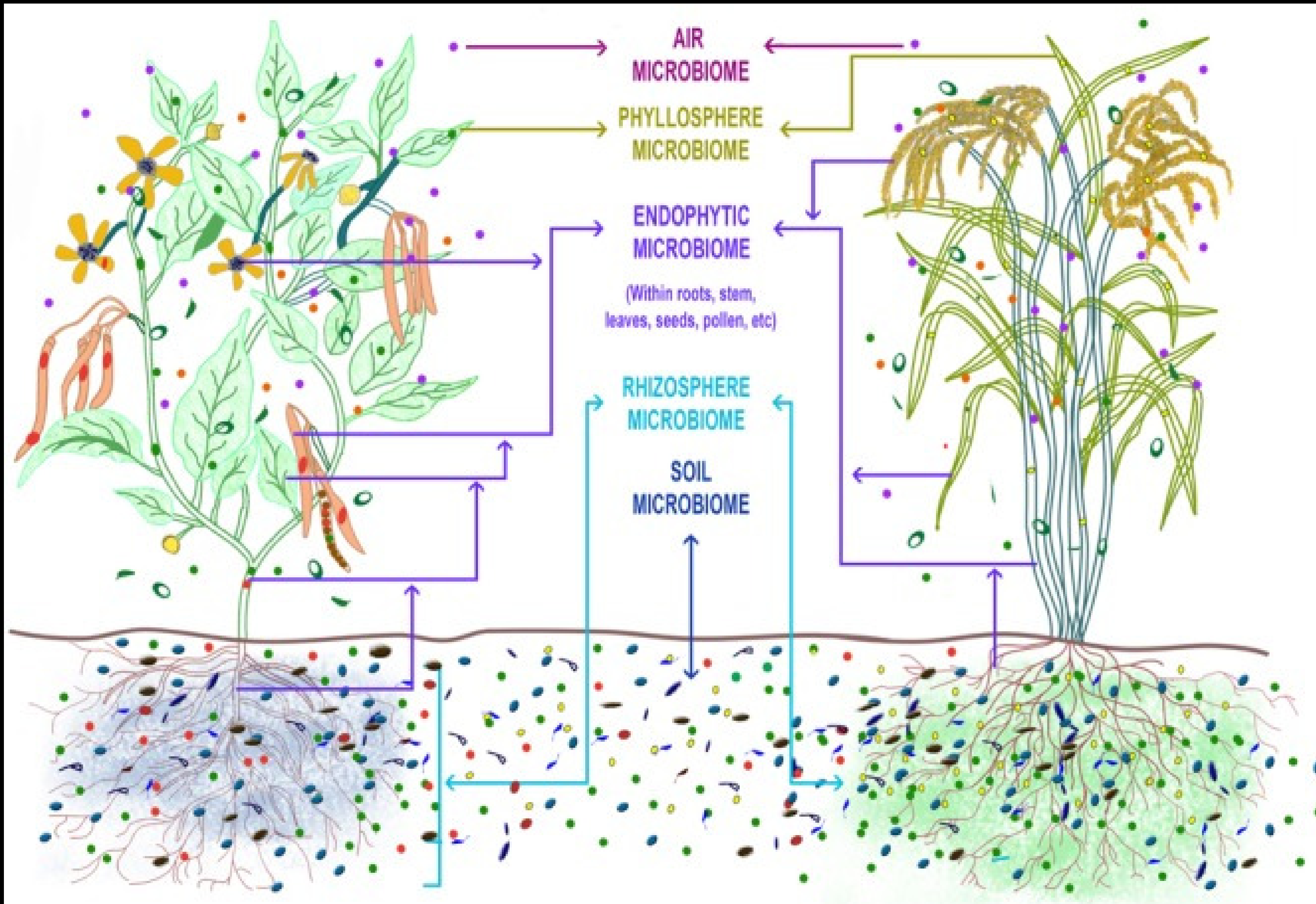
The world has over 50,000 edible plants.
Just three of them, rice, maize and wheat, provide 60 percent of the world's food energy intake

FAO: http://www.fao.org/3/u8480e/u8480e07.htm

But that's enough about humans … let's talk about plants

Plant genes determine the plant species and cultivar

The plant's microbiome determines plant health



Gopal, M., & Gupta, A. (2016). Microbiome Selection Could Spur Next-Generation Plant Breeding Strategies. *Frontiers in Microbiology*, *7*, 1971. https://doi.org/10.3389/fmicb.2016.01971

Understanding how it all works …..

(‘show and tell’ explanation of the plant’s core microbiome, biological induction, intergenerational vertical transmission of endophytes and need for recognition of the fact that there are more microbial cells than plant cells in all plant tissue)

Why has it taken us so long to realise all this??

Soil microbes are quiescent under most glasshouse and laboratory conditions

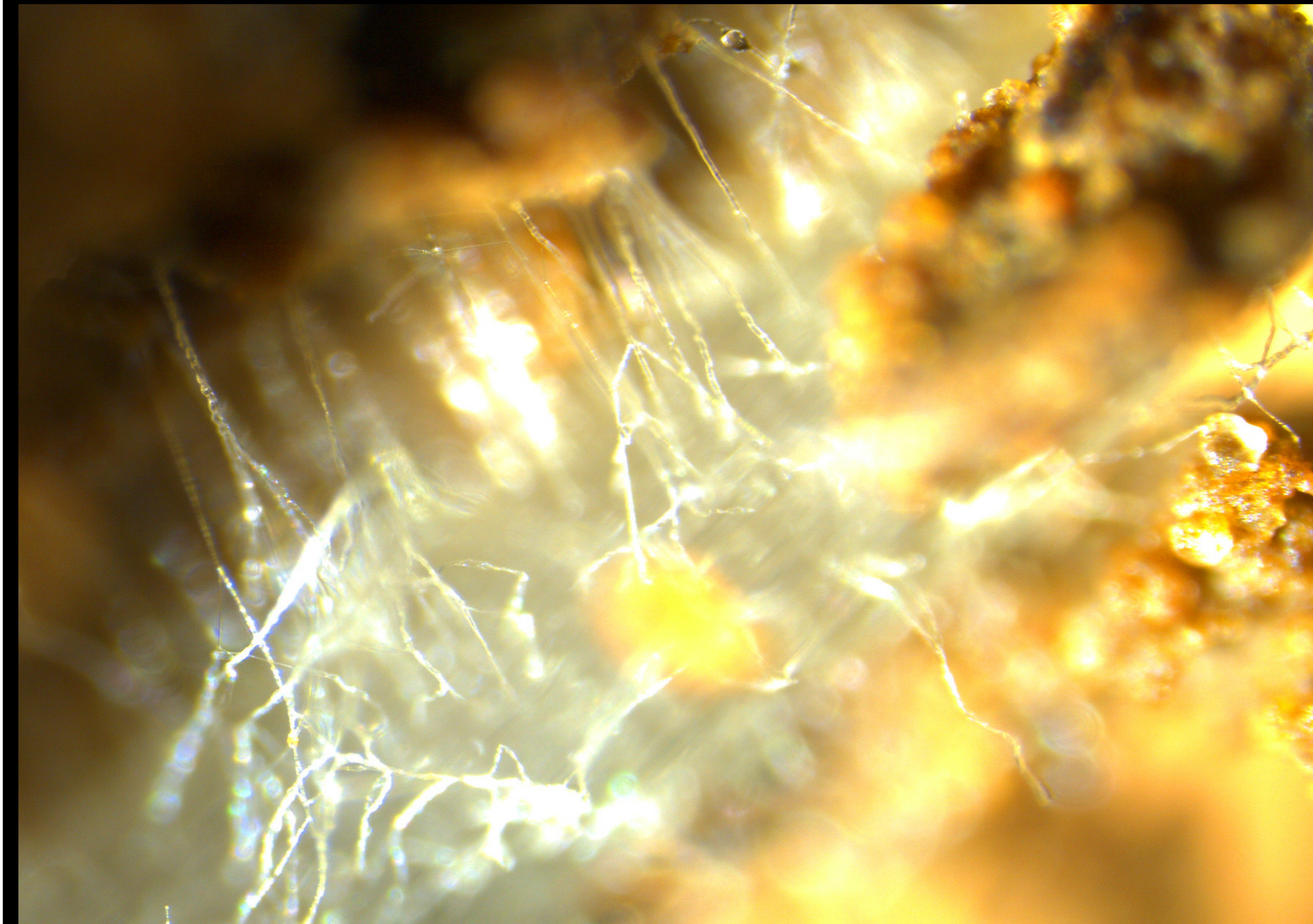
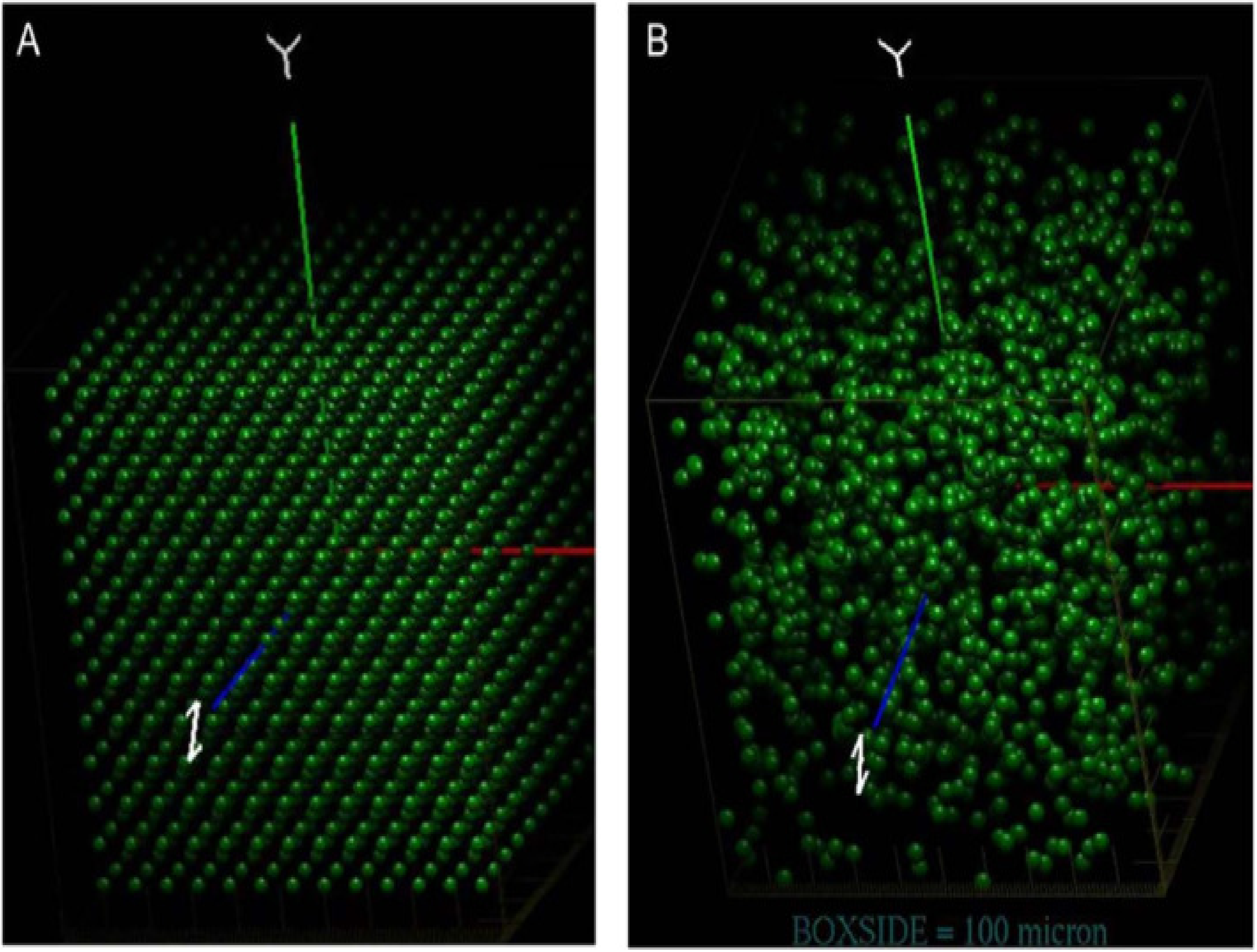


Photo credit Phill Lee

Plants do not have access to this extraordinary rhizosphere microbiome when grown under conditions that disable it


A
Y
Z
B
Y
Z
BOXSIDE = 100 micron

WikiHow “How to grow flowers from seed”
https://www.wikihow.com/Grow-Flowers-from-Seed

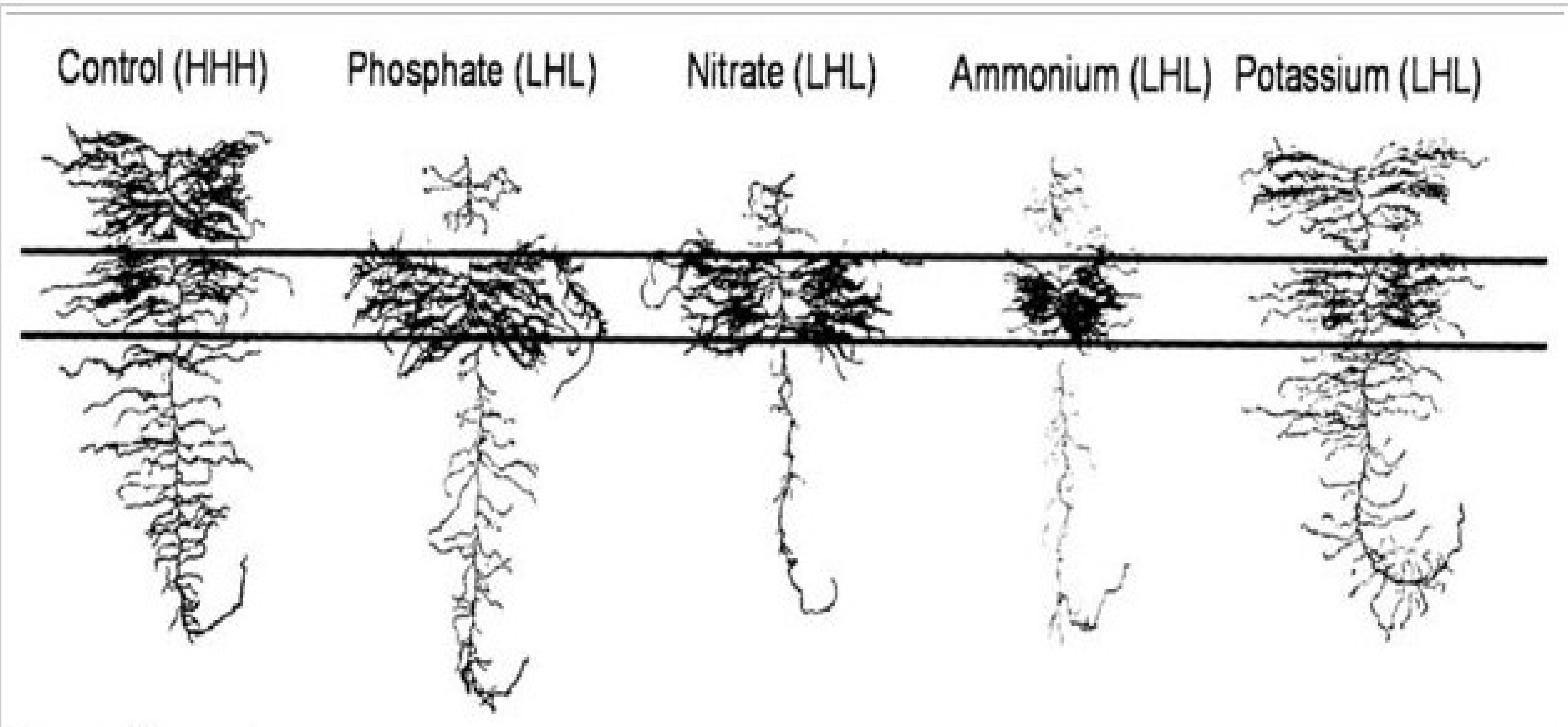
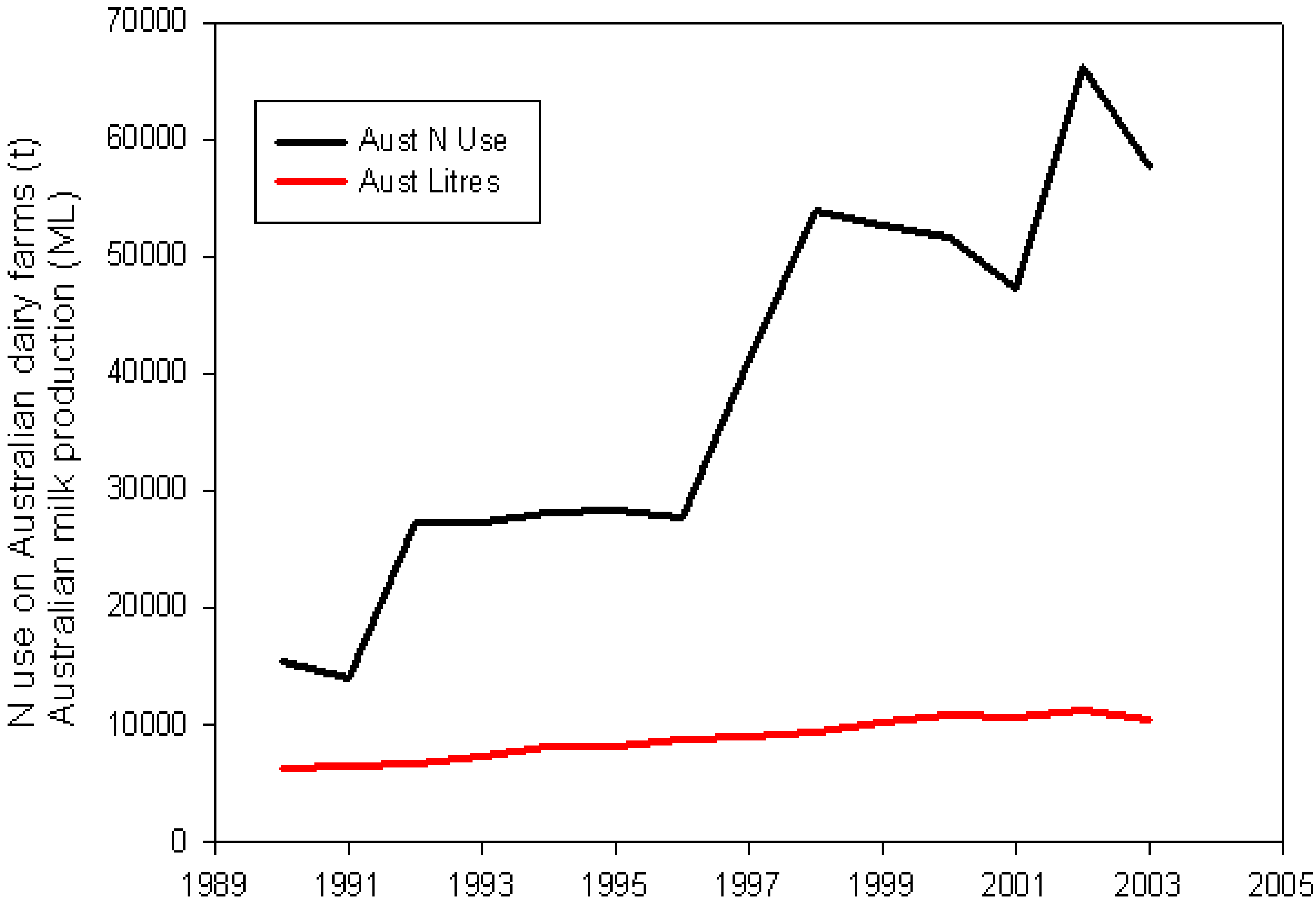


Figure 7

Changes in roots system architecture (RSA) of barely (*Hordeum vulgare*) in response to zones of high phosphate, nitrate, ammonium and potassium availability.

Very poor relationship (if any) between the amount of nitrogen fertiliser applied and the amount of milk produced


N use on Australian dairy farms (t)
Australian milk production (ML)
Aust N Use
Aust Litres
0
10000
20000
30000
40000
50000
60000
70000
1989
1991
1993
1995
1997
1999
2001
2003
2005

Jena experiment

- 1, 2, 4, 8 or 16 plant species
- 4 functional groups

Biomass production, beneficial insects, soil microbial activity, water balance, soil carbon, N, P


Photo: Christoph Scherber

Jena experiment

- 1, 2, 4, 8 or 16 plant species

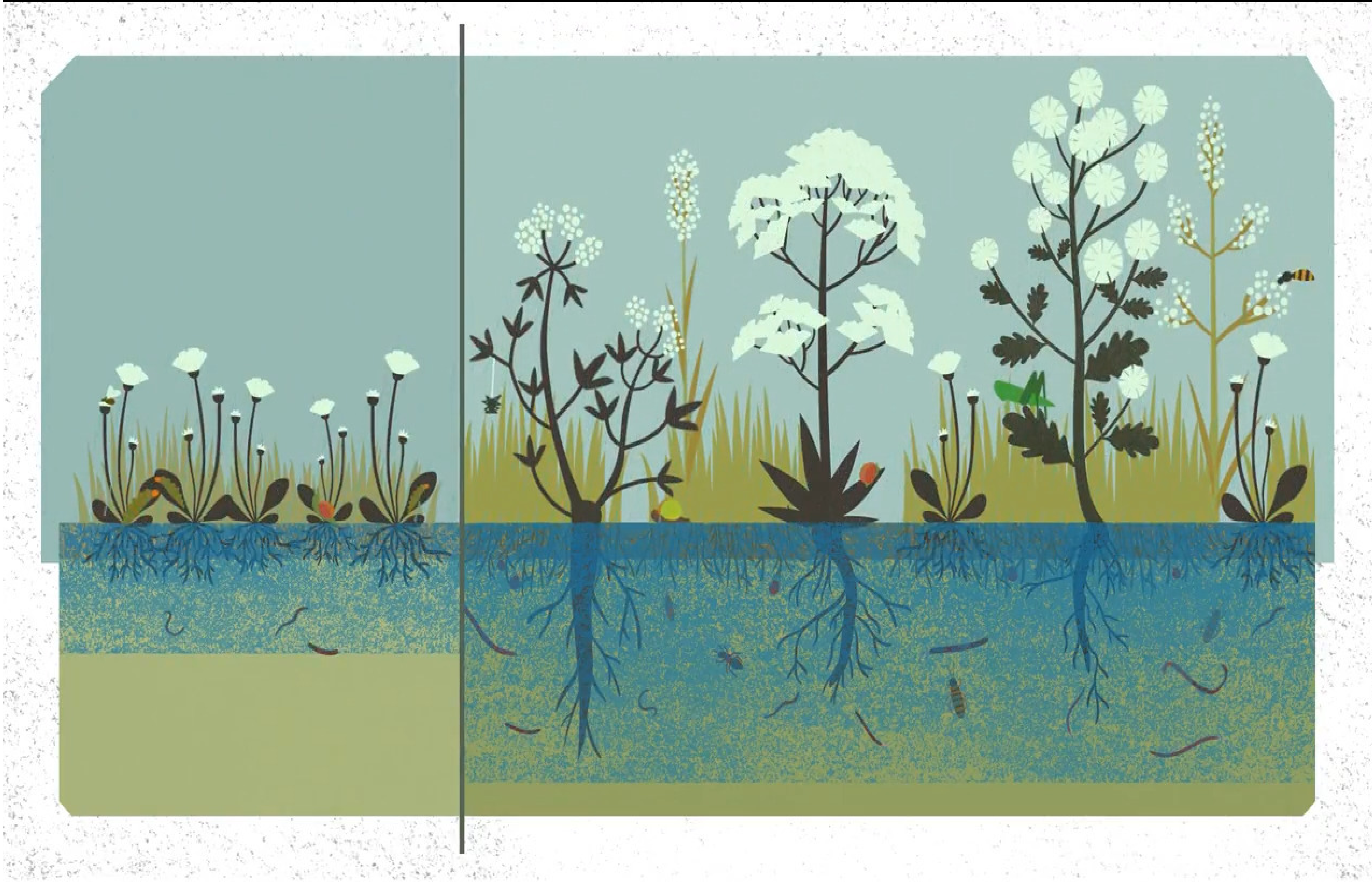
Biomass increased as the number of plant species in the mix increased

Jena Biodiversity Experiment

Jena experiment

High-diversity plots (8 or 16 plant species) accumulated 21.8% more carbon than low-diversity plots (1, 2 or 4 plant species)

Jena Biodiversity Experiment



Jena experiment

- 1, 2, 4, 8 or 16 plant species
- 0, 100 or 200 kg N/ha/yr

High diversity produced greater plant yield than high N

Similar findings in the SmartGrass project in Ireland and the DiverseForages project at Reading University in England

Rhizosphere of cereal oats in the presence (left) and absence (right) of N fertiliser

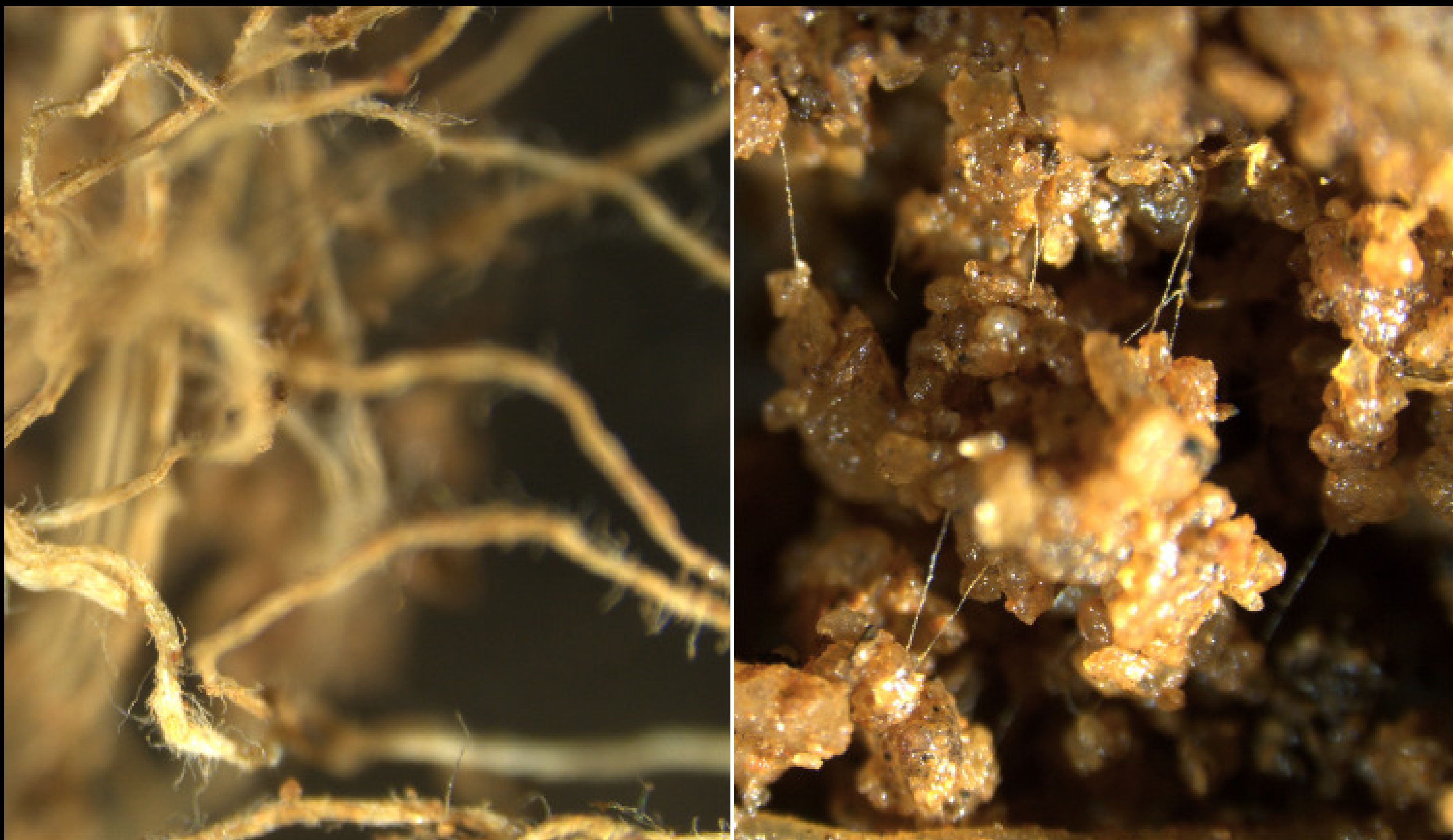


Photo credit Phill Lee

Research into soil carbon dynamics in New Zealand's pastoral soils reveal that many soils are <u>not</u> in 'steady state' with respect to carbon, as had previously been believed

Progressive carbon enrichment of soil in the 40-100cm increment demonstrated deep carbon is more reactive than originally considered

Baisden, W. T. and Parfitt, R. L. (2007). Bomb 14C enrichment indicates decadal C pool in deep soil? *Biogeochemistry* 8: 59-68. doi: 10.1007/s10533-007-9101-7

Professor Louis Schipper and colleagues recorded soil carbon losses averaging 21 tC/ha in the top one metre of soil at 31 sites on flat to rolling pastoral land in New Zealand

- Schipper, L. A., Baisden, W. T., Parfitt, R. L., Ross, C., Claydon, J. J. and Arnold, G. (2007). Large losses of soil C and N from soil profiles under pasture in New Zealand during the past 20 years. *Global Change Biology* 13: 1138–1144. doi: 10.1111/j.1365-2486.2007.01366.x

Further research involving analysis of 83 sites revealed significant amounts of soil carbon were lost where dairy cattle grazed flat land. In contrast, soil carbon levels improved under drystock grazing on hill country

- Schipper, L. A., Parfitt, R. L., Ross, C., Baisden, W. T., Claydon, J. J. and Fraser, S. (2010). Gains and losses in C and N stocks of New Zealand pasture soils depend on land use. *Agriculture Ecosystems and Environment* 139: 611-617. doi: 10.1016/j.agee.2010.10.005

The largest <u>soil carbon losses</u> in the intensively managed dairy soils occurred in the <u>20cm to 80cm</u> increment of the soil profile

- Schipper, L. A., Parfitt, R. L., Ross, C., Baisden, W. T., Claydon, J. J. and Fraser, S. (2010). Gains and losses in C and N stocks of New Zealand pasture soils depend on land use. *Agriculture Ecosystems and Environment* 139: 611-617. doi: 10.1016/j.agee.2010.10.005

Soil C improvements on North Island hill country grazed by dry stock were most evident in the 30-60cm increment

- Schipper, L. A., Parfitt, R. L., Ross, C., Baisden, W. T., Claydon, J. J. and Fraser, S. (2010). Gains and losses in C and N stocks of New Zealand pasture soils depend on land use. *Agriculture Ecosystems and Environment* 139: 611-617. doi: 10.1016/j.agee.2010.10.005

Andisols - inherently fertile volcanic soils once thought to be protective of soil carbon - lost similar amounts of carbon to other soil orders under intensive dairying

- Schipper, L. A., Parfitt, R. L., Ross, C., Baisden, W. T., Claydon, J. J. and Fraser, S. (2010). Gains and losses in C and N stocks of New Zealand pasture soils depend on land use. *Agriculture Ecosystems and Environment* 139: 611-617. doi: 10.1016/j.agee.2010.10.005

In other words, the changes in the level of soil carbon were <u>management related</u> rather than a function of soil type

- Schipper, L. A., Parfitt, R. L., Ross, C., Baisden, W. T., Claydon, J. J. and Fraser, S. (2010). Gains and losses in C and N stocks of New Zealand pasture soils depend on land use. *Agriculture Ecosystems and Environment* 139: 611-617. doi: 10.1016/j.agee.2010.10.005

While deeply sequestered carbon alleviates subsoil constraints, improves farm productivity, enhances hydrological function and improves mineral density in plants, animals and people, the loss of deep carbon has the opposite effect

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The Carbon Capture Farm

(see explanatory notes)

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Soil carbon builds rapidly under high diversity pastures containing at least eight species from four functional groups

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Which future will New Zealand choose?

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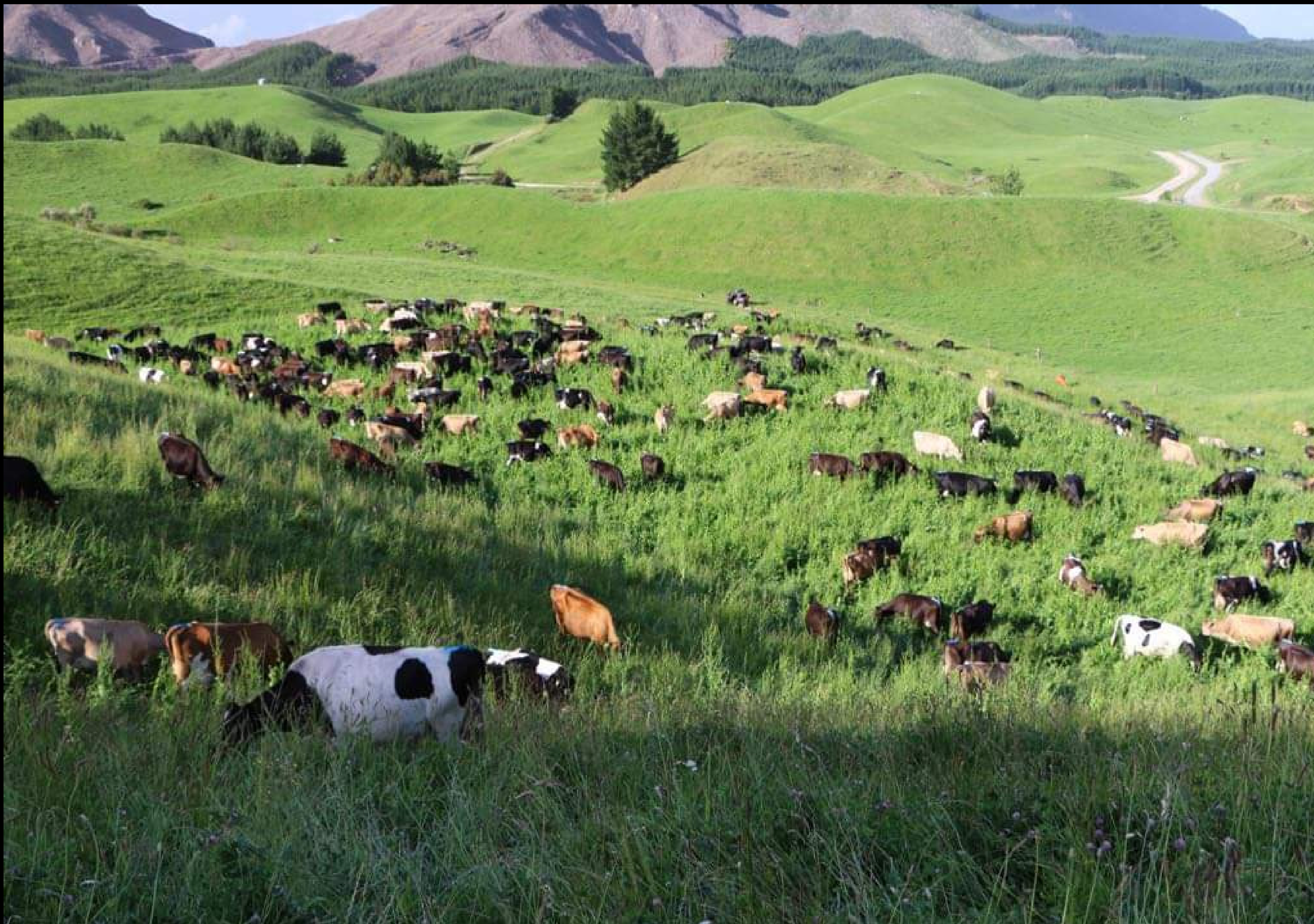
Foreground – multi-species pasture nourishing healthy cows and sequestering deep soil carbon

Middle ground – monoculture ryegrass doing none of the above

Background – recently harvested monoculture of *Pinus radiata* that has destroyed topsoil and provided zero net carbon sequestration



Wilith Farm (January 2019). Photo credit Miah Smith