

“How the Hidden Universe of Soils Could Solve Global Warming & Food Security”

by

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Vancouver, Canada

Presented to Transition Town Thames (T3)
Thames, New Zealand

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7:00 pm

End

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SUSTAINABILITY

Only 60 Years of Farming Left If Soil Degradation Continues

Generating three centimeters of top soil takes 1,000 years, and if current rates of degradation continue all of the world's top soil could be gone within 60 years, a senior UN official said

By Chris Arsenault (Thomson Reuters Foundation), Dec. 5, 2014

The primary causes of soil degradation include:

Chemical-intensive farming,

Plowing or tilling,

Current livestock management,

Deforestation,

Global warming.

About 1/3 of the world's soil has already been degraded.

Soil degradation

To keep up with the global food demand, the United Nations estimates,

6 million hectares of new farmland needed every year.

Instead,

12 million hectares/year are lost through soil degradation.

Rickson, R.J., Deeks, L.K., Graves, A. et al. Food Security (2015) 7: 351.

<http://www.un.org/en/events/desertificationday/background.shtml>

1 hectare =2.47 acres

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12 million hectares/year are lost through soil degradation.

For comparison the area of England is
13 million hectares.

We are going backwards at a rate of
18 million hectares/ year.

1 hectare =2.47 acres

My Investigation

Decided that I needed to investigate the subject to make my own assessment and to discover what if anything could be done.

This led me on a fascinating three year journey into current agricultural practices, soil biology, desertification, and grazing practices.

I learned about some amazing advances that have been made in the last 20 to 30 years and especially in the arena of soil biology and understanding nature's complexity.

I benefitted from 4 courses that I completed from one of the pioneers of this new revolution, Dr. Elaine Ingham.

The Good News

My findings indicate that we now possess the knowledge to:

- 1) rapidly reverse the degradation of soils,**
- 2) sequester much of the excess atmospheric carbon
(perhaps all of it) in the soil,**
- 3) and mitigate the root cause of much of the suffering in Africa
and the Middle East caused by the collapse of agriculture.**

The Good News

My findings indicate that we now possess the knowledge to:

- 1) rapidly reverse the degradation of soils,**
- 2) there is good evidence to suggest that we can sequester much of the excess atmospheric carbon (perhaps all of it) in the soil,**
- 3) and mitigate the root cause of much of the suffering in Africa and the Middle East caused by the collapse of agriculture.**

They are all connected and the solution may not be that expensive as nature can do a lot of the work.

The real challenge is to re-educate ourselves in the limited time frame available.

An Astronomer's Perspective

This short video features another astronomer, Dr. Laura Danly of California's Griffith Observatory. She is helping the U.S. Department of Agriculture promote its “healthy soils” campaign.

Permission granted by USDA Natural Resources Conservation Service

<https://www.youtube.com/watch?v=6tJlkAjDjjo&index=6&list=PL4J8PxoprGZ-uMTxScBBn9nYT6CMX8aD>

Laptop link

Microbes are the secret behind healthy soil.

Each teaspoon of healthy soil contains as many microbes as the population of humans on earth.



The Soil Food Web

(Some of the key players)

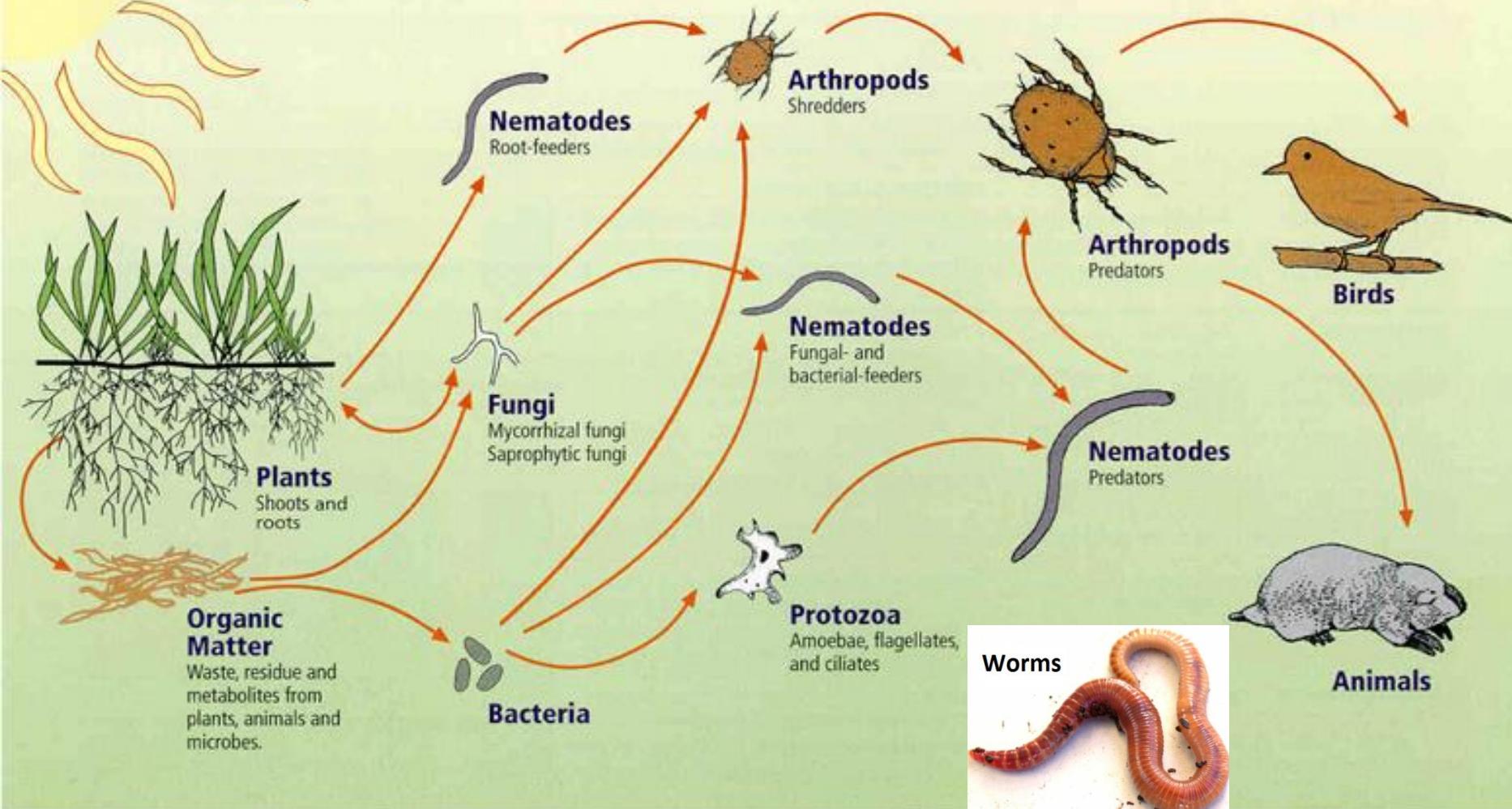


Image courtesy of USDA Natural Resources Conservation Services
<http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/biology/>

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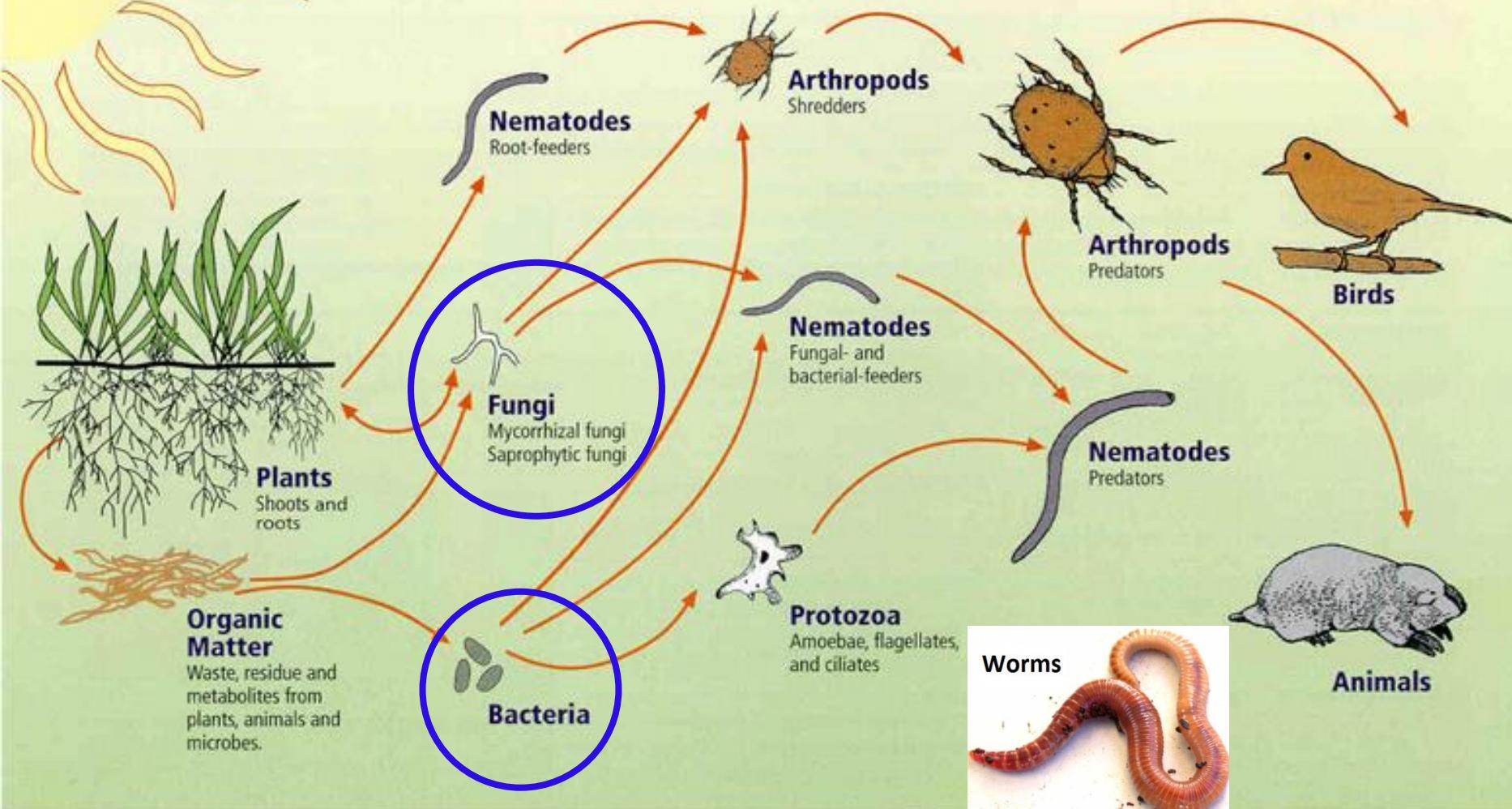
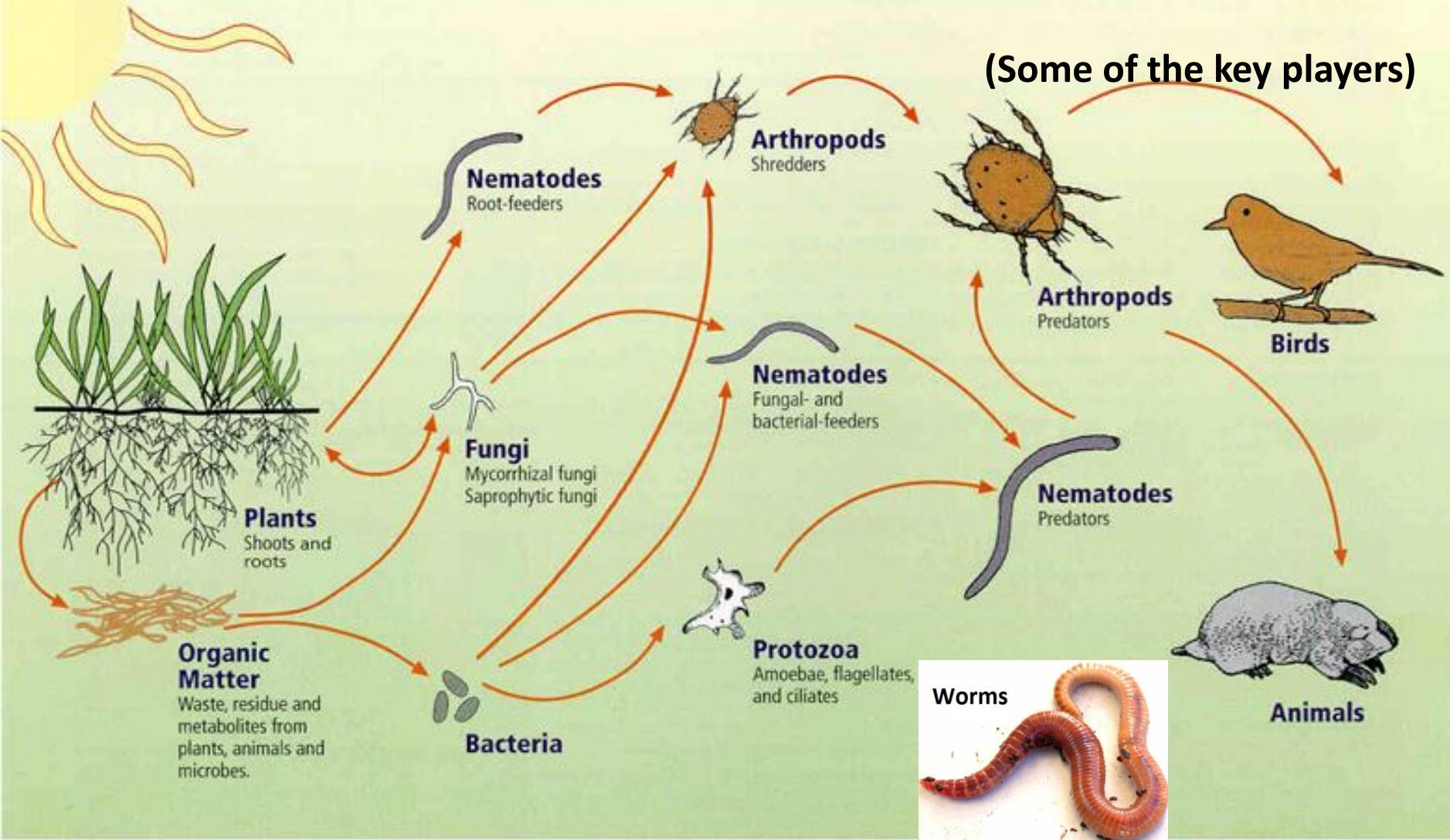


Image courtesy of USDA Natural Resources Conservation Services
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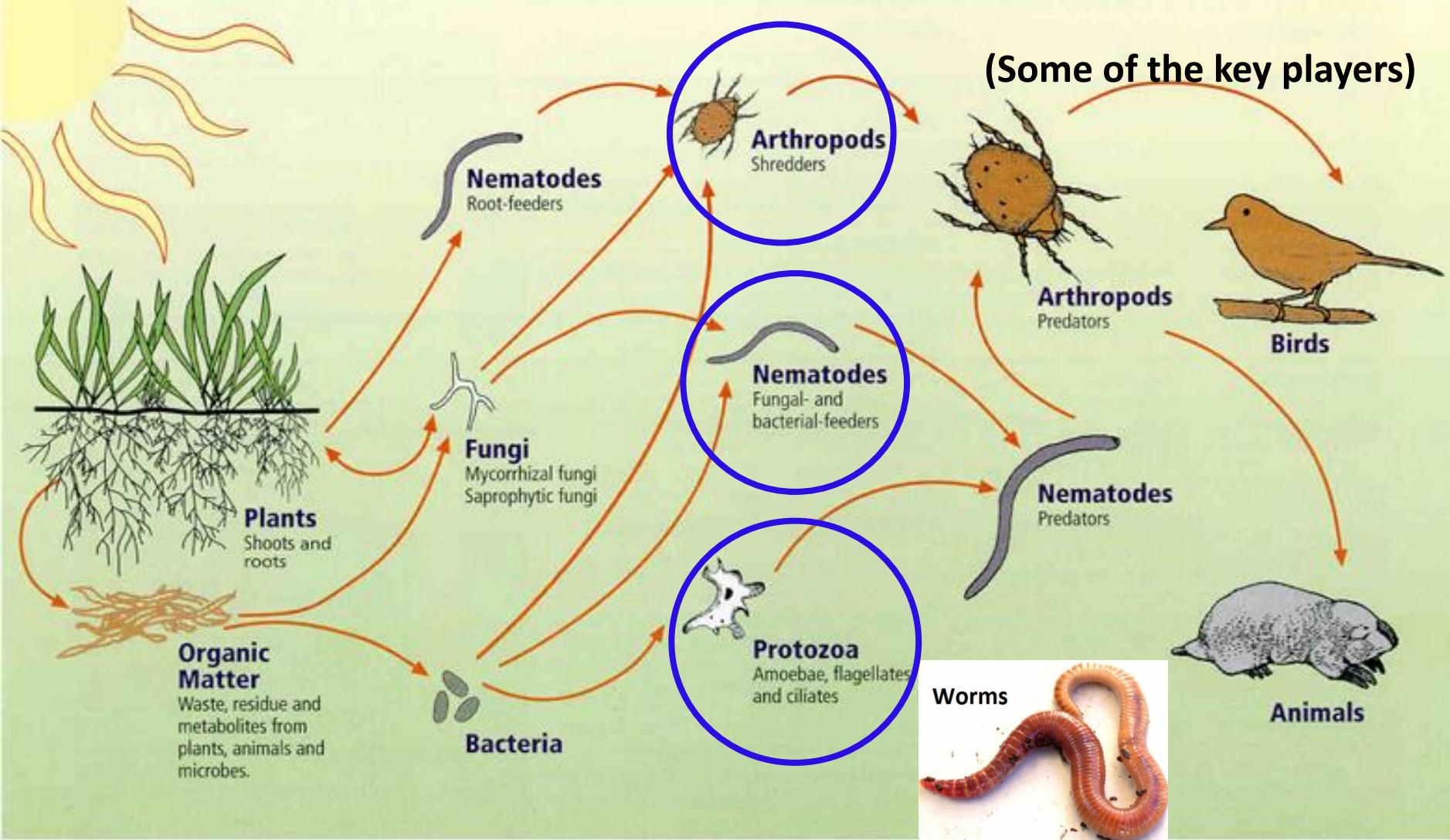
For a fascinating account of the mining capabilities of fungi see:

1) 'The World's Largest Mining Operation Is Run by Fungi'

Jennifer Frazer, Scientific American Nov. 5, 2015

2) 'Linking Plants to Rocks: ectomycorrhizal fungi mobilize nutrients from minerals'

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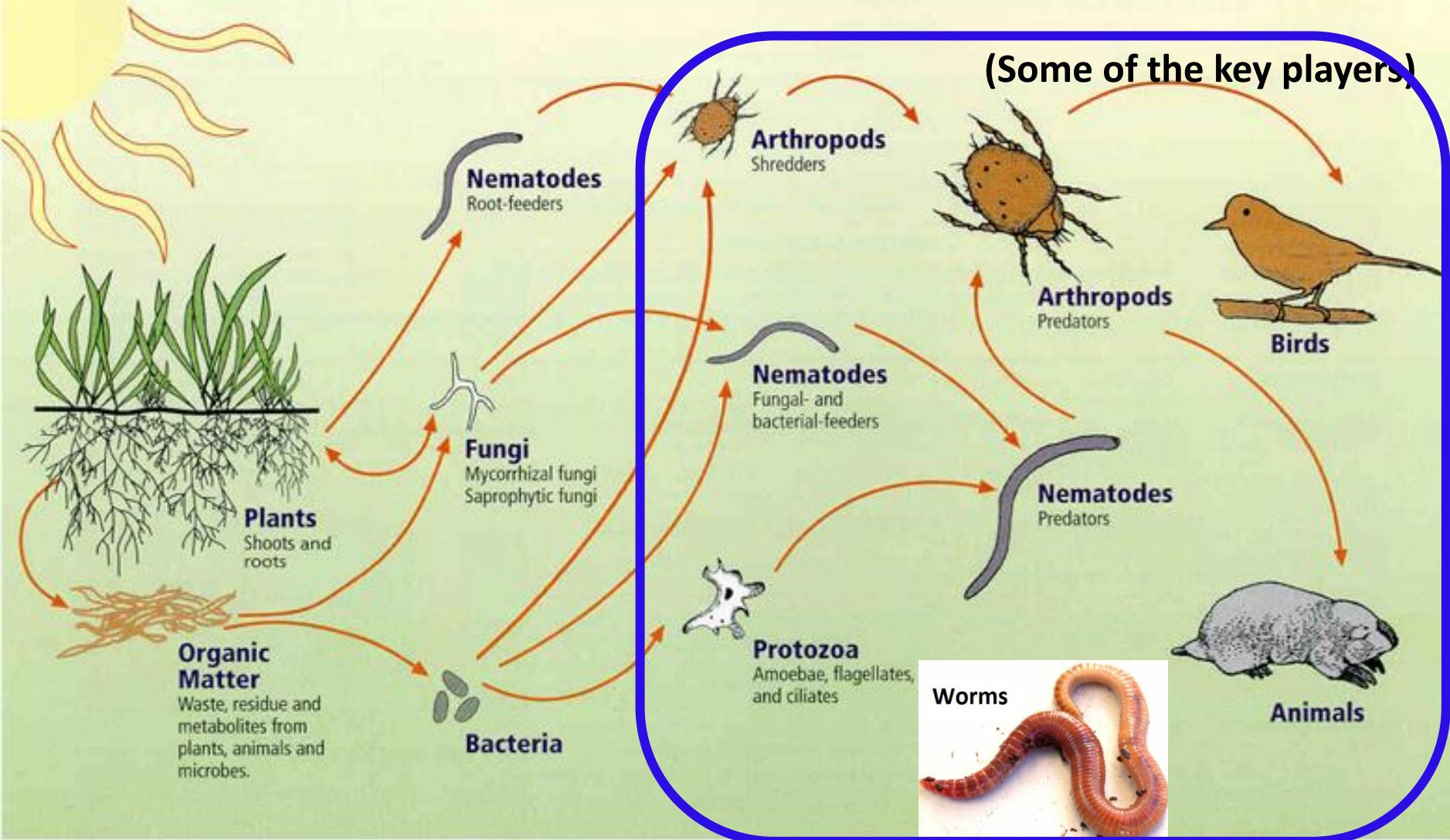
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**Plants are the
conductors of
this symphony
of nature**

How do they do it?



Credit: Argan tree at Agadir by lgt 1400 CC BY SA 4.0
https://commons.wikimedia.org/wiki/File:Argan_tree @_Agadir.jpg

Plants are the conductors of this symphony of nature

Up to 40% of the sugars, carbohydrates and proteins that plants produce are released from their roots to attract and feed the microbes the plant requires.

Called root exudates.



Credit: Argan tree at Agadir by lgt 1400 CC BY SA 4.0
https://commons.wikimedia.org/wiki/File:Argan_tree @_Agadir.jpg

“What do you make when you mix sugar, a carbohydrate like flour and protein like eggs and milk?

That’s a recipe for cakes and cookies. So the plant is putting out cakes and cookies to attract the microbes.”

Dr. Elaine Ingham



Credit: Argan tree at Agadir by lgt 1400 (CC BY SA 4.0)

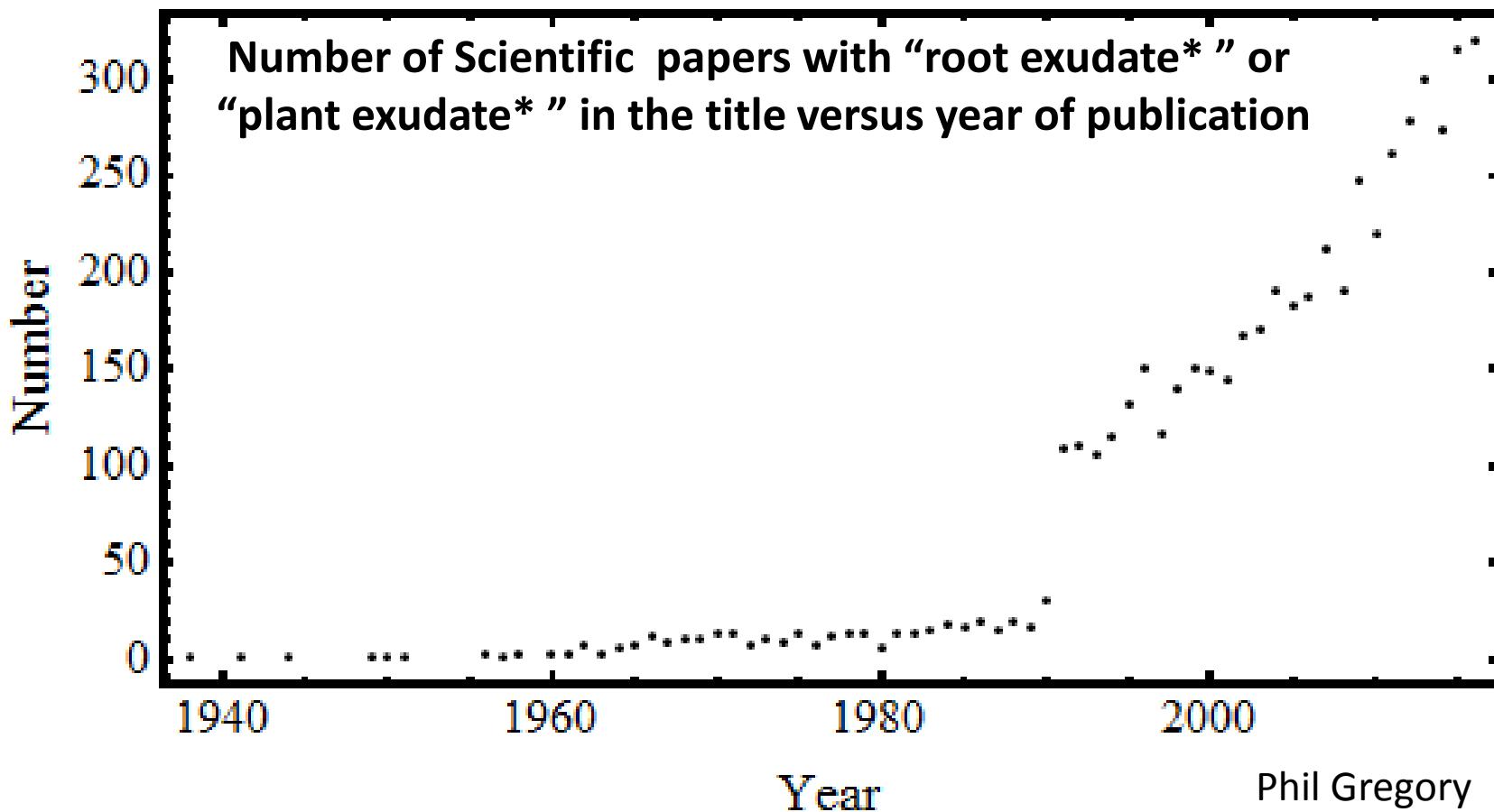
Plants also release exudates through their foliage.

In healthy soil conditions leaf surfaces are covered by microbes held to the plant by the strong biotic glues. That protective layer is one of nature's way of achieving disease suppression.

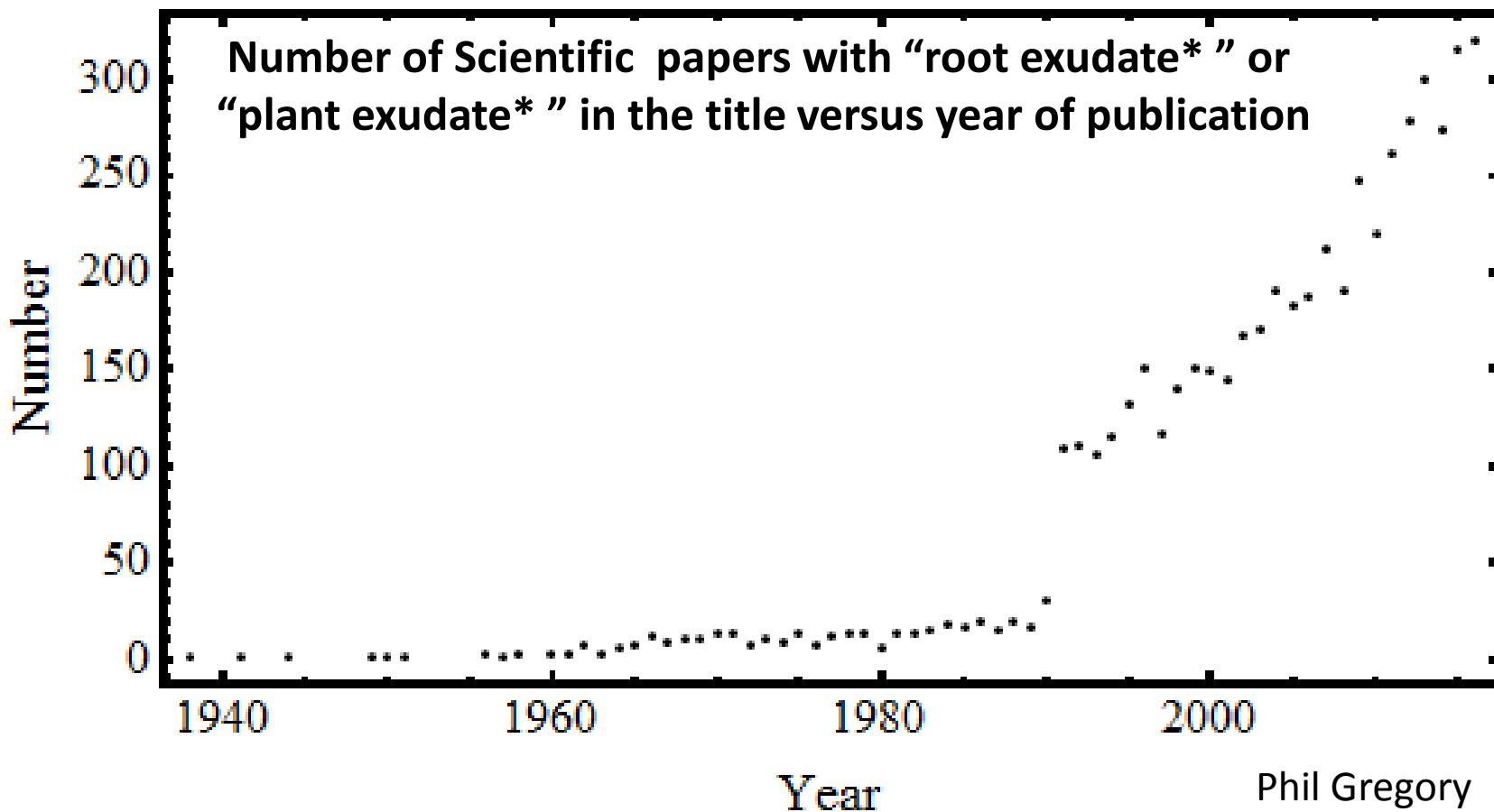


Credit: Argan tree at Agadir by lgt 1400 CC BY SA 4.0
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One indicator of the recent revolution in soil biology (sudden jump in publication rate in 1991)



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One of the key papers indicating the important role of soil biology:

“Interactions of Bacteria, Fungi, and their Nematode Grazers: Effects on Nutrient Cycling and Plant Growth,” by Russell E. Ingham, J. A. Trofymow, Elaine R. Ingham, and David C. Coleman, *Ecological Monographs*, Vol. 55, No. 1 (Mar., 1985), pp. 119-140. (672 citations to 2016)

Bacteria and fungi build soil structure



Together they build underground cities for the microbes to live in.

Bacteria secrete biotic glues that stick soil minerals and organic matter together in what are called microaggregates.

Fungal strands (right) tie microaggregates together forming aggregates.

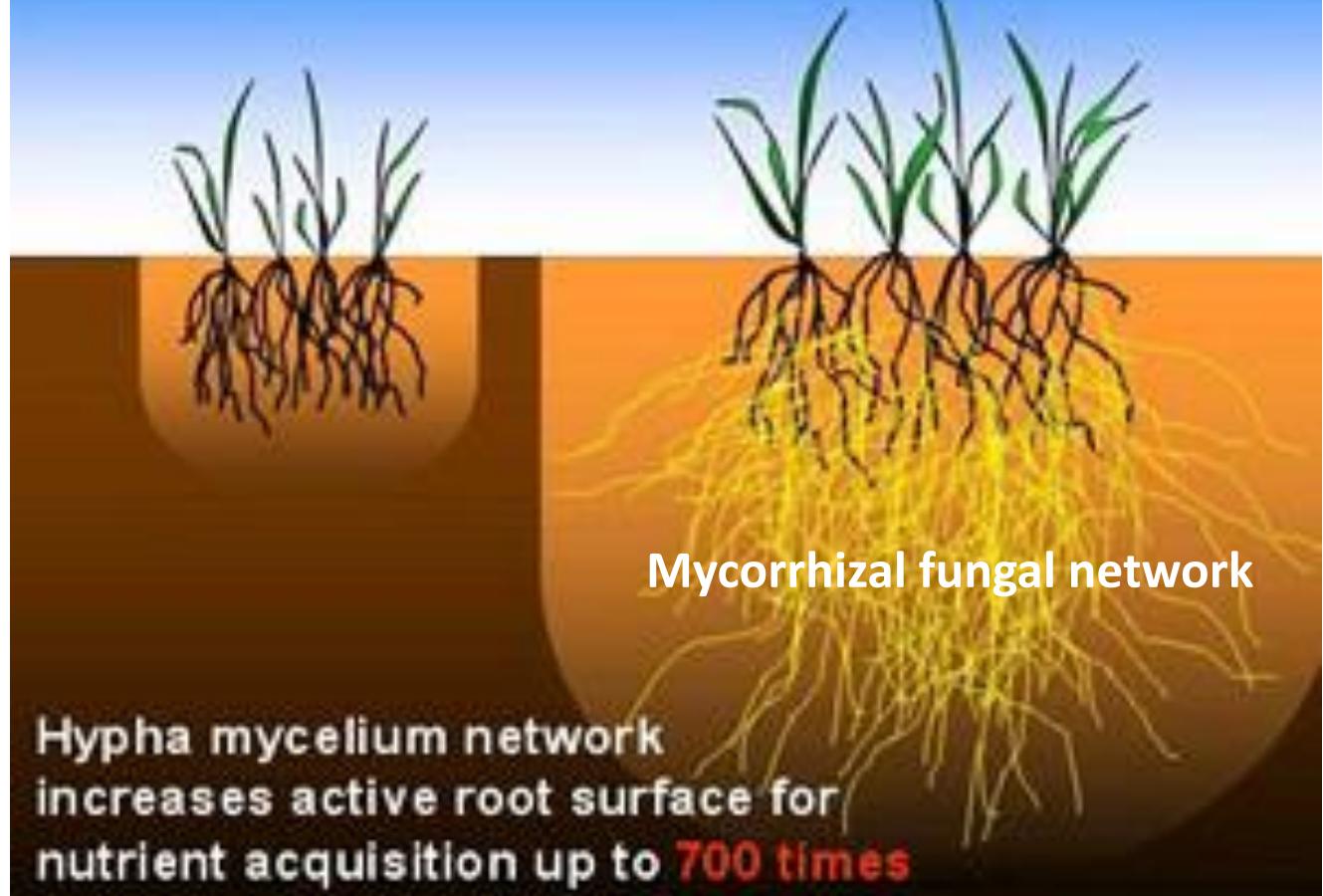


Largest organism

Mycorrhizal Fungal Network

Fungal hyphae are long thin strands, invisible to the naked eye.

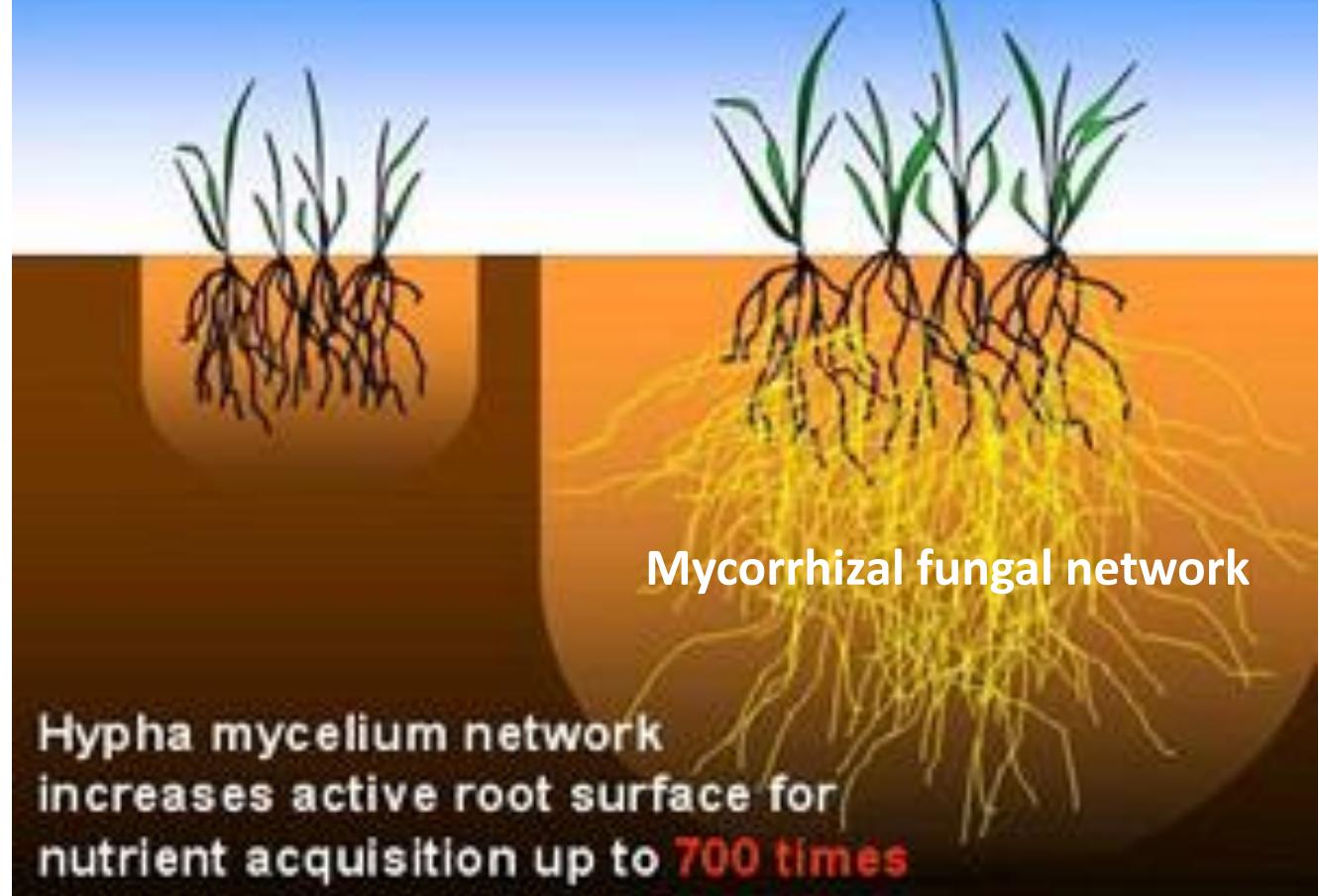
Mycelium is a visible network or bundle of hyphae, for example mold on spoiled food.



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Through the work of researchers like Professor Suzanne Simard of the University of British Columbia, we now know that fungal networks can link trees together in a **Wood Wide Web** allowing them to exchange signals as well as nutrients.

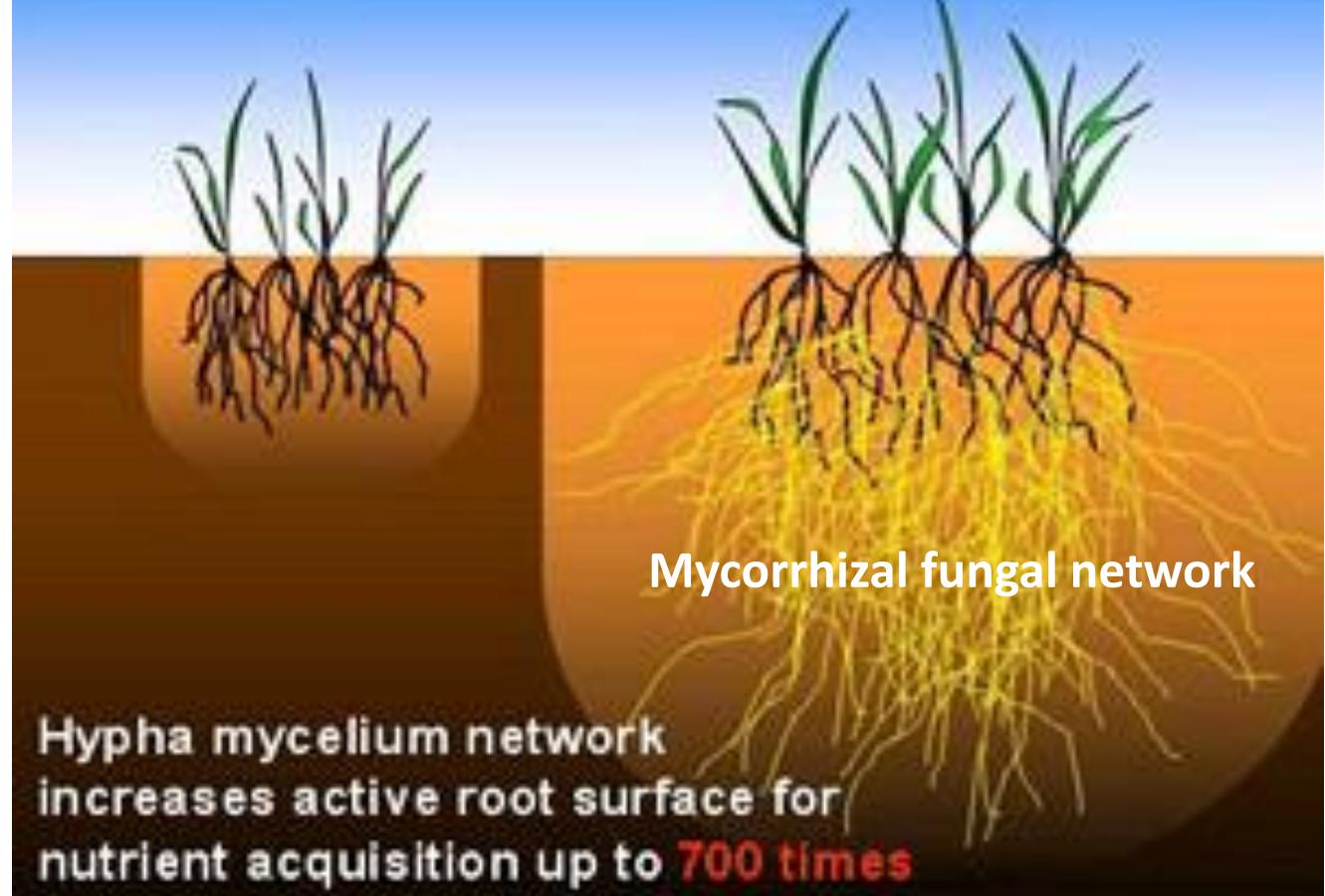
NATURE | VOL 388 | 7 AUGUST 1997

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Strange but True: the largest organism on Earth is a fungus, nearly 10 square km in size and estimated to be 2400 years old. (Oregon Blue Mountains)

Current Agricultural Practices

- Plowing or tillage
- Growing of monocultures in the belief that diversity means competition.
- Application of chemical fertilizers, herbicides and pesticides



https://commons.wikimedia.org/wiki/File:Potato_blight_spraying_system.jpg
Credit: Chafer Machinery (CC BY 2.0)



- Livestock in confinement (from poultry battery cages to feed lots)



Credit: SlimVirgin U.S. EPA, Public Domain
<https://commons.wikimedia.org/wiki/File:Confined-animal-feeding-operation.jpg>

**Plowing slices and dices
the soil structure built by
bacteria and fungi with
their biotic glues - turning
living soil into dirt.**

Credit: Trish Steel, (CC BY-SA 3.0)



https://commons.wikimedia.org/wiki/File:Feeding_Frenzy,_Faulston_Farm_-_geograph.org.uk_-_702677.jpg



Credit: Aalang (CC BY-SA 3.0)

https://commons.wikimedia.org/wiki/File:Plowing_ecomat.jpg

Credit: Trish Steel, (CC BY-SA 3.0)



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Credit: Aalang (CC BY-SA 3.0)
https://commons.wikimedia.org/wiki/File:Plowing_ecomat.jpg

Those underground cities were home to a diverse ecosystem capable of providing all the nutrients plants required without the need for chemical fertilizers.

About 20 years ago it was discovered that plowing releases additional soil carbon into the atmosphere as climate warming CO₂

Credit: Trish Steel, (CC BY-SA 3.0)



https://commons.wikimedia.org/wiki/File:Feeding_Frenzy,_Faulston_Farm_-_geograph.org.uk_-_702677.jpg



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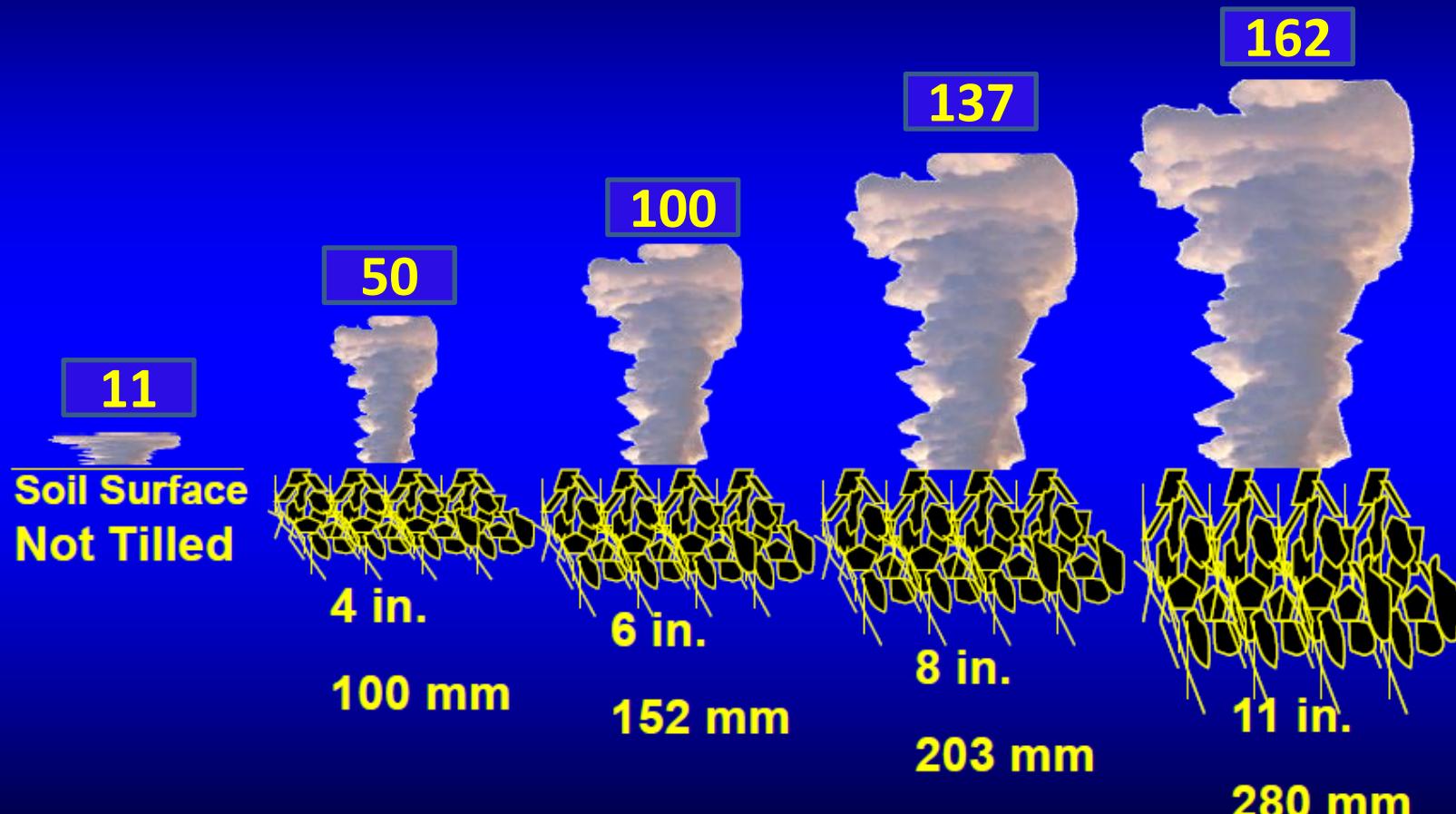
CO₂ loss

Effect of tilling on CO₂ emission

Dr. Don Reicosky , USDA
Agricultural Research Services

12 Aug., 1998 Plow Depth Study Swan Lake Farm

24 hour cumulative CO₂ losses (g CO₂ m⁻²)



Improved analysis allowing for weather-induced temporal variability

D.C. Reicosky and D. W. Archer, Soil and Tillage Research, Vol. 94, Issue 1, pp. 109–121, 2007

Tillage and planting: impact on carbon and soil quality

Dr. Don Reicosky USDA-ARS

M = Mobile

R. = Research

G = Gas

E = Exchange

M = Machine

MR. GEM



<http://www.fairfieldswcd.org/Attachments/Soil%20Quality.pdf>

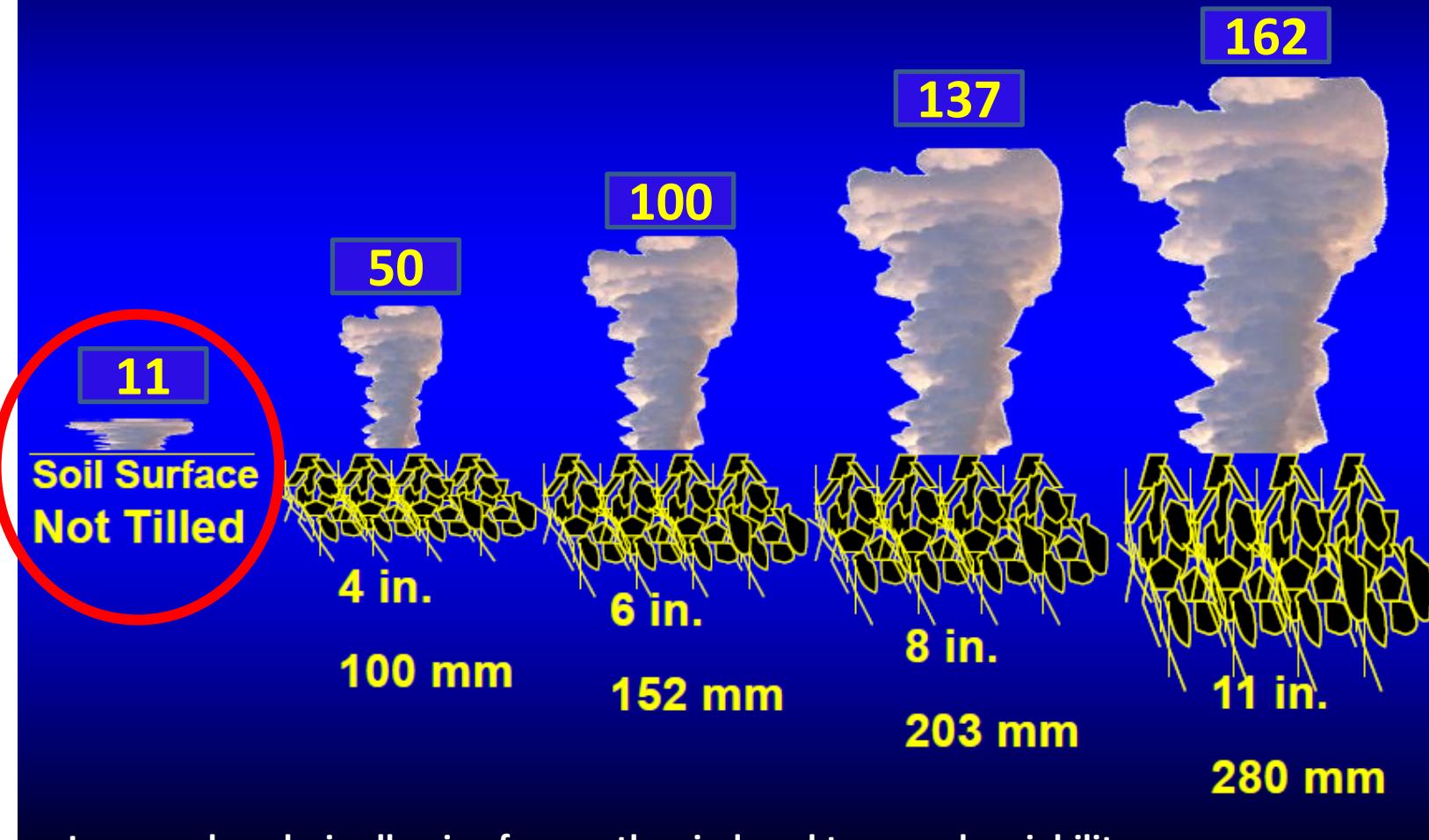
1 min soil videos

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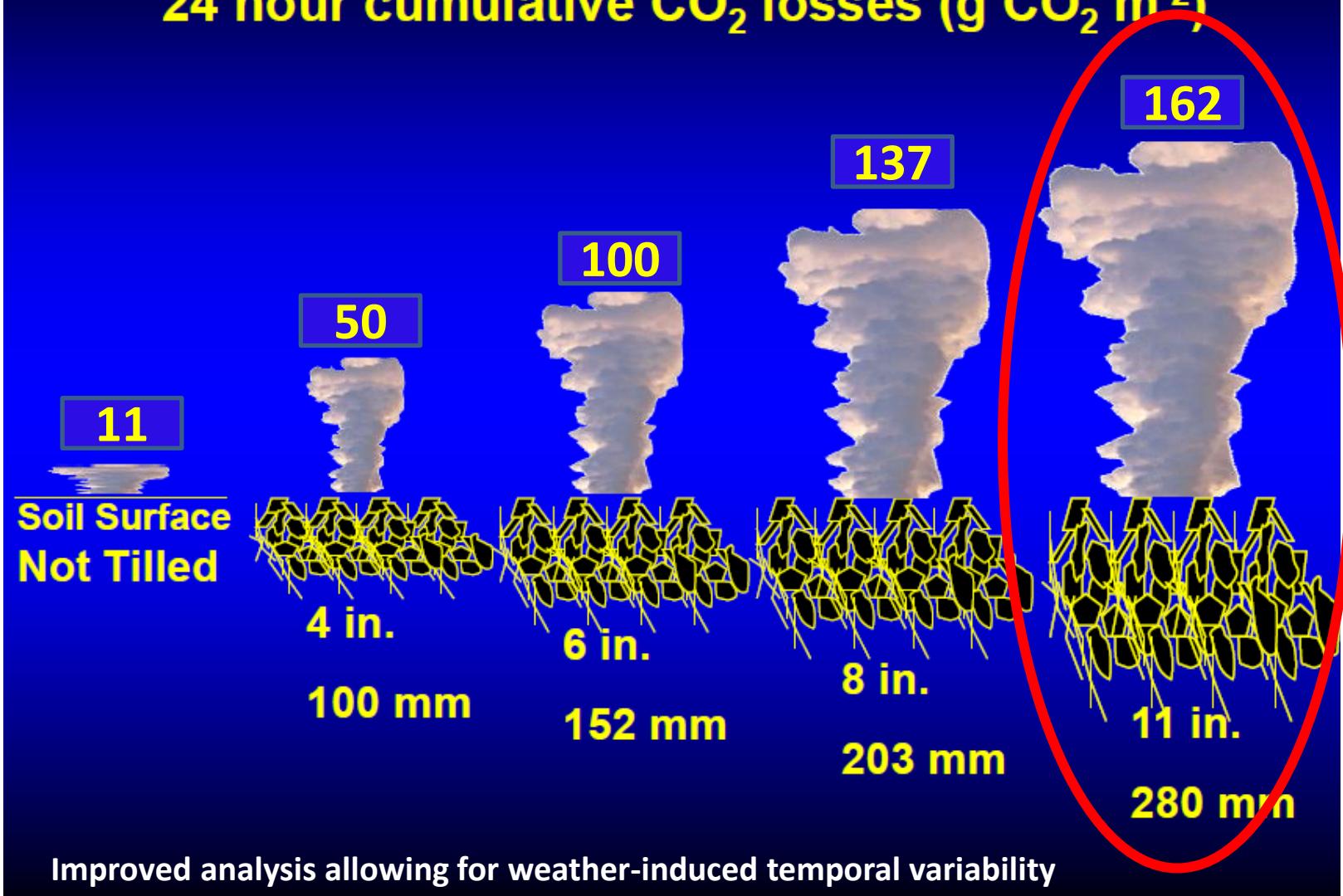


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Soil health lessons in a minute

by Ray Archuleta, USDA

Water infiltration test: shows how healthy soil can infiltrate and capture much more of the rainfall and store it in the soil. This alleviates drought and prevents soil erosion

Permission granted by USDA Natural Resources Conservation Service

https://www.youtube.com/watch?v=Rpl09XP_f-w

Laptop link

Each soil sample used in the demonstration was air dried

Soil health lessons in a minute

by Ray Archuleta, USDA

Soil stability test: comparison of healthy soil with lots of microbes creating biotic glues and fungal strands that hold the soil together, to soil that has been turned to dirt by repeated plowing.

Permission granted by USDA Natural Resources Conservation Service

https://www.youtube.com/watch?v=9_ItEhCrLoQ

Laptop link

Each soil sample used in the demonstration was air dried

Soil Erosion

Without the biotic glues and living plant roots, soil is easily washed away by rain or blown away during periods of drought, creating massive dust storms.

Dust storm approaching Stratford, Texas 1935.



Back in the 1930's we had no idea how plowing upset the work of soil biology

Credit: NOAA George E. Marsh Album (Public Domain)

<https://commons.wikimedia.org/w/index.php?title=Special%3ASearch&profile=default&search=2015+dust+storm+Colorado&fulltext=Search&uselang=en>

Try to imagine waking up to your house buried after one of these storms.



SOIL DRIFTING OVER HOO HOUSE - S. DAK. - 1935

Dust storm Phoenix 5 July 2011



Credit: Roxy Lopez (CC BY – SA 3.0)

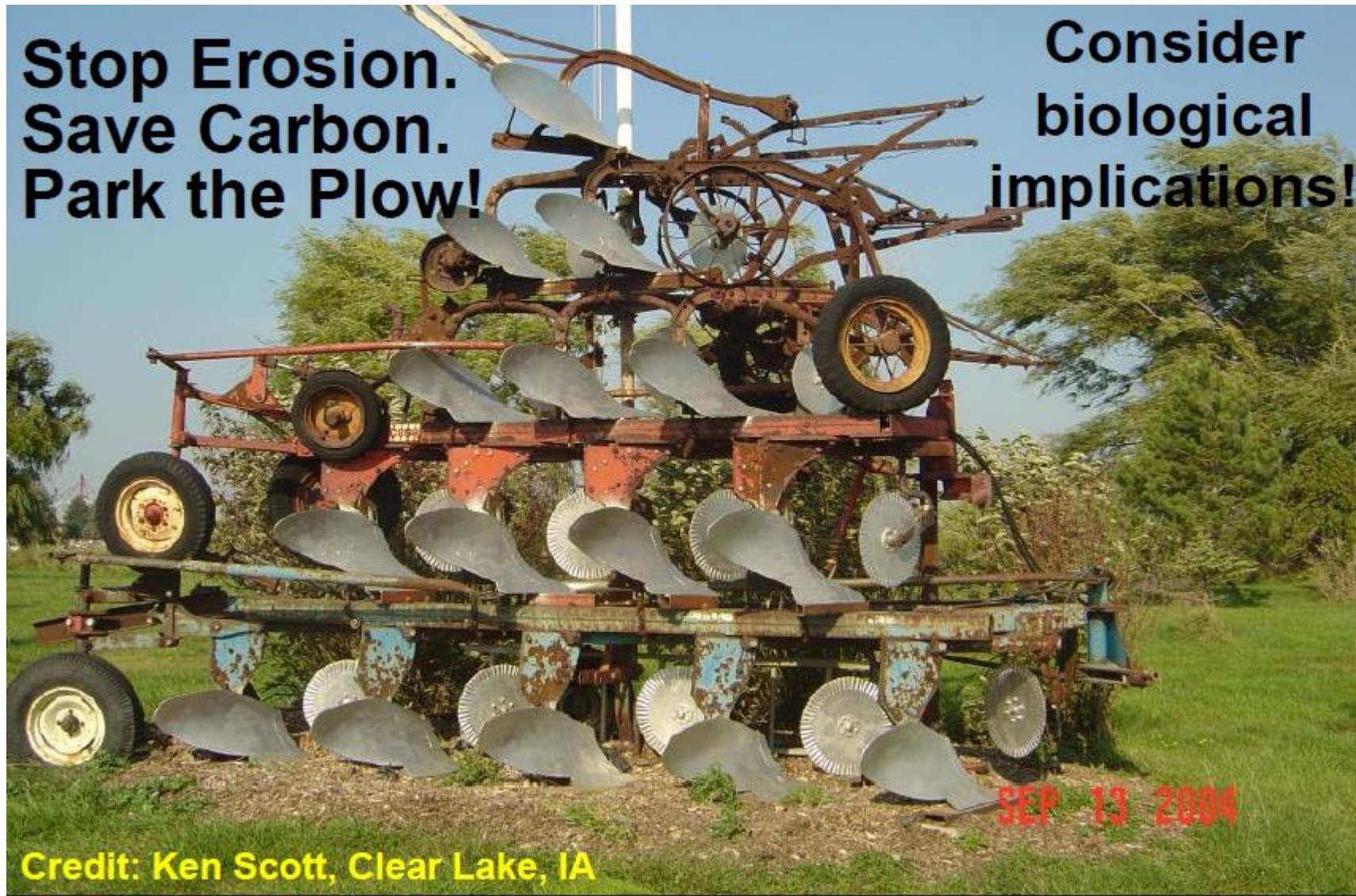
<https://commons.wikimedia.org/wiki/File:Duststorm.jpg>

Retire the plow

Time to Retire the Plow

Stop Erosion.
Save Carbon.
Park the Plow!

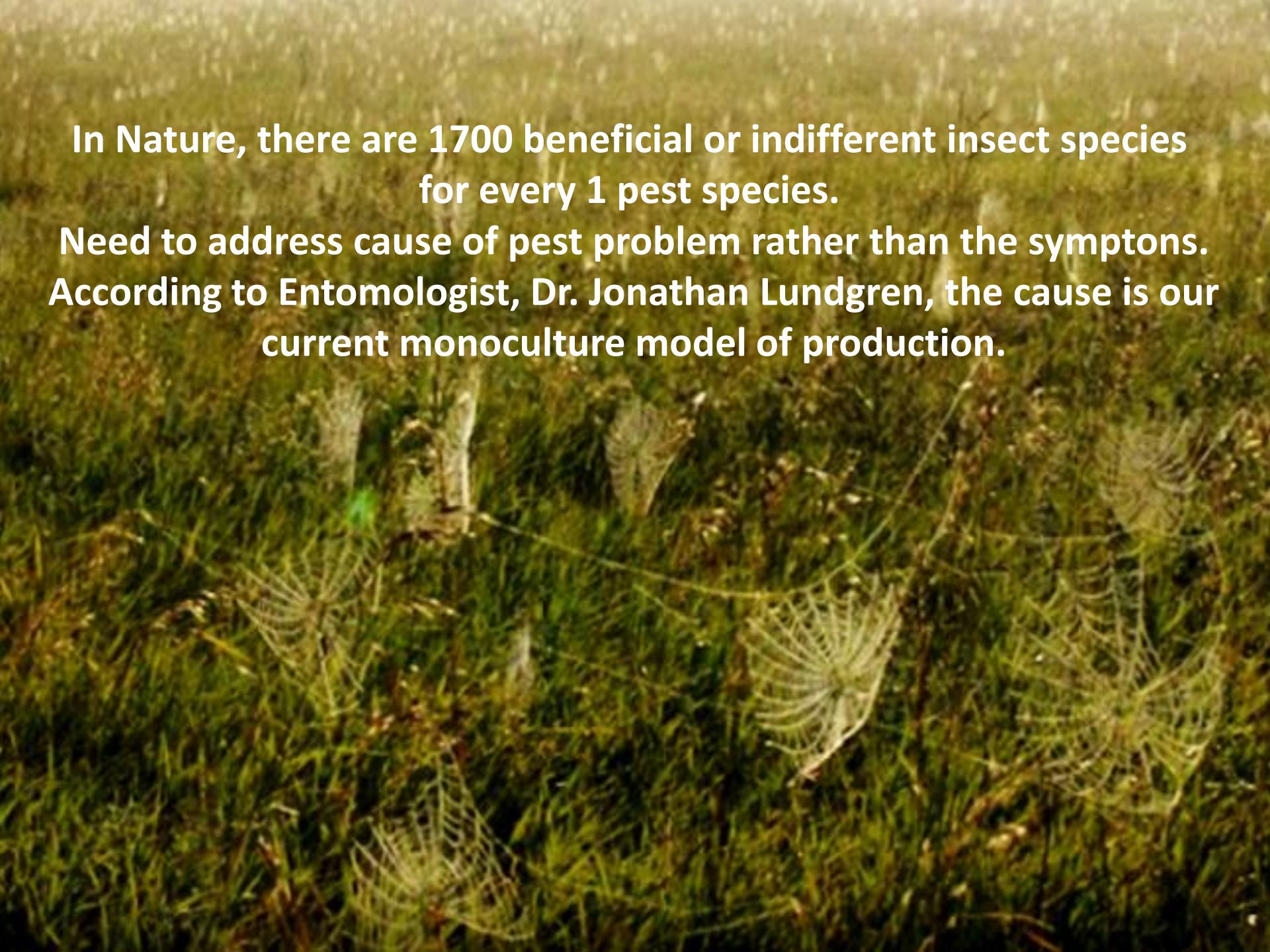
Consider
biological
implications!



Credit: Ken Scott, Clear Lake, IA

**Much of current agricultural is about killing:
weeds, fungi, insects, biodiversity, and even the farmer's profit**





**In Nature, there are 1700 beneficial or indifferent insect species
for every 1 pest species.**

**Need to address cause of pest problem rather than the symptoms.
According to Entomologist, Dr. Jonathan Lundgren, the cause is our
current monoculture model of production.**



We try to keep monoculture production
and the factory-farming of livestock viable
through chemistry, drugs, machinery,
genetic engineering and
ultimately cash subsidy.

(Allan Savory, Holistic Management)



**Current agricultural model uses 10 calories of fossil fuel energy
to produce one calorie of food.**

Alternative Agricultural Model

Nature's way (biomimicry)

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Nature's way is sustainable and more profitable for the farmer

**Move to regenerative agriculture where we
rebuild the soil biology and
sequester more carbon at the
same time as we grow food.**

How to rebuild the soil biology?

- By inoculating the dirt with a thin layer of compost or by spraying with a compost extract or compost tea made from the compost.

It is important to ensure the compost is teeming with a good selection of soil microbes using a soil microscope.



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- Ensure a good cover of plants providing root exudates to feed the microbes.
- **Stop plowing and stop using synthetic fertilizers, herbicides and pesticides.**

Soil Solutions to Climate Problems

**Video created by the Center for Food Safety
19 Nov 2015, Narrated by Michael Pollan**

Permission granted by the Center for Food Safety

<https://www.youtube.com/watch?v=NxqBzrx9yIE>

Laptop link

What about livestock grazing?

According to the UN Food and Agriculture Organization 62% of agricultural land is used for grazing.



NASA

The areas in brown are dryland regions that are the current and former grasslands of the world which are turning or have turned to desert.

Desertification

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According to one of my agricultural heroes, the African biologist Allan Savory, we were once just as certain that the earth was flat. As he has shown, it is not about numbers, it is all about timing.

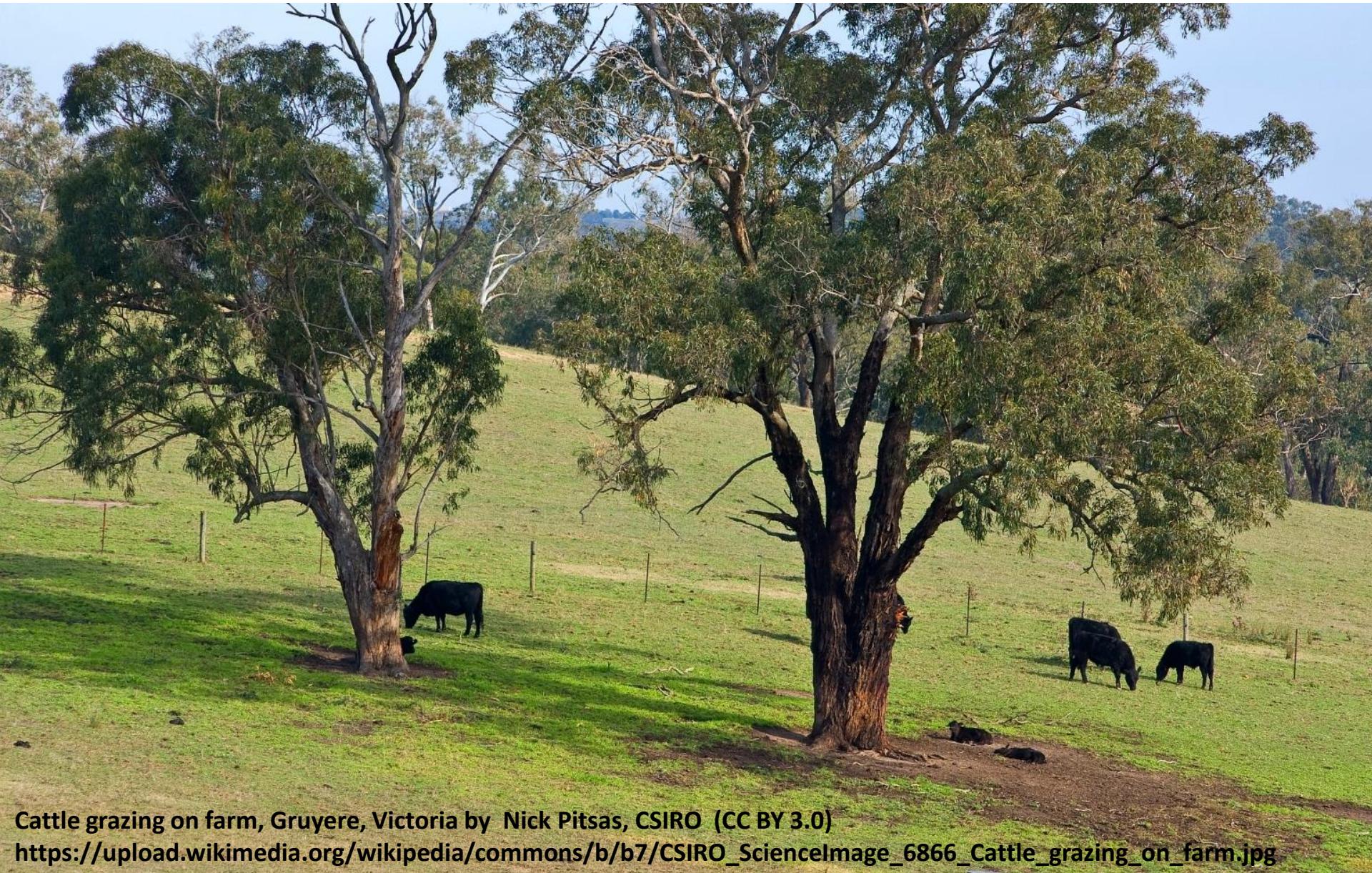
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It's our failure to manage plant recovery time that leads to overgrazing and land desertification.

Continuous grazing is a common practice in which livestock have unrestricted access throughout the grazing season.



Cattle grazing on farm, Gruyere, Victoria by Nick Pitsas, CSIRO (CC BY 3.0)

https://upload.wikimedia.org/wikipedia/commons/b/b7/CSIRO_SciencelImage_6866_Cattle_grazing_on_farm.jpg

Aerial view of a herd of wildebeest



Credit: by T. R. Shanker Raman (CC BY 3.0) http://commons.wikimedia.org/wiki/File:Wbeest_Mara.jpg



Credit: Kevin Pluck (CC BY 2.0)
[https://commons.wikimedia.org/wiki/
File:Lion_waiting_in_Namibia.jpg](https://commons.wikimedia.org/wiki/File:Lion_waiting_in_Namibia.jpg)

**Wildebeests only safe
inside the herd.**



Credit: by Guido Appenzeller (CC BY 2.0)
[https://commons.wikimedia.org/wiki/
File:Spotted_hyena_gnawing_gnu.jpg](https://commons.wikimedia.org/wiki/File:Spotted_hyena_gnawing_gnu.jpg)

Wildebeest close up

Herd has to keep moving to avoid eating their own waste so don't get to eat grass as it regrows.

By the time herd returns from their migration the grass is fully grown and ready to be eaten.



How can humans imitate nature?

One method: use electric fence to emulate the predators



Regenerative Grazing

The farmer spends about 20 minutes each day setting up the electric fence for the next paddock.



Neil Dennis, Saskatchewan rancher

Wait a minute - aren't we supposed to eat less meat?

Methane produced by ruminants is a potent green house gas (GHG)

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Methane produced by ruminants is a potent green house gas (GHG)

But we have been ignoring a whole other side to this story.

When herbivores are adaptively grazed to emulate nature there is a net reduction in GHG. The GHG emission of methane is more than compensated for by the amount of atmospheric carbon sequestered in the soil.

Some of the recent science.

W.R. Teague et al., Journal of Soil and Water Conservation, 71, #2, p. 156, 2016

Tong Wang et al., *Sustainability* **2015**, 7(10), 13500-13521

<https://www.youtube.com/watch?v=crG4L4J-OEg>

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Grass fed cattle, sheep and goats can be a big part of the solution if we manage plant recovery time (regenerative grazing).

See the TED talk by Allan Savory at

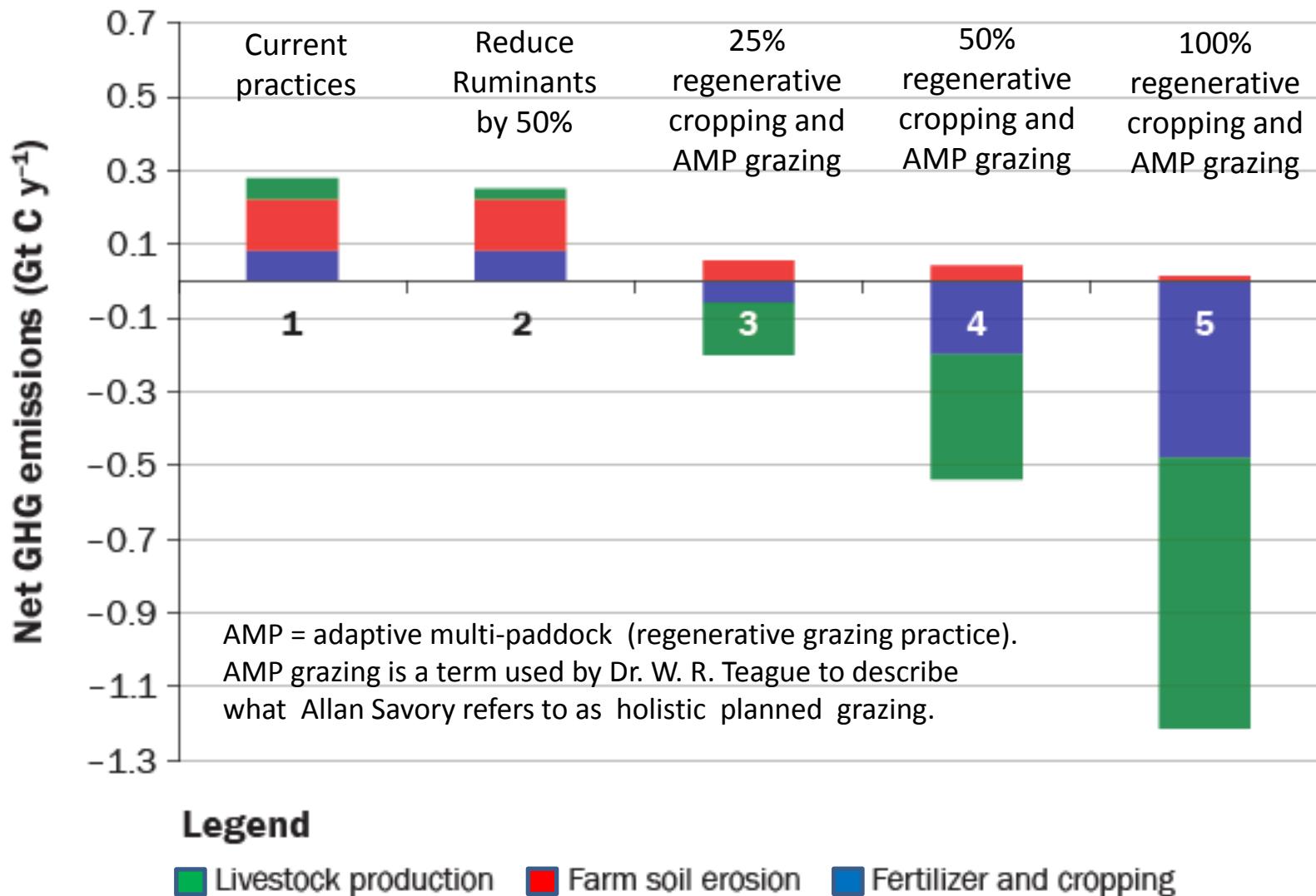
https://www.ted.com/talks/allan_savory_how_to_green_the_world_s_deserts_and_reverse_climate_change?language=en

What is the evidence that regenerative agriculture leads to carbon sequestration?

Best working hypothesis for North American agricultural greenhouse gas (GHG) emissions for a transition to regenerative cropping and regenerative grazing practices

Based on: W.R. Teague + 11 authors, Journal of Soil and Water Conservation, 71, #2, p. 156, 2016

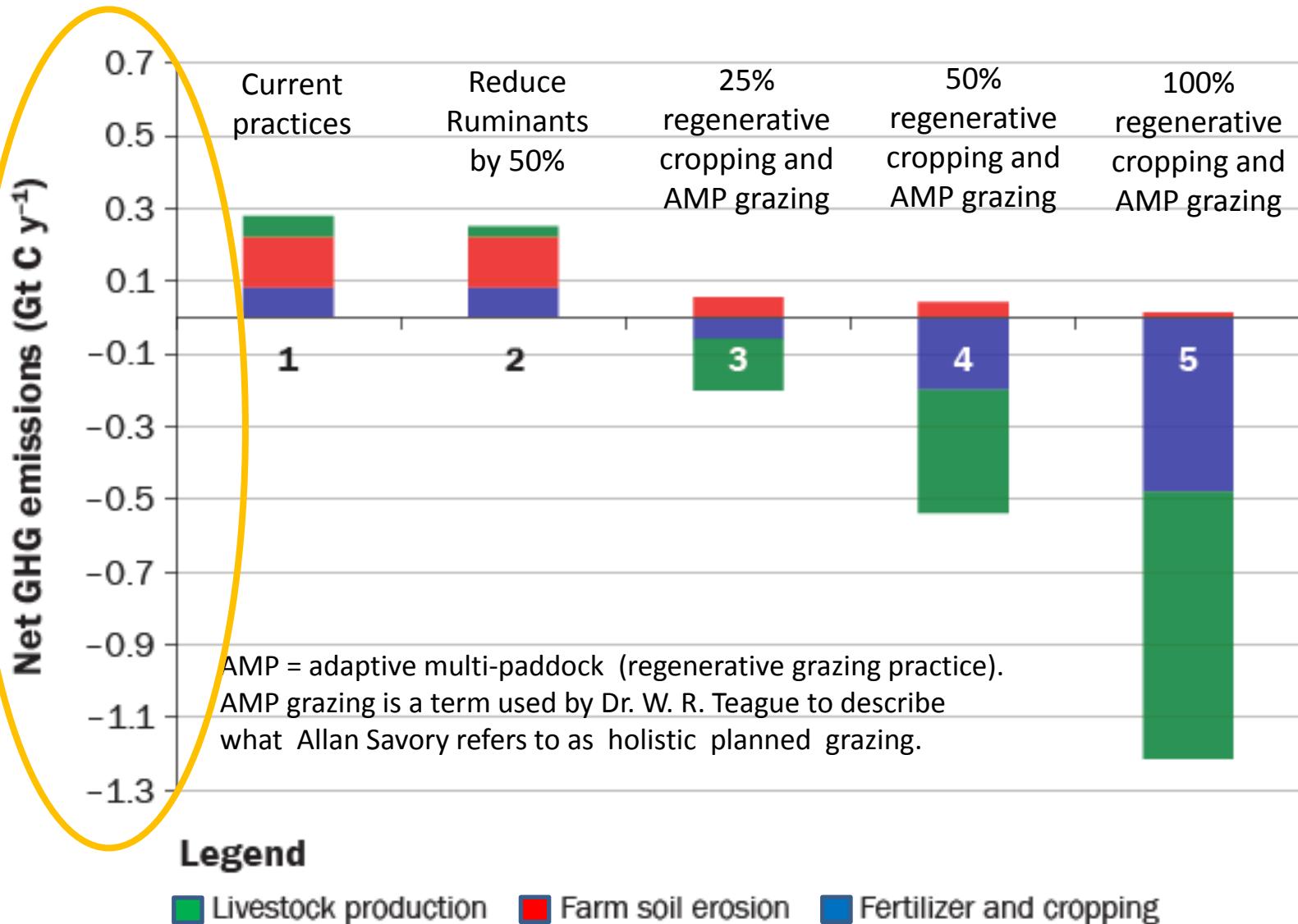
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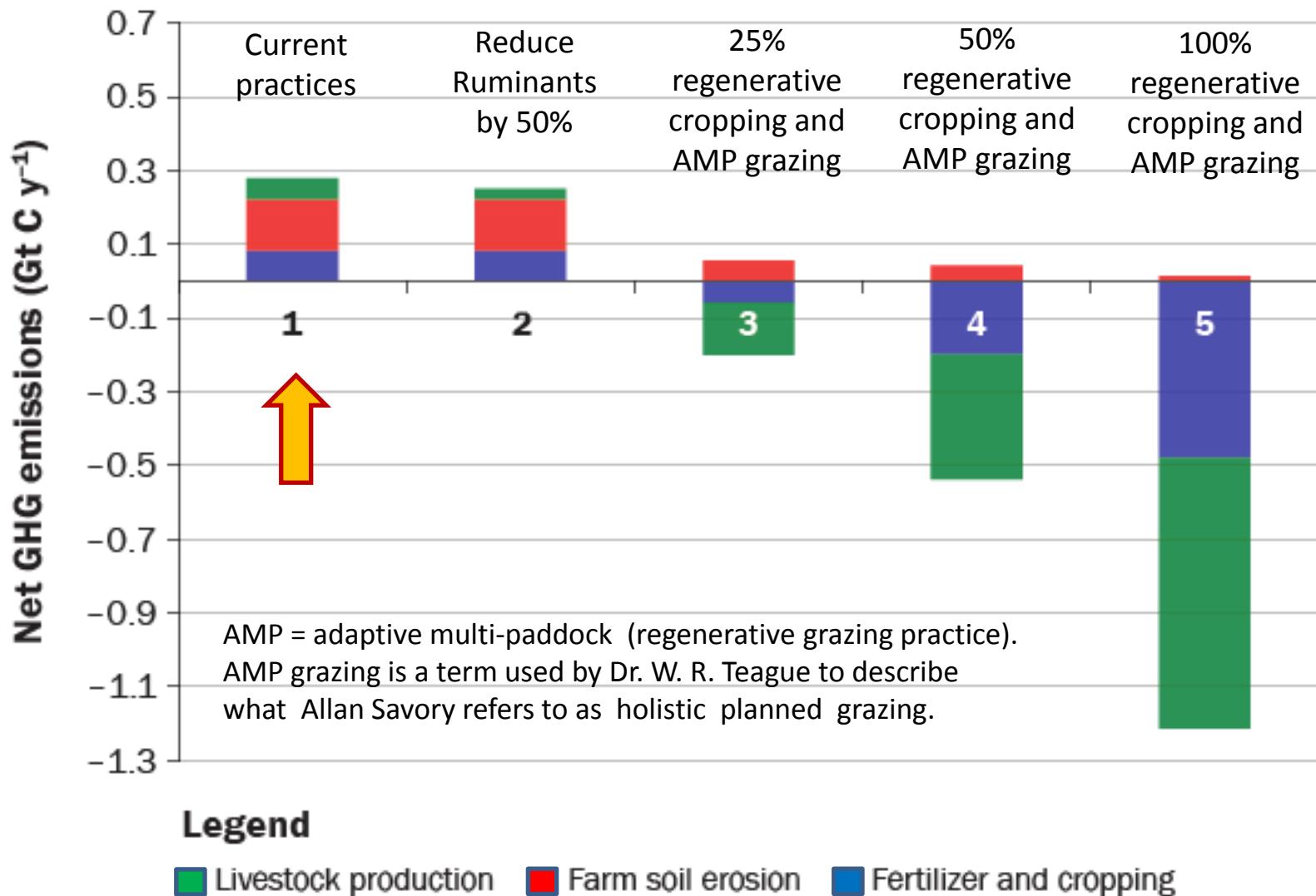
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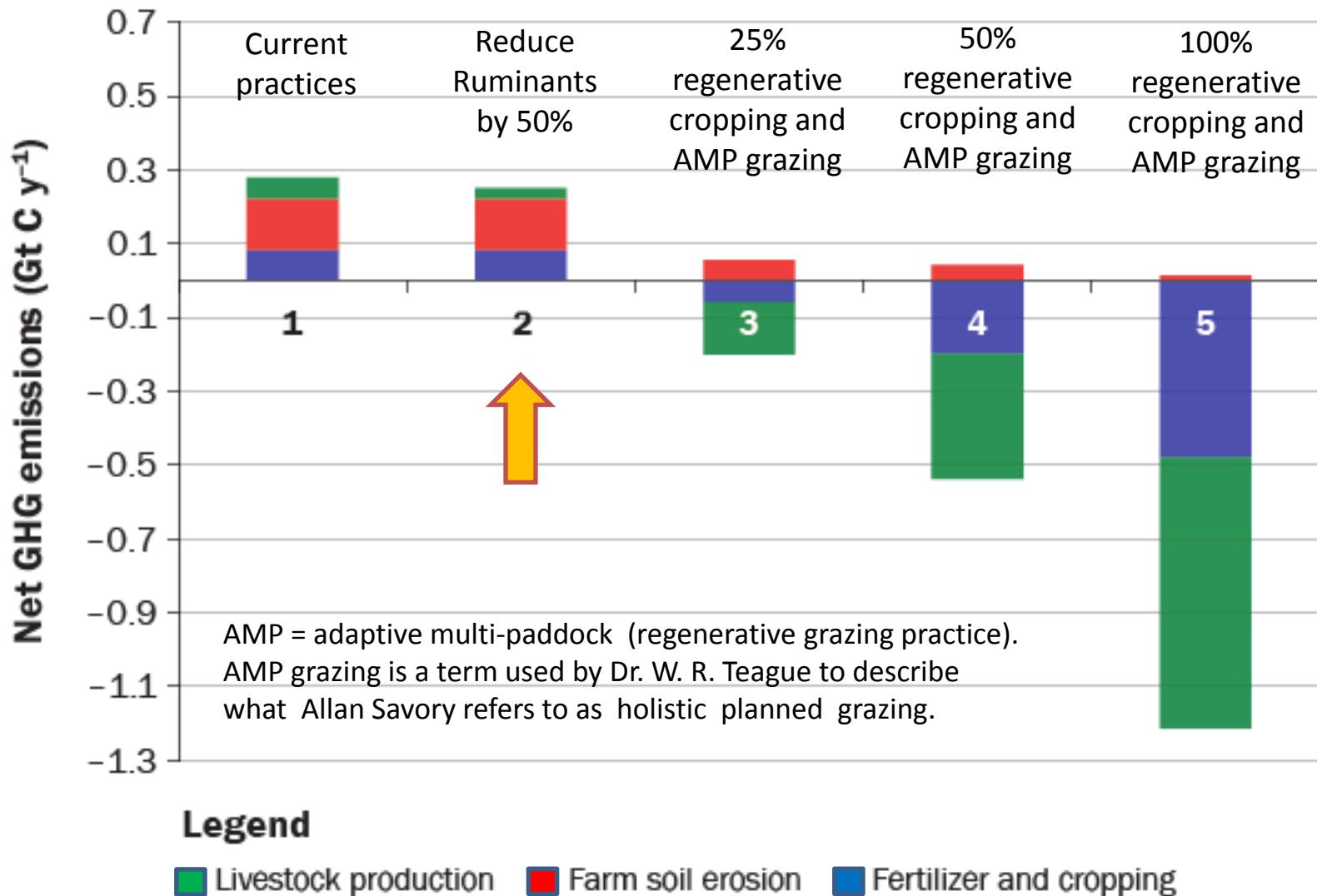
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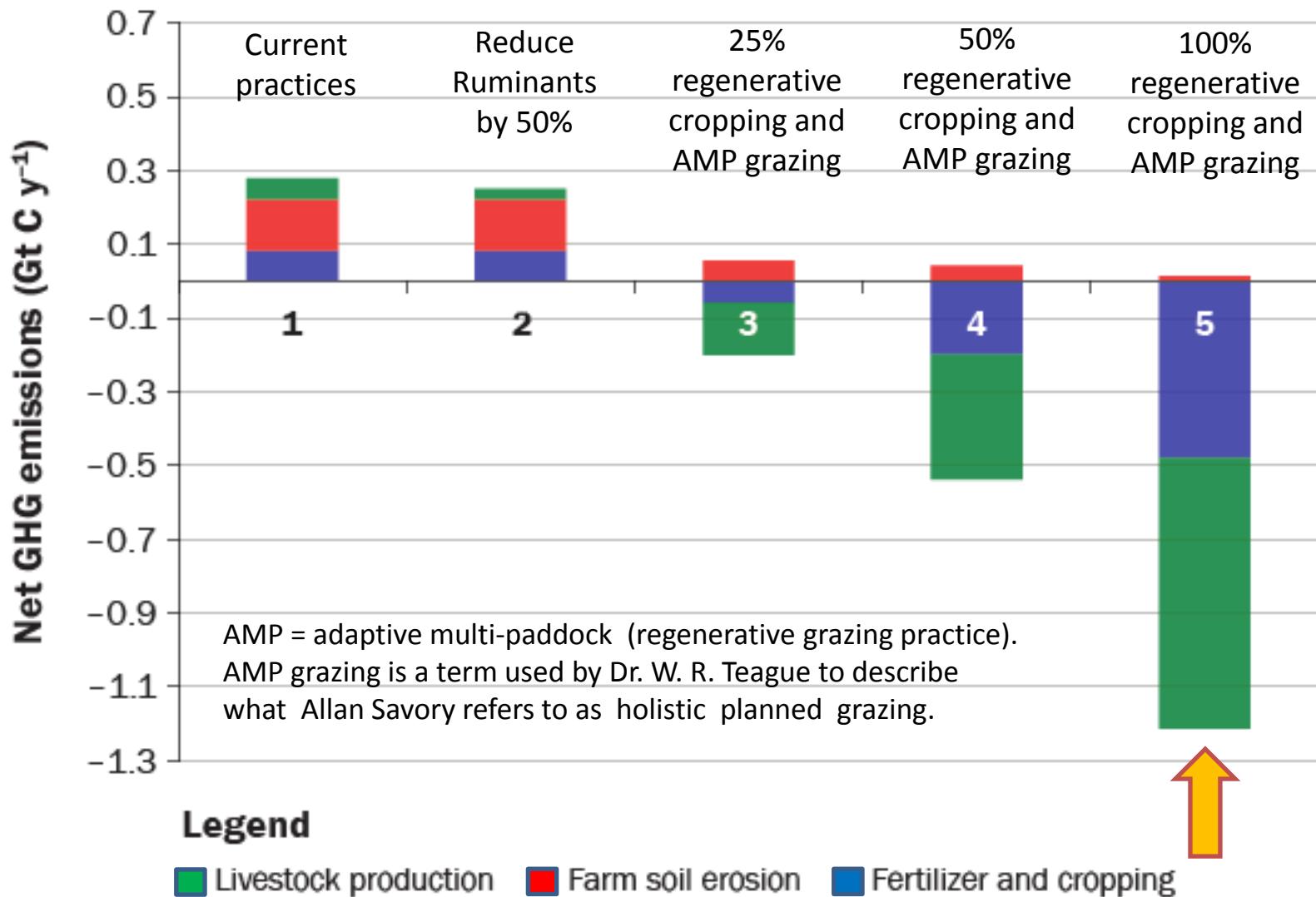
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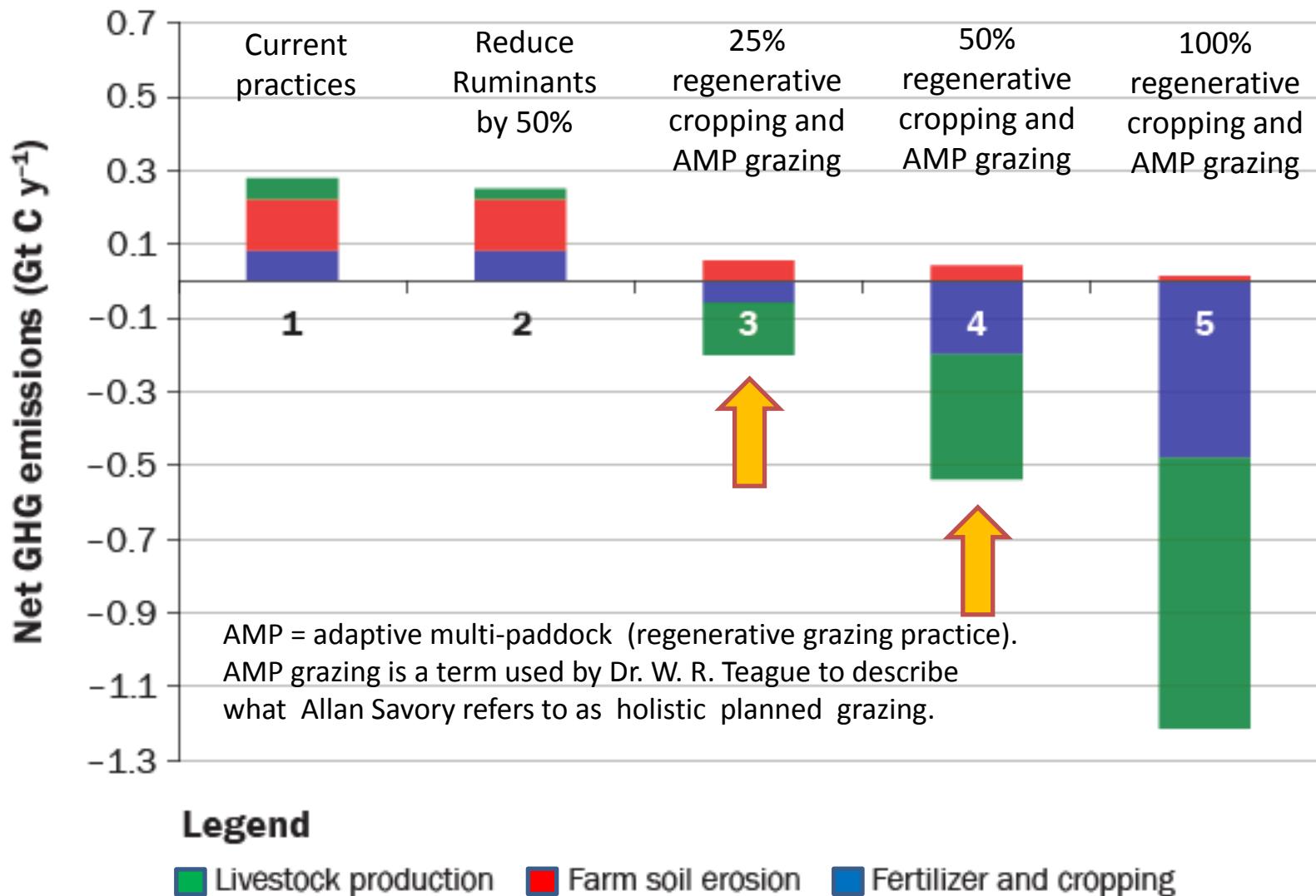
See also Quivira Conference presentation <https://www.youtube.com/watch?v=crG4L4J-OEg>



Best working hypothesis for North American agricultural greenhouse gas (GHG) emissions for a transition to regenerative cropping and regenerative grazing practices

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Two Steps Forward Can McDonald's help solve climate change?

Joel Makower

Monday, December 4, 2017 - 2:11am

Earlier this year, McDonald's stepped in to help fund a project on **Adaptive Multi-Paddock (AMP) Grazing** through a matching grant of \$4.5 million over three years, or 25 percent of the project's overall funding goal.

<https://www.greenbiz.com/article/can-mcdonalds-help-solve-climate-change>

Background

The project was initiated by Peter Byck, a professor in Arizona State University's School of Sustainability. In 2014, Byck produced a 12-minute video on "[Soil Carbon Cowboys](#)," which highlighted some of the innovative farmers employing AMP grazing.

A year later, Byck assembled a team of scientists to study the impacts of AMP grazing with the goal of drawing down greenhouse gas emissions.

<http://www.soilcarboncowboys.com/research>

Potential for Improved Data

Over the next 4 years we may also acquire a lot more data as the French Government has embarked on an regenerative agriculture program aimed at sequestering large amounts of atmospheric carbon with improved soil monitoring.
This ‘4 per 1000’ initiative was announced at the 2015 Paris Climate Meeting COP 21.

(For more ongoing research in regenerative agriculture see the supplementary notes.)

French Government's '4 per 1,000' Initiative proposed at the Paris Climate meeting COP 21

France is committed to ensuring that at least 50% of its agricultural holdings will have adopted this approach by 2020.

4 PER 1000 CARBON SEQUESTRATION IN SOILS FOR FOOD SECURITY AND THE CLIMATE

Ministère de l'Agriculture, de l'Agroalimentaire et de la Forêt

The quantity of carbon contained in the **atmosphere** increases by 4.3 billion tons every year

+4.3

bn tons carbon / year



CO₂ emissions



Forests ⊕⊕

Oceans ⊕⊕

Human activities ⊕⊕⊕⊕

Deforestation ⊕

⊖ absorption ⊕ emission

The world's **soils** contain 1 500 billion tons of carbon in the form of organic material

absorption of CO₂ by plants



storage of organic carbon in soils

1500

bn tons carbon

If we increase by 4‰ (0.4%) a year the quantity of carbon contained in soils, we can halt the annual increase in CO₂ in the atmosphere, which is a major contributor to the greenhouse effect and climate change

increased absorption of CO₂ by plants :



farmlands, meadows, forests...



+4‰ carbon storage in the world's soils

= more fertile soils
= soils better able to cope with the effects of climate change

Countries participating in the French “4 pour 1000” initiative (as of Nov. 2016)

Australia	Mexico
Austria	Morocco
Bulgaria	Netherlands
Costa-Rica	New Zealand
Croatia	Philippines
Denmark	Poland
Estonia	Portugal
Ethiopia	Slovenia
Finland	Spain
France	Sweden
Germany	Tunisia
Hungary	Ukraine
Iran	United Kingdom
Ireland	Uruguay
Japan	Andalusia
Latvia	Wallonie Region
Lithuania	

**Hopefully more countries
will join this important
initiative**

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- 7) Reduced workload for farmer as the soil biology does most of the work.
- 8) More nutritious food.

Video showing the connections between Soil Carbon, Climate Change, and Food Security

“The Soil Story”

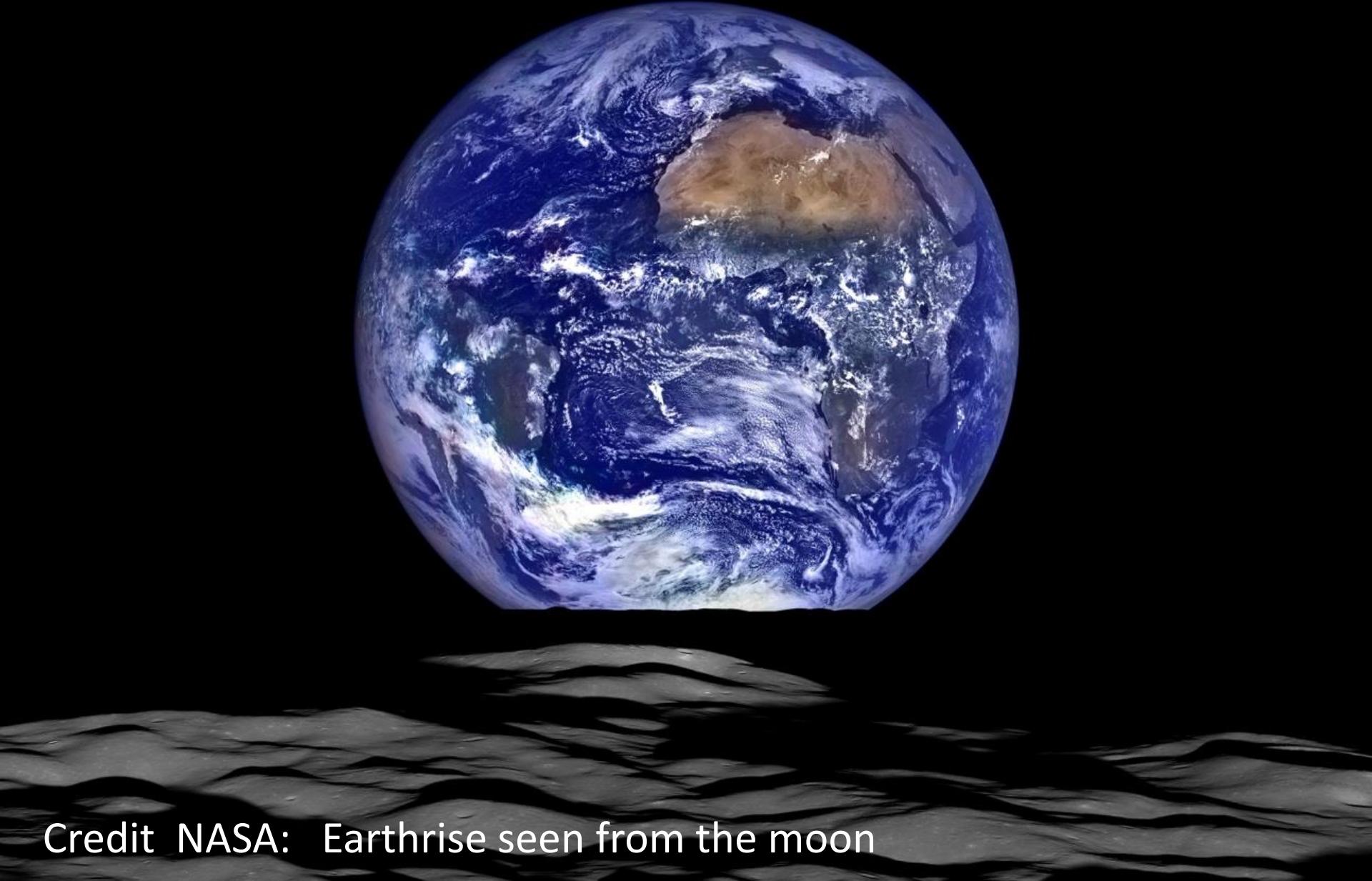
was produced by Kiss the Ground and is narrated by the Carbon Underground President Larry Kopald.

It is open source and free to use for educational purposes.

<https://thecarbonunderground.org/the-carbon-underground-president-larry-kopald-narrates-the-soil-story/>

Laptop link





Credit NASA: Earthrise seen from the moon

A 39 minute YouTube version of my presentation is available at

<https://www.youtube.com/watch?v=AWILIYSf5ts>

Supplementary material for Phil Gregory's lecture

<http://www.phas.ubc.ca/~gregory/papers/SupplementaryMaterial.pdf>

Phil Gregory's University of British Columbia website

<http://www.phas.ubc.ca/~gregory/gregory.html>

END