



**“The Magic of Soil”**

**by**

**Phil Gregory**

**Professor Emeritus**

**Physics & Astronomy**

**University of British Columbia**

**Sept. 16, 2019**

**Bowen Island Garden Club**

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SUSTAINABILITY

# Only 60 Years of Farming Left If Soil Degradation Continues

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

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

**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>

**The primary causes of soil degradation include:**

**Plowing or tilling,**

**Chemical-intensive farming,**

**Current livestock management,**

**Deforestation,**

**Industrial or urban uses**

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

# Soil degradation

R



**For every ton of food produced  
we lose 7 tons of soil**

<http://www.farmlandlp.com/2012/01/one-acre-feeds-a-person/>

<http://www.cornandsoybeandigest.com/soil-health/economics-soil-loss>

[David Montgomery, Professor of Geomorphology, Washington University https://www.youtube.com/watch?v=c4p-kQ6D8aA](https://www.youtube.com/watch?v=c4p-kQ6D8aA)

Proceedings of the National Academy of Sciences, 08/2007, Volume 104, Issue 33, pp. 13268-13272

[https://www.amazingcarbon.com/PDF/JONES-OurSoilsOurFuture\(8July08\).pdf](https://www.amazingcarbon.com/PDF/JONES-OurSoilsOurFuture(8July08).pdf)

## **My Investigation**

**A fascinating 4 year journey into current agricultural practices, soil biology, climate change, and human health**

**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' which is what my talk is all about

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) reduce chronic disease epidemics,
- 4) 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.

### **The Washington Post**

**The world has barely a decade to avoid disaster. We need to combat climate change — now.**

OCT 8, 2018

# 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=6tJlAjDjjo&index=6&list=PL4J8PxoprGZ-uMTxScBBn9nYT6CMX8aD>

Laptop link

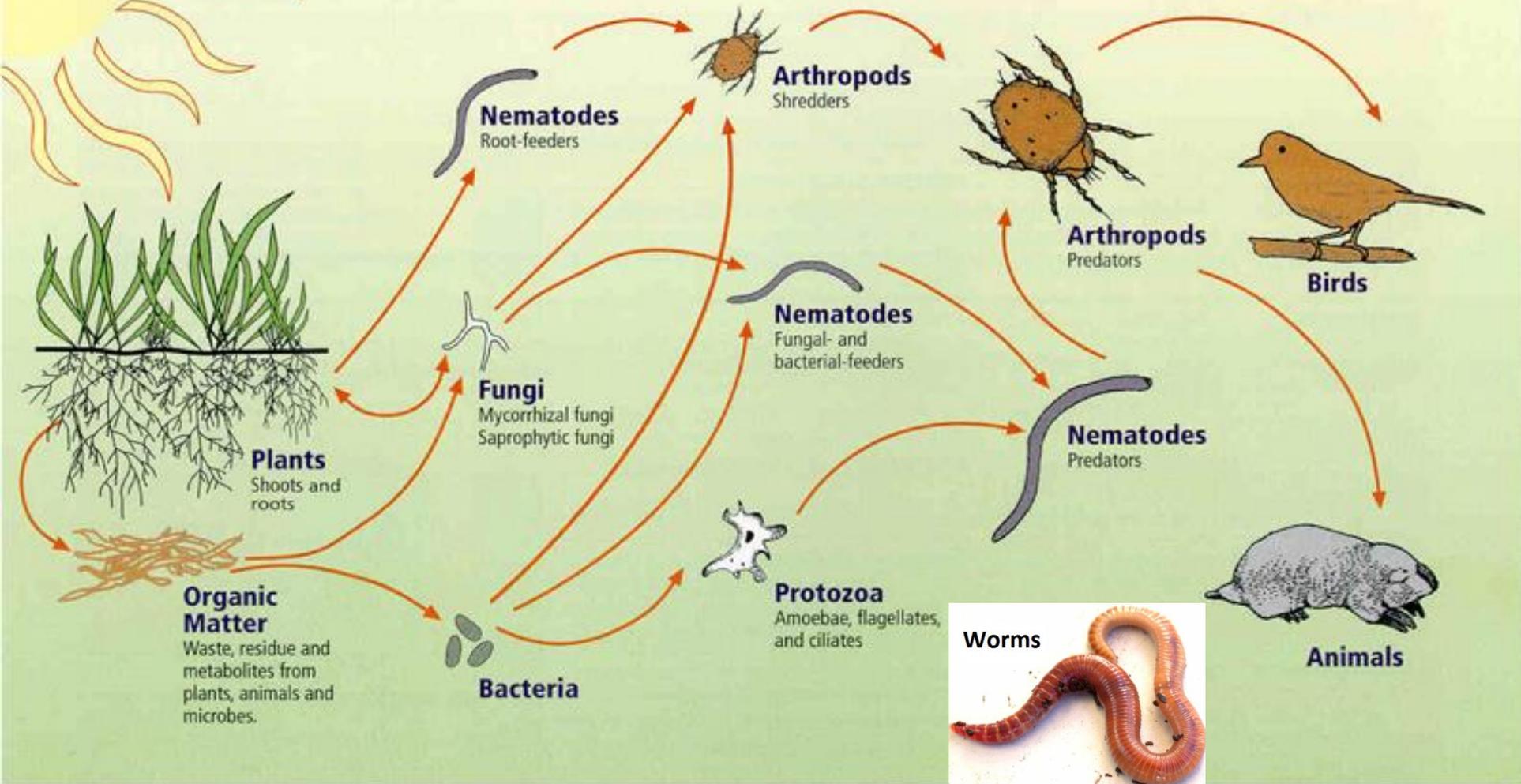
# Microbes are the secret behind healthy soil.

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



# The Soil Food Web

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

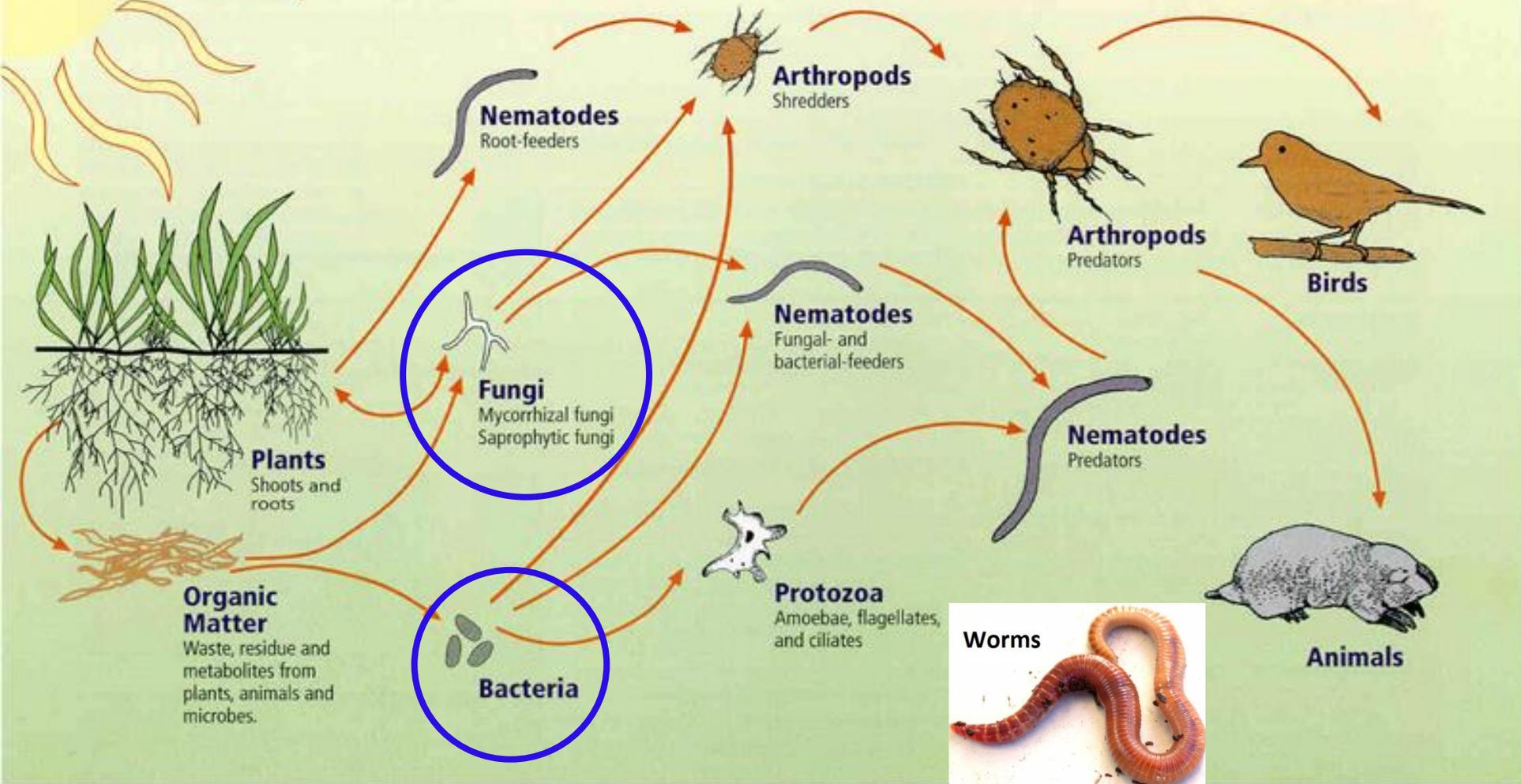


Some of the microscopic and visible actors in this soil food web

Understanding their roles is key to appreciating the new revolution in soil biology

# The Soil Food Web

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



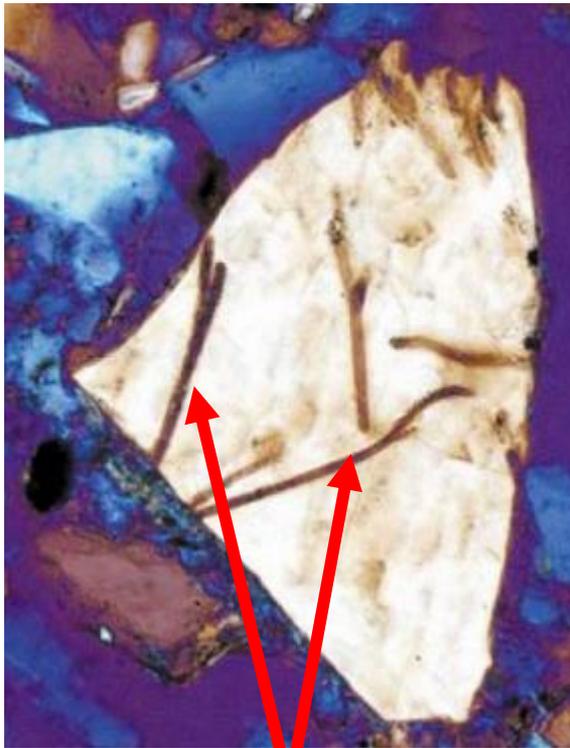
**Bacteria and fungi are at the base of this predator-prey relationship**

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<https://blogs.scientificamerican.com/artful-amoeba/the-world-s-largest-mining-operation-is-run-by-fungi/>

By Jenifer Fraser on November 5, 2015

# The World's Largest Mining Operation Is Run by Fungi



**Fungal mining tunnels**

**"Linking plants to rocks:  
ectomycorrhizal fungi  
mobilize nutrients from  
minerals."**

Thin-section micrograph of a tunneled feldspar.  
Box 4 I(c) from Renske Landeweert et al. *Trends  
in Ecology & Evolution* 16, no. 5 (2001): 248-  
254.

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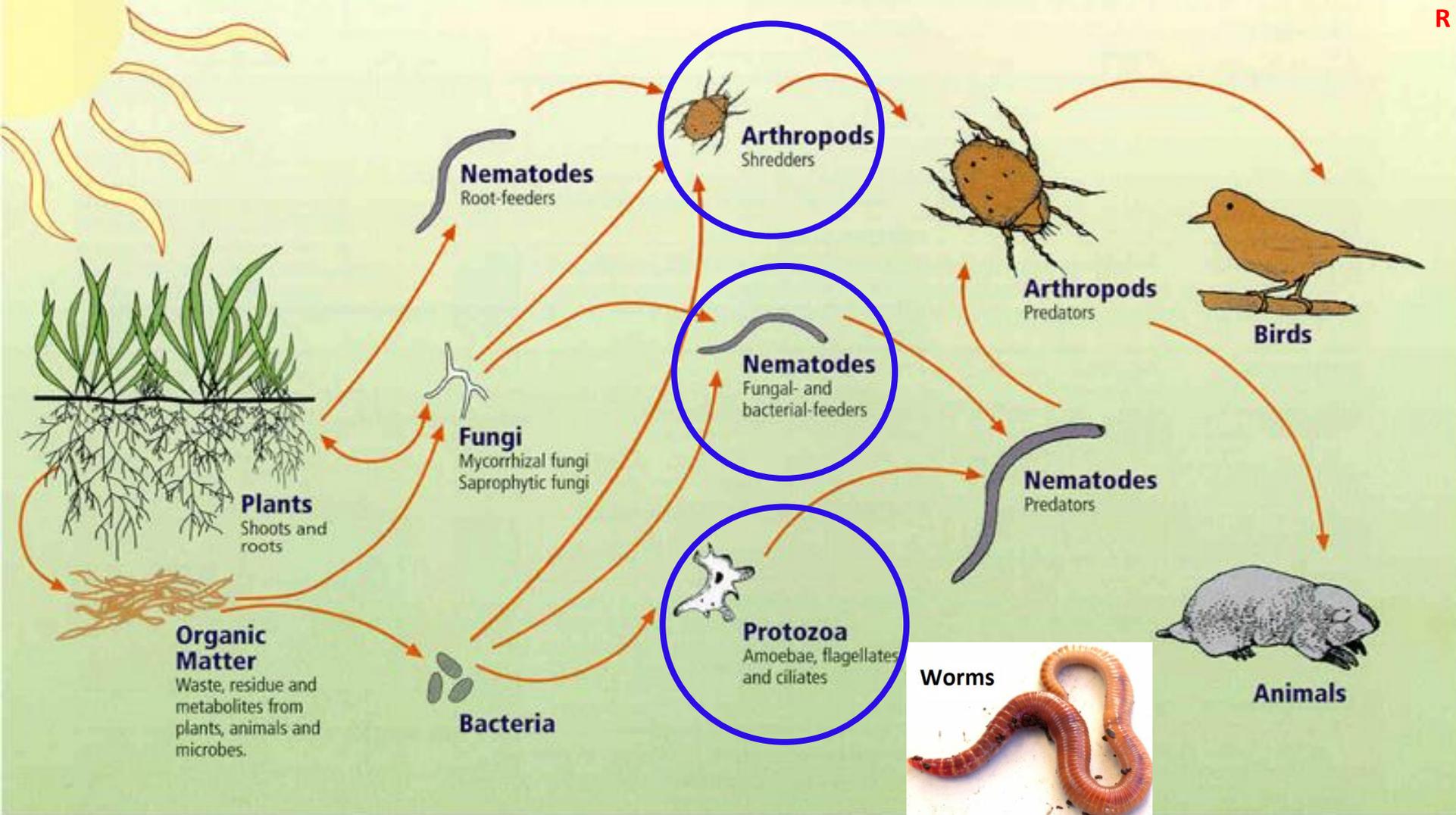
<https://blogs.scientificamerican.com/artful-amoeba/the-world-s-largest-mining-operation-is-run-by-fungi/>

By Jenifer Fraser on November 5, 2015

# The World's Largest Mining Operation Is Run by Fungi



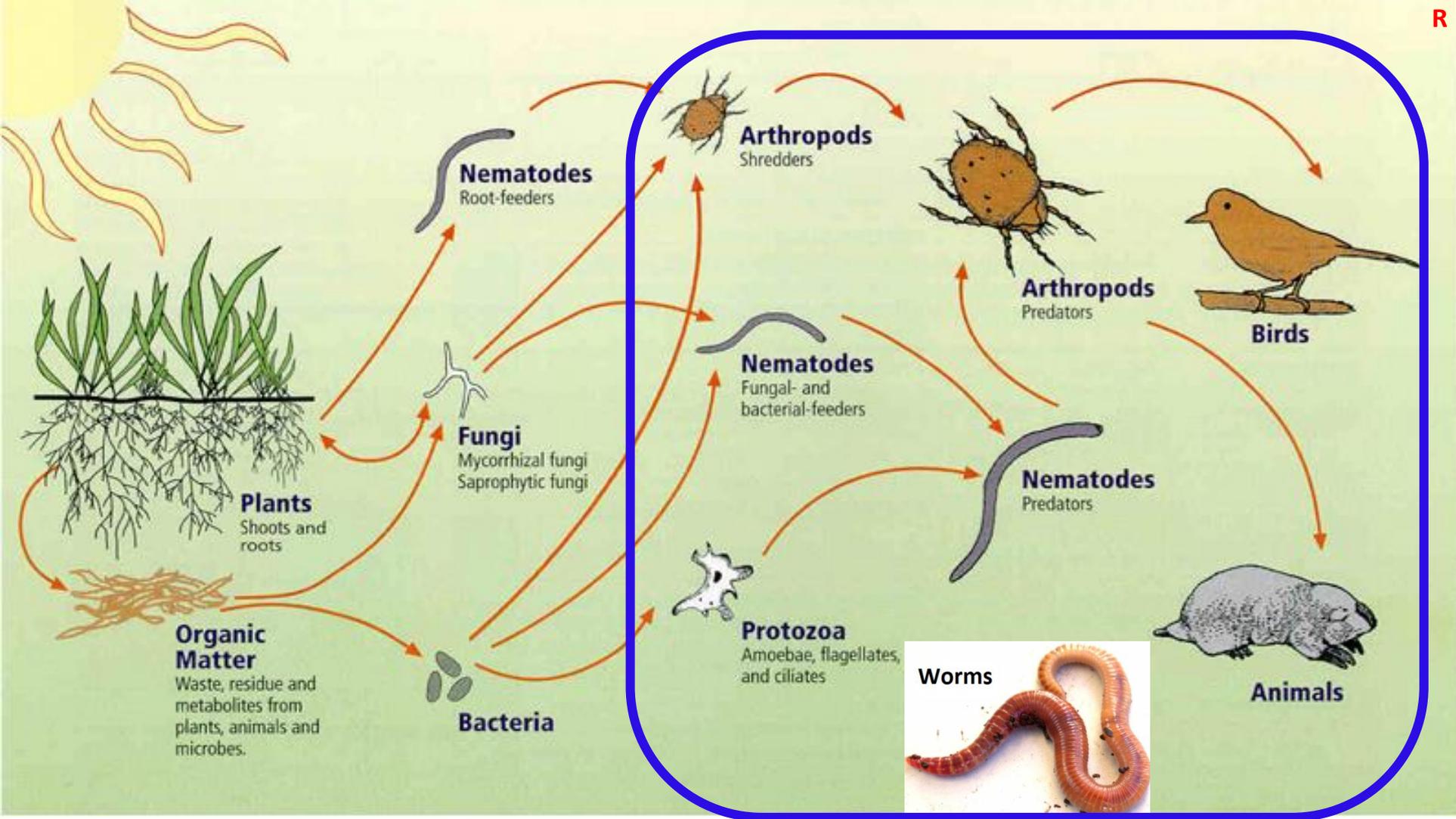
**When we kill off the soil microbes with current agricultural practices, we shut down nature's mining operation and turn living soil into dirt.**



## The important role of the microscopic predators

The bacteria and fungi store the nutrients in high concentrations in their bodies because they need them for life.

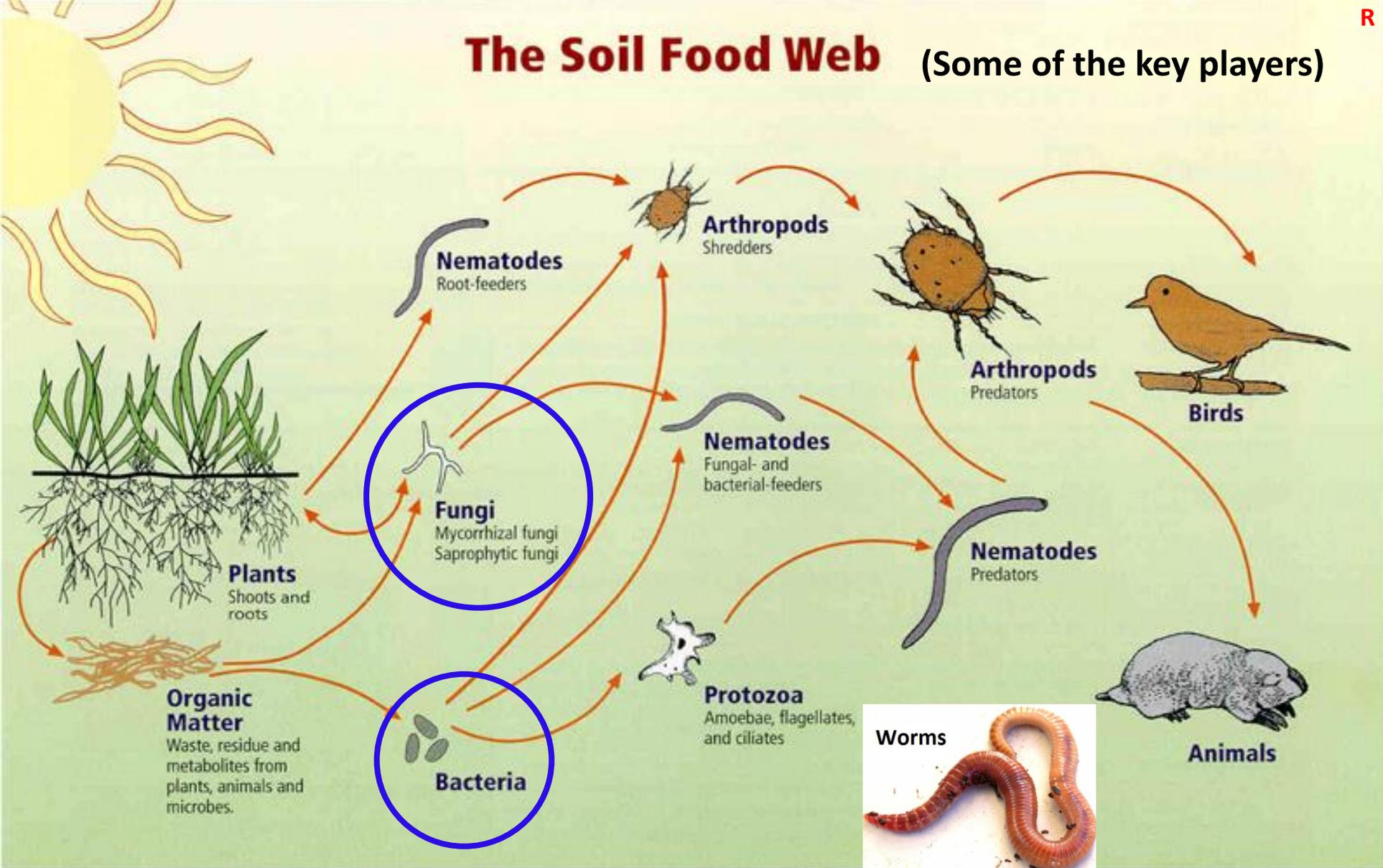
Their predators don't need such high concentrations of the nutrient and poop out the excess in a plant available form.



**We need a hierarchy of predators to preserve a stable balance of predators and prey.**

**In Nature high biodiversity translates to population stability.**

# The Soil Food Web (Some of the key players)



The bacteria and fungi are concentrated right next to the plant root because the plants attract and feed them

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](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.



“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



# 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](https://commons.wikimedia.org/wiki/File:Argan_tree_@_Agadir.jpg)

# Bacteria and fungi build soil structure

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

Image credit UN FAO.

**microaggregate (too small to see by eye)**

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)

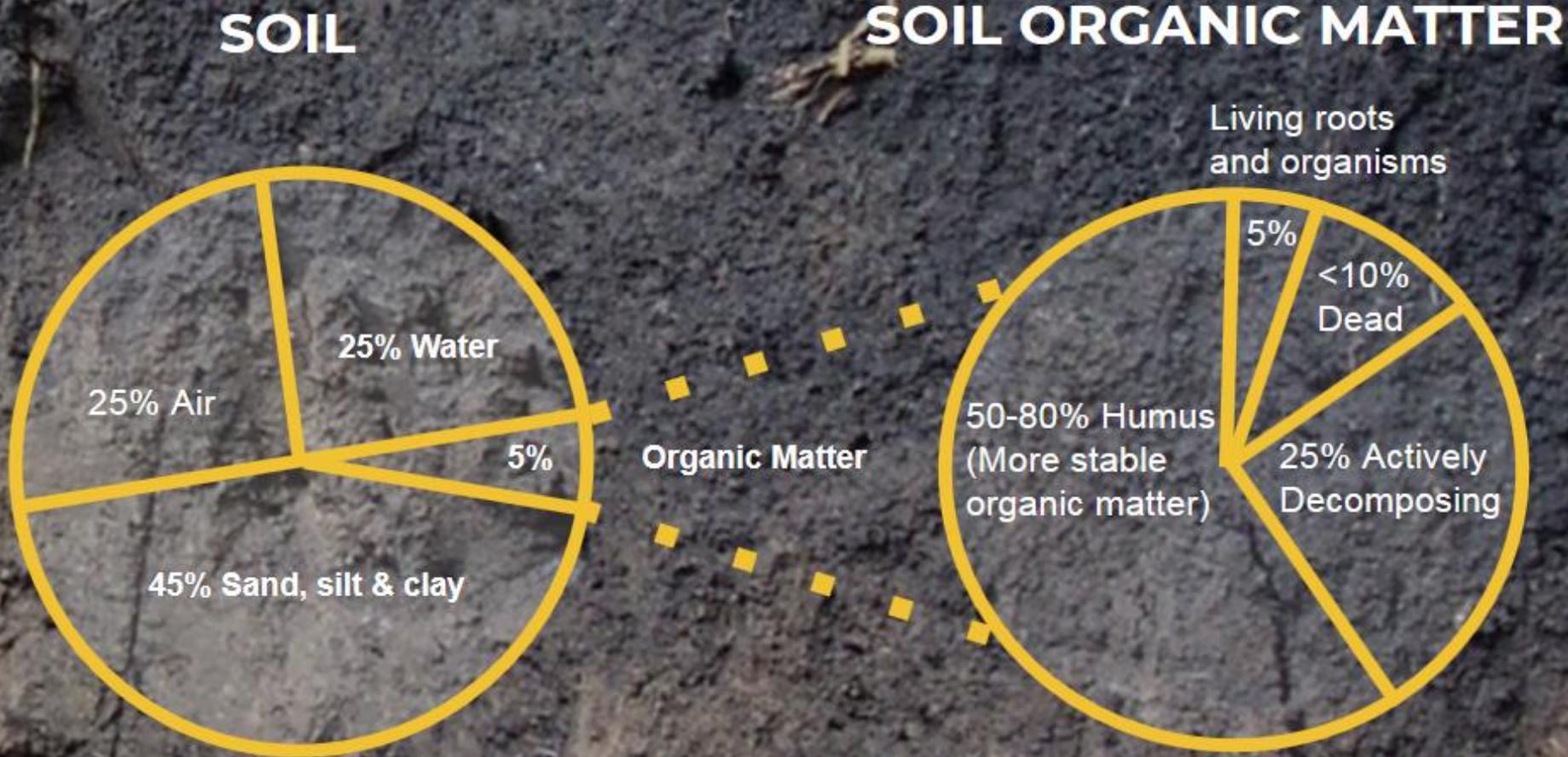


Largest organism

# Soil Aggregates Formed Around Plant Roots



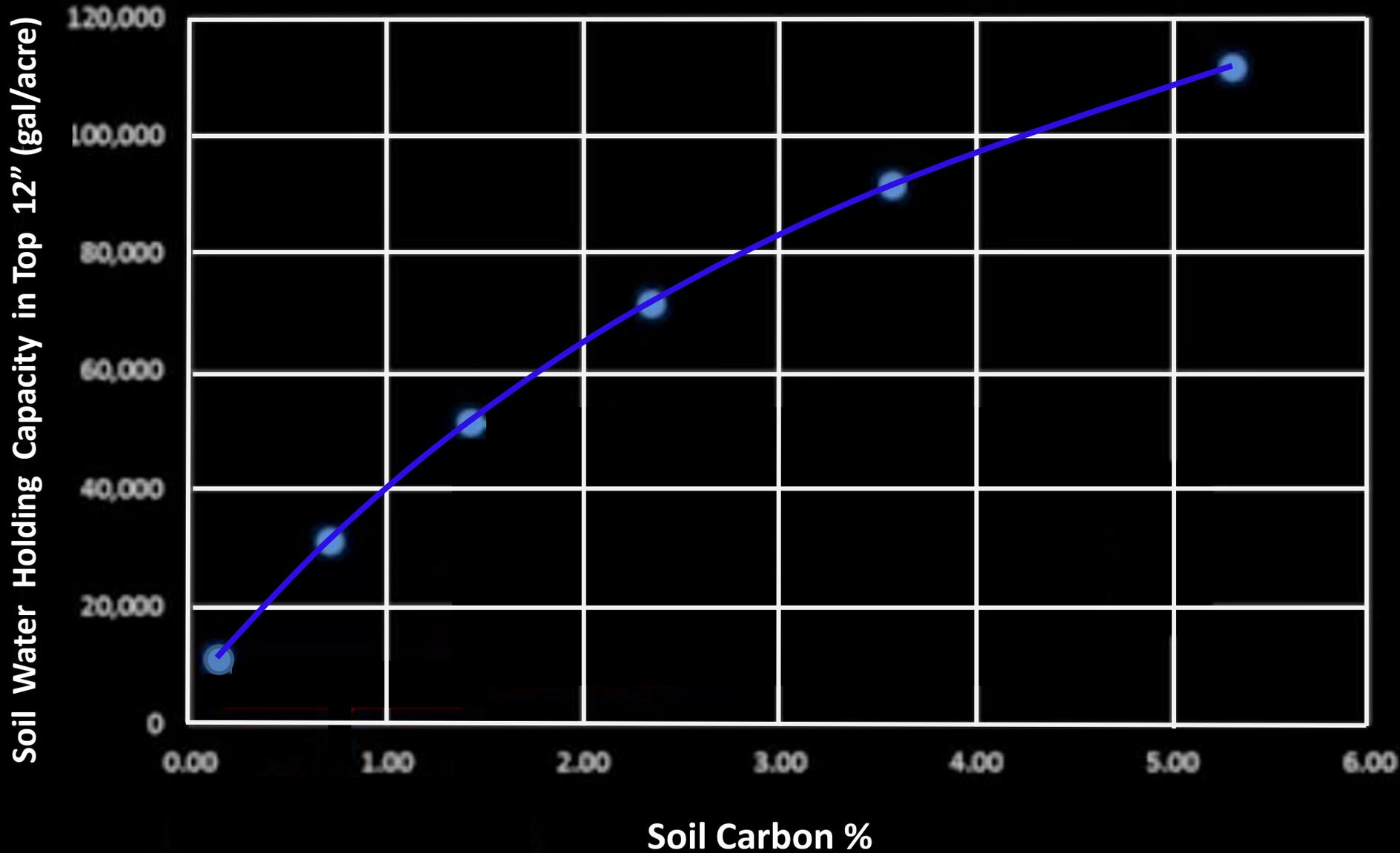
# Make-up of average or 'good soil', contains about 5% soil organic matter



- Really healthy soil can go up to 18-20% soil organic matter
- About 58% of the mass of organic matter exists as carbon
- Soil carbon acts as a sponge that can hold a lot of water

# Soil water holding capacity depends on soil carbon

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# Current Agricultural Practices

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



- 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](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](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](https://commons.wikimedia.org/wiki/File:Plowing_ecomat.jpg)

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



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

[https://commons.wikimedia.org/wiki/File:Feeding\\_Frenzy,\\_Faulston\\_Farm\\_-\\_geograph.org.uk\\_-\\_702677.jpg](https://commons.wikimedia.org/wiki/File:Feeding_Frenzy,_Faulston_Farm_-_geograph.org.uk_-_702677.jpg)

About 20 years ago it was discovered that plowing releases additional soil carbon into the atmosphere as climate warming CO<sub>2</sub>



Credit: Aalang (CC BY-SA 3.0)

[https://commons.wikimedia.org/wiki/File:Plowing\\_ecomat.jpg](https://commons.wikimedia.org/wiki/File:Plowing_ecomat.jpg)

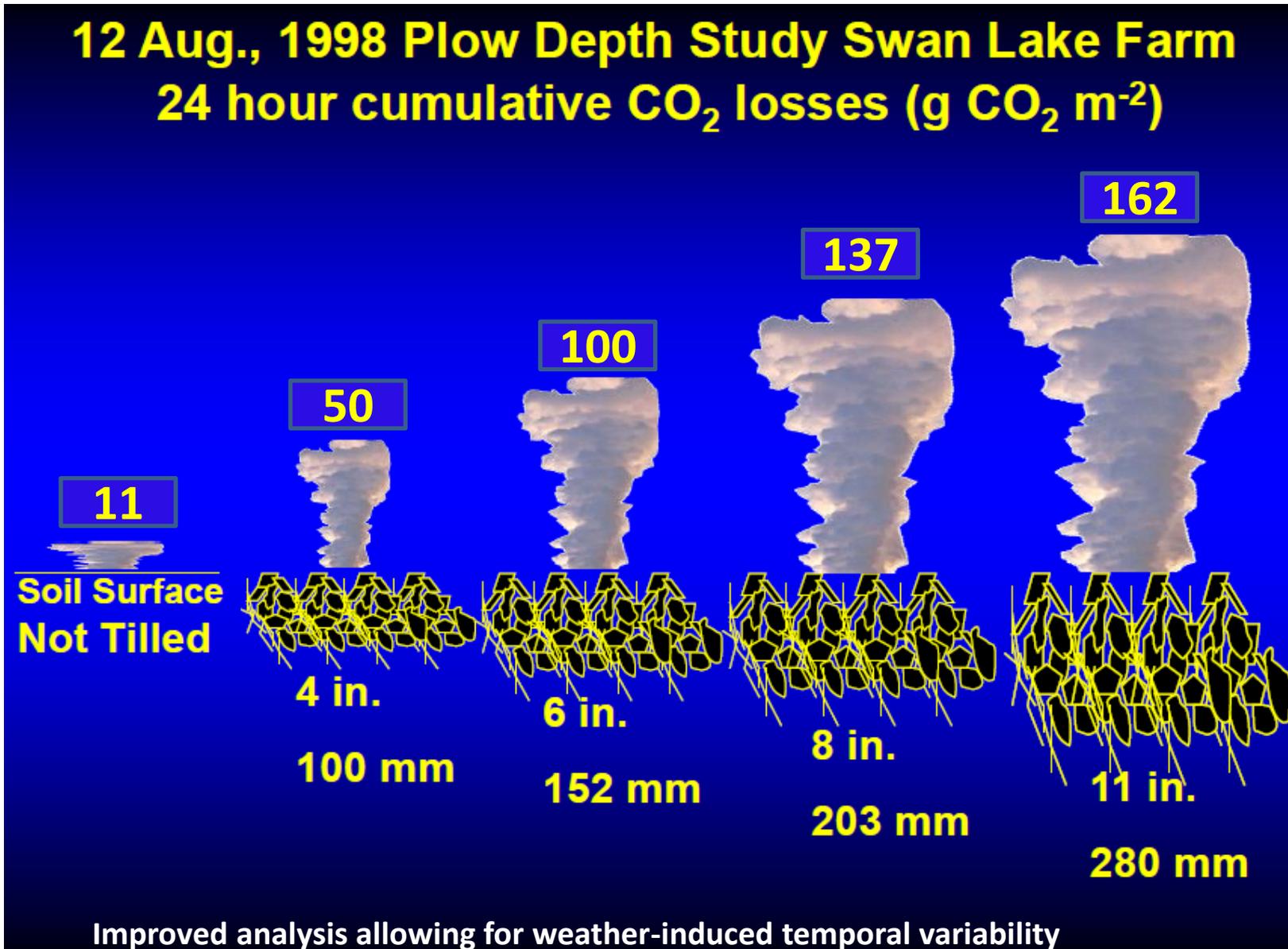


[https://commons.wikimedia.org/wiki/File:Feeding\\_Frenzy,\\_Faulston\\_Farm\\_-\\_geograph.org.uk\\_-\\_702677.jpg](https://commons.wikimedia.org/wiki/File:Feeding_Frenzy,_Faulston_Farm_-_geograph.org.uk_-_702677.jpg)

# Effect of tilling on CO<sub>2</sub> emission

Dr. Don Reicosky , USDA  
Agricultural Research Services

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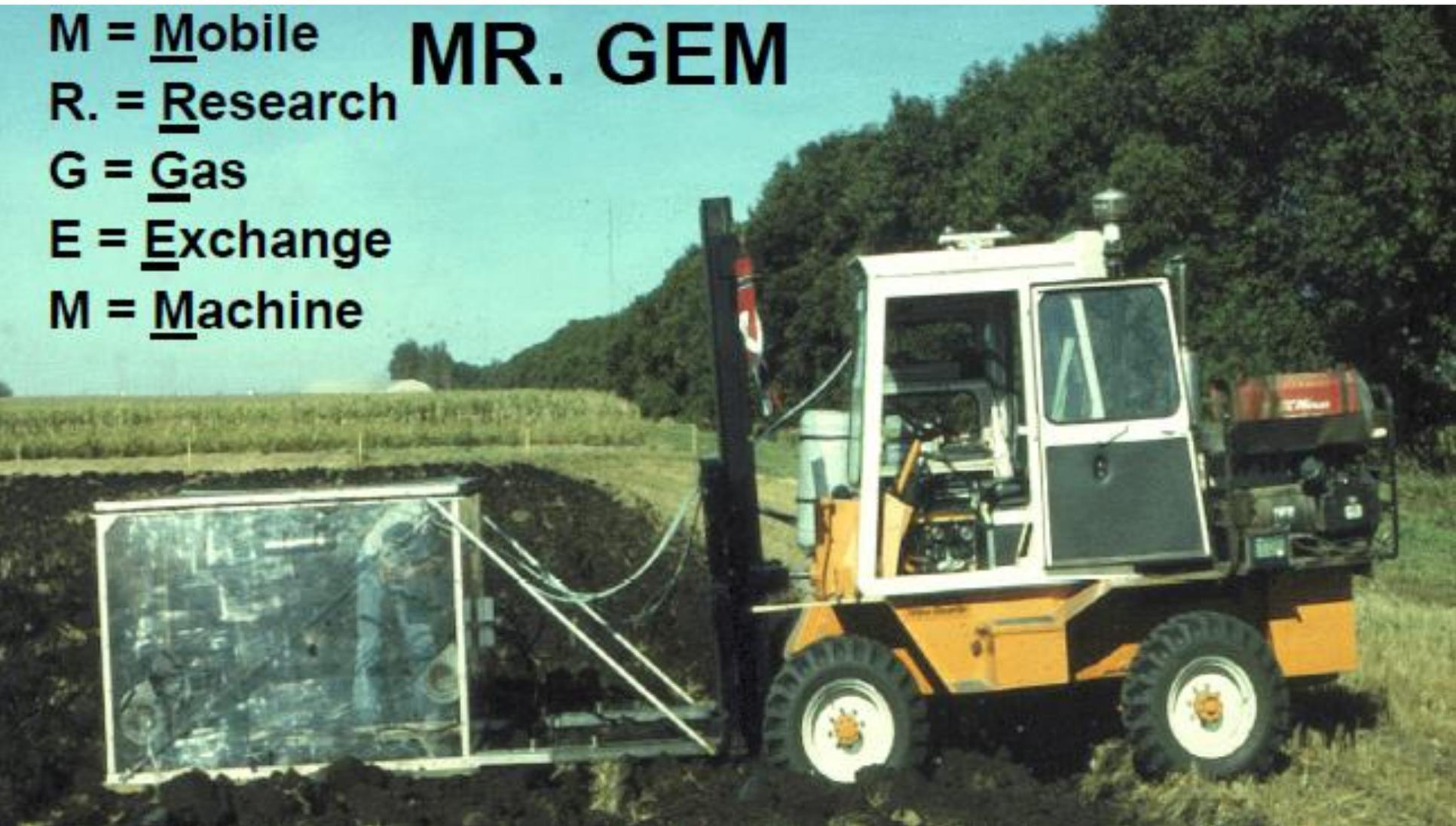
D.C. Reicosky and D. W. Archer, Soil and Tillage Research, Vol. 94, Issue 1, pp. 109–121, 2007

# 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>

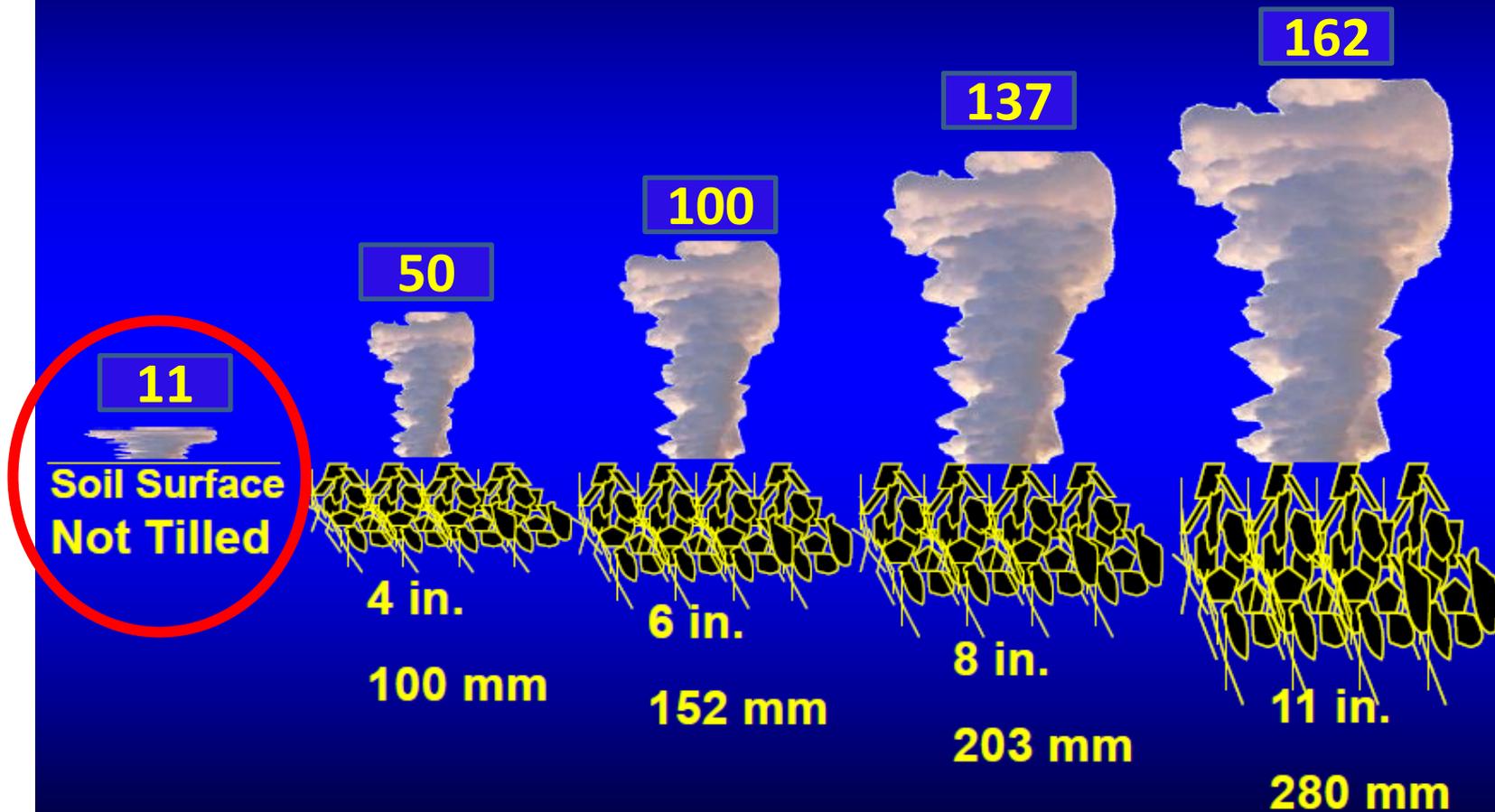
1 min soil videos

# Effect of tilling on CO<sub>2</sub> emission

Dr. Don Reicosky , USDA  
Agricultural Research Services

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**12 Aug., 1998 Plow Depth Study Swan Lake Farm  
24 hour cumulative CO<sub>2</sub> losses (g CO<sub>2</sub> m<sup>-2</sup>)**

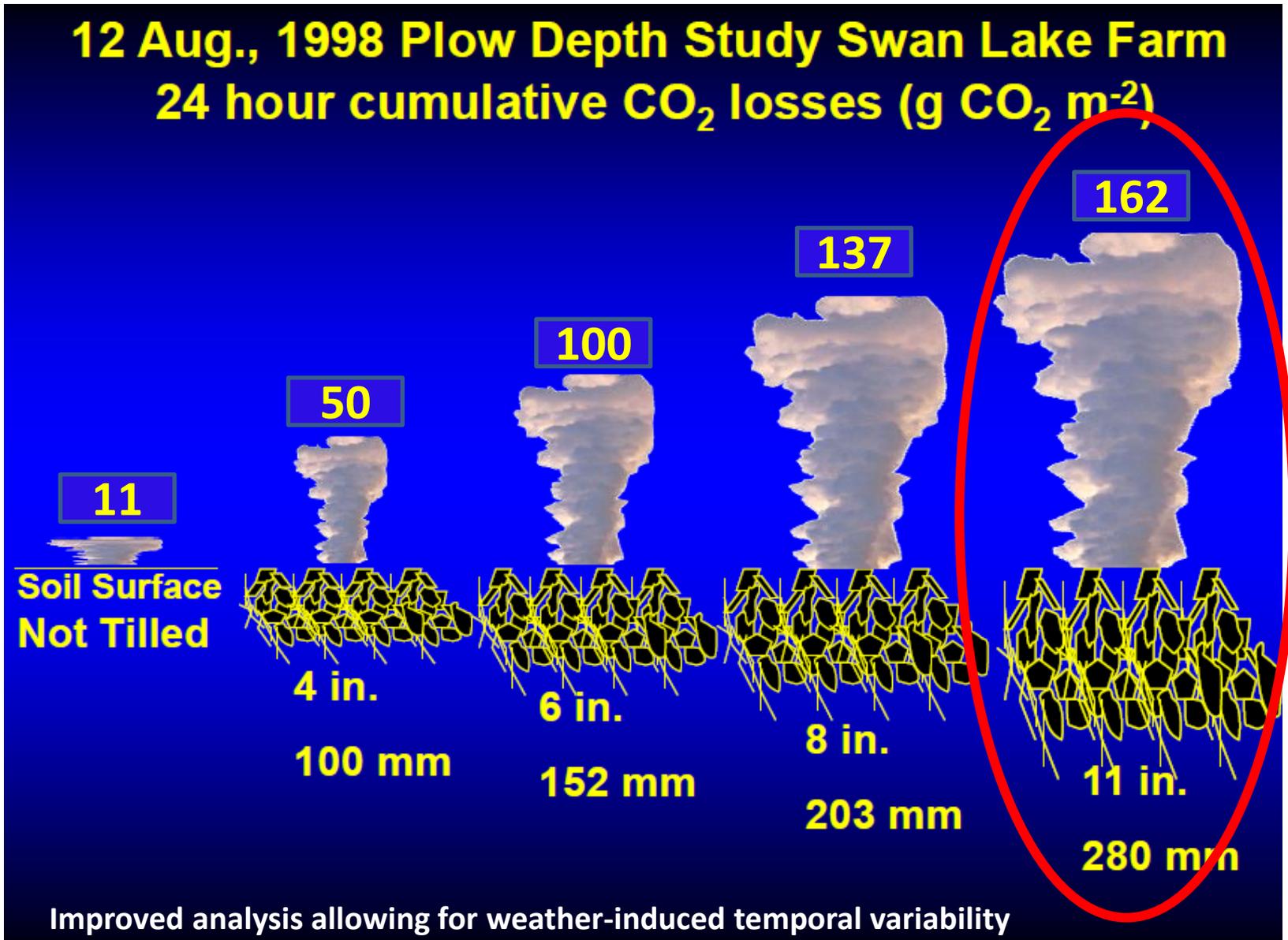


Improved analysis allowing for weather-induced temporal variability

# Effect of tilling on CO<sub>2</sub> emission

Dr. Don Reicosky , USDA  
Agricultural Research Services

R



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

# 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](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](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.

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**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)

# Dust storm Phoenix 5 July 2011

R



Credit: Roxy Lopez (CC BY – SA 3.0)

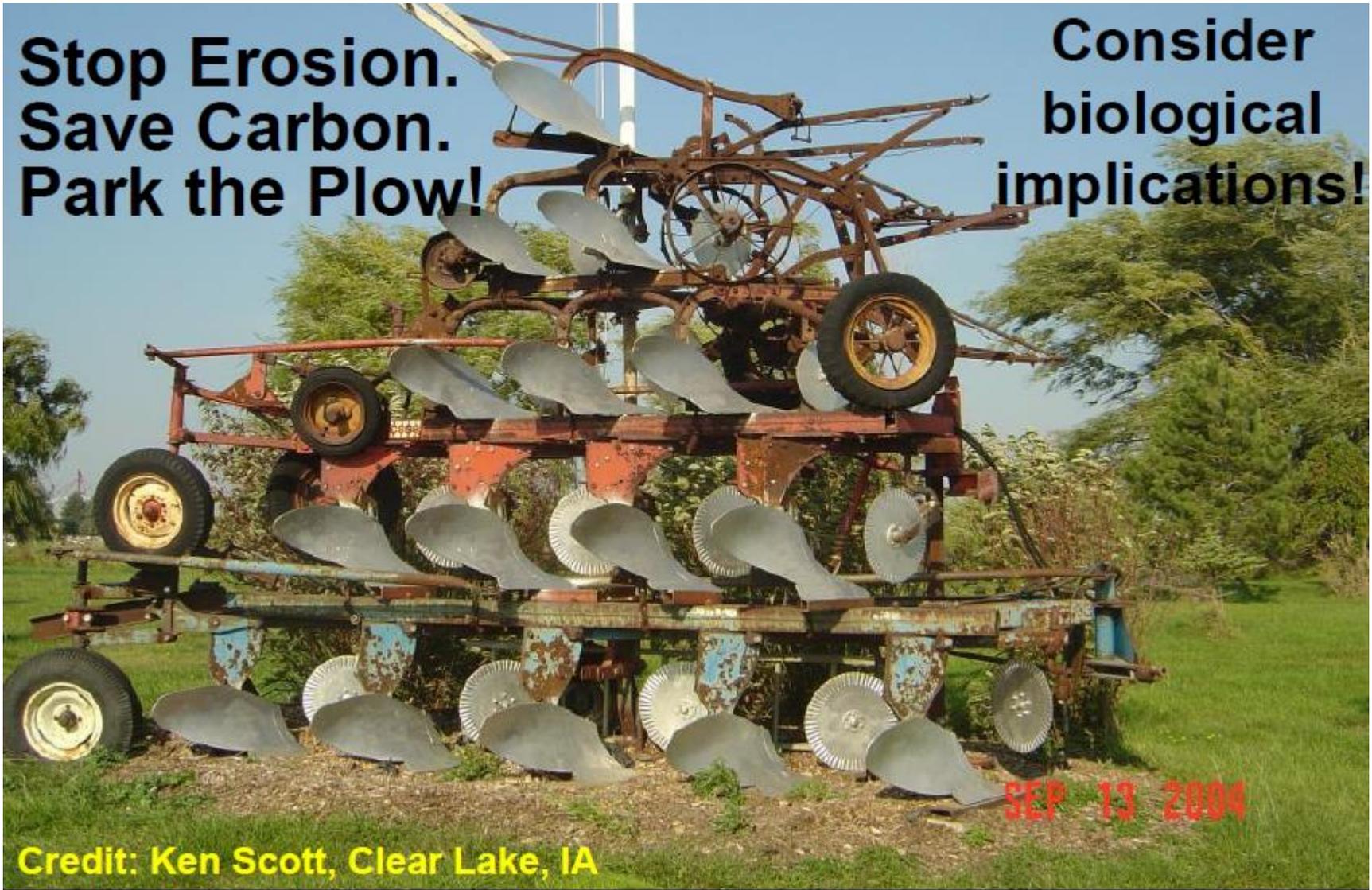
<https://commons.wikimedia.org/wiki/File:Duststorm.jpg>

Retire the plow

# Time to Retire the Plow

**Stop Erosion.  
Save Carbon.  
Park the Plow!**

**Consider  
biological  
implications!**



**Credit: Ken Scott, Clear Lake, IA**

**SEP 13 2004**

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

[https://www.youtube.com/watch?v=\\_t3zlg00ZvU](https://www.youtube.com/watch?v=_t3zlg00ZvU)



**In Nature, there are 1700 beneficial or indifferent insect species, for ever 1 pest species. We're focused on killing that one pest but meanwhile we're killing everything else.**

**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 energy.**

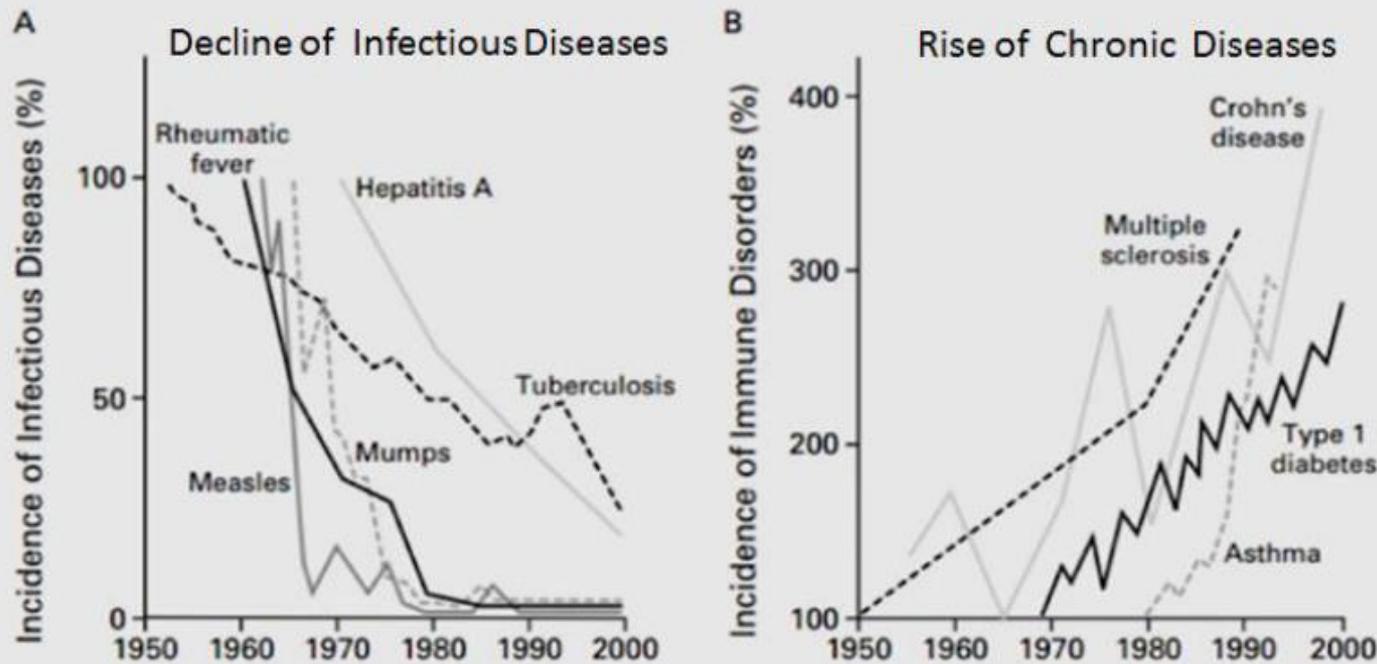
**Before 1940, you could produce six calories of food energy for one calorie of fossil fuel.**

**For too long we have relied on technology to carry out  
chemical warfare against microbes, weeds, insects,  
and nature,  
only to discover we are killing ourselves.**

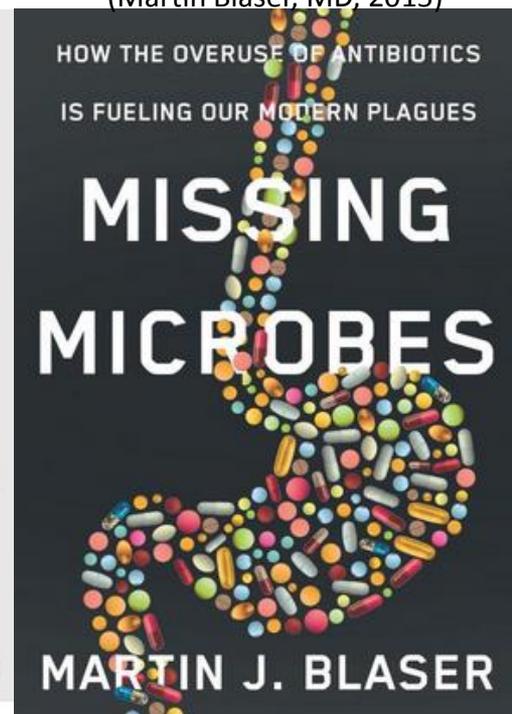
# The Largest Use of Antibiotics Occurs in Agriculture

Glyphosate, the active ingredient in herbicides like Roundup™, is a broad spectrum antibiotic.

(Martin Blaser, MD, 2015)



J. F. Bach (2002) N Engl J Med, Vol 347, 911



**39 times more Glyphosate is used than all the antibiotics in medicine (US).**

Dr. Zach Bush <https://www.youtube.com/watch?v=HL6OPzQe9Is>

<http://winewaterwatch.org/2018/01/glyphosate-5-billions-pounds-of-this-poison-sprayed-last-year/>

Dr. Rob Knight <https://www.youtube.com/watch?v=2iKHMMyWzclM>

# The Human Microbiome

**Back in 2000 we didn't know about our gut microbiome**

**We didn't know that our health is dependent on 3 pounds of microbes living in our gut**

**That these microbes outnumber the cells in our body by 10 times**

**We depend on these microbes**

- **to help digest our food**
- **produce certain vitamins**
- **make neurotransmitters for our brain**
- **regulate our immune system**

**Now we know!**

**but are our antibiotics destroying them?**

# First World Epidemics

Data for the US

(Jan. 2019 Dr. Zach Bush)

<https://www.youtube.com/watch?v=HL6OPzQe9Is>

**In 1965, 4% of the US population had a chronic disease**

**Today, 46% of the children have chronic disease**

**We clearly have to change the way we do agriculture.**

**If we use our new knowledge of soil biology we can farm in ways that don't require all these chemicals that are killing us.**

# Alternative Agricultural Model

## Nature's way (biomimicry)

### -Nature doesn't plow or till the soil

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

### -Nature favors biodiversity

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

### -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.

### -Nature has plants covering the ground year round

### -Nature integrates animals

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

# Move to **Regenerative Agriculture** which prioritizes soil health across all areas of farming

- based on mimicking nature to rebuild soil biology
- supports biodiversity
- sequesters atmospheric carbon & builds soil
- uses nature's barter system for more nutritious food

## Useful references

David Johnson, New Mexico State University (NMSU), 'Rapid Carbon Sequestration'

[https://www.youtube.com/watch?v=Fdh\\_j\\_KOmrY](https://www.youtube.com/watch?v=Fdh_j_KOmrY)

For a Sustainable Climate and Food System, Regenerative Agriculture Is the Key

<https://www.yesmagazine.org/soil-farming-greenhouse-IPCC-2019-08102019>

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

Since most agricultural soils have been degraded this is not a situation we want to sustain – so we need to move beyond sustainability to regenerative agriculture.



# Regenerative grazing practices can reverse desertification using Allan Savory's Holistic Grazing

How to Green the deserts and Reverse Climate Change, Allan Savory

[http://www.ted.com/talks/allan\\_savory\\_how\\_to\\_green\\_the\\_world\\_s\\_deserts\\_and\\_reverse\\_climate\\_change](http://www.ted.com/talks/allan_savory_how_to_green_the_world_s_deserts_and_reverse_climate_change)



*Regenerative  
Holistic Grazing  
Ranch*

*Desertifying  
Ranch*

Photo: Savory Institute

**It is not about the number of animals, it is all about timing.  
It's our failure to manage plant recovery time.**

## Some useful regenerative agriculture examples

- Gabe Brown's story: a farmer ahead of his time

<https://www.youtube.com/watch?v=GxlyKfWf9kU>

- Gabe Brown's Book 'Dirt to Soil'

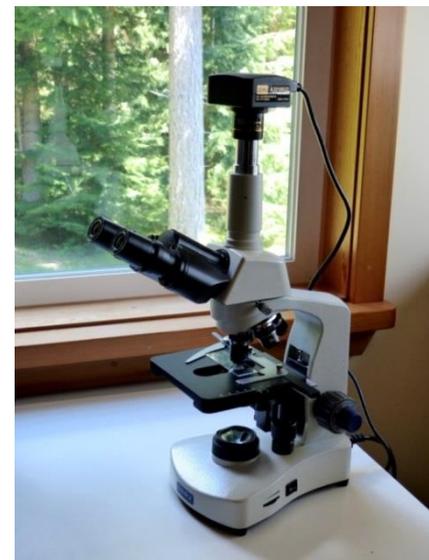
- Jeff Moyer, Rodale Institute 2014 , 'Terminating Cover Crops for Maximum Benefits'

<https://www.youtube.com/watch?v=FBt1OH6yIP4>

# 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.



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

# Experimental Johnson-Su Composting Bioreactor

A collaboration between the Grafton Community Gardens and the Bowen Island Food Sovereignty Group



Regenerative Agriculture relies on nature's barter system between plants and soil microbes instead of fossil-fuel based fertilizers and pesticides.

An important step is to restore the soil microbes by inoculating the damaged soil or dirt with compost that contains a healthy balance of indigenous microbes.

Research by Dr. David Johnson at New Mexico State University indicates that compost with a higher fungal to bacterial ratio (> 0.4) can achieve a remarkable yield increase (up to 8 times for chile peppers).

The Johnson-Su bioreactor is a new composting system he developed with his wife that can achieve a much higher fungal to bacterial ratio compost with a very diverse microbe population. It is a no turn composting procedure that has a short thermal phase ( $T > 131^{\circ}\text{F}$ ,  $55^{\circ}\text{C}$ ), followed by a worm composting phase. It requires a full year to complete.

<https://www.donobow.com/v11owmgted97oJohnson-Su%20Bioreactor.pdf>

Thermal phase of composting is underway. The heat is produced by bacteria rapidly reproducing in a high nitrogen environment. Steam emerges from the holes left from pulling out the PVC pipes. The black plastic pipes visible above the compost material are an irrigation system to add water to the pile.



4 temperature probes at a variety of locations. During the thermal phase our highest temperature recorded was  $161^{\circ}\text{F}$ ,  $71^{\circ}\text{C}$



Cutting holes for 4" PVC tubes that create 6 air channels into the compost pile.

## Compost Recipe

10% high nitrogen (Carbon to Nitrogen ratio 10:1) = 8 buckets  
(beer mash = spent organic barley, brewery waste product)

30% greens (C:N ratio 30:1) (grass) = 24 buckets

60% browns (C:N ratio 200:1) = 47 buckets  
(31 buckets organic straw + 15 buckets leaves + 1 sawdust)

Total = 79 buckets

(1 bucket is 5 gallons)



Attaching the wire frame to pallet. The 6 holes will hold the PVC pipes.



Bucket sized piles of straw, leaves, grass and beer mash, help to achieve the right proportions of ingredients when assembling the compost layer cake. When loading into the bioreactor the materials get randomly mixed together. The orange buckets contain fresh beer mash acquired on loading day.



Completed layer cake of ingredients before loading bioreactor  
Our team (left to right): Meribeth Deen, Jessica Mitts, Denise Richards, David Griffith, Julie Sage, Phil Gregory



Attaching the PVC pipes to metal frame mounted on top of bioreactor cage. The pipes are pulled out 24 hr after loading, leaving behind 6 air channels to provide oxygen to the rapidly reproducing bacteria.



Grass cut the day before loading. When assembling the layer cake, layers of mash & grass should be kept thin to avoid going anaerobic.



Loading the bioreactor

# Video on 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



Drifting together through space on our small blue lifeboat called Earth, guided by our new understanding of soil biology and nature's complexity, we urgently need to pull together to survive and prosper. So lets get started rebuilding soil biology and putting carbon back in the soil.



Credit NASA  
Earthrise seen from the moon

## **Farmers Market Posters and Supplementary Material**

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

**2017 YouTube version of my presentation is available at**

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

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

R

**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**     **Gabe's 2018 book "Dirt to Soil"**

<https://www.youtube.com/watch?v=GxlyKfWf9kU>

**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](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](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/0B6tV3TorfmstbXIIUU5yMXB2MWM/view>

# Supplementary material continued

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**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 Soil Foodweb Lectures** (updated recordings in progress available in 2019)

<https://www.soilfoodweb.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](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>

**Dr. Johnson on rapid carbon sequestration** [https://www.youtube.com/watch?v=Fdh\\_j\\_KOMrY](https://www.youtube.com/watch?v=Fdh_j_KOMrY)

**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=FBt1OH6yIP4>

**TEDx Collingwood "Eating our way out of this Mess," Gillian Flies of The New Farm**

<https://www.youtube.com/watch?v=O2bNVHbp3vM>

# Supplementary material continued

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**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](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 , 3<sup>rd</sup> Edition, 2016.

**Co-creating with Nature – An Exploration of Holistic Management** by Phil Gregory

<http://www.phas.ubc.ca/~gregory/papers/HolisticManagement%20BowenGregory10Jun2018Sum.pdf>

**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://www.youtube.com/watch?v=fQ4hm1N1mVw>

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