Free talk supported by The Sharing Farm, Richmond, BC

"The Magic of Soil"

by
Phil Gregory
Professor Emeritus
Physics & Astronomy
University of British Columbia

The Red Barn at Terra Nova Rural Park,
2631 Westminster Highway, Richmond

Wednesday, 19 Sept. 2018
7:00 – 8:30 pm

REUTERS

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

https://www.scientificamerican.com/article/only-60-years-of-farming-left-if-soil-degradation-continues/

R

The primary causes of soil degradation include:

Plowing or tilling,

Chemical-intensive farming,

Current livestock management,

Deforestation,

Used for industrial or urban purposes

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

Soil degradation

R

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

Soil degradation

R

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

For comparison the total agricultural land area of the UK is
18 million hectares

1 hectare =2.47 acres

Soil degradation

R

http://www.farmlandlp.com/2012/01/one-acre-feeds-a-person/
http://www.cornandsoybeandigest.com/soil-health/economics-soil-loss
https://www.youtube.com/watch?v=c4p-kQ6D8aA

R

In Oct. 2017

UK environmental secretary, Michael Gove, warned that the UK is 30-40 years away from eradication of soil fertility.

https://www.theguardian.com/environment/2017/oct/24/uk-30-40-years-away-eradication-soil-fertility-warns-michael-gove

https://www.theguardian.com/environment/2018/mar/21/europe-faces-biodiversity-oblivion-after-collapse-in-french-bird-populations

R

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.

R

The Good News

If we change the way we do agricultural in response to the recent revolution in soil biology, we can:

1) rapidly reverse soil degradation,

2) avoid the looming collapse of agriculture,

3) and go a long way to solving global warming.

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.

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

Understanding this revolution is crucial to human survival.

R

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=6tJIkAjDjjo&index=6&list=PL4J8PxoprpGZ-uMTxScBBn9nYT6CMX8aD

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Microbes are the secret behind healthy soil.

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

R

The Soil Food Web (Some of the key players)

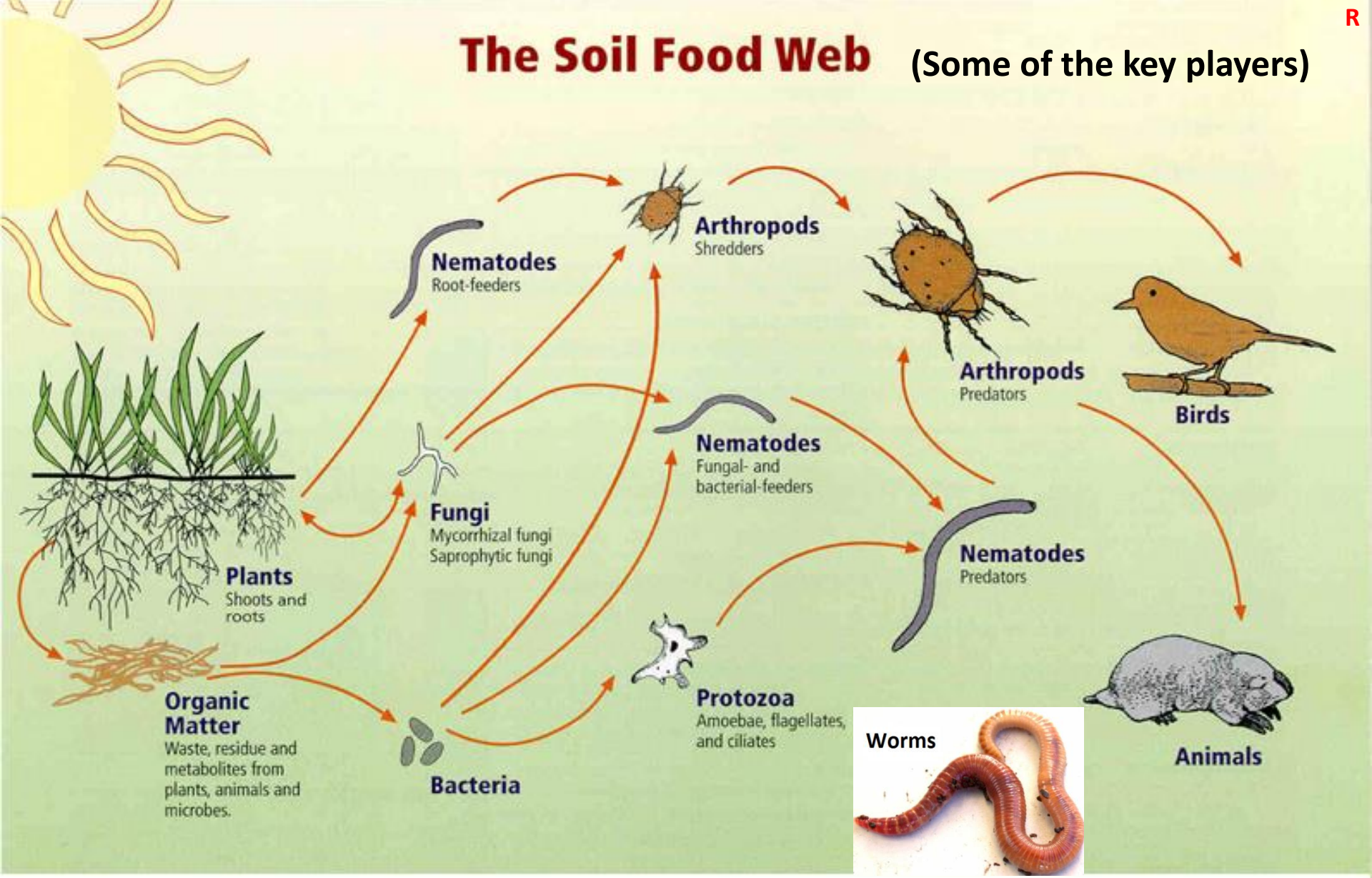

Image courtesy of USDA Natural Resources Conservation Services
http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/biology/

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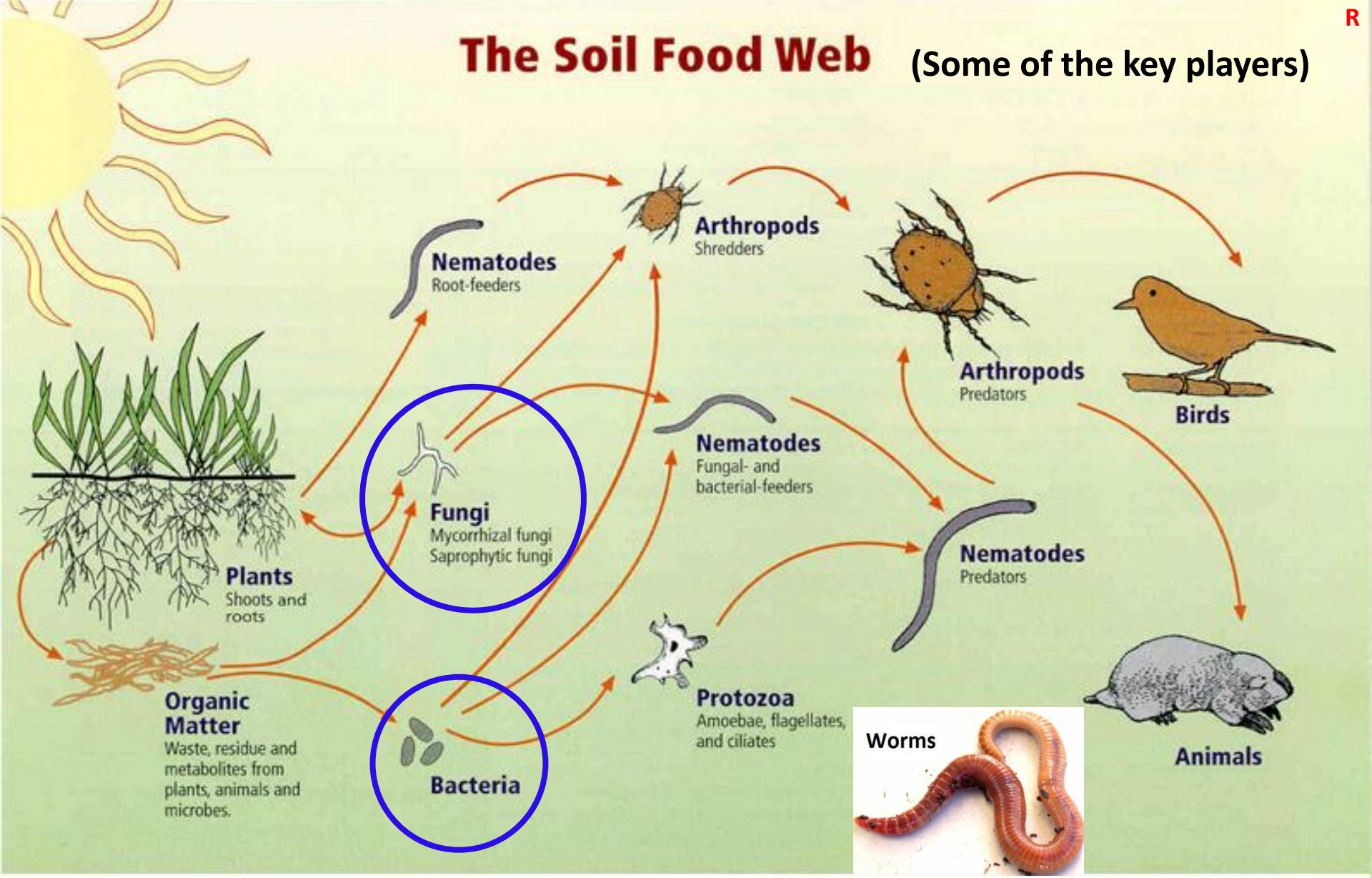

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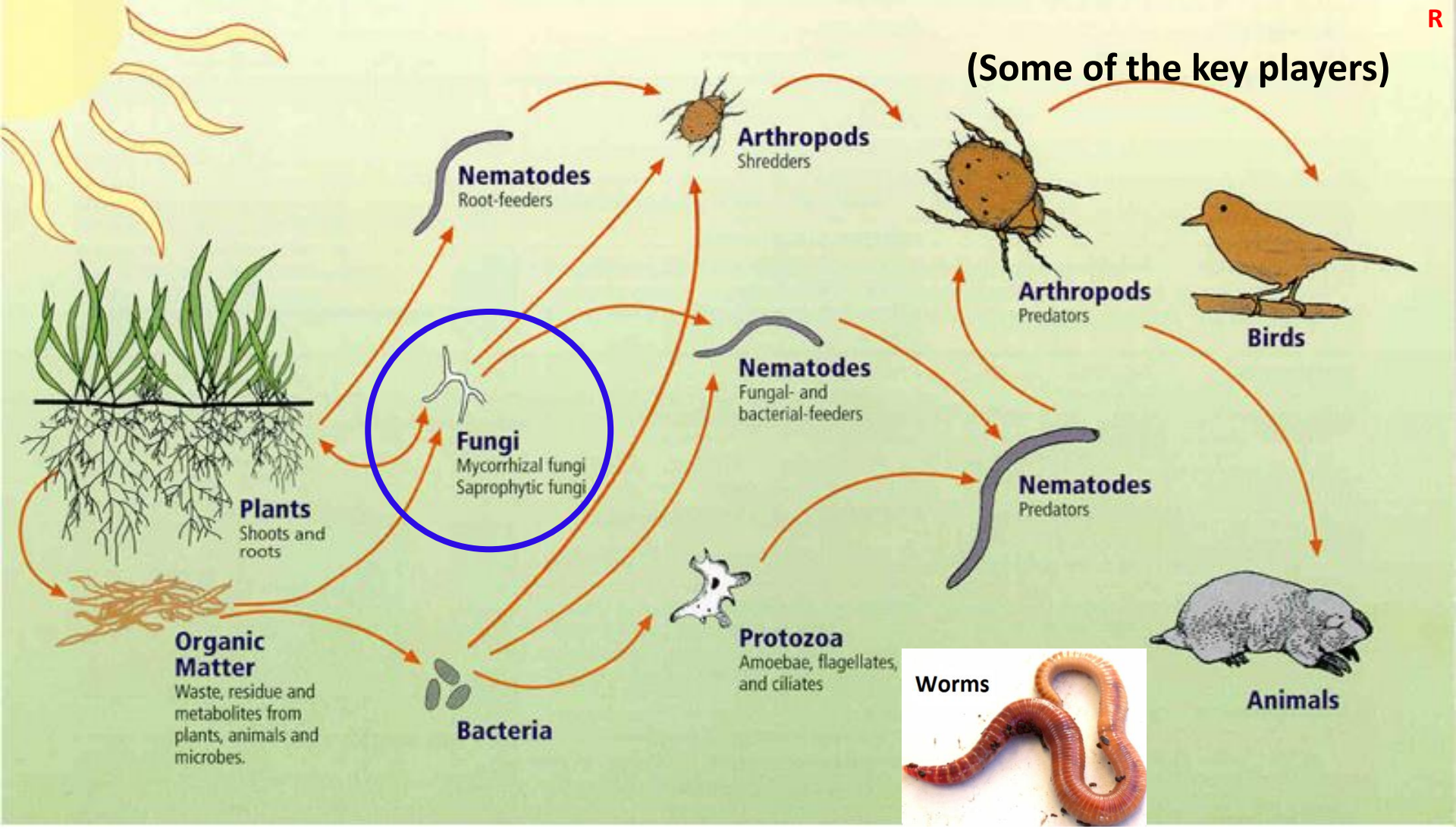
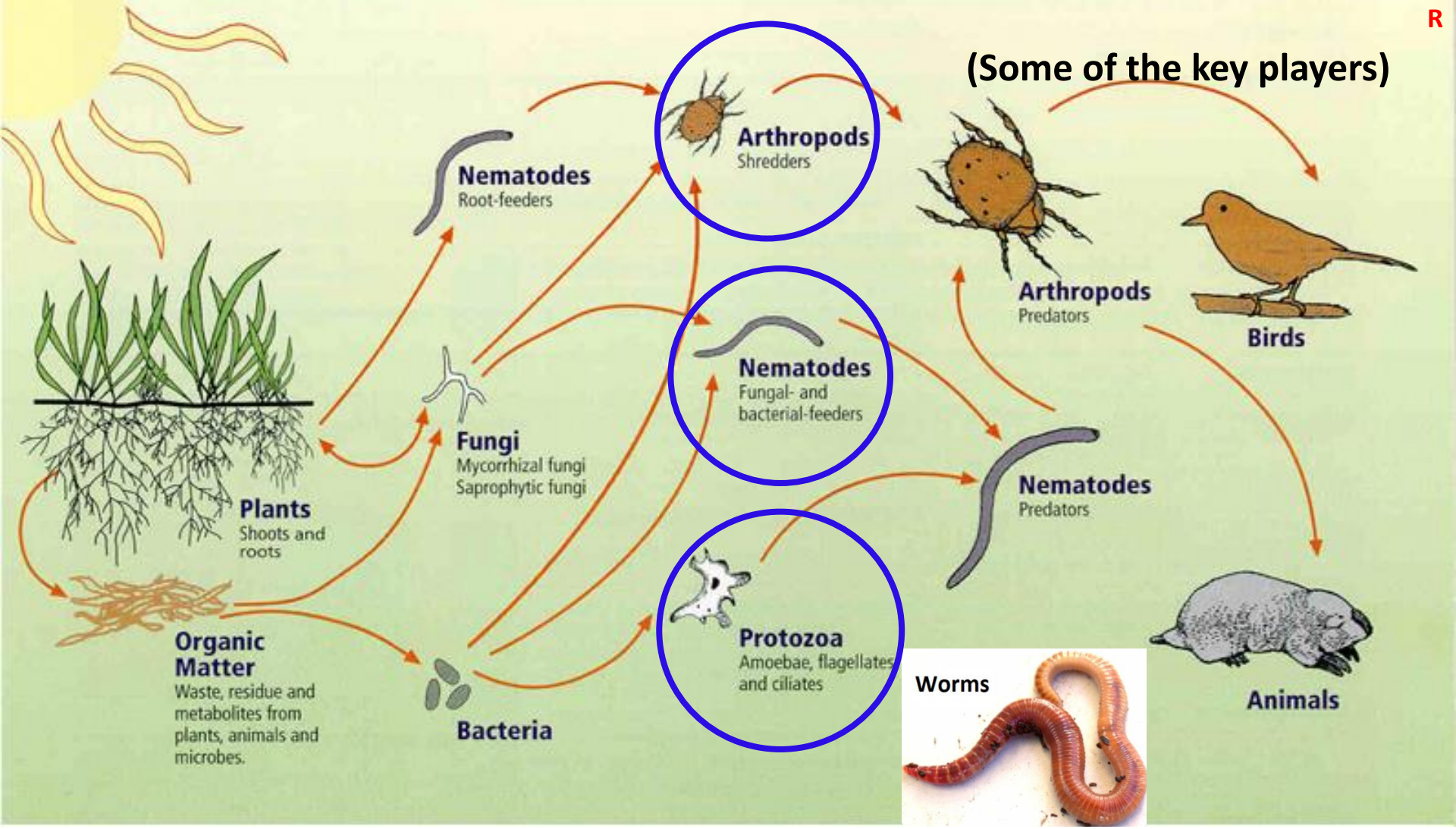


For a fascinating account of the mining capabilities of fungi see:

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'
   Renske Landeweert et al., Trends in Ecology & Evolution 16, no. 5 (2001): 248



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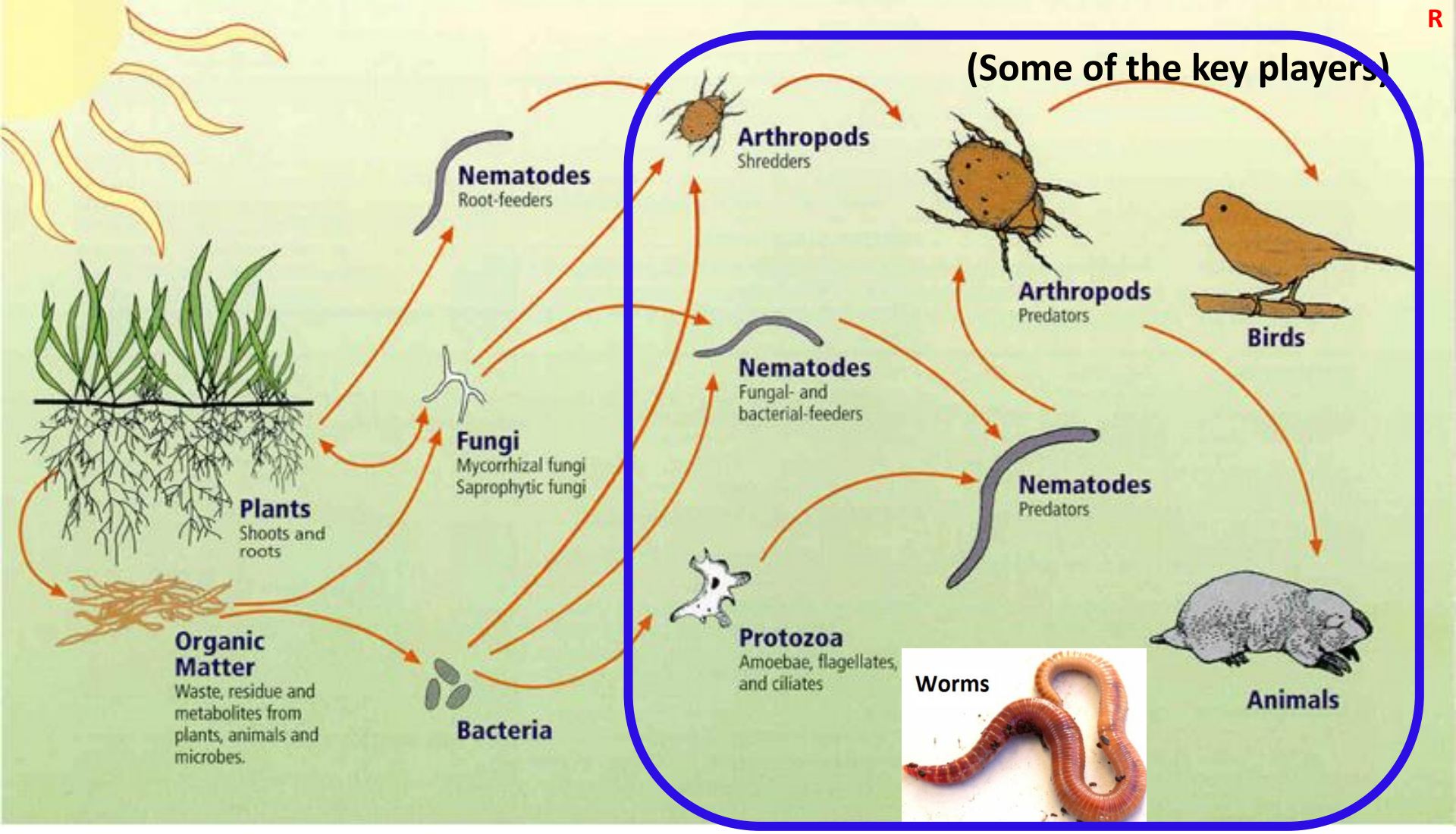

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Plants are the conductors of this symphony of nature

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

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“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

R

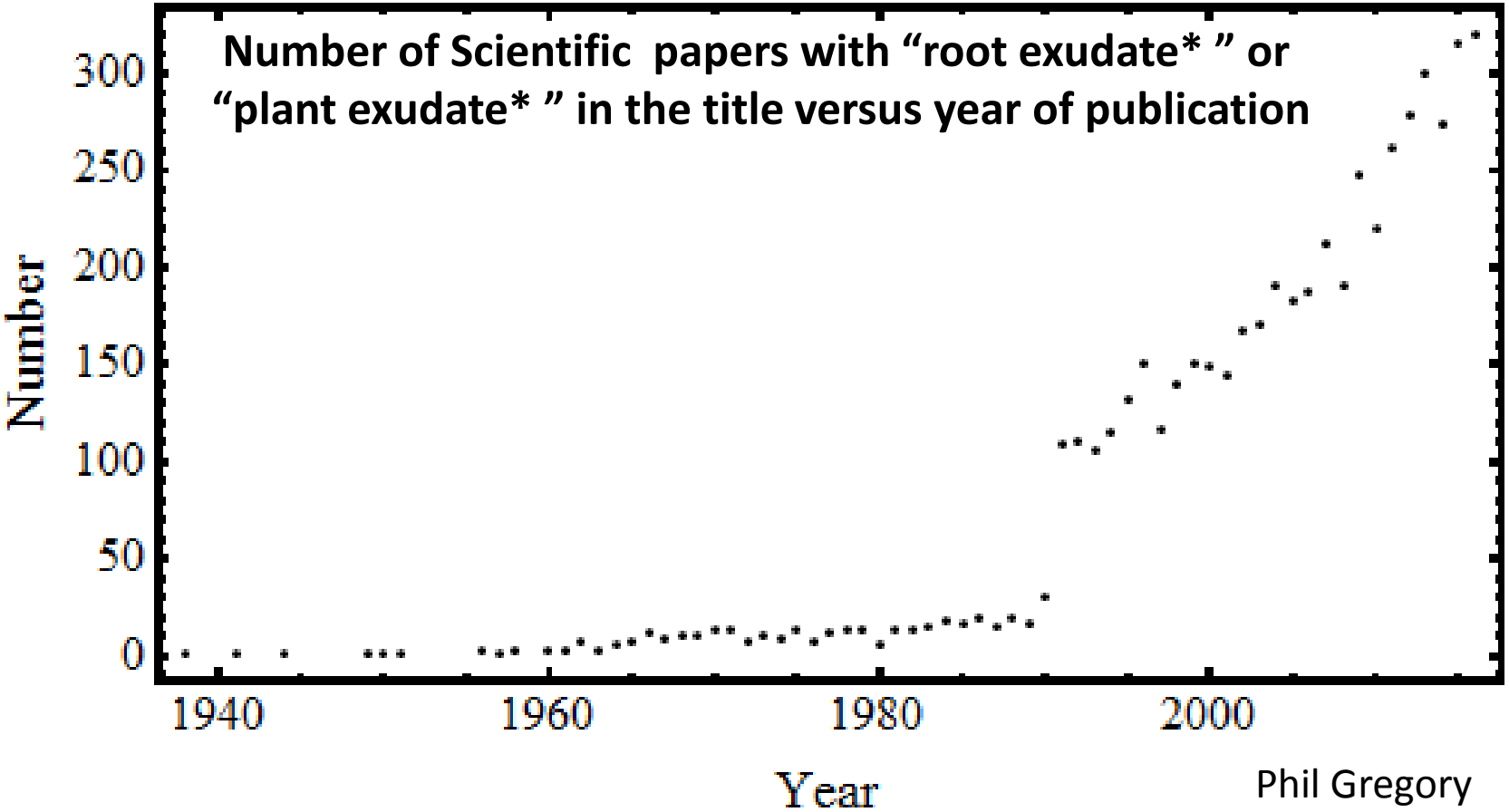
Plants also release exudates through their foliage.

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
https://commons.wikimedia.org/wiki/File:Argan_tree_@_Agadir.jpg

One indicator of the recent revolution in soil biology

(sudden jump in publication rate in 1991)



Phil Gregory

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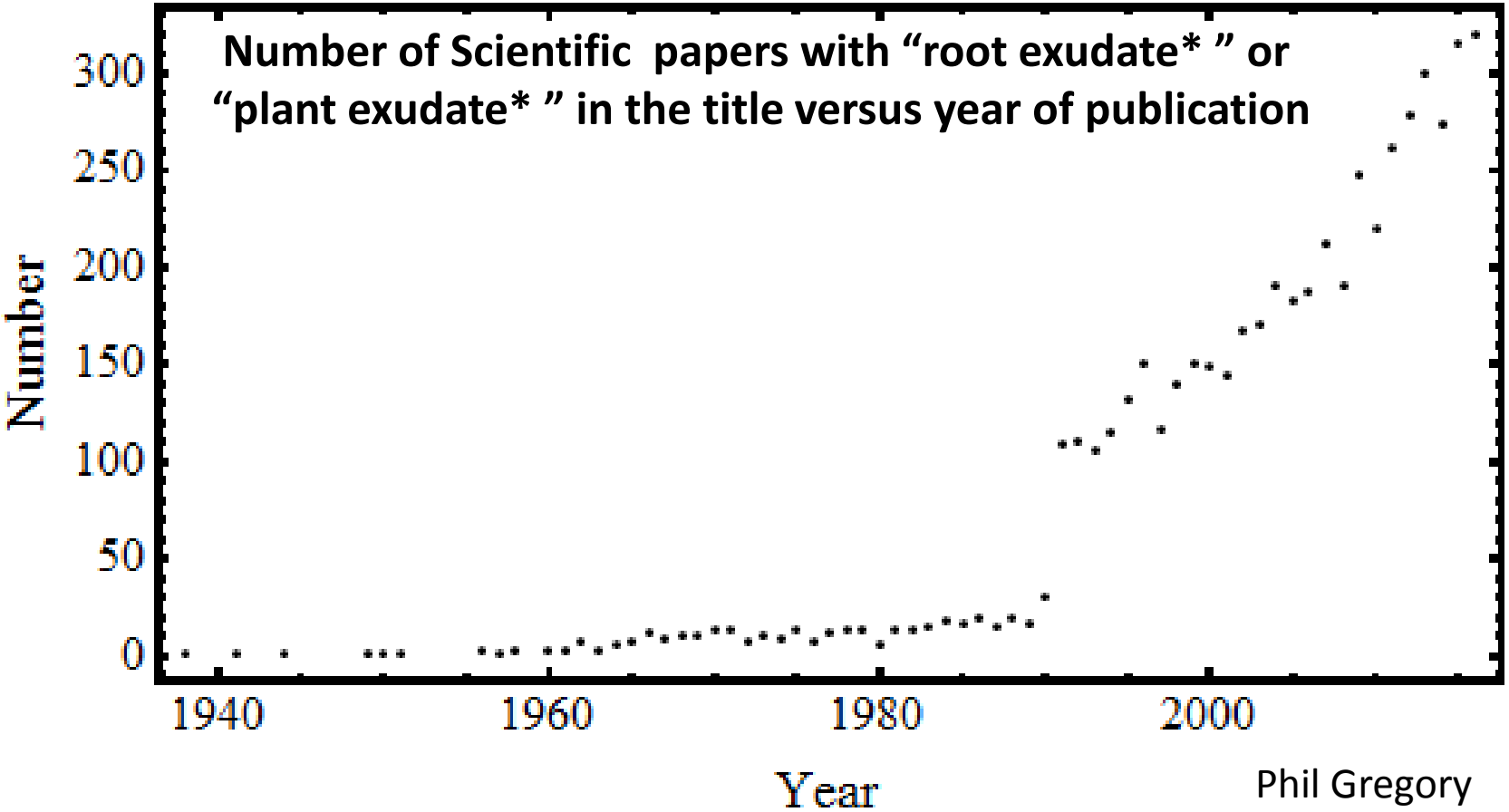


Phil Gregory

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

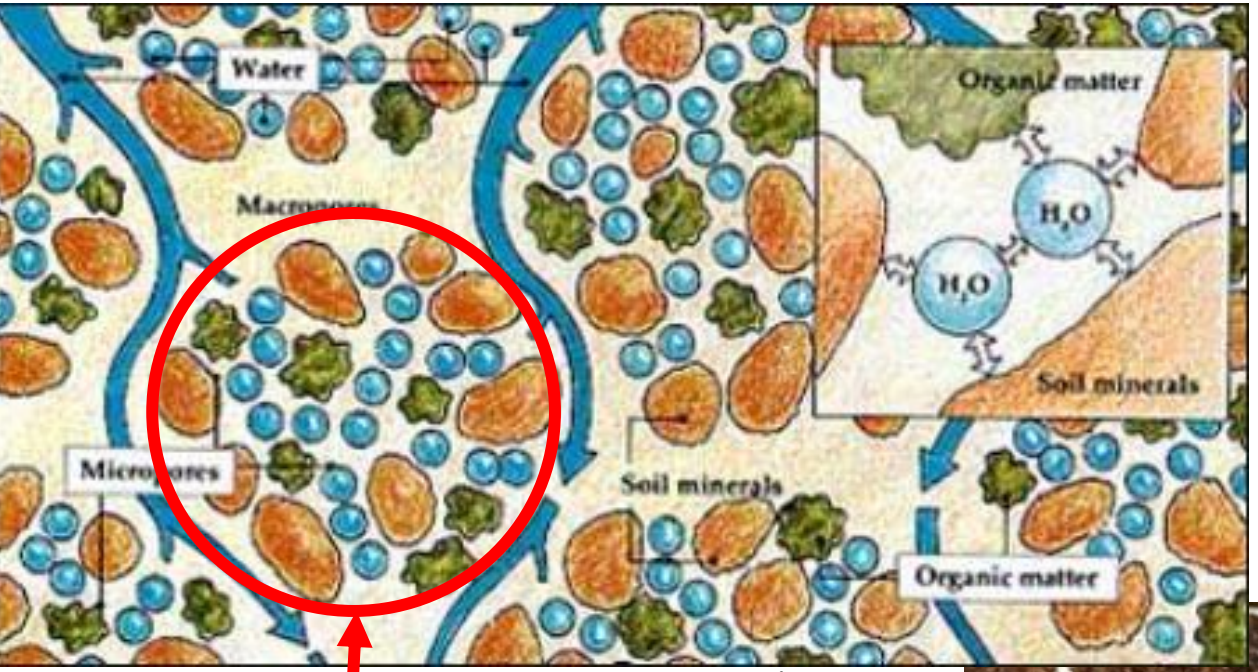


Image credit UN FAO.

microaggregate (too small to see by eye)

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

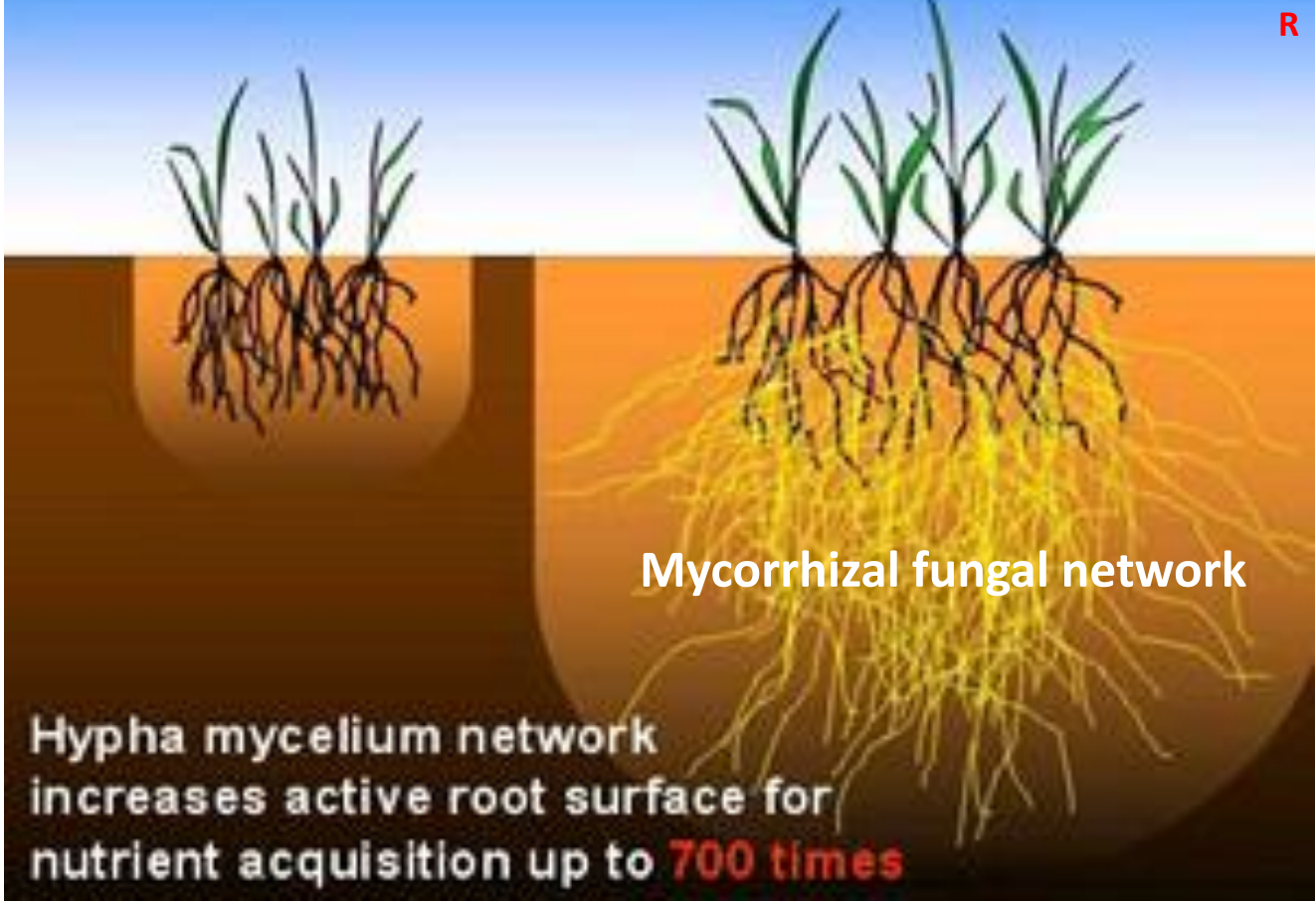
Bacteria secrete biotic glues that stick soil minerals and organic matter together in what are called microaggregates.

Fungal strands (right) tie microaggregates together forming aggregates (2-5 mm)

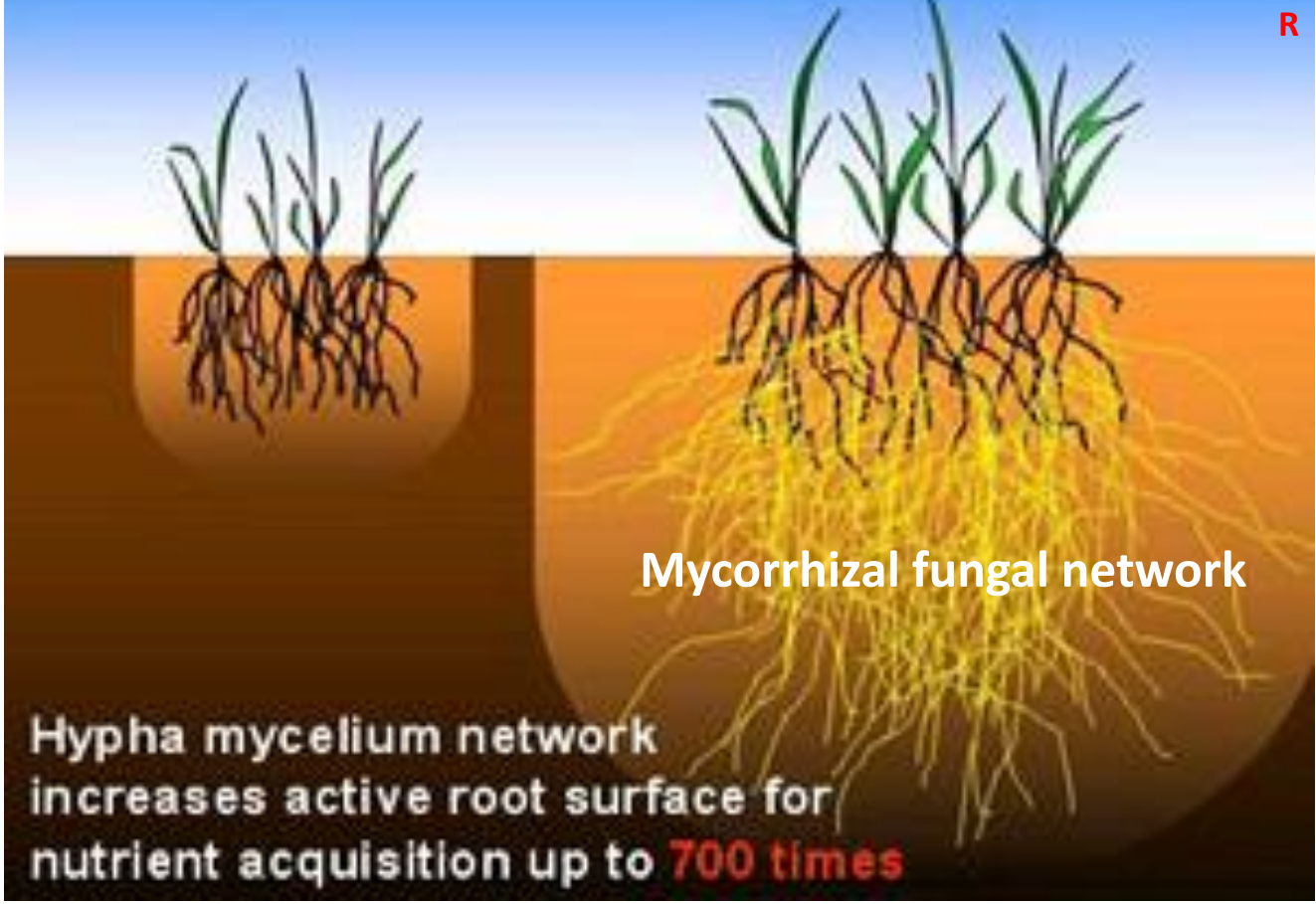
Mycorrhizal Fungal Network

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.



Mycorrhizal Fungal Network

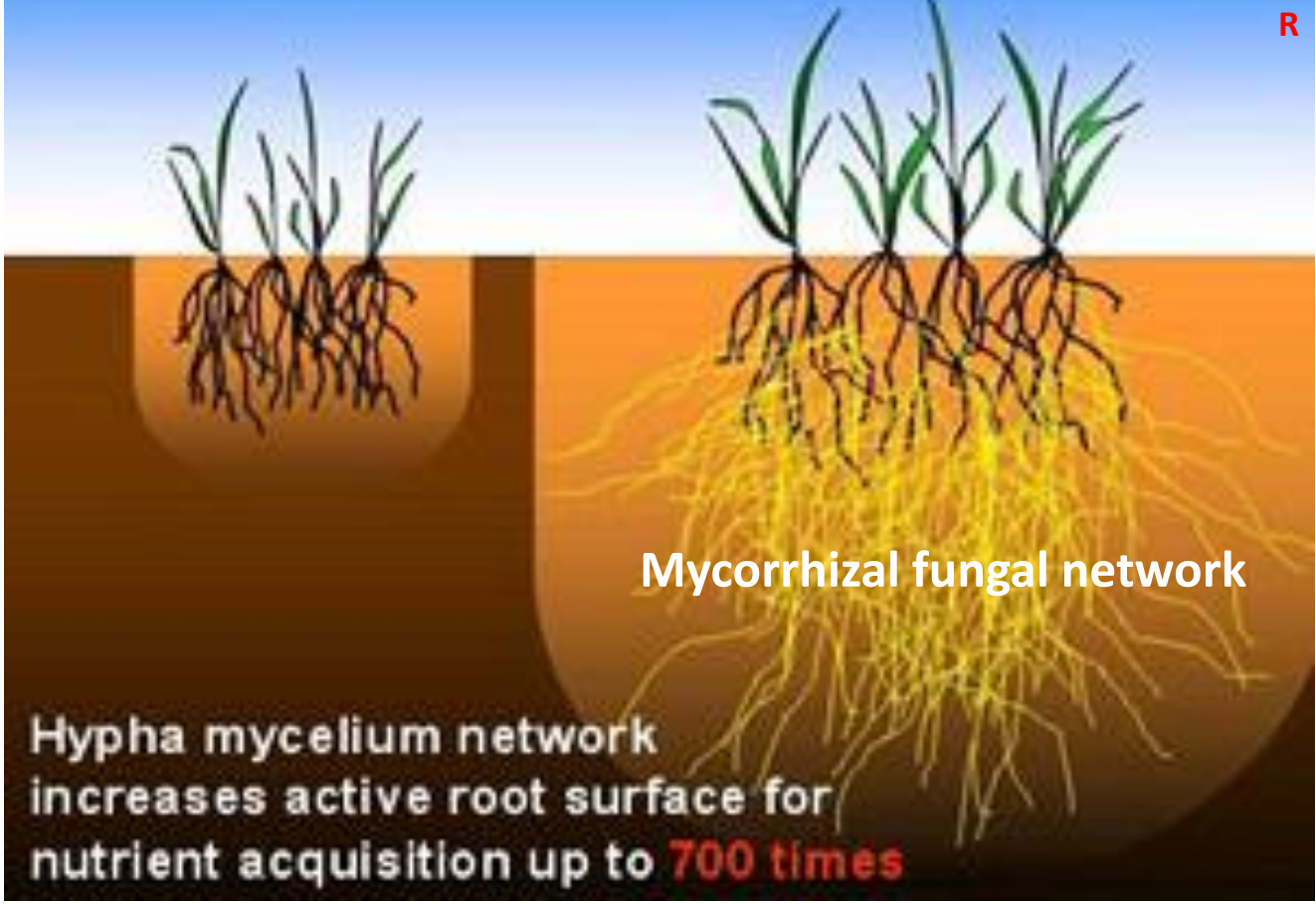


Through the work of researchers like Professor Suzzane Simard of the University of British Columbia, we now know that fungal networks can link plants together in a Wood Wide Web allowing them to exchange signals as well as nutrients.

NATURE | VOL 388 | 7 AUGUST 1997

Largest organism

Mycorrhizal Fungal Network



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)


Public Domain
http://www.epa.gov/region7/water/cafo/images/hogssm2.jpg


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

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)
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Credit: Trish Steel, (CC BY-SA 3.0)
https://commons.wikimedia.org/wiki/File:Feeding_Frenzy,_Faulston_Farm_-_geograph.org.uk_-_702677.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 CO_2

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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Effect of tilling on CO_2 emission

Dr. Don Reicosky , USDA
Agricultural Research Services

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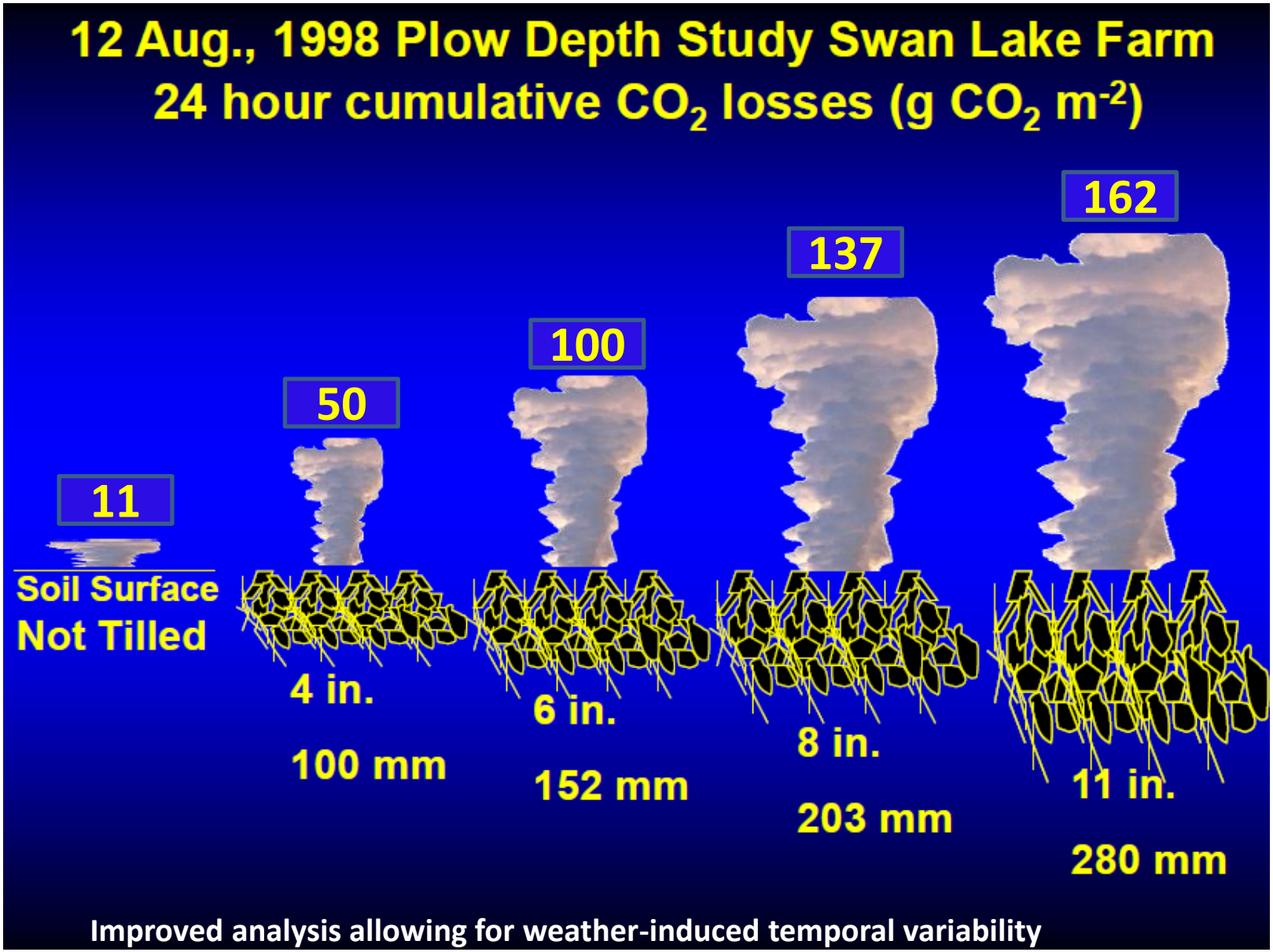

D.C. Reicosky and D. W. Archer, Soil and Tillage Research, Vol. 94, Issue 1, pp. 109–121, 2007

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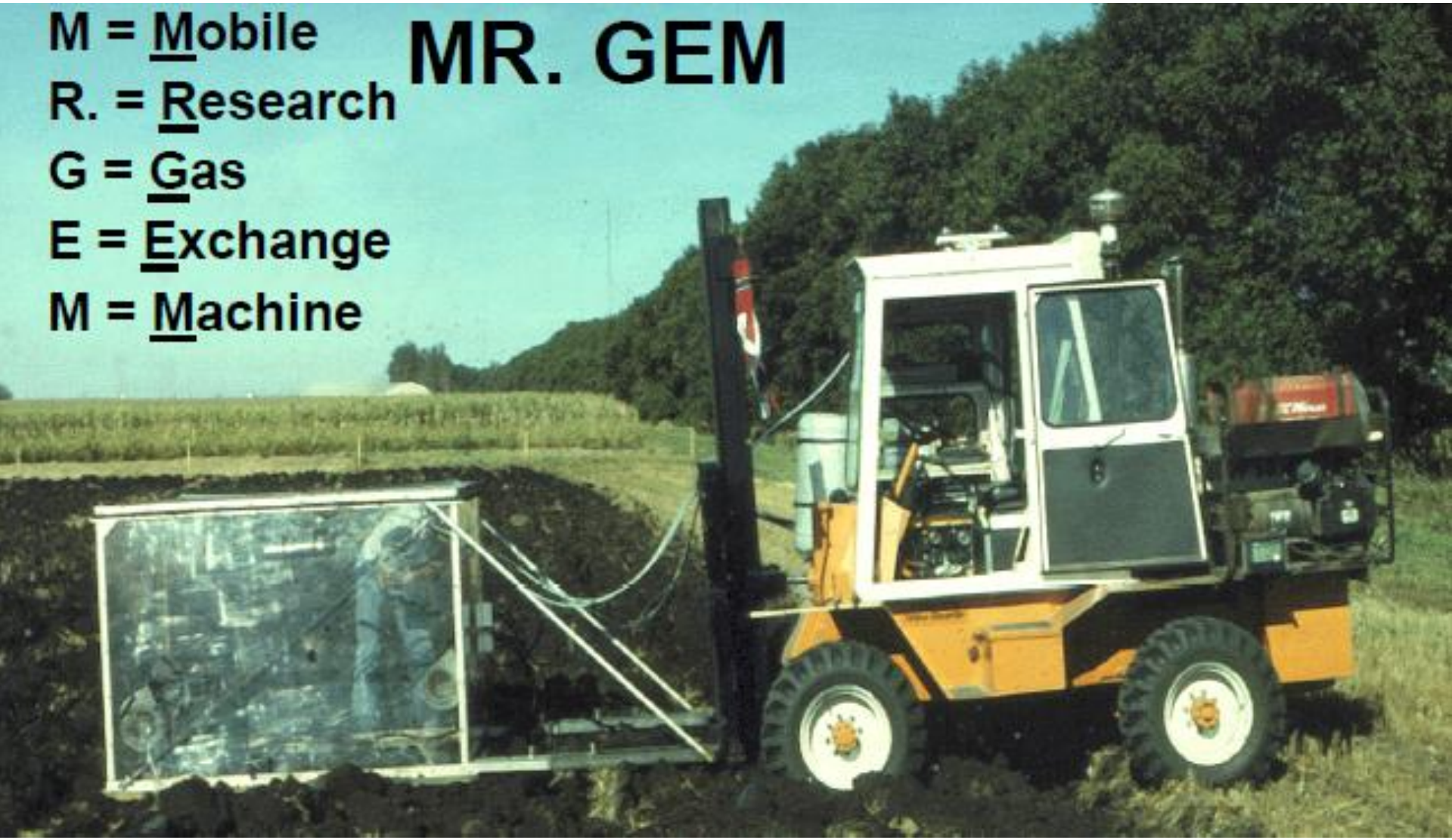
Tillage and planting: impact on carbon and soil quality

Dr. Don Reicosky USDA-ARS



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

1 min soil videos

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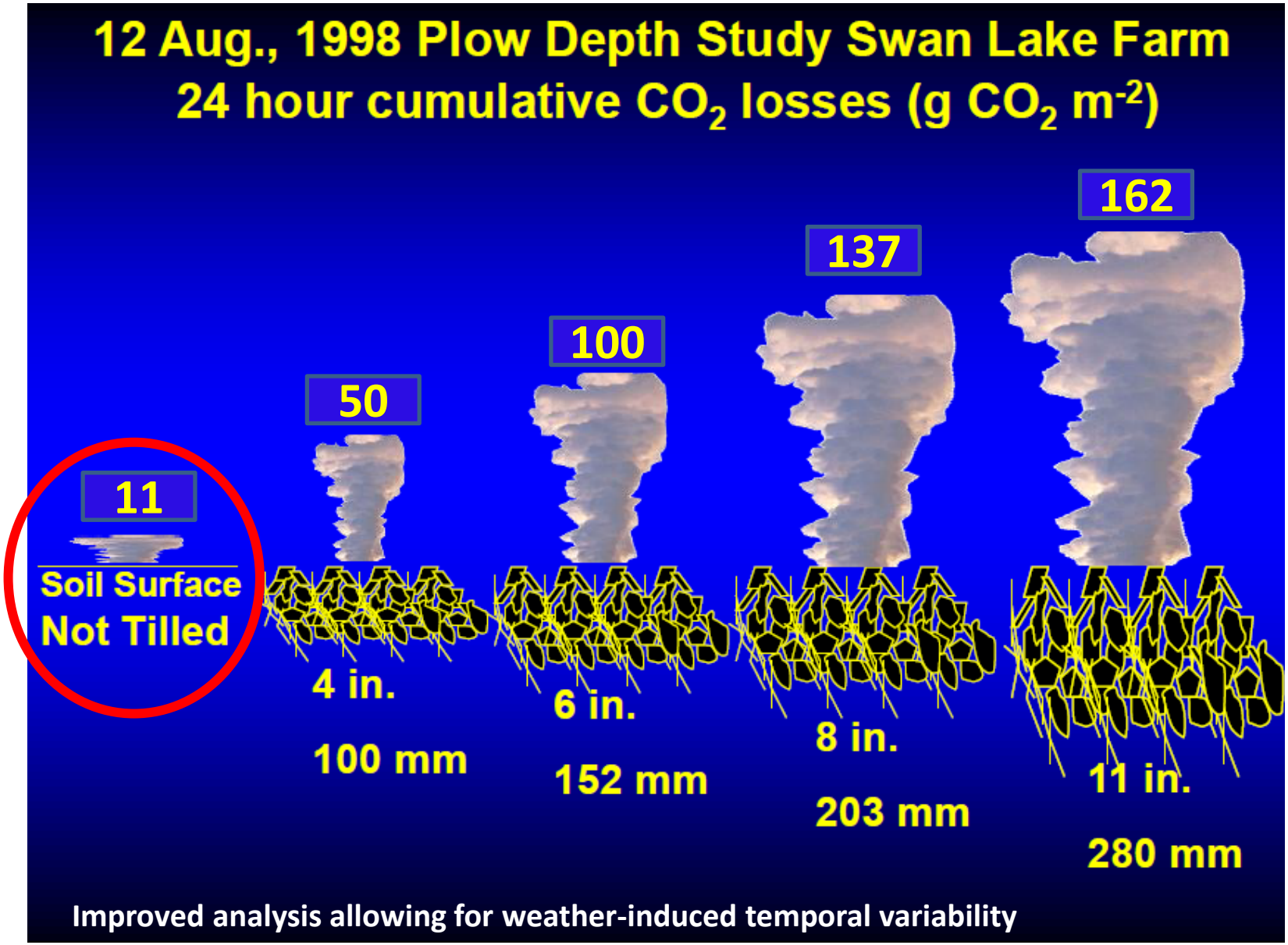

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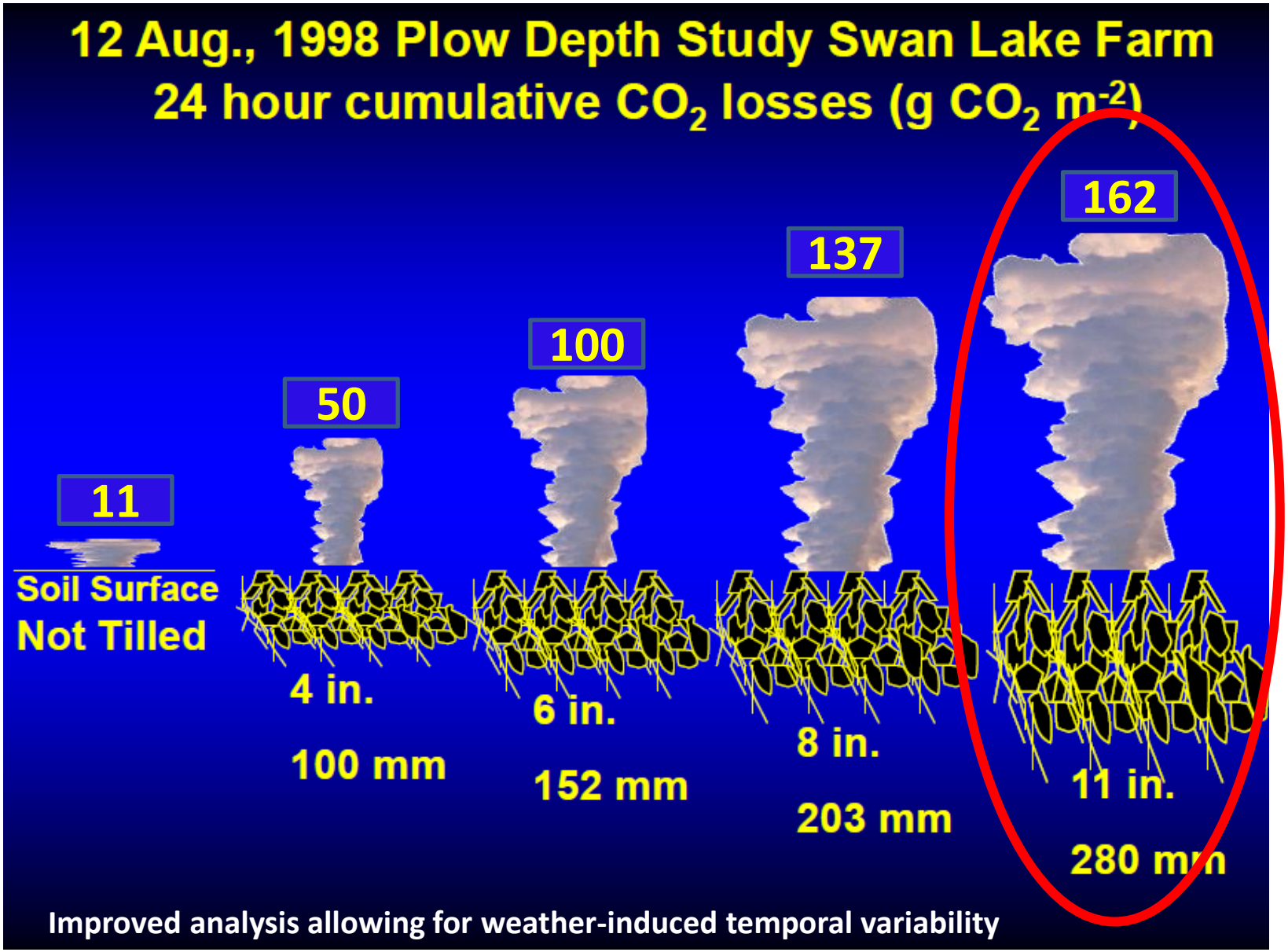

D.C. Reicosky and D. W. Archer, Soil and Tillage Research, Vol. 94, Issue 1, pp. 109–121, 2007

R

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

Each soil sample used in the demonstration was air dried

R

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

Each soil sample used in the demonstration was air dried

R

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.

R

Dust storm approaching Stratford, Texas 1935.

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

Dust storm Phoenix 5 July 2011

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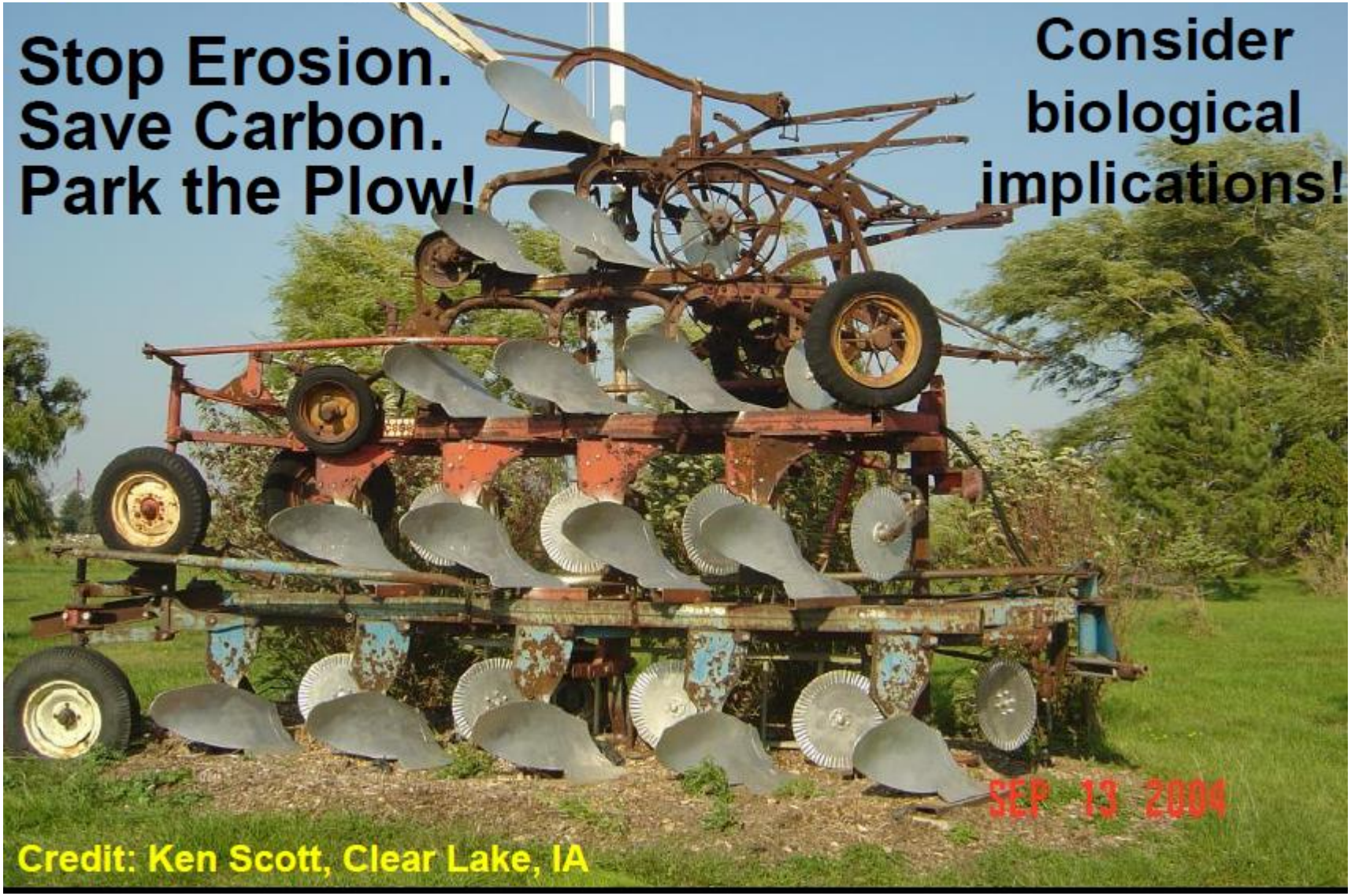
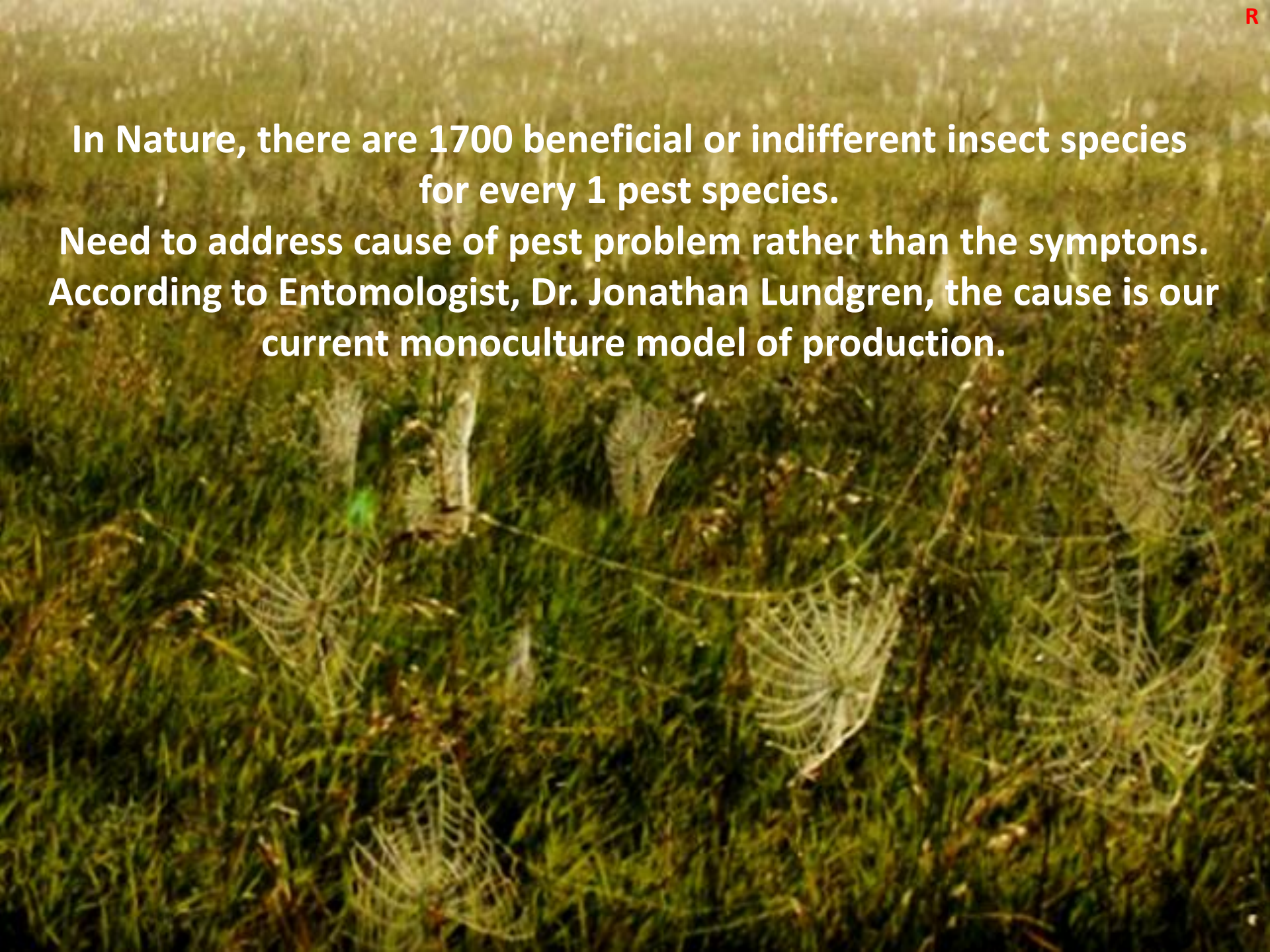
Time to Retire the Plow



Conventional Agric. about killing

Much of current agricultural is about killing:

weeds, fungi, insects, biodiversity, and even the farmer's profit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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 symptons.
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.

https://blogs.scientificamerican.com/plugged-in/10-calories-in-1-calorie-out-the-energy-we-spend-on-food/

R

Alternative Agricultural Model

Nature’s way (biomimicry)

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-Nature doesn't plow or till the soil

A certain amount of disturbance by animals is natural as plants and animals co-evolved together.

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A typical natural prairie grassland has over 100 different plants living together in a mutually beneficial symbiotic relationship.

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-Natural soil is full of living microbes

They provide all the nutrients plants need, protect against disease, and increase soil carbon. Adding fertilizers upsets this ecology.

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-Nature has plants covering the ground year round

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

R

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

R

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.

R

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

What about livestock grazing?

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

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.

R

Desertification

Conventional wisdom has it that one of the main causes of desertification is overgrazing by herbivores like cattle, sheep and goats. This is especially true in drought prone regions.

R

Desertification

According to the African biologist Allan Savory, we were once just as certain that the earth was flat.

He has shown, it is not about the number of animals, it is all about timing.

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Desertification

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

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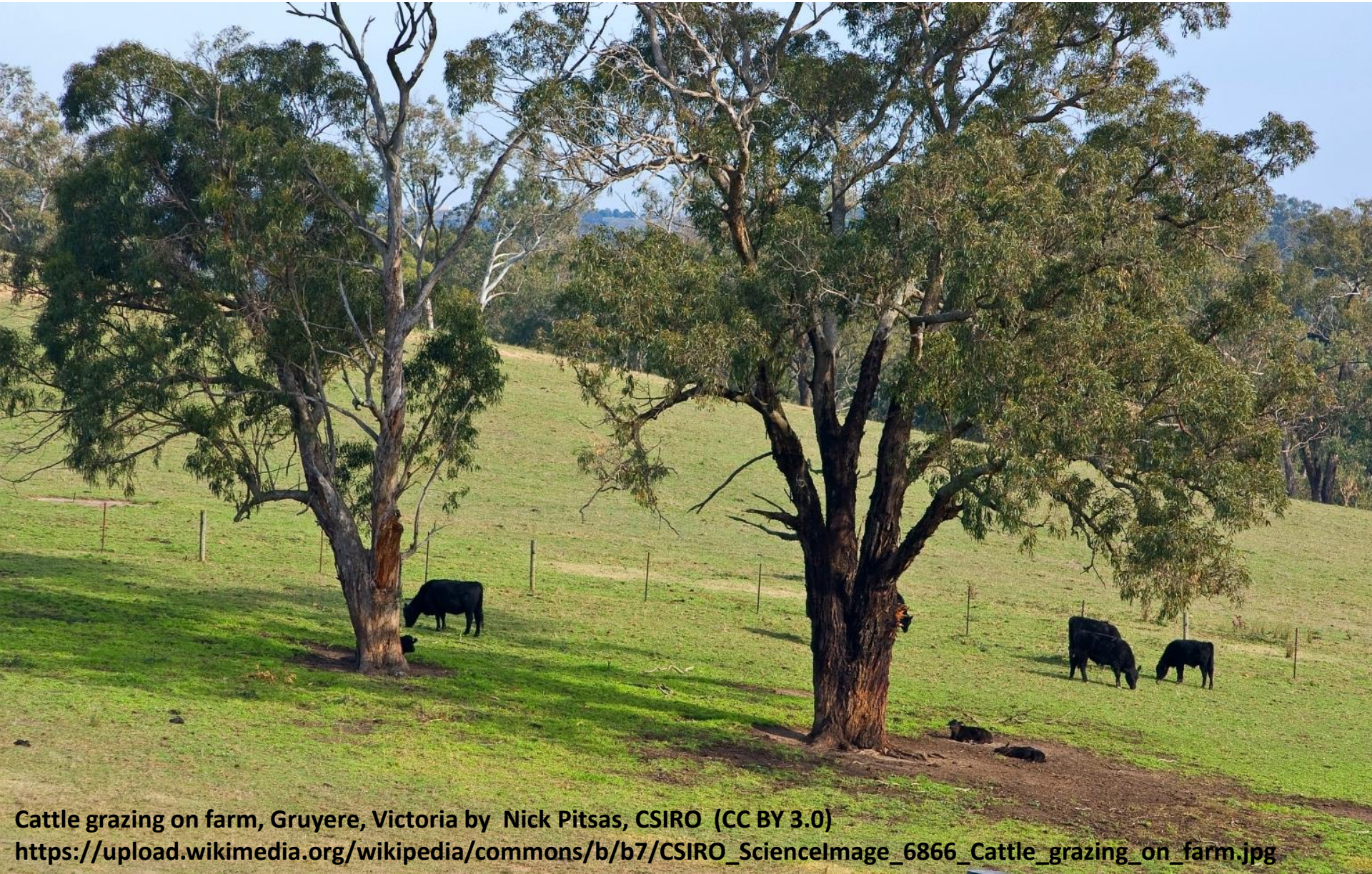
Continuous grazing is a common practice in which livestock have unrestricted access throughout the grazing season.



Cattle grazing on farm, Gruyere, Victoria by Nick Pitsas, CSIRO (CC BY 3.0)
https://upload.wikimedia.org/wikipedia/commons/b/b7/CSIRO_ScienceImage_6866_Cattle_grazing_on_farm.jpg

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

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Credit: Kevin Pluck (CC BY 2.0)
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

Wildebeest close up

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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.

R

How can humans imitate nature?

One method: use electric fence to emulate the predators

Credit: Peter Byck © ESEF 2015 (with permission), "Soil Carbon Cowboys" https://vimeo.com/80518559

R

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

Credit: Peter Byck © ESEF 2015 (with permission), "Soil Carbon Cowboys" https://vimeo.com/80518559

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

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.

P. L. Stanley & Jason E. Rowntree et al., Agricultural Systems 162, p.249, 2018

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

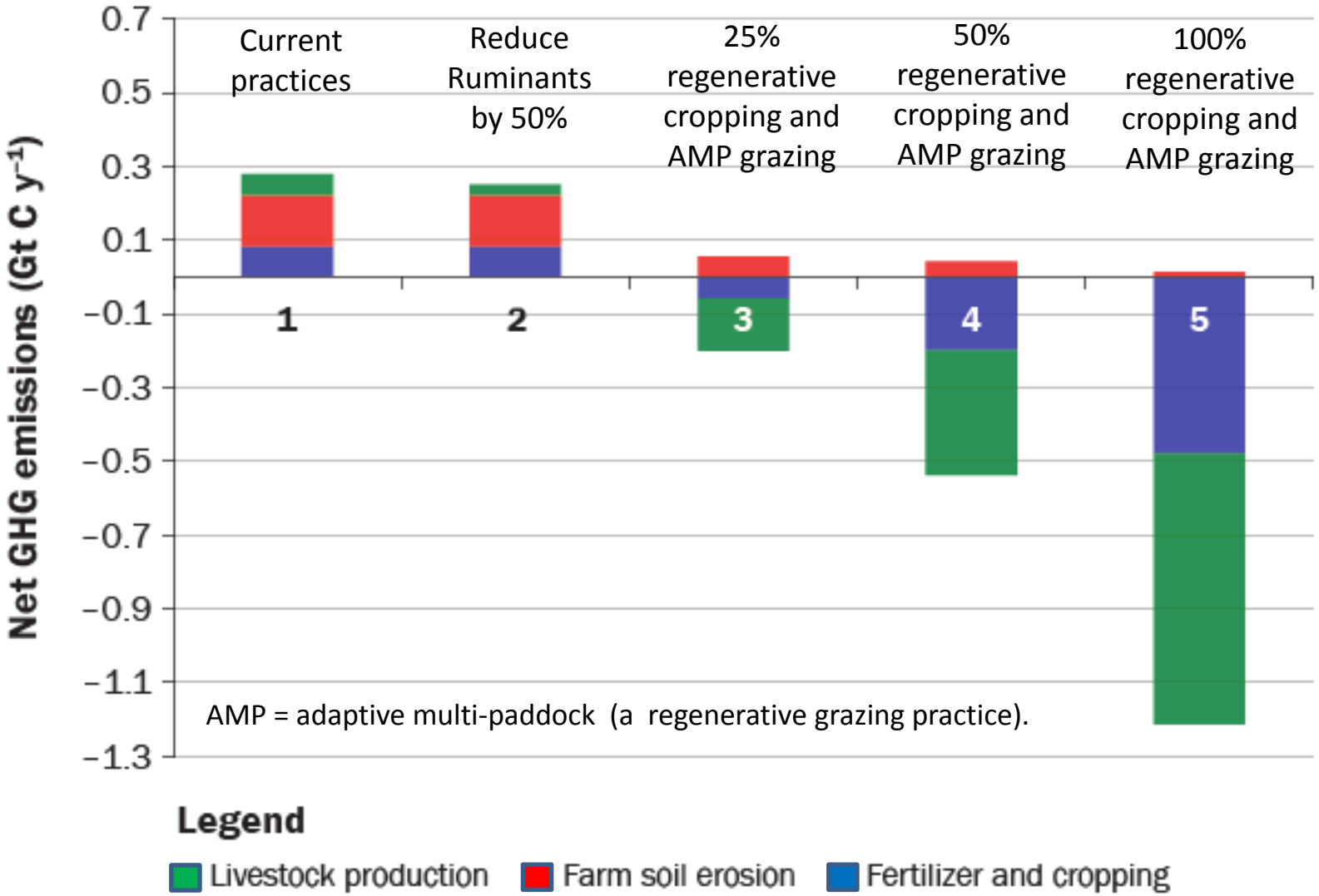
R

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

R

Based on: W.R. Teague + 11 authors, Journal of Soil and Water Conservation, 71, #2, p. 156, 2016
See also Quivira Conference presentation https://www.youtube.com/watch?v=crG4L4J-OEg



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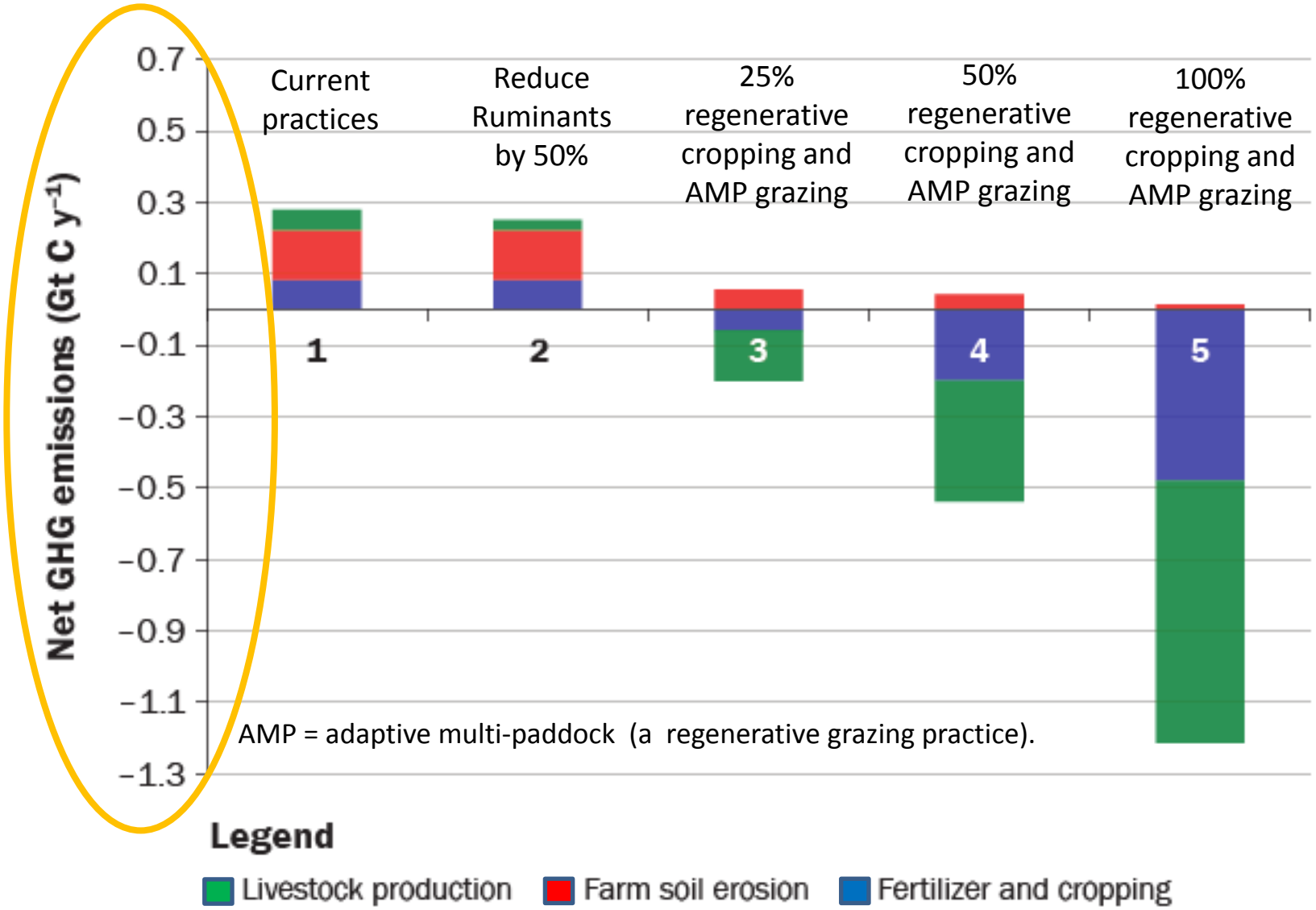

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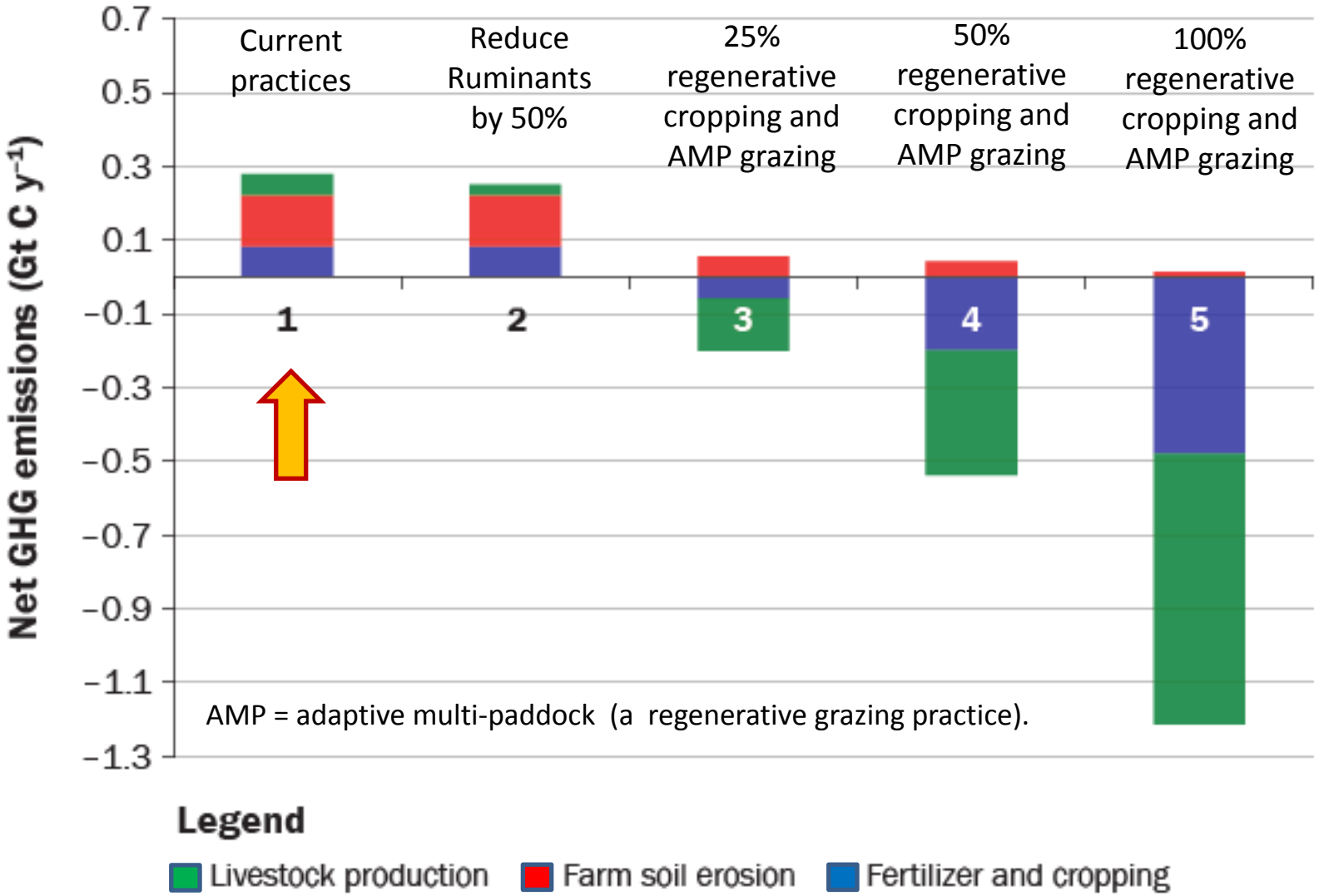

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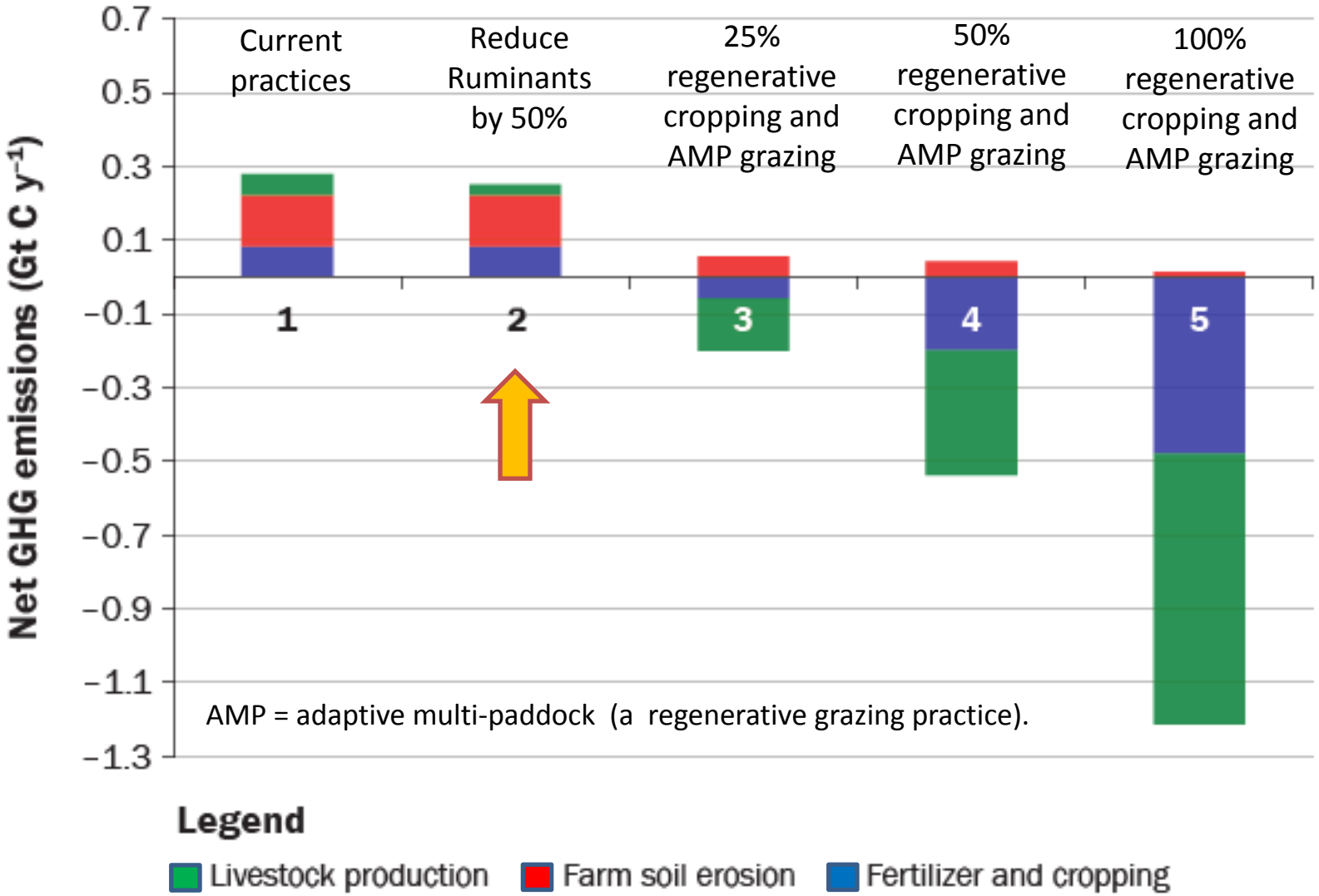

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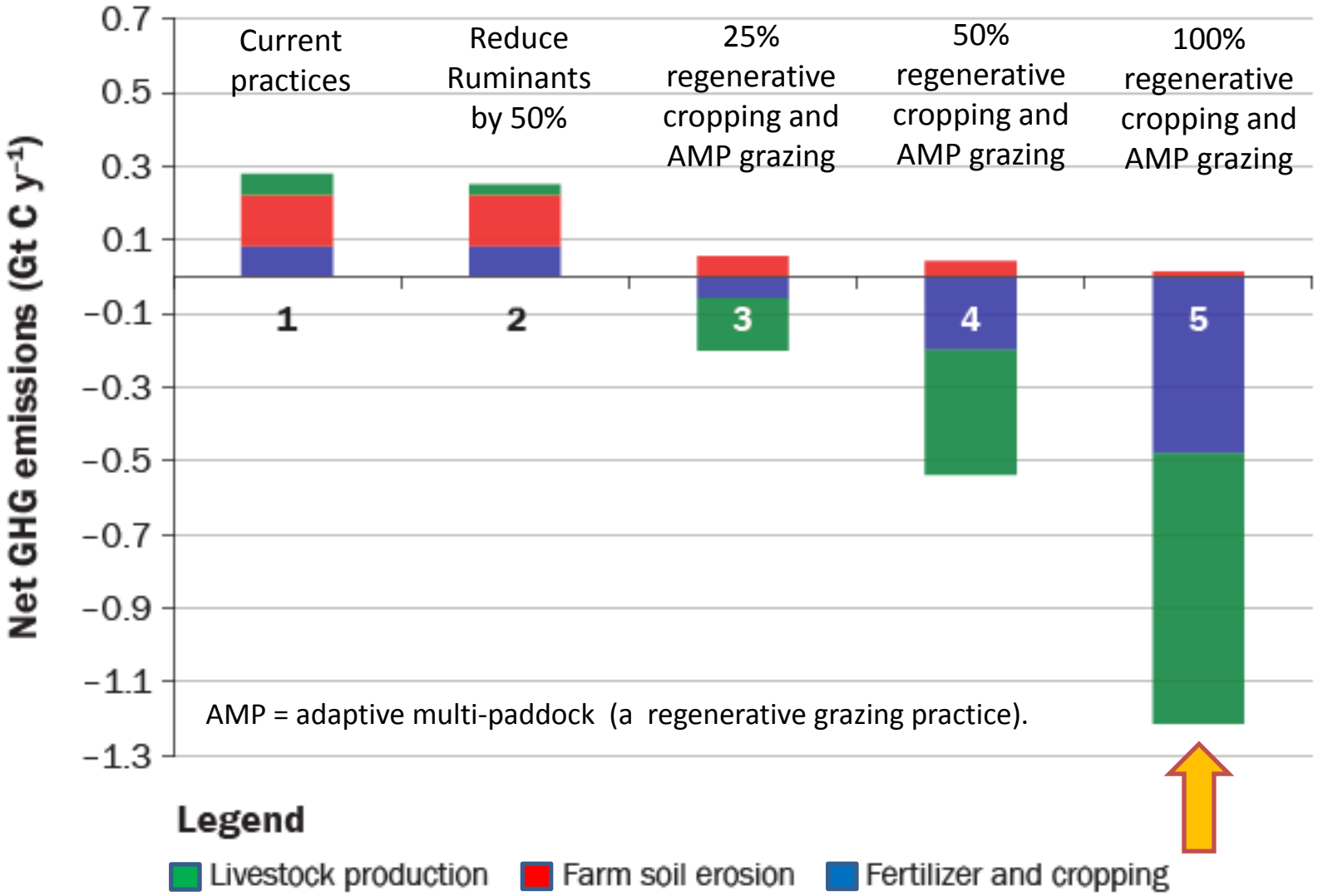

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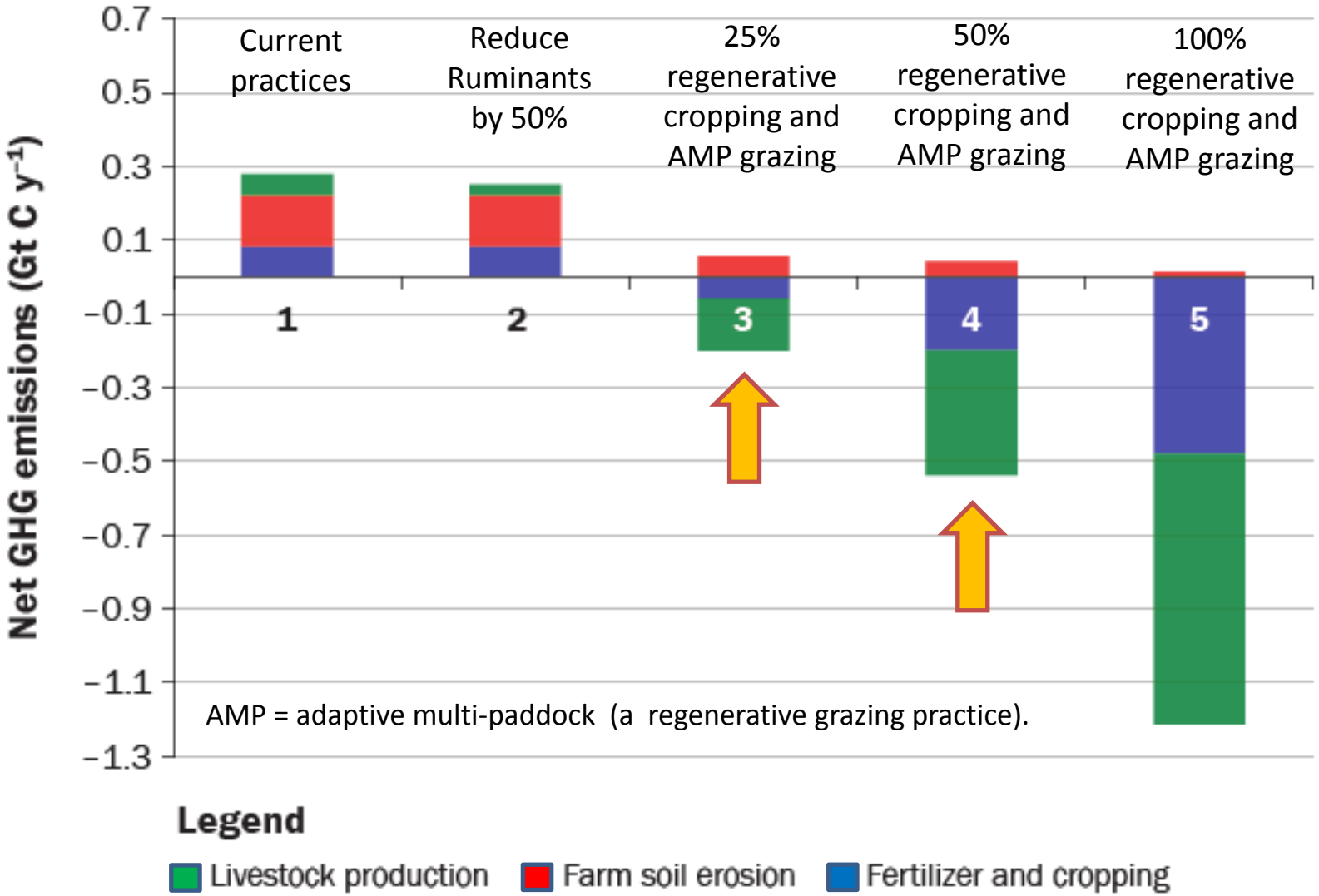
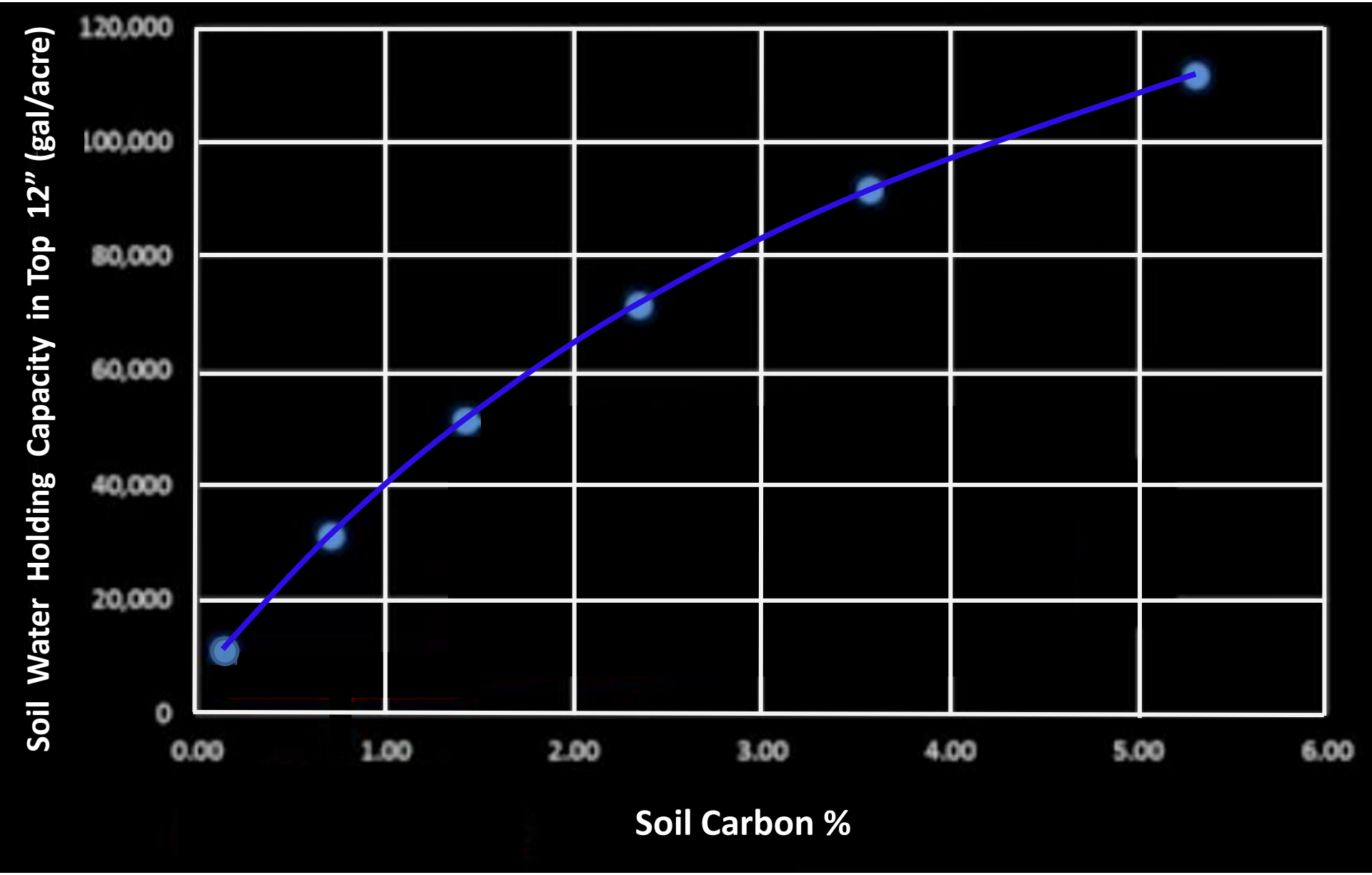


Soil water holding capacity depends on soil carbon



Adapted by Phil Gregory from Dr. David Johnson's "The Beam Approach" https://www.youtube.com/watch?v=79qpP0m7SaY&t=6s

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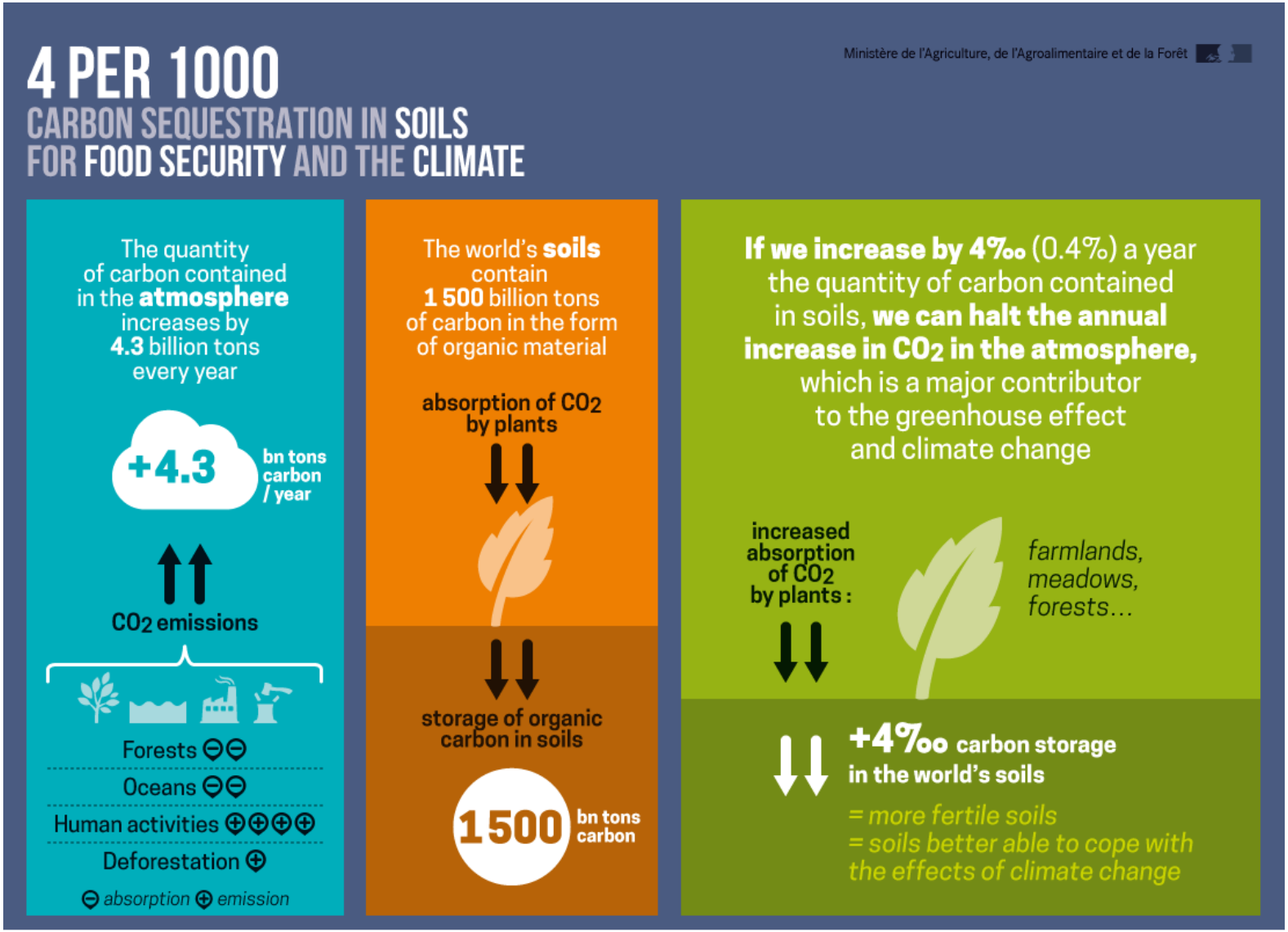
Potential for Improved Data

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.



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

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

Hopefully more countries will join this important initiative

http://4p1000.org/partners

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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/

PRODUCED & PRESENTED BY

KISS the GROUND

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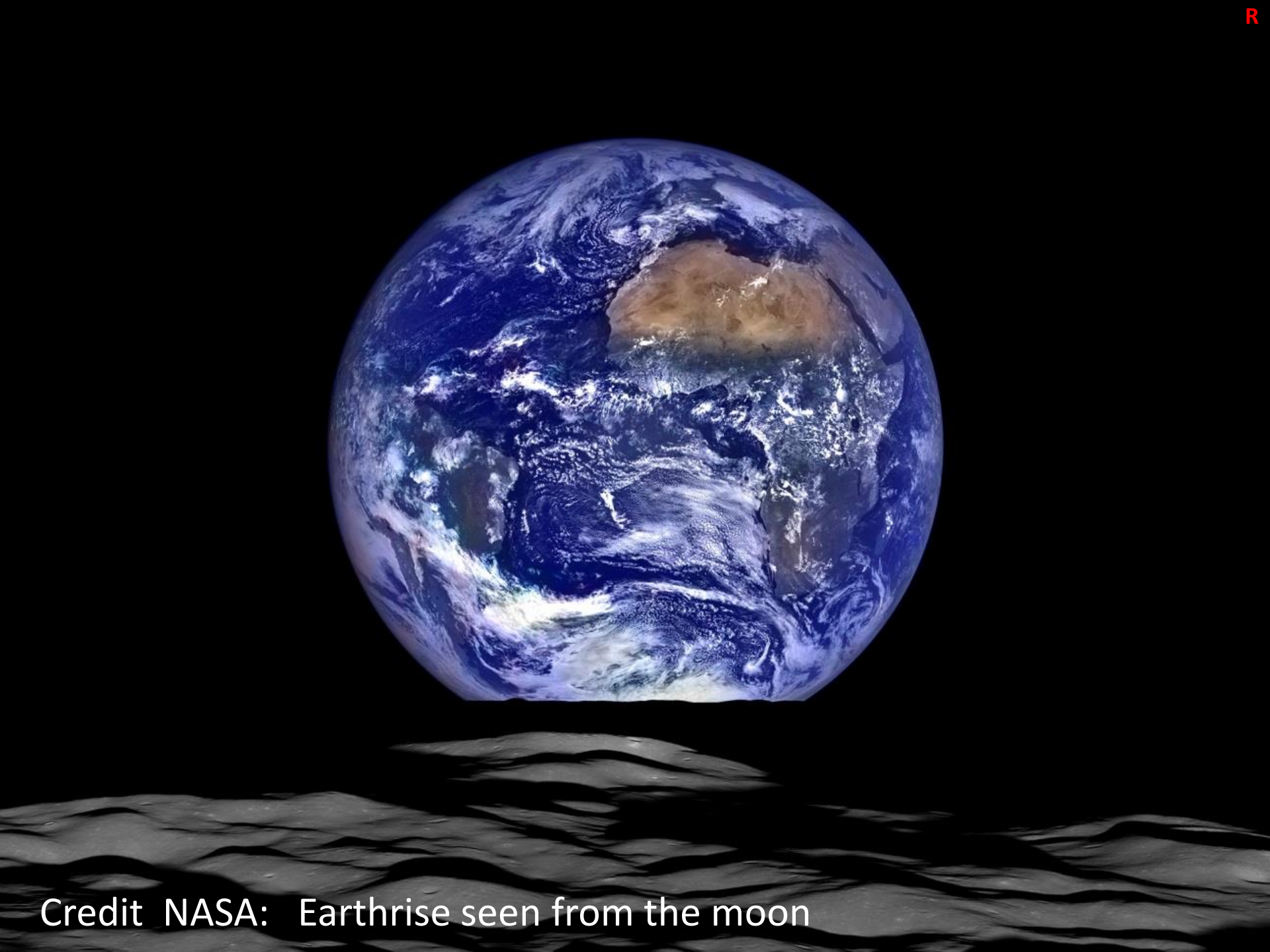

Credit NASA: Earthrise seen from the moon

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A 39 minute YouTube version of "The Magic of Soil" is available at
https://www.youtube.com/watch?v=AWILIYSf5ts

Professor Gregory's website with other presentations
http://www.phas.ubc.ca/~gregory/gregory.html

Supplementary material for soil talk by Dr. Phil Gregory, Physics and Astronomy Dept., University of British Columbia

How are seeds planted in no-till farming
https://www.youtube.com/watch?v=V5uK-1dclRY

Gabe Brown's story: a farmer ahead of his time
https://www.youtube.com/watch?v=GxIyKfWf9kU

Singing Frogs Farm https://www.youtube.com/watch?v=zAn5YxL1PbM

Call of the Reed Warbler by Charles Massey 2017

Kiss the Ground by Josh Tickell 2017

The Hidden Half of Nature: The Microbial roots of Life and Death
by David R. Montgomery and Anne Bilké 2016

Carbon cowboys https://www.youtube.com/results?search_query=Carbon+cowboys

Soil Food Web (Dr. Elaine Ingham)
https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/soils/health/biology/?cid=nrcs142p2_053868

We need regenerative farming, not geoengineering
https://www.theguardian.com/sustainable-business/2015/mar/09/we-need-regenerative-farming-not-geoengineering

Oxford Real Farming Conference keynote talk by Dr. Elaine Ingham

https://www.youtube.com/watch?v=x2H60ritjag

Slides for this talk are online here

https://drive.google.com/file/d/0B6tV3TorfmstbXllUU5yMXB2MWM/view

Supplementary material continued

French initiative 4 per 1000 to sequester C in the soil for food security and climate

http://4p1000.org/understand

https://concilium.digital/wp-content/uploads/2016/11/Leaflet-4per1000-GB.pdf

Scientific talk on 4p1000 program

https://www.youtube.com/watch?v=sBeCHZNf2L4

Dr. Elaine Ingham's Life in the Soil Classes http://www.lifeinthesoilclasses.com/

Introduction to gardening with nature by Dr. C. A. Rollins and Dr. Elaine Ingham

http://www.soilfoodweb.com/Article.html

Industrial Farming Threatens Food Security in the US, Dr. Mercola, 10 Jan 2017

http://articles.mercola.com/sites/articles/archive/2017/01/10/industrialization-versus-regenerative-agriculture.aspx?utm_source=dnl&utm_medium=email&utm_content=art1&utm_campaign=20170110Z1&et_cid=DM132724&et_rid=1836044384

What If the World's Soils Run Out?

http://world.time.com/2012/12/14/what-if-the-worlds-soil-runs-out/

Water in Plain Sight: Hope for a Thirsty World, by Judith D. Schwartz 2016

Dr. David Johnson 2018 EcoFarm Keynote https://www.youtube.com/watch?v=dmj611RfBgs

Cover Crop Management in your Garden http://cru.cahe.wsu.edu/CEPublications/FS119E/FS119E.pdf

Terminating Cover Crops for Maximum Benefits - Jeff Moyer, Rodale Institute 2014

https://www.youtube.com/watch?v=FBt1OH6ylP4

Draft Policy for Long Term Food Security and Climate Action,

by Phil Gregory, UBC, Submitted to the Canadian Federal Government, 2016

http://www.phas.ubc.ca/~gregory/papers/CanadaFoodSecurityClimateActionPolicyProposalPhilipGregory5Dec2016.pdf

Supplementary material continued

My 39 minute YouTube version of "The Magic of Soil" presentation 2017
https://www.youtube.com/watch?v=AWILIYSf5ts

How to Green the deserts and Reverse Climate Change, Allan Savory TED talk
http://www.ted.com/talks/allan_savory_how_to_green_the_world_s_deserts_and_reverse_climate_change

The Savory Institute http://savory.global/

Eating Our Way To A Healthy Planet with Allan Savory, Allan Savory 5 Jun 2013
https://www.youtube.com/watch?v=sNDCMUgNQtg

Holistic Management: A Common Sense Revolution To Restore Our Environment
by Allan Savory with Jody Butterfield published by Island Press , 3rd Edition, 2016.

Dr. Christine Jones `Digging Deeper' soil biology in Ag. (published Dec 17, 2017)
https://www.youtube.com/watch?v=EKHchVlwNRg

What Gets Me Up in the Morning, Joel Salatin TEDxUVA, 28 Feb. 2017

Pasture Cropping - Profitable Regenerative Agriculture, by Colin Seis, 18 Aug. 2013
Australian farmer in NSW. Fascinating account of the farm's evolution from 1886 to date.
https://www.youtube.com/watch?v=AAei0NBVBIM

Treating the Farm as an Ecosystem with Gabe Brown Part 1
https://www.youtube.com/watch?v=uUmIdq0D6-A

The following is a fictional story that I created for my granddaughter when she was 10 after I learned about regenerative agriculture. Please share it with any young person in your life. https://youtu.be/fQ4hm1N1mVw

What can you do to help?

R

Gardeners and Farmers :

- Explore low disturbance (no till) gardening
- Learn how to add the soil biology back with compost or compost extract
  - have your soil biology tested – in Vancouver http://www.rootshootsoils.com/contact/
  - consult on a good source of soil with active biology
- No bare soil. Keep your soil covered at all times with organic matter & diverse cover crops
- Reduce chemical use that kill soil microbes and shuts down nature's bartering system

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Urbanites :

- Help increase awareness of soil biology and its role in food security (share my video) https://www.youtube.com/watch?v=AWILIYSf5ts
- Join a community supported agriculture (CSA) program = a "share" of the vegetables a local farm produces. During the growing season receive a weekly delivery of fresh food.
- Think about starting a garden or volunteering at The Sharing Farm
- Use your purchase power to support organic agriculture and grass-fed meat production
- Support the Savory Institute's Global Network https://www.savory.global/
- Consider fund raising to allow a local person to take Dr. Elaine Ingham's Soil Foodweb training to support local regenerative agriculture http://www.soilfoodweb.com/
- Recognize that most urbanites have lost contact with how their food is produced and how strongly agricultural practices effect our health and future.

https://articles.mercola.com/sites/articles/archive/2018/05/15/glyphosate-in-food.aspx

https://www.theguardian.com/business/2018/aug/10/monsanto-trial-cancer-dewayne-johnson-ruling

https://articles.mercola.com/sites/articles/archive/2017/01/10/industrialization-versus-regenerative-agriculture.aspx?utm_source=dnl&utm_medium=email&utm_content=art1&utm_campaign=20170110Z1&et_cid=DM132724&et_rid=1836044384

Gabe Brown's 5 Tenets of Soil Health

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1. **Least amount of soil disturbance possible, preferably no-till**.
2. **No bare soil.** The role of plants is to cover soil whether dead or alive. It's litter (or as Brown refers "armour") which insulates soil surfaces against weather, preventing drying out and erosion of sediment. Litter also stimulates soil fungi which pull litter into soil and stop movement. This provides a bed and breakfast for other organisms to enhance soil function, including earthworms
3. **Diversity; nature never has monocultures.** Dr Ademir Caligari a Brazilian scientist and a leading expert on cover crops inspired Brown to go beyond 2-3 species companion plant mixes to sowing 15-25 simultaneously.
4. **Keep a living root in the ground for as long as possible.** Brown extend his 100-day growing season in North Dakota by sowing species from all four groups - cool season grasses and broadleaves, warm season grasses and broadleaves. Living plants produce exudates to feed soil life which renew soil aggregates that normally break down after four weeks.
5. **Livestock integration** lifts availability of nutrients for pastures and crops. Researchers again have documented that livestock grazing significantly increases the availability of major nutrients versus crop land where livestock are absent.

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END