"The Magic of Soil: 2nd Chapter on Thermal Composting"

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

Introductory talk for Composting Workshop
at Grafton Community Gardens
Sponsored by Bowen Agricultural Alliance
& Bowen in Transition

Fri. April 6, 2018
7:00 pm

End

Thermal Composting Workshop

Hosted by Jessica Mitts of the
Grafton Community Gardens

Speakers:

Phil Gregory: UBC Professor and creator of The Magic of Soil video

Jo Castaneda Tobias: soil food web consultant Vancouver www.rootshootsoils.com

Dates:

April 6, 7pm "The Magic of Soil: Second Chapter": a presentation at BICS on thermal composting as a tool for restoring soil biology.

April 7, 1pm, Assemble a thermal compost at the Grafton Community Garden.

May 12th Biological analysis of the compost and making compost extract that participants take home.

Workshop Fee: By donation.
Suggested amount $20-$50

Land heart and sky
Heart-based land care services

To sign up for the event or to learn more:
landheartandsky@gmail.com
http://graftonlake.ca/gardens/

GRAFTON COMMUNITY GARDEN

Outline of Phil Gregory's Presentation

- Food security and climate change challenges
- Recent revolution in soil biology offers a way forward
- Regenerative agriculture and what it can do for us
- Composting key to rebuilding soil biology
- Thermal composting
  - Planning considerations
  - 2017 successful example
  - 2018 recipe
  - Ways to apply compost
  - Making compost extract
  - Effect on soil

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/

Oct. 2017

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

"If you drench soil in chemicals that improves yields ... but ultimately you are cutting the ground away from beneath your own feet. Farmers know that," said Gove.

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,

Global warming.

Average North American eats about 1 ton of food each year.

Conventional agriculture uses one acre to grow that much food.

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

At the same time we lose 6 to 7 tons of soil per acre each year.

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

Prof. David Montgomery, Washington University https://www.youtube.com/watch?v=c4p-kQ6D8aA

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

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.

Here is the good news!

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.

For details see my YouTube video "The Magic of Soil"

The Good News

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.

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.

For details see my YouTube video "The Magic of Soil"

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)

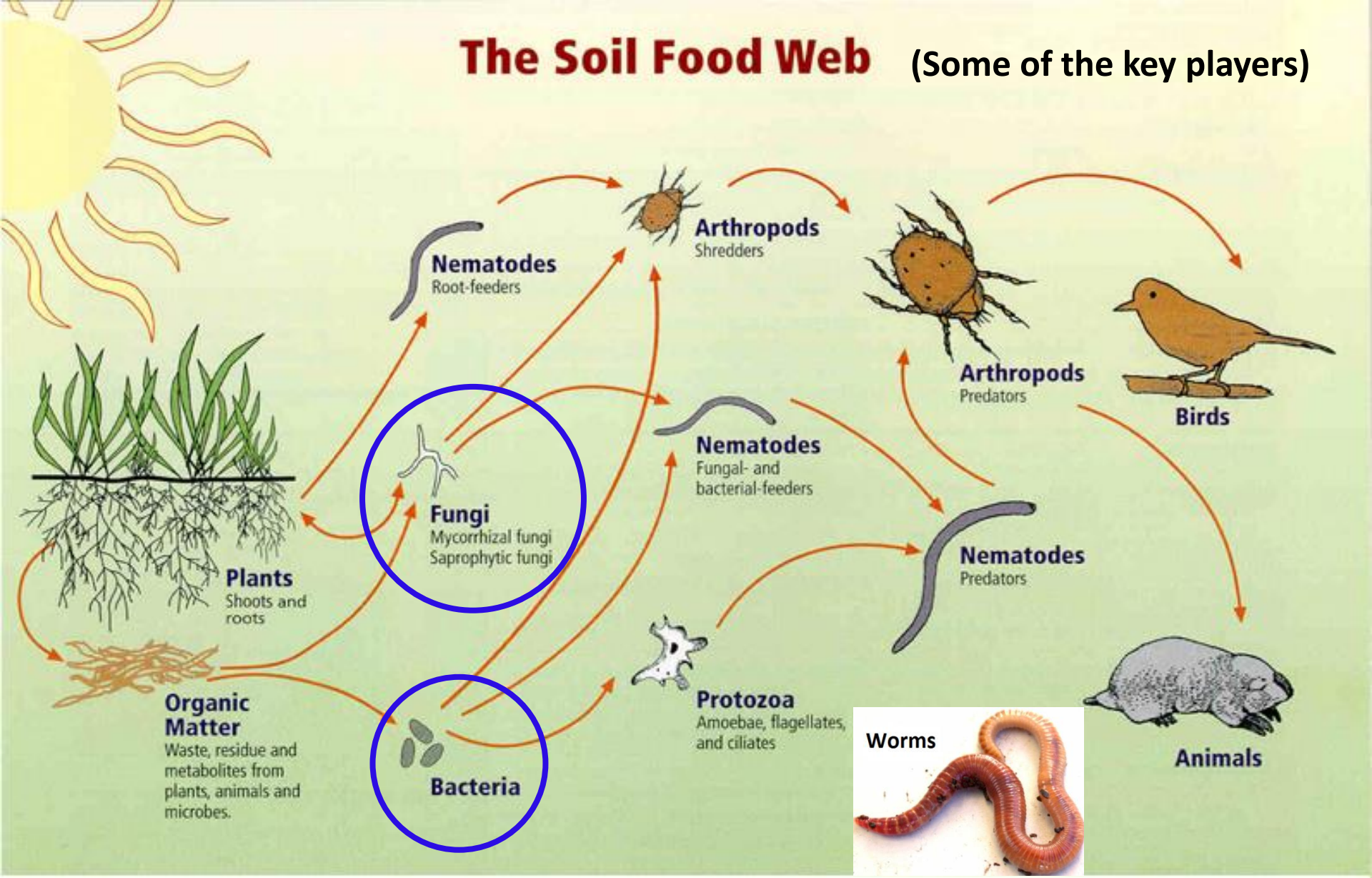
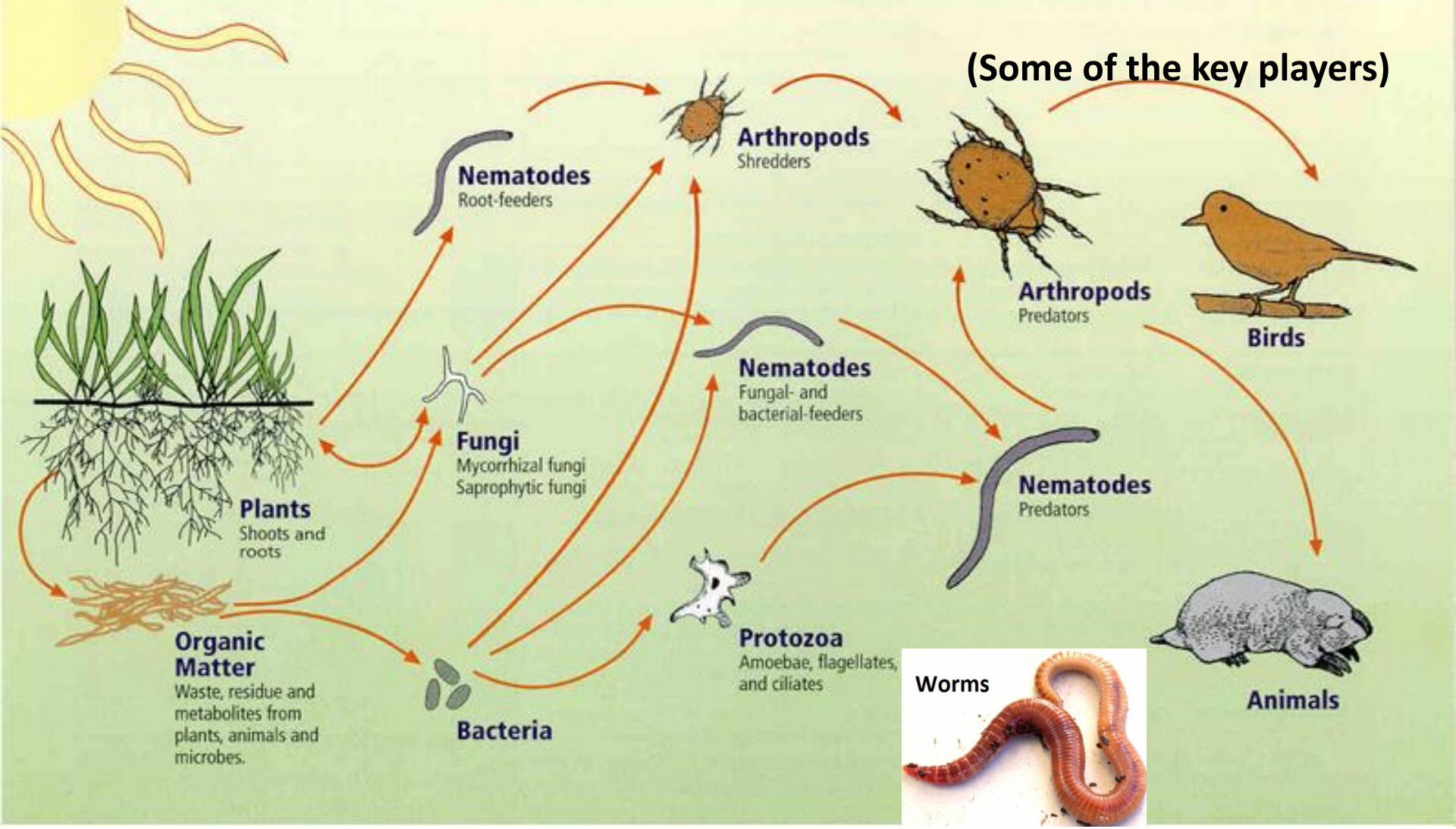
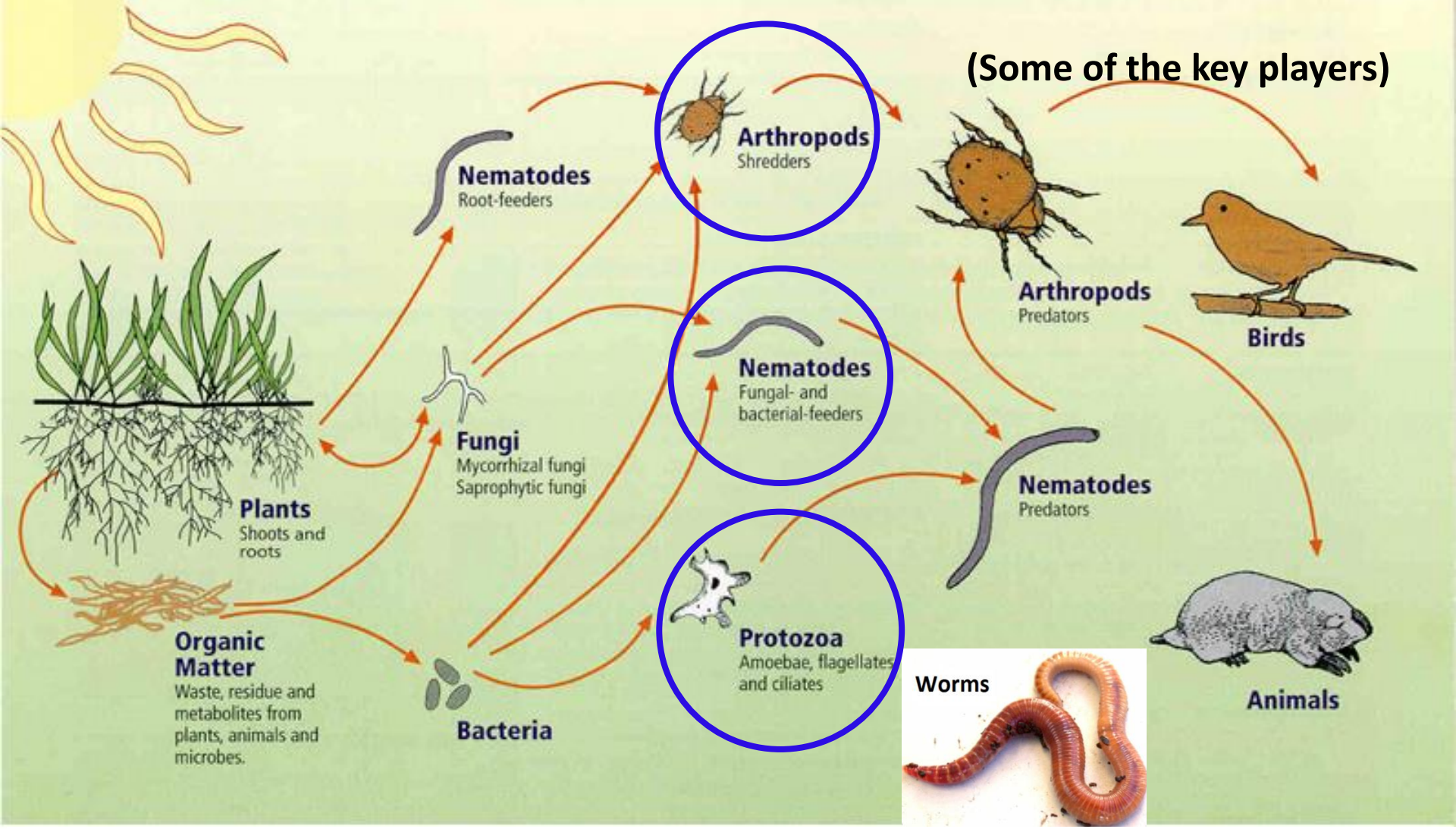


Image courtesy of USDA Natural Resources Conservation Services
http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/biology/



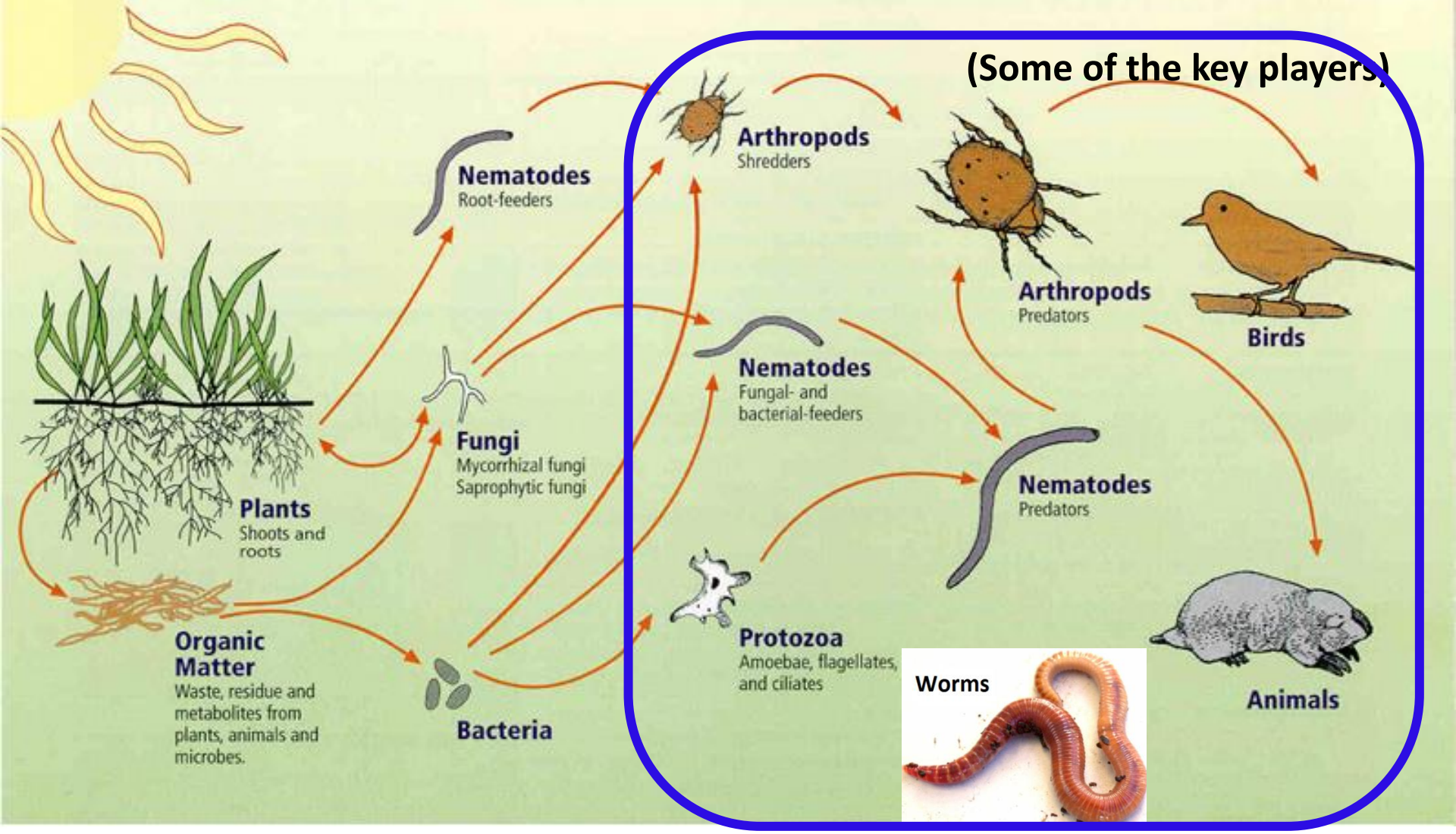
For a fascinating account of the mining capabilities of fungi see:

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



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

1) 'he 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



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

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.

For the microbes these root exudates are like cakes and cookies.

Dr. Elaine Ingham

Plants also release exudates through their leaves.

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.

Natures Bartering system

Plants release carbon compounds to attract and feed soil microbes.

In return the plants receive approximately 38 other elements that they require to grow strong and healthy.

Bacteria and fungi build soil structure

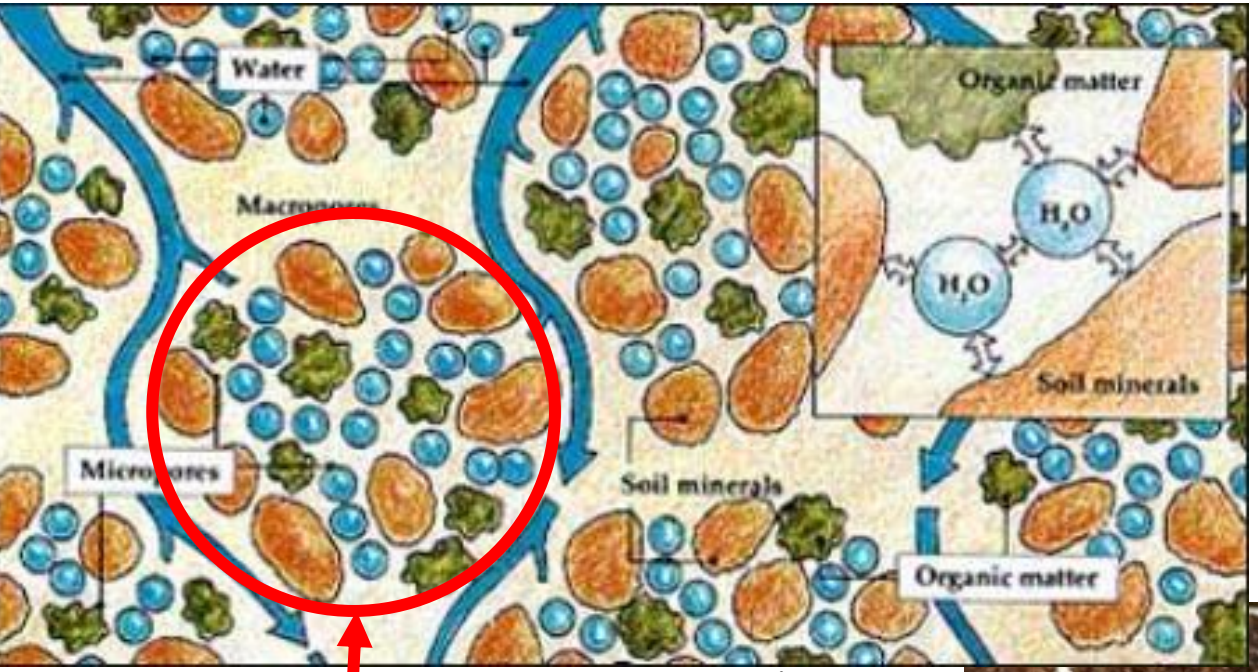


Image credit UN FAO.

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)

Conventional Agriculture

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

Current Agricultural Model Unsustainable

For a start, we use 10 calories of fossil fuel to produce 1 calorie of food

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

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

Soil is being lost at between 10 and 40 times the rate at which it can be naturally replenished.

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

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)
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

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

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

Soil Erosion

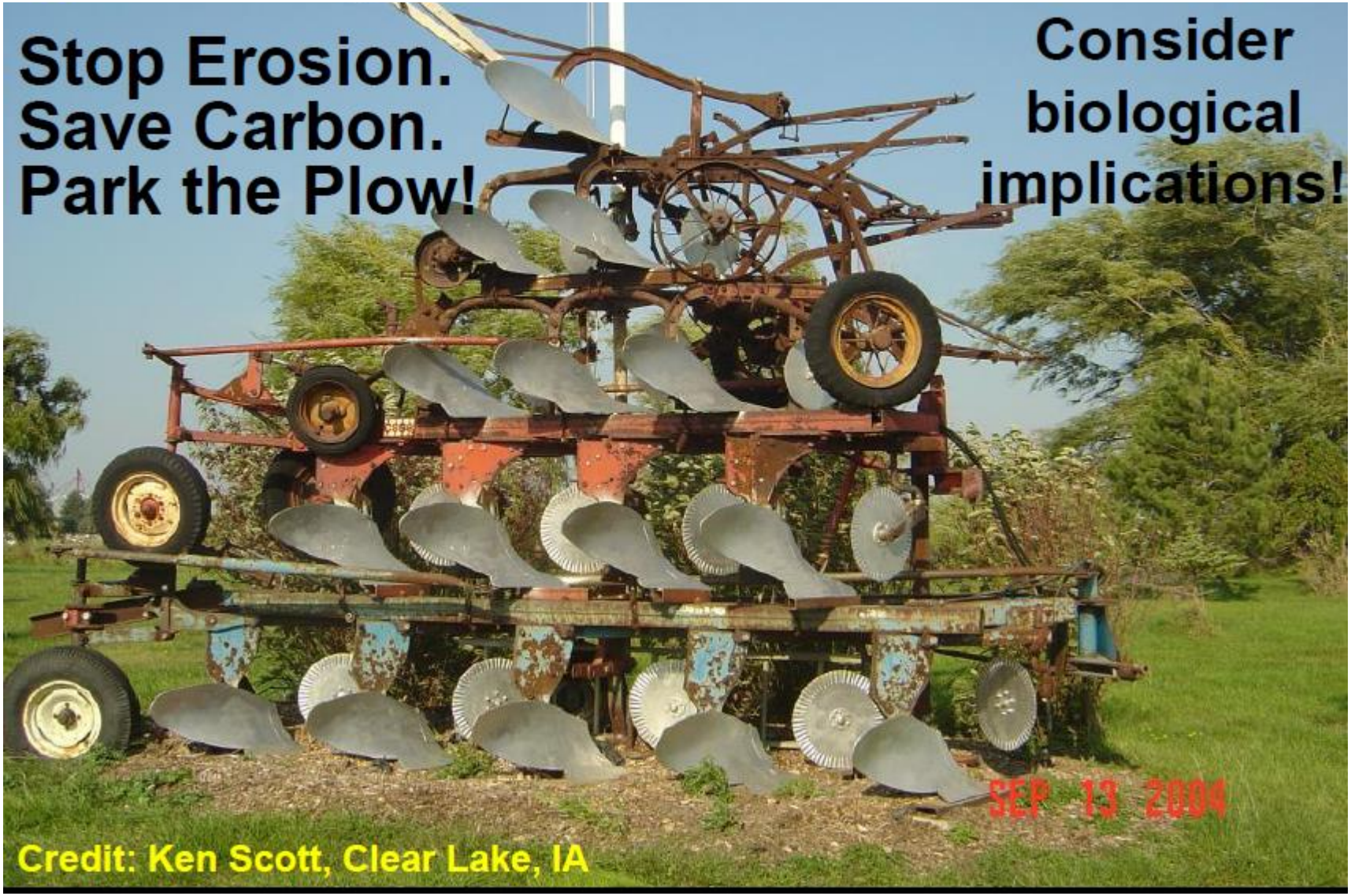
Without the biotic glues and living plant roots, soil is easily washed away by rain or blown away during periods of drought, creating massive dust storms.

Dust storm approaching Stratford, Texas 1935.

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 July 2011

Time to Retire the Plow



About 20 years ago it was discovered that plowing releases additional soil carbon into the atmosphere as climate warming CO_2

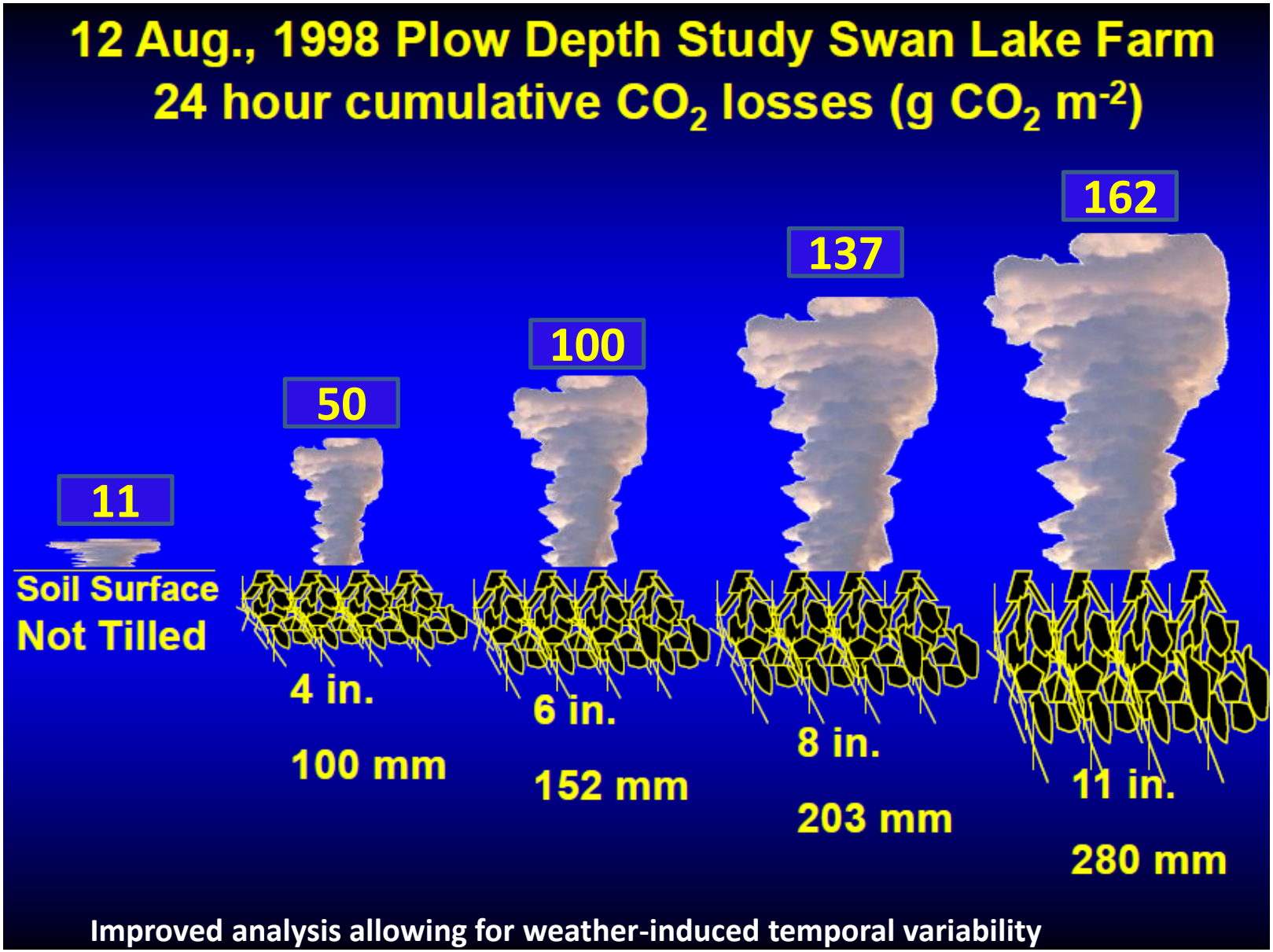
Credit: Aalang (CC BY-SA 3.0)
https://commons.wikimedia.org/wiki/File:Plowing_ecomat.jpg

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

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

Effect of tilling on CO_2 emission

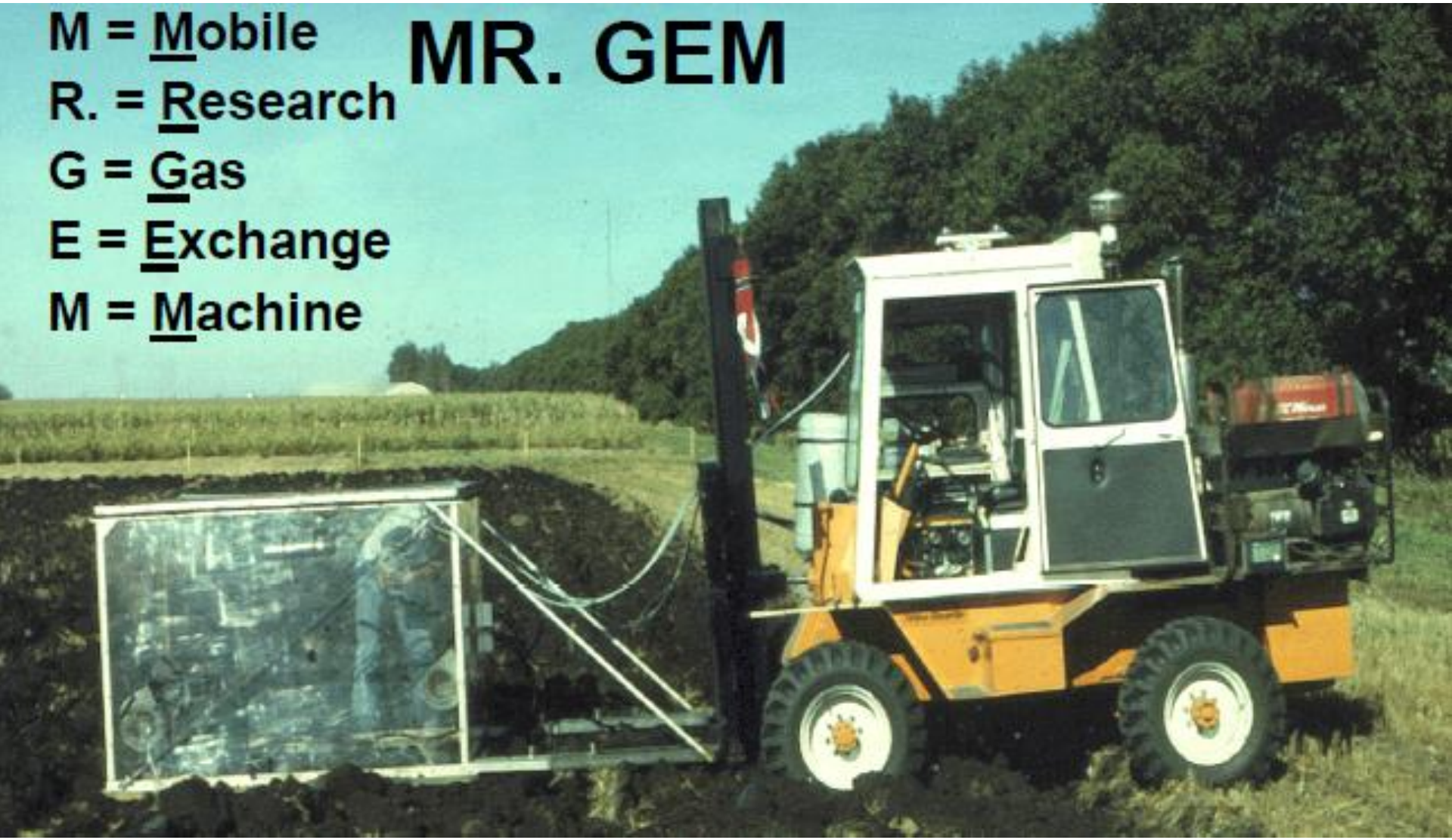
Dr. Don Reicosky , USDA
Agricultural Research Services



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

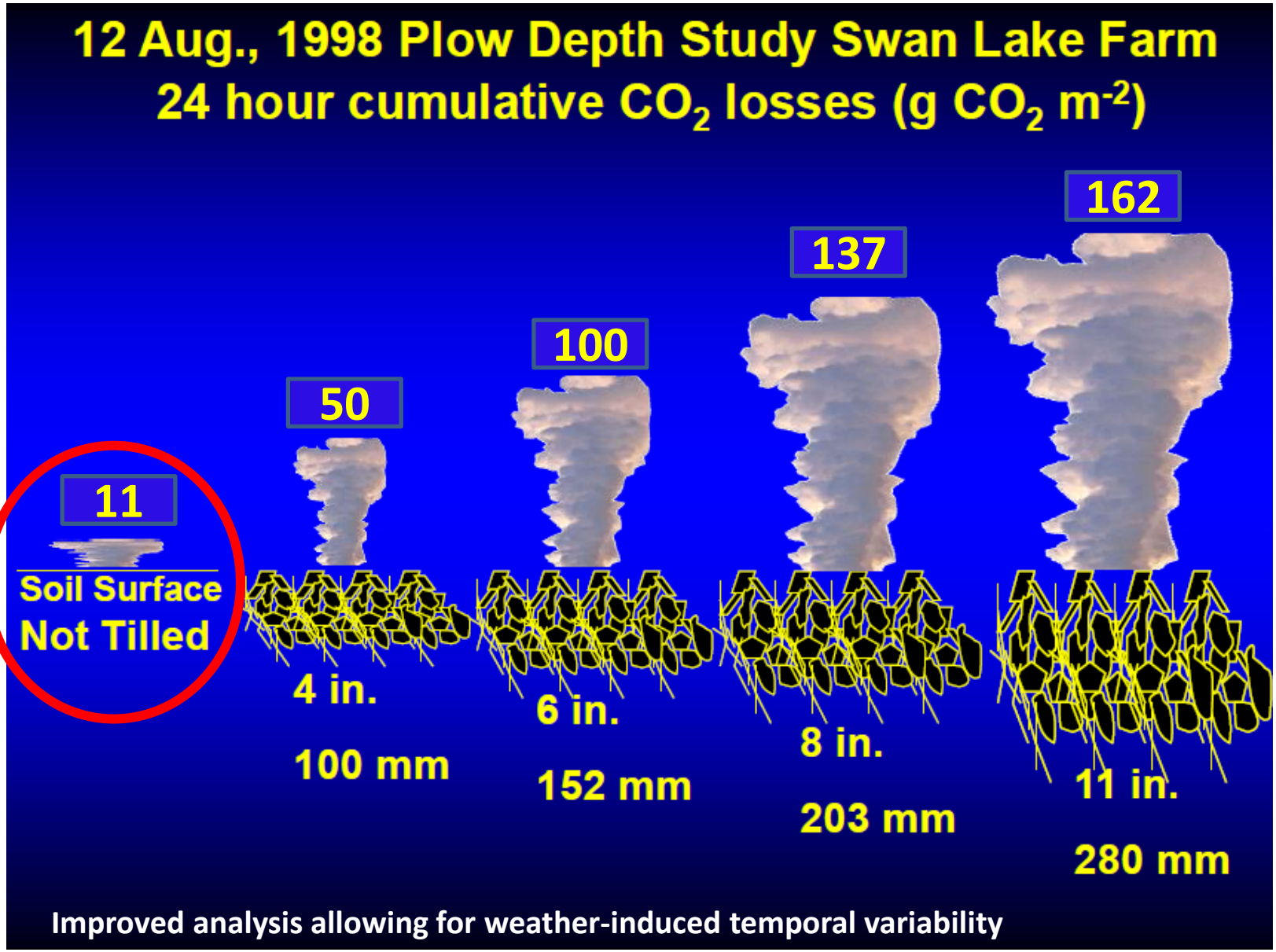
Dr. Don Reicosky USDA-ARS



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

Effect of tilling on CO_2 emission

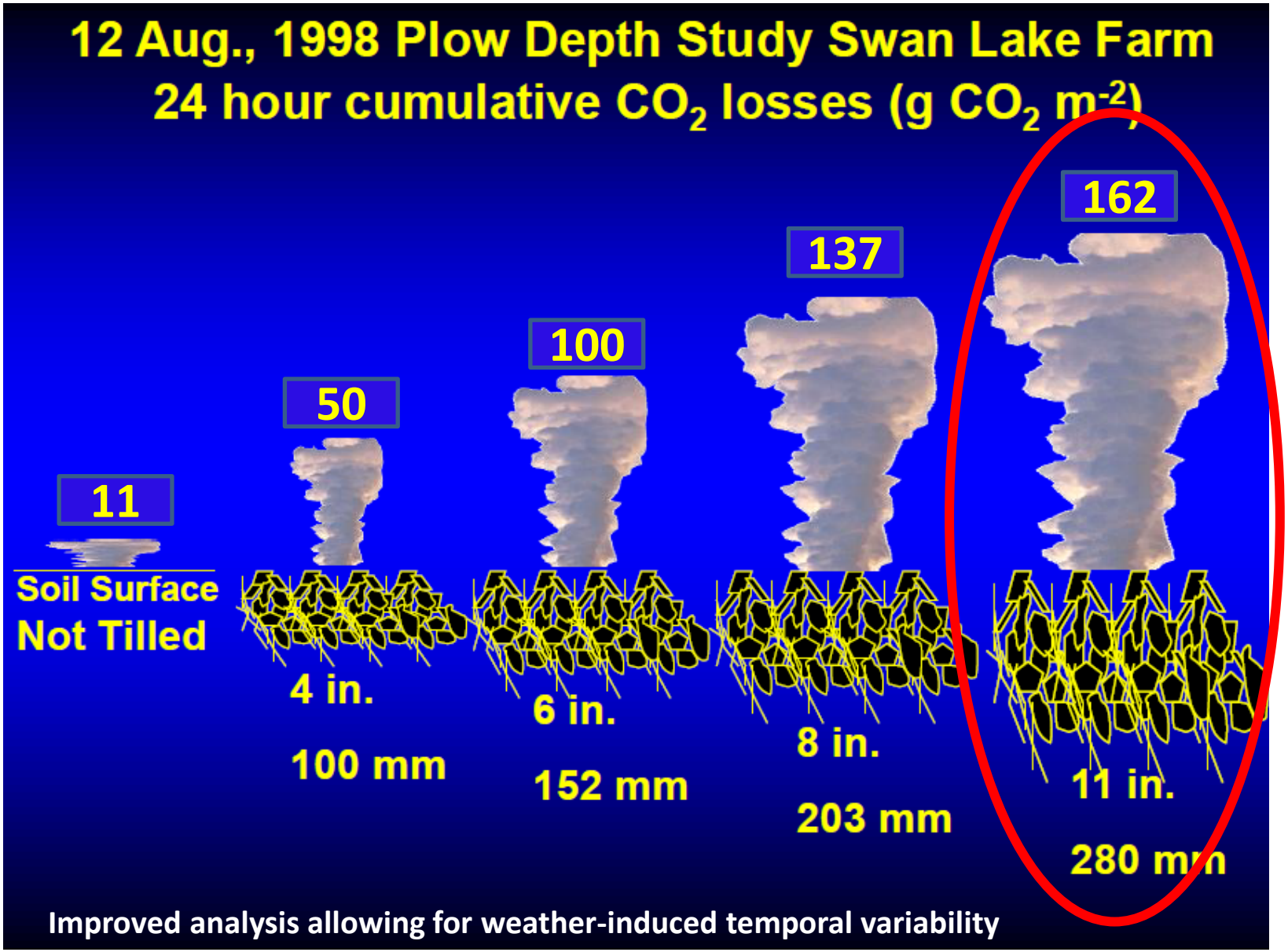
Dr. Don Reicosky , USDA
Agricultural Research Services



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

Effect of tilling on CO_2 emission

Dr. Don Reicosky , USDA
Agricultural Research Services



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

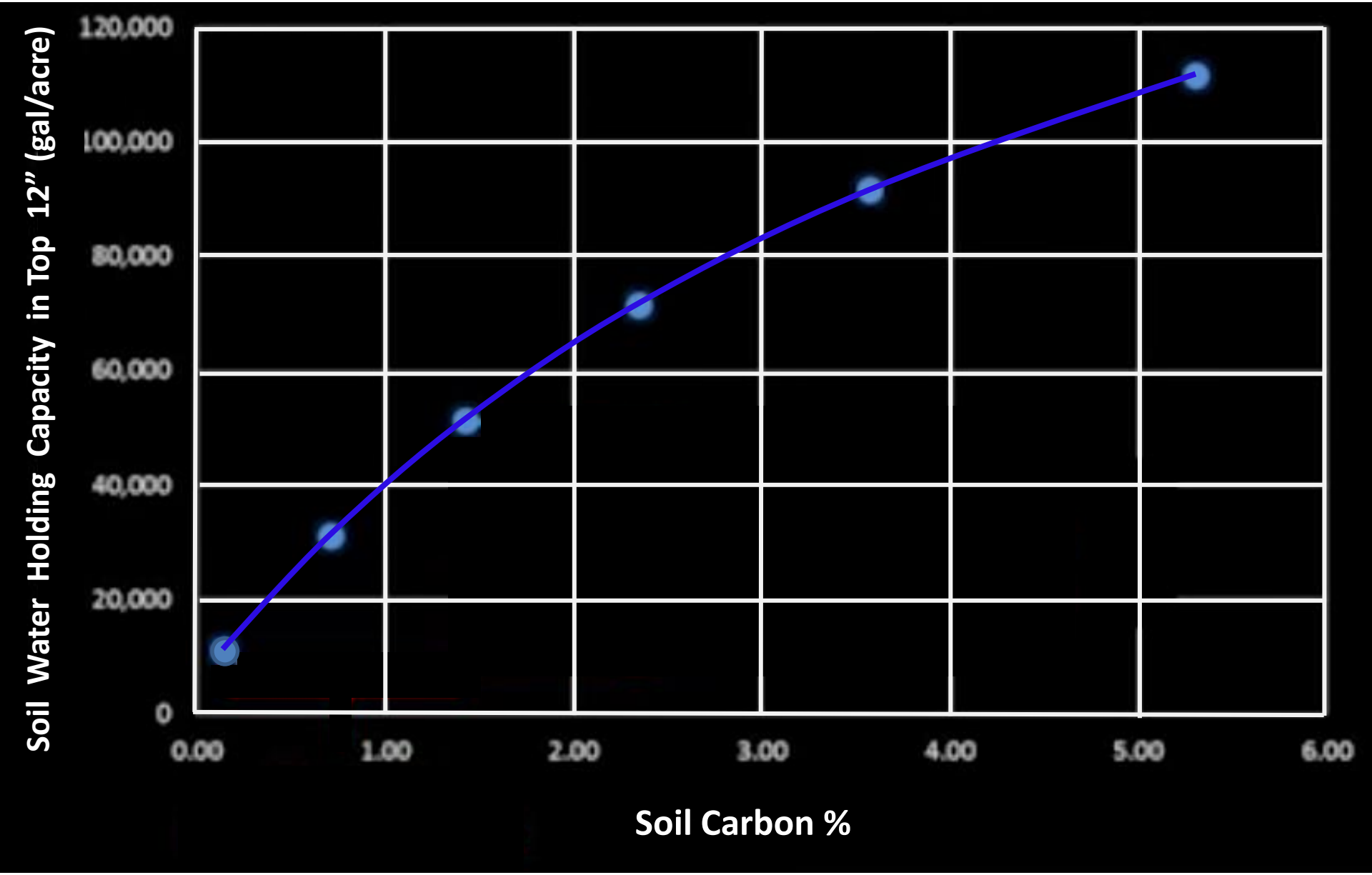
Much of current industrial agriculture is about killing:

weeds,
fungi,
insects,
biodiversity,
soil biology,
nutrition,
soil carbon,
soil water holding capacity,
soil itself,
sustainability,
and even farmer's profit

We need to retire most current agriculture practices

One solution to these problems is to move to regenerative agriculture where we restore nature's soil biology which can sequester carbon, build soil and store more water, at the same time as we grow food.

Soil water holding capacity depends on soil carbon



Dr. David Johnson The Beam Approach https://www.youtube.com/watch?v=79qpP0m7SaY&t=6s

Video showing the connections between soil biology, 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

How to restore 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.

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.

- **By ensuring a good cover of plants providing root exudates to feed the microbes.**

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.

- By ensuring a good cover of plants providing root exudates to feed the microbes.

- **By ending plowing and stopping the use of synthetic fertilizers, herbicides and pesticides.**

Now that we understand the important role of soil biology, let’s examine how to make first class biologically active compost

Many different ways to compost (two examples)

Hot or Thermal Compost (takes 1 month) aerobic, 50% moisture optimal

- **Kills human & plant pathogens, pest larvae and eggs, weed seeds, and root feeding nematodes**

  Beneficial organisms can either survive that temperature or go into dormant stages during the high temperature phase. Fungal content slowly increases with time following cool-down (time scale 6 months to a year) and will happen in the pile or in the soil if the compost applied sooner.

- **Warning:** things happen quickly in the first 10d, can't leave pile unattended for a weekend or it might catch on fire.

Worm or Vermi-compost (3-6 months) aerobic, 60-70% moisture

- **Worm digestion destroys pathogens, pest larvae and eggs, and root feeding nematodes.**

  Worms don't kill weed seeds

  The same benefits extend to contact with the outside of the worm.

- Things happen slowly so you can leave the compost unattended for periods of time

2017 Thermal Compost

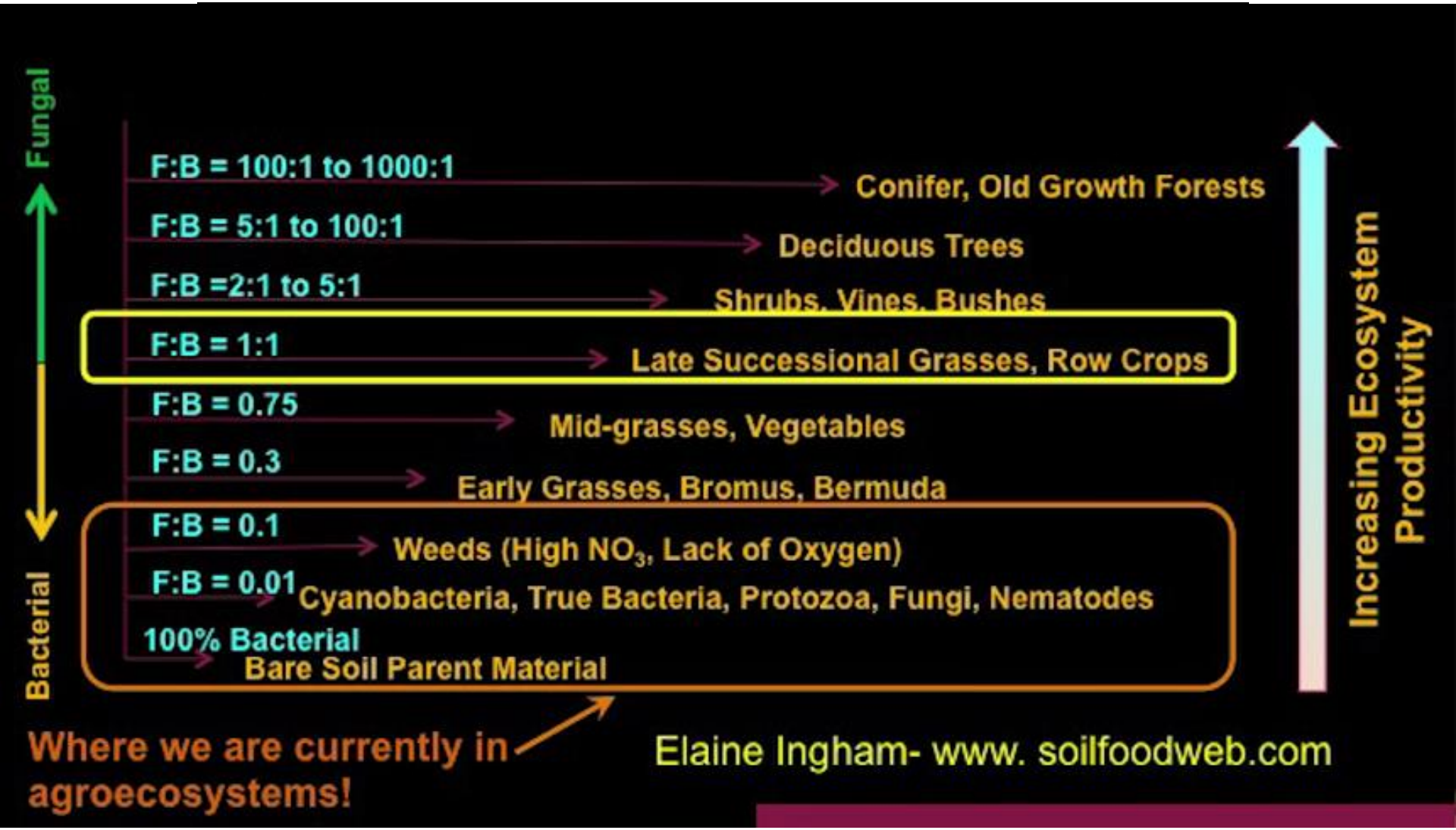
Planning considerations for compost ingredients

1. **Diversity of ingredients good for diversity of bacteria and fungi**
   - With good diversity, there are always some microbes providing the plants with nutrients no matter what the weather conditions.

Planning considerations for compost ingredients

1. **Diversity of ingredients leads to diversity of bacteria and fungi**
   - With good diversity, there are always some microbes providing the plants with nutrients no matter what the weather conditions.
2. **What plants do we want to grow?**
   - different plants prefer different fungal/bacteria ratios
   - most composts are low on fungal matter

Plant succession ladder in terms of Fungal to Bacterial Ratio
Where our soil is and where we want it to be



Dr. David Johnson NM State Univ. https://www.youtube.com/watch?v=dmj611RfBgs

Chile Pepper Plant Growth in 10 Different Local Composts

Dr. David Johnson, New Mexico State University

Greenhouse Trials

Chile Pepper Plant Growth in 10 Different Local Composts

Chemical and biological analysis of the different composts

	Peat Humus	Omni	Miracle Grow	Premium Org Potting Soil	Sterilized Manure	Composted Cow Manure	Organic Top Soil Top Choice	Potting Soil Natures Way	Charcoal Compost	Charcoal Compost (watered 4 months)
Trial Number	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*10*	*12*
% Saturation	122	110	237	121	91.4	111	115	117	126	156
Calcium (meq/L)	96.6	7.48	7.34	43.6	5.44	43.7	72.8	7.59	6.9	10.1
ESP (%)	27.3	21.3	12.1	32.3	39.3	30.9	28.4	21.7	1	3.2
Copper (ppm)	3.96	9.39	1.8	4.4	15.29	9.72	2.77	5.57	1.43	1.81
EC (mmhos/cm)	58.1	15.3	11.7	40.5	39.9	66.3	60.3	6.05	2.92	3.84
Fe (ppm)	65.1	194.9	39.58	52.05	146.5	59.23	41.16	74.44	7.97	15.49
K (ppm)	13300	3640	4450	7480	102	15600	11700	975	945	1010
Mg (meq/L)	65.1	8.02	8.01	31.3	3.71	55.7	57.8	3.83	3.53	10.8
Mn (ppm)	5.66	24.19	45.17	6.74	13.61	6.26	7.64	16.4	12.89	22.16
NO3-N (ppm)	3052.7	12.2	30.5	74.7	1057.6	1971.9	2115.3	5.1	19.1	20.13
Org Matter (%)	21.35	19.23	38.5	20.98	15.27	20.05	18.44	20.1	14.57	16.54
pH	7.2	8.5	7.8	7.5	9.6	7.8	7.1	7.7	7.9	7.78
P (ppm)	752.6	482.1	869.4	957.8	2285.9	434.7	365.6	298.9	656.9	835.4
Na (meq/L)	237	53.4	28.2	203	95.6	220	224	47	6.21	10.1
SAR	26.36	19.18	10.18	33.17	44.7	31.21	27.72	19.67	2.72	3.12
Zn (ppm)	32.9	63.67	24.34	26.52	43.82	29.11	28.72	30.8	16.32	27.88
Fungal:Bacterial	0.027	0.007	0.031	0.003	0.067	0.060	0.194	0.070	0.404	0.420
Growth Volume (mL)	**3804**	**732**	**2994**	**1680**	**1096**	**7984**	**8923**	**325**	**15626**	**17579**

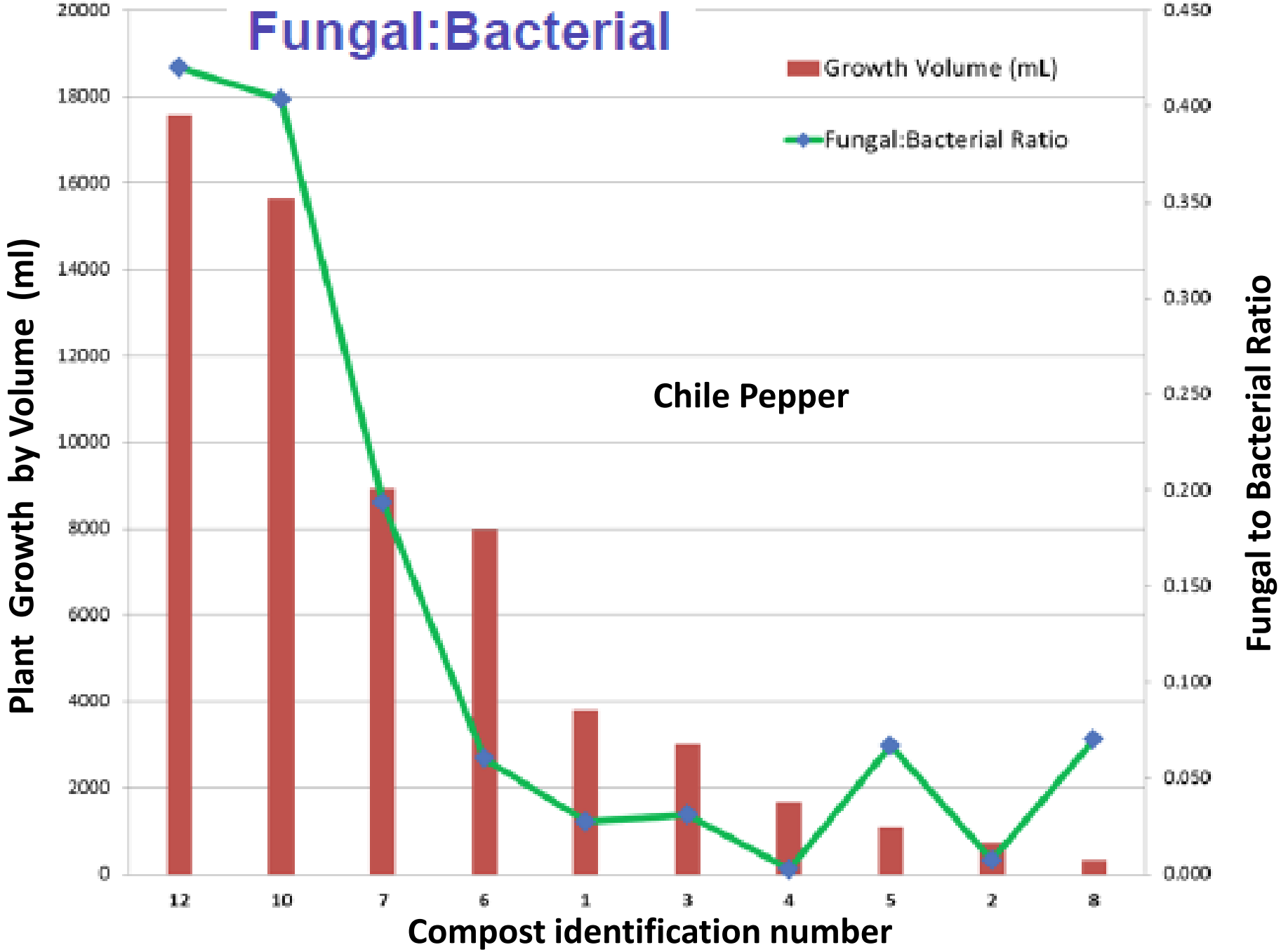
Standard Soil Tests

Biological Test

Greenhouse Trial

Dr. David Johnson New Mexico State University

https://holisticmanagement.org/wp-content/uploads/2015/05/Quivira_Johnson1.pdf

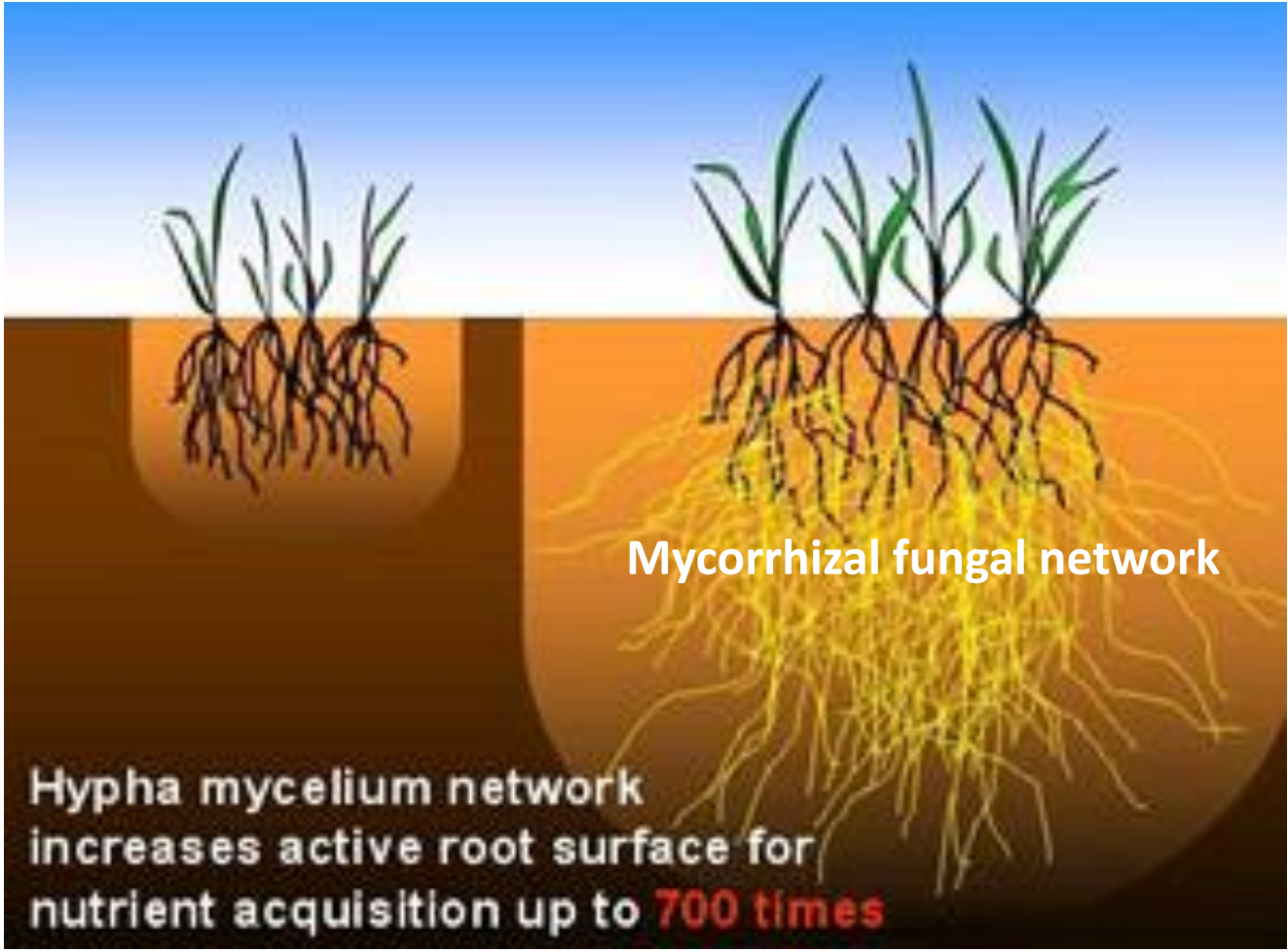


Dr. David Johnson NMSU https://holisticmanagement.org/wp-content/uploads/2015/05/Quivira_Johnson1.pdf

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.



Another benefit provided by certain types of Fungi

Planning considerations for compost ingredients

1. **Diversity of ingredients good for diversity of bacteria and fungi**
   - With good diversity, there are always some microbes providing the plants with nutrients no matter what the weather conditions.
2. **What plants do we want to grow?**
   - different plants prefer different fungal/bacteria ratios
   - most composts are low on fungal matter
3. **Chlorine and chloramine in water supply**
   - **can kill your bacteria and prevent pile heating up**
   - **adding a small amount of humic acid will solve that**

Planning considerations for compost ingredients

1. **Diversity of ingredients good for diversity of bacteria and fungi**
   - With good diversity, there are always some microbes providing the plants with nutrients no matter what the weather conditions.
2. **What plants do we want to grow?**
   - different plants prefer different fungal/bacteria ratios
   - most composts are low on fungal matter
3. **Chlorine and chloramine in water supply**
   - can kill your bacteria and prevent pile heating up
   - adding a small amount of humic acid will solve that
4. **Avoid inputs high in herbicides and pesticides (organic best)**

2017 Recipe measured in 5 gallon bucket units

15% high nitrogen party food (C:N around 10:1)	Fresh organic chicken manure	4 units
	Beer mash (spent grains)	2 units
30% greens) (C:N around 30:1)	Fresh cut grass/reed (no chemicals)	12 units
55% browns (C:N above 100:1)	Alder wood chips (aged 5 months)	22 units
	Conifers aged until no distinctive odour	

100% Total = 40 units = 200 gallons

2018 Workshop recipe in 5 gallon bucket units

15% high nitrogen party food (C:N around 10:1)	Fresh organic chicken manure	4 units
	Beer mash (spent grains)	0.5 units
27% greens (C:N around 30:1)	Organic spoiled lettuce	8 units
	Coffee grounds	
58% browns (C:N above 100:1)	Alder wood chips (aged 5 months)	17.5 units
	Conifers aged until no distinctive odour	

100% Total = 30 units = 150 gallons

Organic Chicken Manure from Rabbit Farms in Richmond

Beer mash (spent grains)

From Faculty Brewery

Assembling Materials

Beer mash
spent barley grains

Building the base

To allow air access through pile bottom

Preliminary layering of ingredients

Adding a layer of chicken manure

More layers

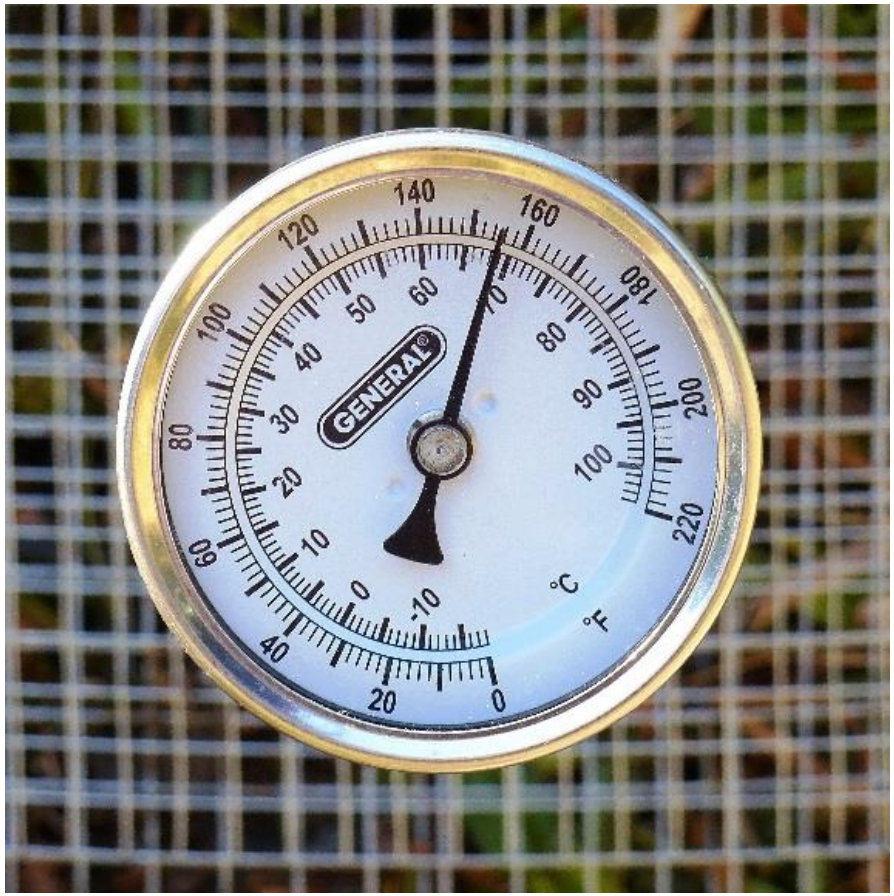
Finish our compost layer cake

Assembling compost container

Transfer layer cake to compost container

In the process we create a uniform compost mixture Saves one turn

Temperature rose rapidly during the first day

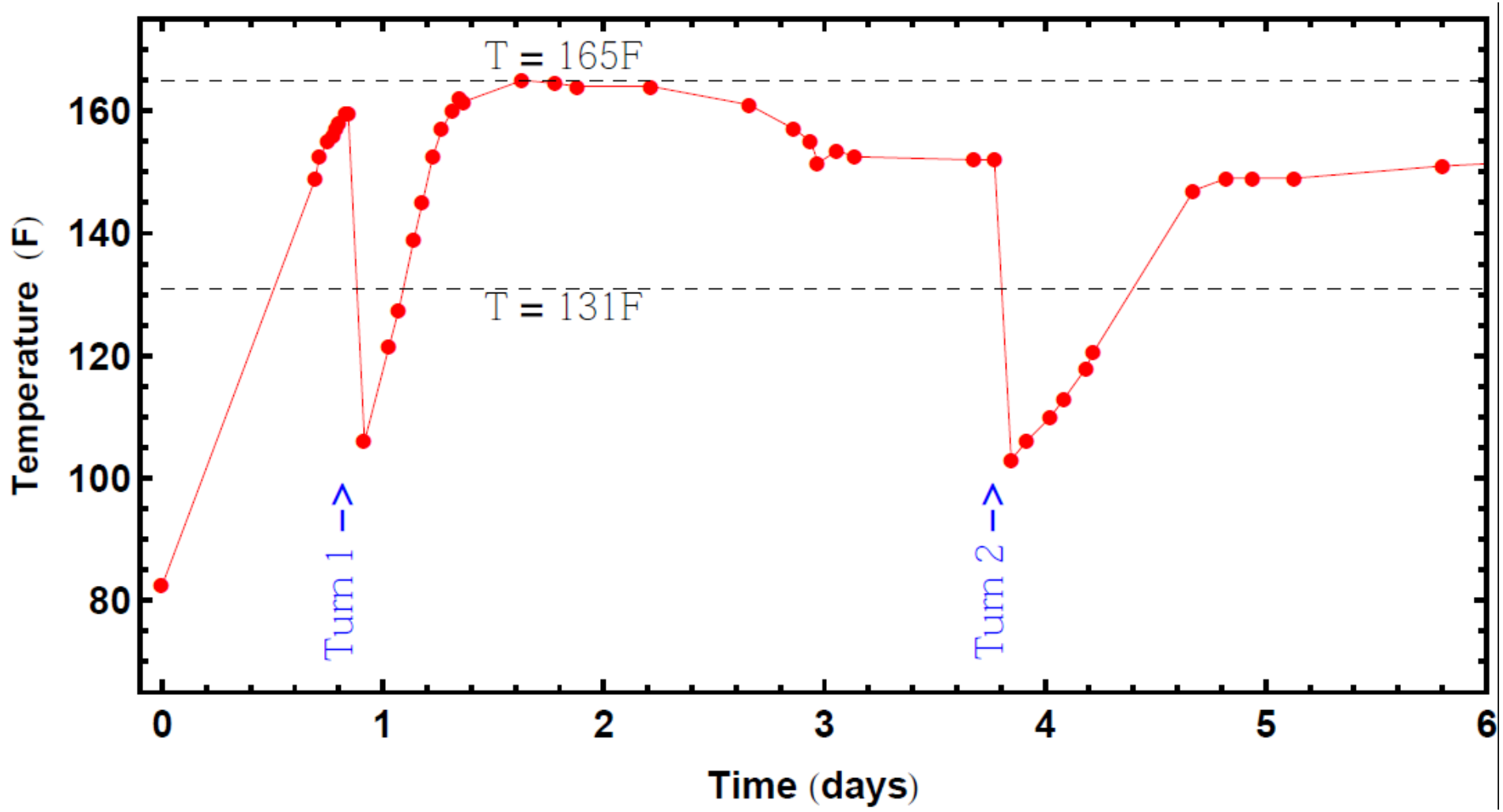


Removing wire mesh in preparation for turning

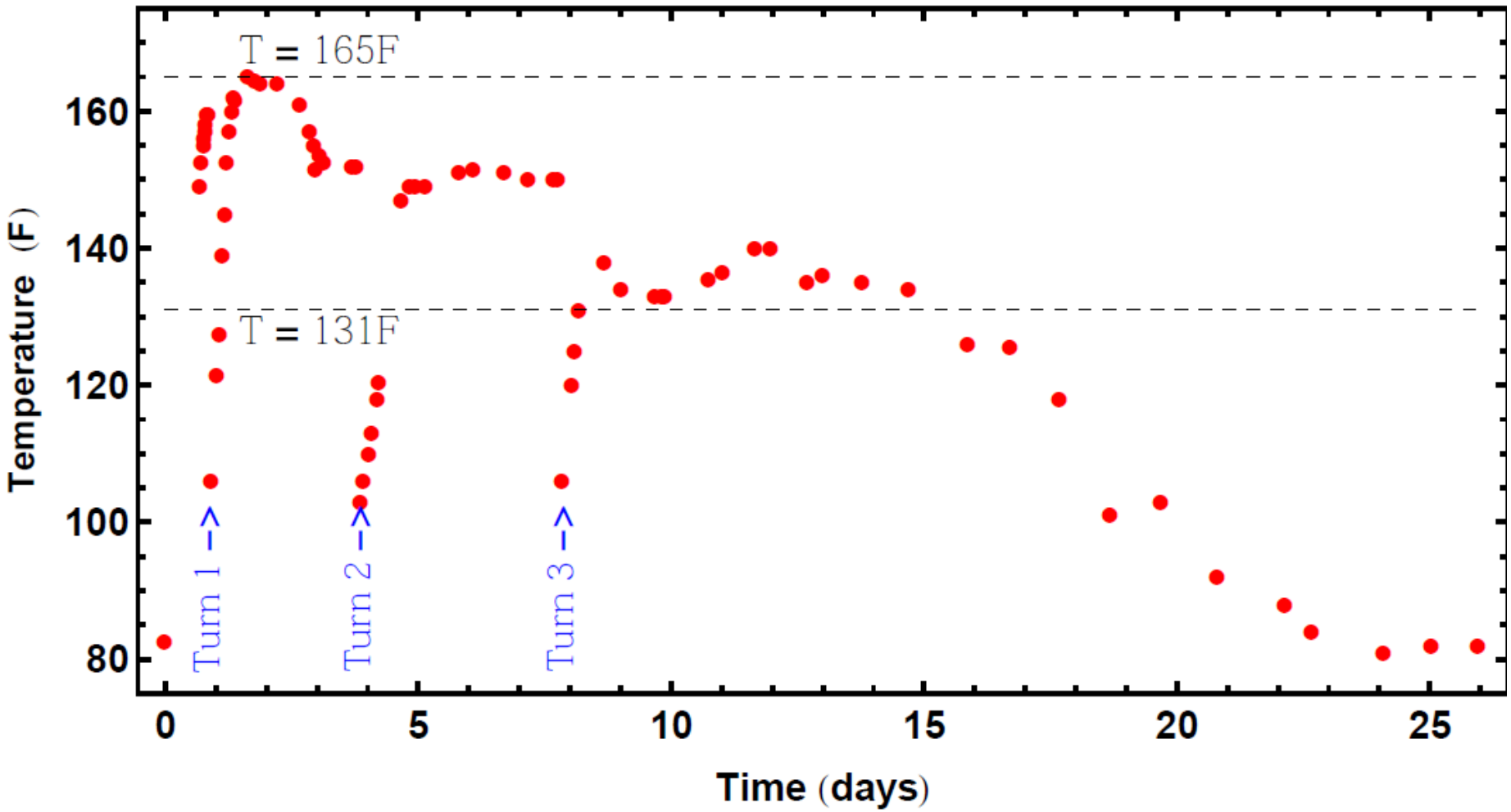
Breaking into the hot core (160F or 72C)

Rebuilding so that in the course of 3 turns all material gets heated to a T $\geq$ 131 F for 3 days or $\geq$ 150 F for 2 days

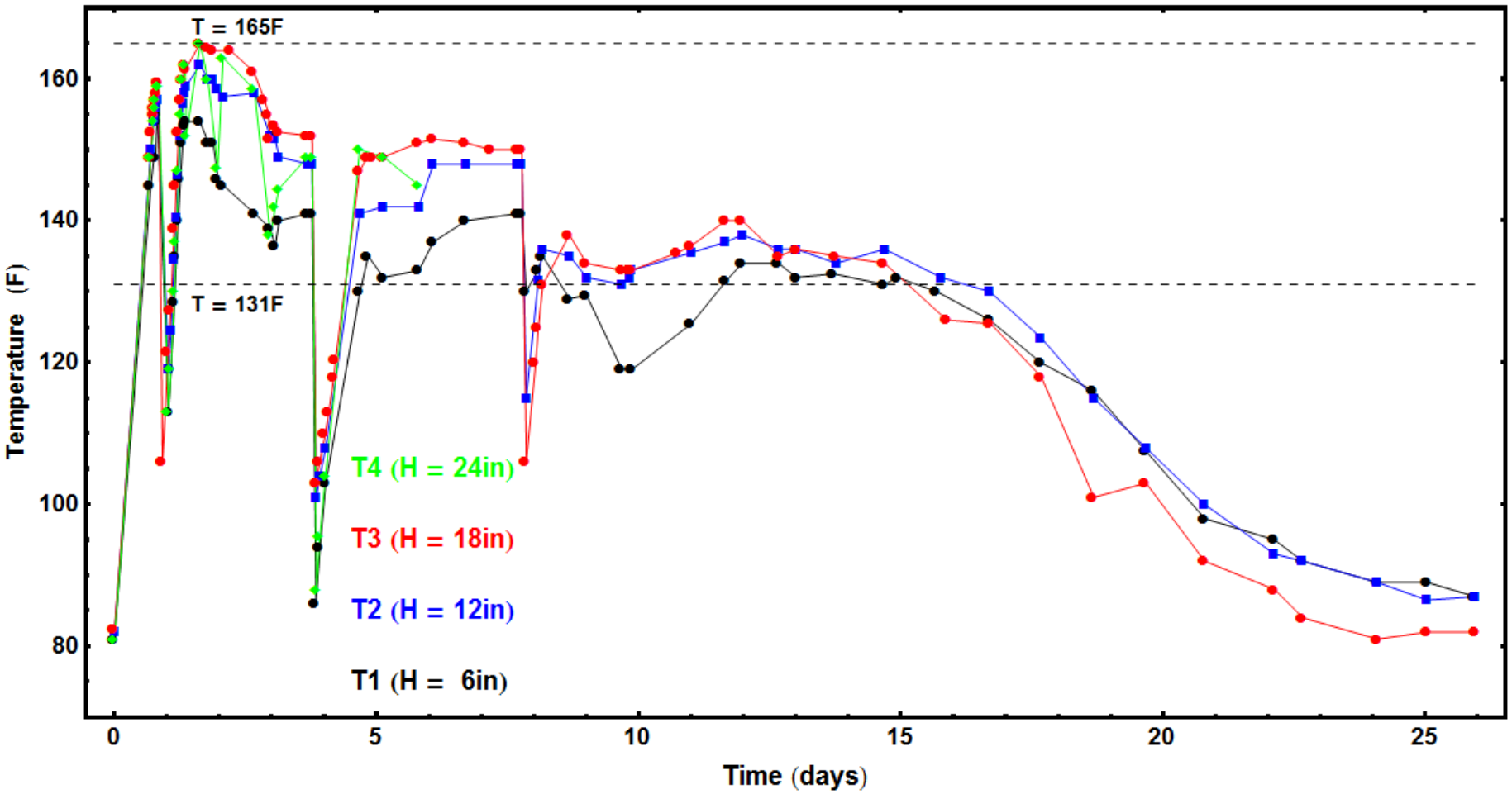
Central core temperature during first six days



Compost core temperature history



3 and 4 level compost temperature history



Completed 2017 Thermal Compost

Ways to apply the compost

1. Apply it directly to the land (expensive)
   - 500 to 3000 lb/acre or 560 to 3400 kg/ha or 0.560 to 3.4 kg/m^2

2. Inoculate with compost extract (simple and much cheaper)
   - 0.5 to 1 lb compost per 5 US gallons. 5 to 20 gallons per 1 acre
   - Only spray around the plants because the microbes need root exudates
   - Most efficient, soak the seeds for 15 min. in extract before application
   - The sooner you apply the extract the less likely it is to go anaerobic

3. Brew compost tea by adding microbe food
   - Bacteria very active making lots biotic glues and so tea is very sticky
   - Good for leaf application or inoculating seeds before planting
   - Will start to go anaerobic as soon as aeration ends so apply directly

Making Compost Extract

Soil Improves for 6 years

BEAM = Biologically Enhanced Agricultural Management

Sunflower plants

Changes in the productive capacity of the soil over time after one compost inoculation

Dr. David Johnson **Introduction to Soil Microbes** https://www.youtube.com/watch?v=34gvBb3gP0E

Rapid Carbon Sequestration

By Center For Food Safety

Published on 11 Oct 2017

Close with some comments about the benefits of restoring the soil biology with compost

by

Dr. David C. Johnson,

Director of the Institute for Sustainable Agricultural Research

New Mexico State University, Engineering Microbiology

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

(dur = 1:55m)

END