
SOIL HEALTH and Organic Grains
Joel Gruver
WIU Agriculture

WIU AGRICULTURE

Joel Gruver

Since WWII,
soil management
research & practice
has done a remarkable job of
identifying and alleviating
limiting factors

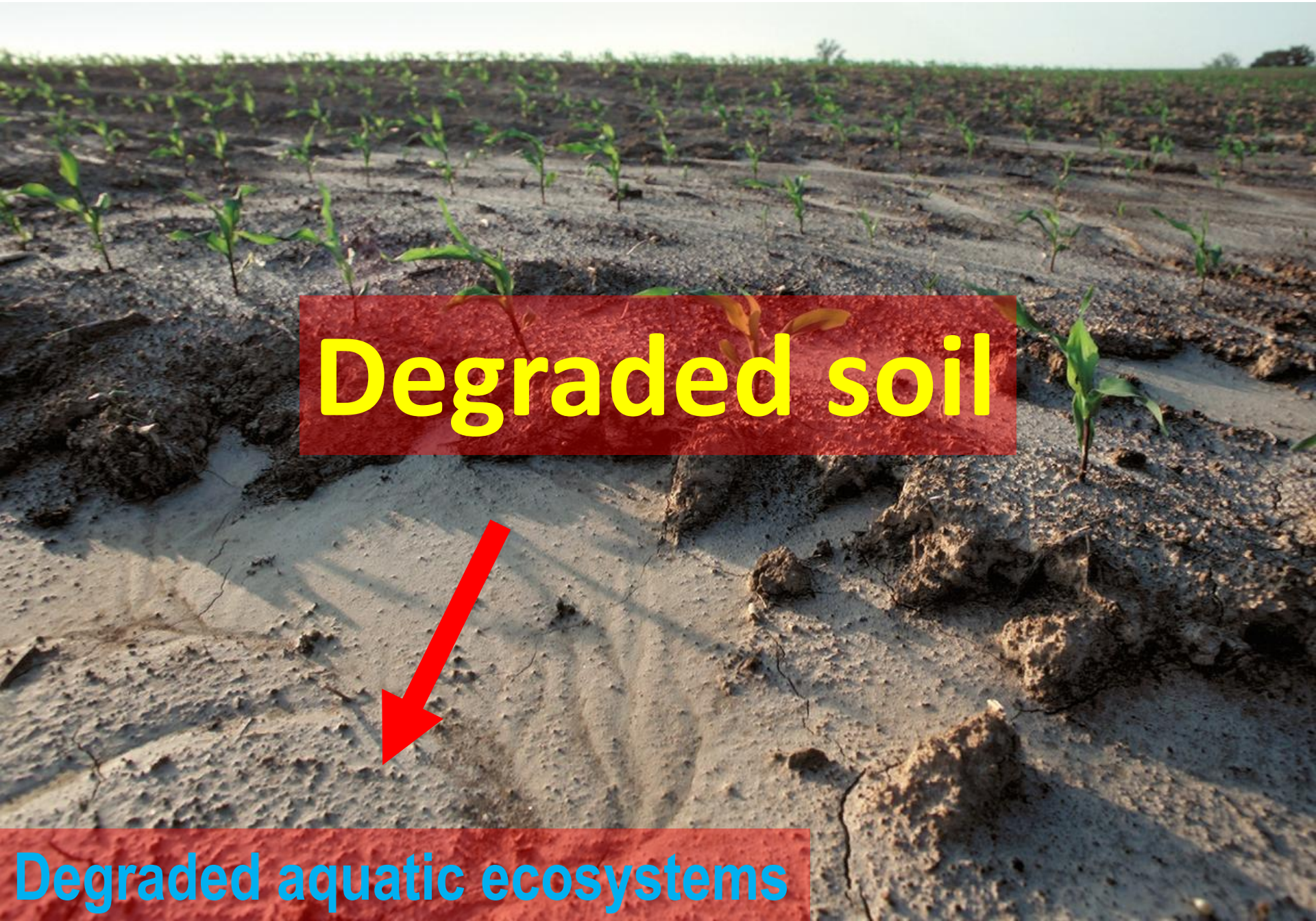
How have these limiting factors been managed on your farm?

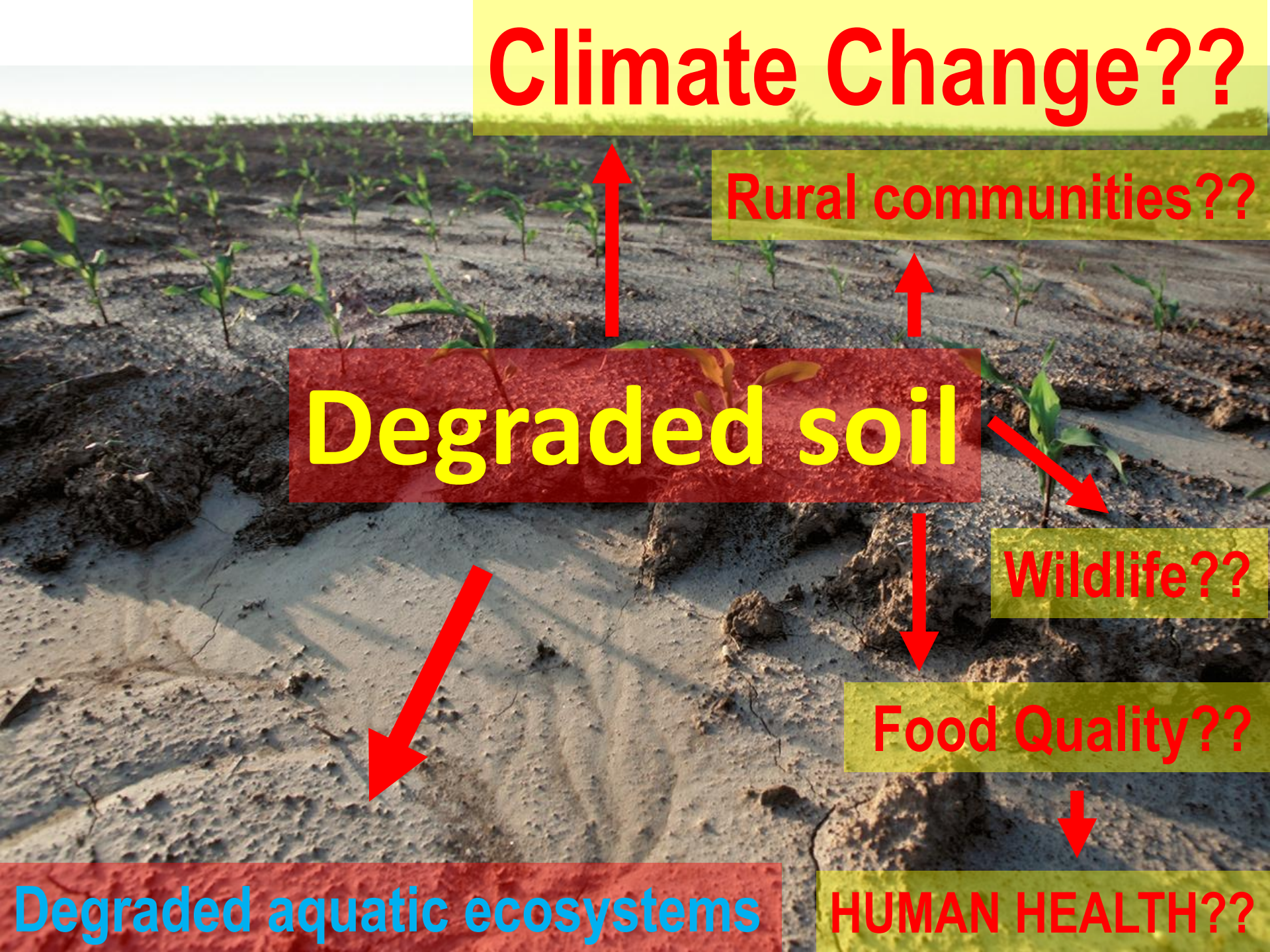
Drainage
Compaction
Soil acidity
Low nutrient levels
Pests & Pathogens

What has been the impact of managing these limiting factors?


Jimmy, this farm's yields have tripled!


Grandpa, has our SOM tripled?


Degraded soil
Degraded aquatic ecosystems


Climate Change??
Rural communities??
Degraded soil
Wildlife??
Food Quality??
Degraded aquatic ecosystems
HUMAN HEALTH??

There is growing recognition that optimum soil management involves more than alleviation of limiting factors

OPTIMUM

SOIL MANAGEMENT

increases crop productivity

&

REGENERATES

other important soil functions

including C sequestration,

water purification,

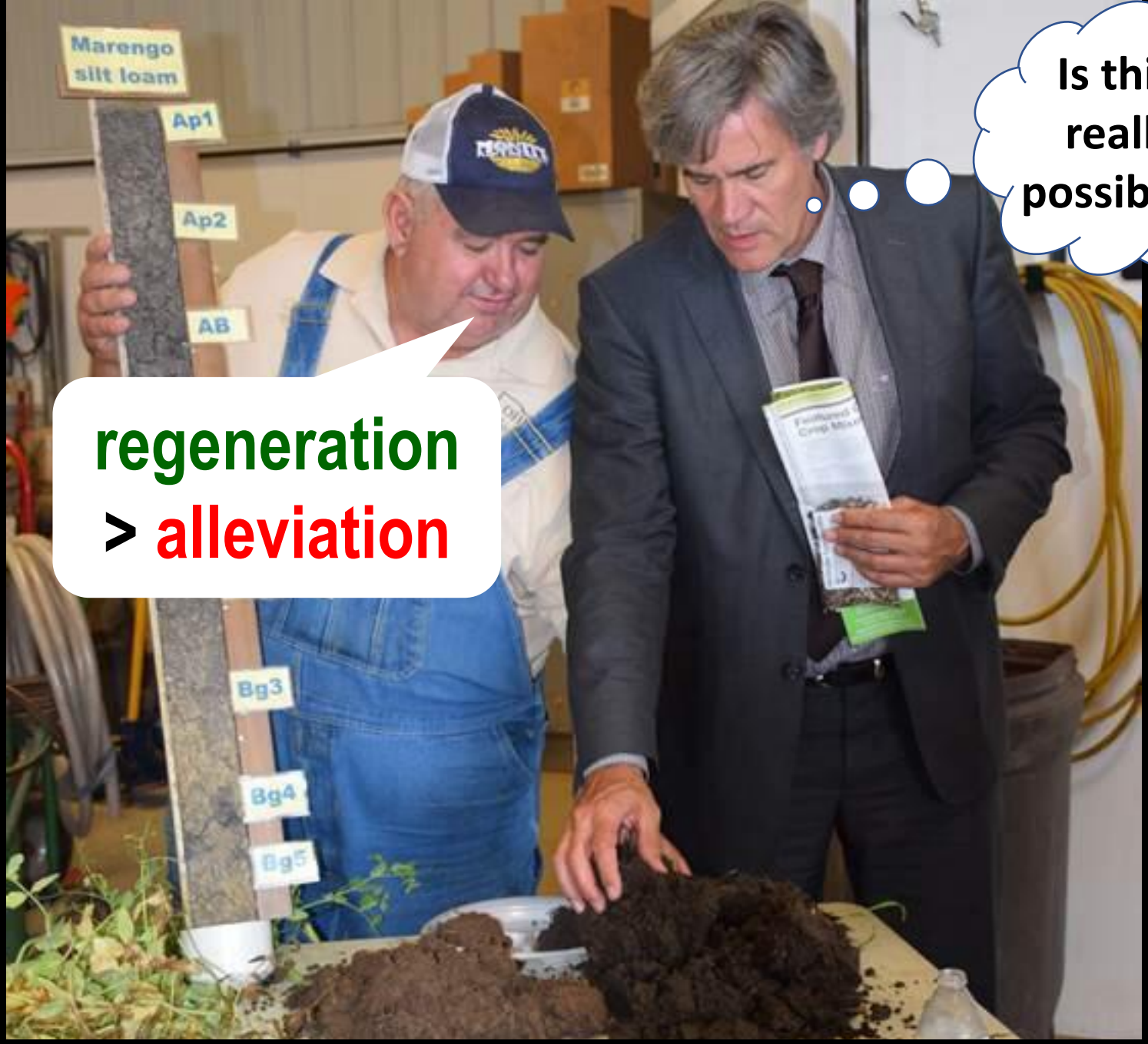
resisting degradation…

IN SIMPLER TERMS

Optimum soil management

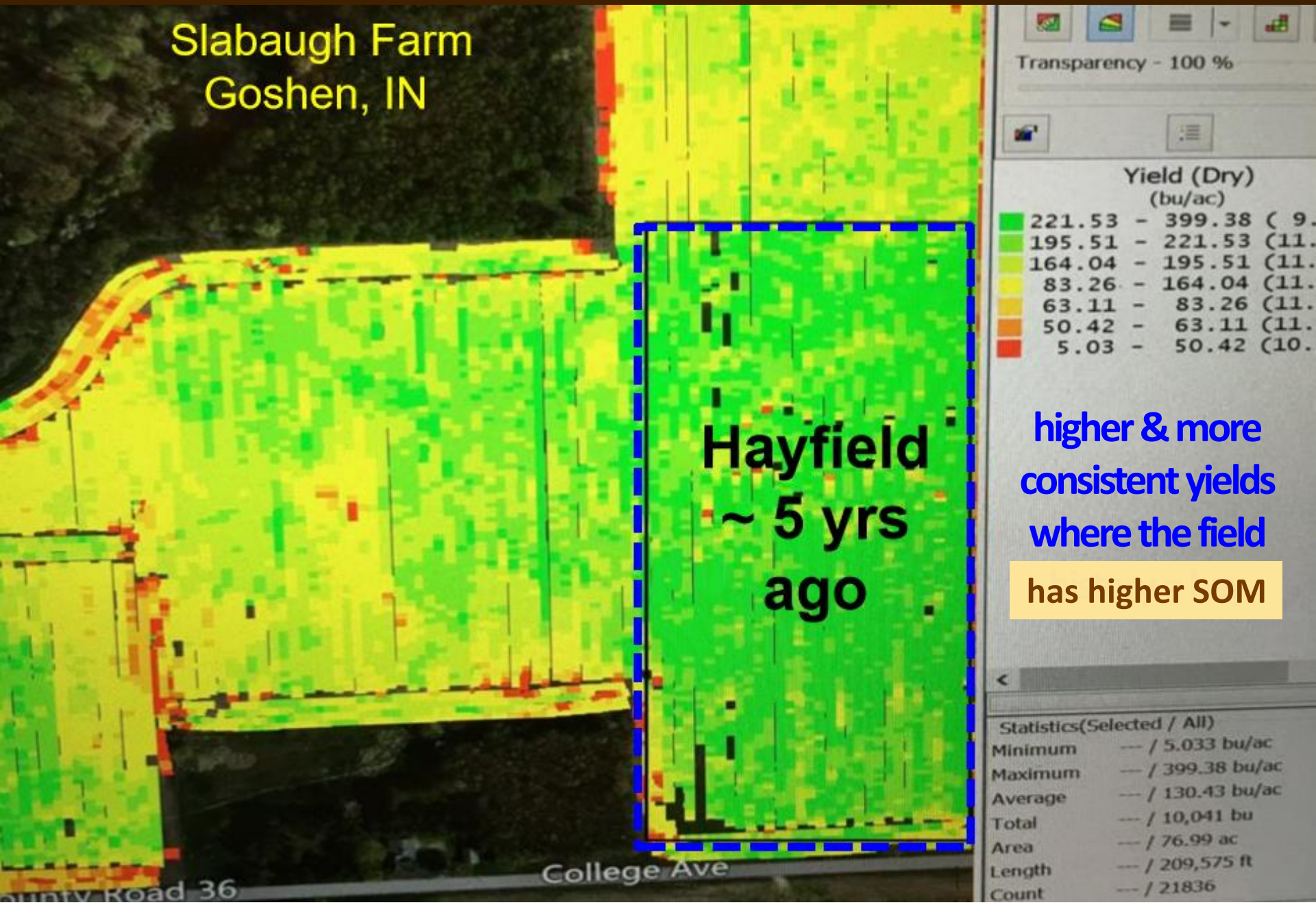
improves crops &

Soil HEALTH



Soil improved by >40 yrs of NT w/cover crops on Dave Brandt's farm in Carroll, OH

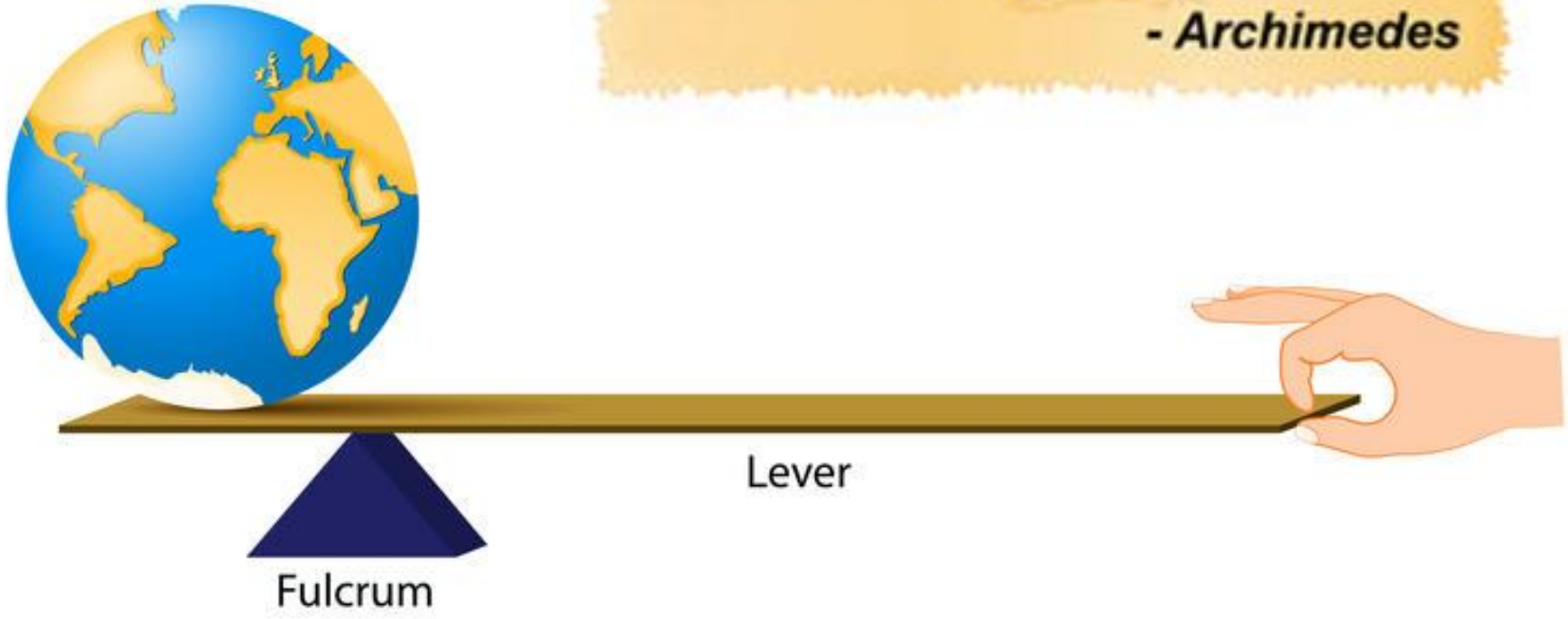
Many farmers have observed the benefits of higher SOM



What is a fulcrum?

"Give me a lever long enough,
and a fulcrum strong enough,
and I will move the Earth."

- Archimedes




19-19-19
WARNCO
GRANULAR
SUPERIOR QUALITY
FERTILIZER
19-19-19
GUARANTEED ANALYSIS
NET WT. 50 LBS. (22.68 kg)
MANUFACTURED BY
WARNER FERTILIZER CO.


PRAIRIE HYBRIDS
NON-GMO
SEED CORN
PRAIRIE HYBRIDS
NON-GMO
PRAIRIE HYBRIDS
NON-GMO

Inputs

SOM

Soils with a little more SOM normally produce higher yields

Disproportionate impact!

How does SOM have so much impact?

SOM enhances biological activity

Energizes most biological processes in soil
Promotes healthy root growth and function
Promotes biocontrol of pests and pathogens

SOM improves soil structure

Resists erosion and compaction
Creates porosity and stabilizes aggregation
Prevents crusting, especially in fine-textured soils

SOM increases water availability

Improves water infiltration
Improves rooting depth
Increases water holding capacity, especially in sandy soils

SOM increases nutrient availability

Increases the nutrient holding capacity of soils
Serves as a slow release form of nutrients
Chelates nutrients increasing their bioavailability
Enhances biological cycling of nutrients

How does SOM have so much impact?

SOM enhances biological activity

Energize… …es in soil
Promote… …function
Promotes… …athogens

SO… …ure

Re… …on
Creates … …regation
Prevents cr… …xtured soils

SOM … …bility

Increases water… …ly in sandy soils

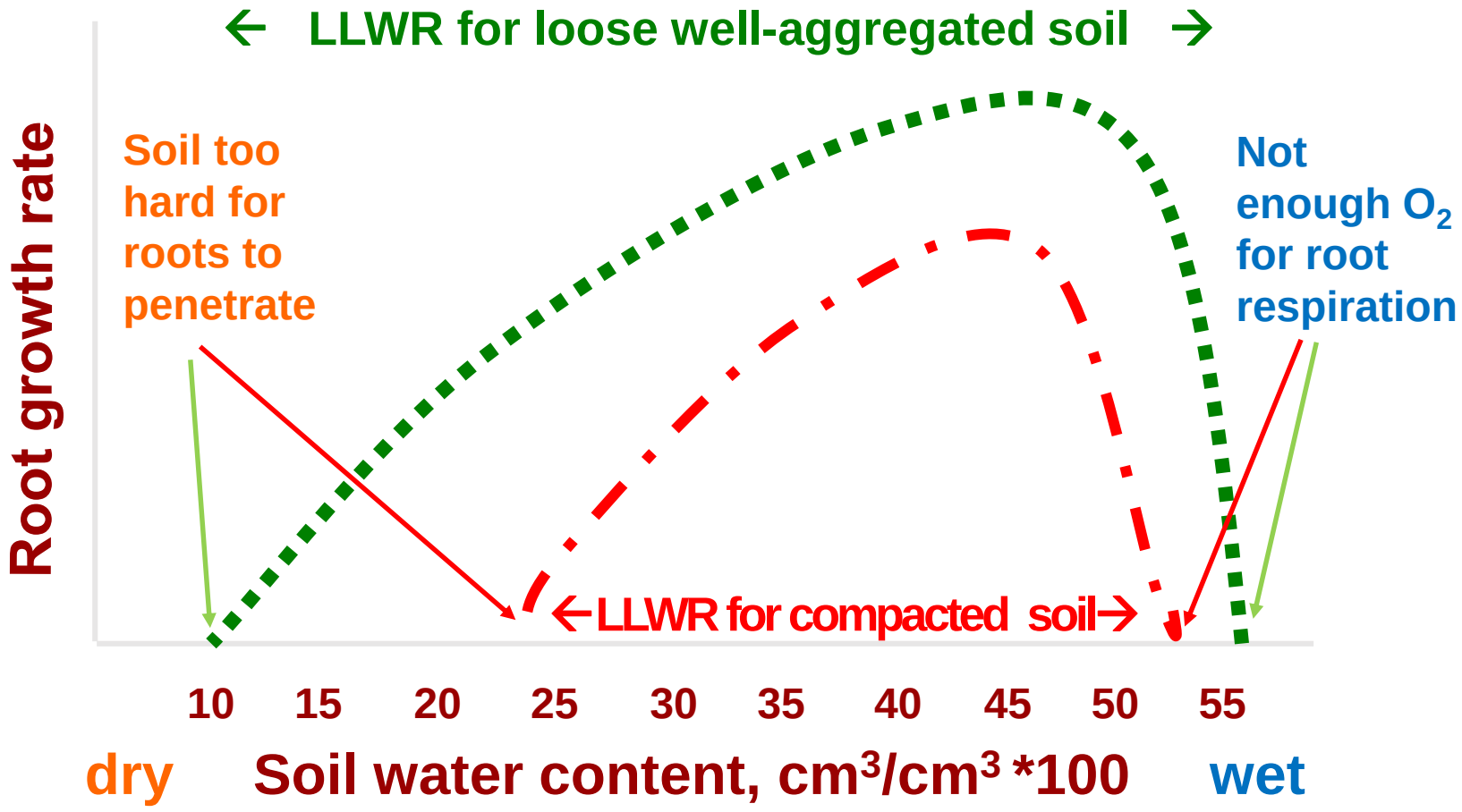
Inputs such as fertilizer, irrigation, and pesticides can substitute for <u>some</u> of the functions of **SOM** but no input is as multi-functional as **SOM**

SOM increases nutrient availability

Increases the nutrient holding capacity of soils
Serves as a slow release form of nutrients
Chelates nutrients increasing their bioavailability
Enhances biological cycling of nutrients

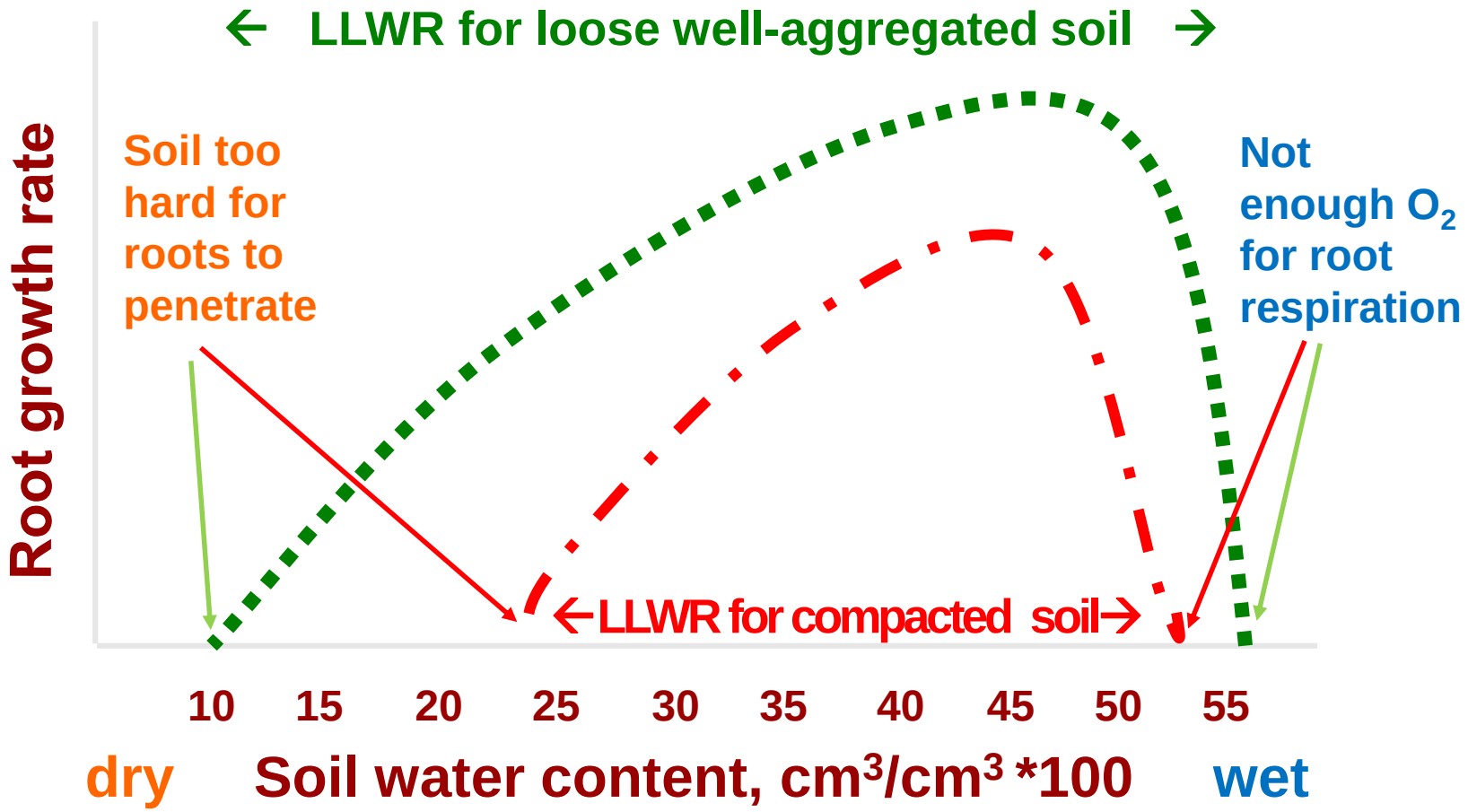

SOM creates
porosity
and stabilizes
soil aggregates

Least Limiting Water Range



Ray Weil

Least Limiting Water Range



Difficult to measure ☹

Ray Weil

Your Soil...

UNITED STATES DEPARTMENT OF AGRICULTURE

Soil Conservation Service

Leaflet No. 328

Easy to observe ☺

Your Soil...

CRUMBLY or CLODDY ?

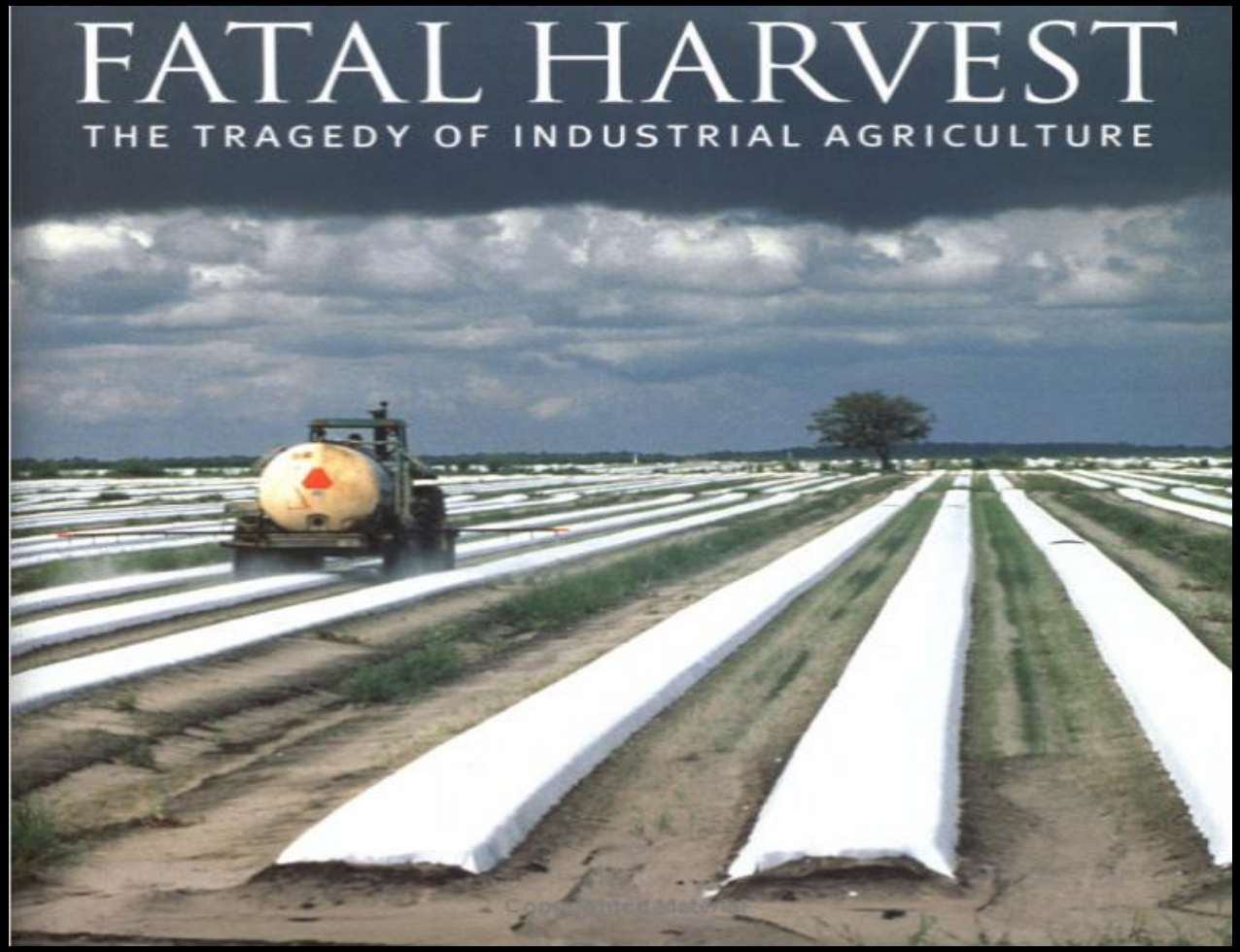
Improvements in soil structure are a good early indicator that C is accumulating

UNITED STATES DEPARTMENT OF AGRICULTURE

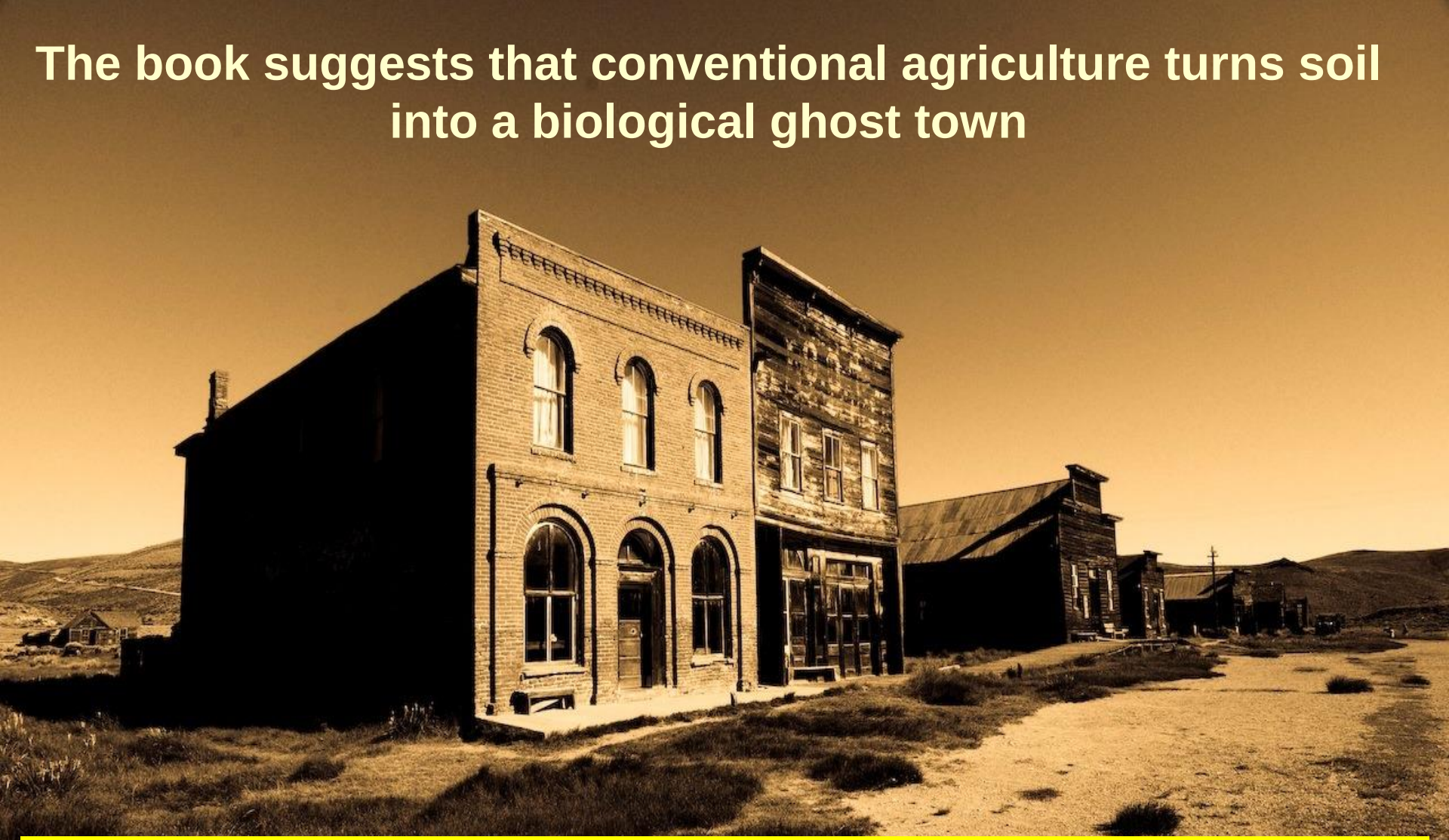
Soil Conservation Service — Leaflet No. 328

Easy to observe ☺

I received this book for Xmas shortly before I arrived at WIU



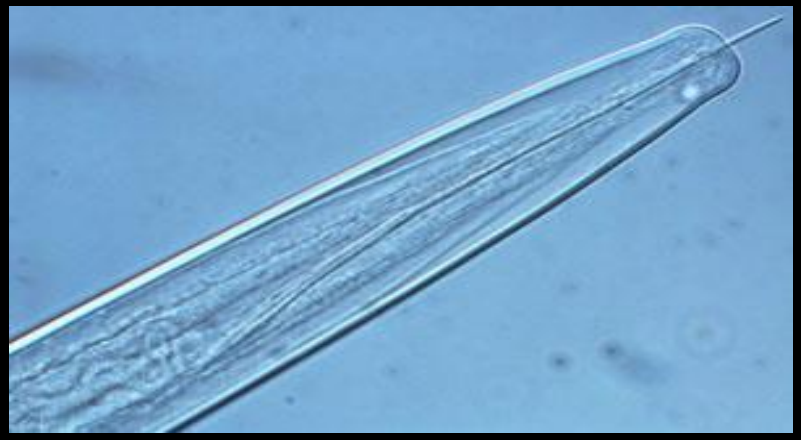
The book suggests that conventional agriculture turns soil into a biological ghost town

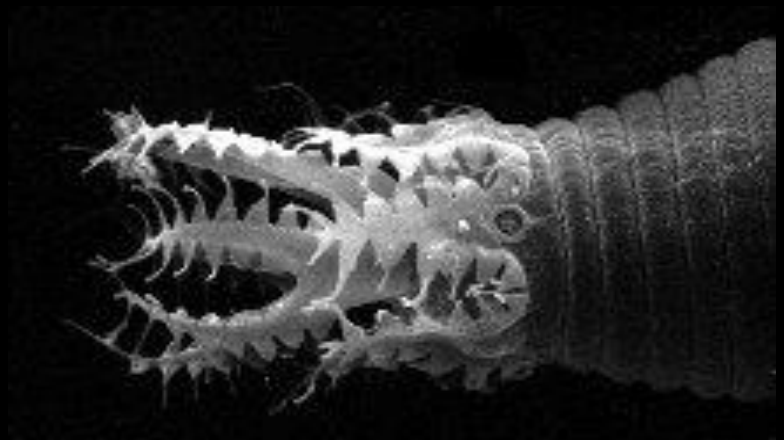


Is this an accurate description of the soil on OH/IN/MI farms that receive conventional management (i.e., tillage, fertilizers, pesticides…)?

Conventional soil management practices do NOT normally sterilize soils

Ecological categories of nematodes





but do modify the composition and function of soil biology

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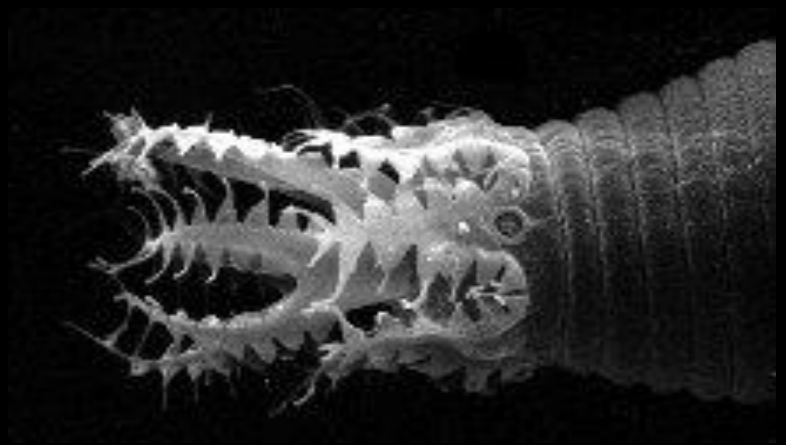
Ecological categories of nematodes

Plant parasitic nematodes often dominate in conventional management systems but tend to be a small part of the nematode community in diversified cropping systems



but do modify the composition and function of soil biology


Sooo… what is different in diversified cropping systems?

DIVERSIFIED CROPPING SYSTEMS can:

ENHANCE SOIL HEALTH

Solve specific agronomic problems (weeds, pests, diseases)

Overcome bottlenecks

Offset inputs

Reduce risk

What is a bottleneck?

the performance of an entire system
is limited by a single or small #
of components or resources

Assuming the same # of total crop acres, which of these rotations warrants a bigger planter?

Assuming the same # of total crop acres,

which of these rotations warrants a bigger planter?

Many types of bottlenecks

(e.g., limited availability of manure,
limited time when crop size & soil conditions
are appropriate for cultivation,
limited availability of labor for walking beans,
limited availability of equipment or skilled labor for
planting/cultivation/harvesting, …)

can be resolved by

DIVERSIFIED CROPPING SYSTEMS

Climate

Weather

Soil types

SOIL HEALTH

Soil seed bank

Human resources

Types & scales of enterprise$

Every farm has a UNIQUE CONTEXT

Topography

Field shapes & sizes

Geographic spread of fields

Built Infrastructure (buildings, bins fencing, tile…)

Available Inputs

Available equipment

Designing and testing crop rotations for organic farming

Proceedings from an International workshop

Jørgen E. Olesen, Ragnar Eltun, Mike J. Gooding, Erik Steen Jensen & Ulrich Köpke (Eds.)

If you are looking for some interesting winter reading…

a good **article**
in the collection

Designing crop rotations for organic farming: importance of the ley/arable balance

C.A. Watson, D. Younie and G. Armstrong
SAC, Craibstone Estate, Aberdeen AB21 9YA, UK

Summary

The design of crop rotations is fundamental to the success of organic farming systems. In particular, the ratio
agronomic success an
onal trials, establishe
lloch and Woodside
balance, productivi
higher in the first
Woodside respective
pectively). Earthwor
formation on the overall relationship between the ley/arable balance and rotational productivity is currently being analysed.

What do the National Standards require?

§205.205 Crop rotation practice standard.
The producer must implement a crop rotation including but not limited to sod, cover crops, green manure crops, and catch crops that provide the following functions that are applicable to the operation:

(a) Maintain or improve soil organic matter content;

(b) Provide for pest management in annual and perennial crops;

(c) Manage deficient or excess plant nutrients; and

(d) Provide erosion control.

Simple rotations such as corn-soybean or even continuous corn w/ CCs are **NOT** explicitly prohibited

When evaluating if the crop rotation standard is being met on a farm, review the following 7 points:

1) Are practices used which increase or maintain organic matter content? Is monitoring done?

2) Are pests and weeds controlled adequately?

Organic farmers who want to use simple rotations should be prepared to answer these Qs

3) Do the yields reflect acceptable fertility for soil? Is soil testing done? Manure used? Compost? Off-farm fertility inputs?

4) Are there erosion concerns? Slope? Soil type? Are conservation measures such as contoured strips and waterways employed?

5) Are cover crops used if hay/sod is not part of the rotation?

6) What other practices might be in place to reflect stewardship?

7) What about one/two-year deviations because of crop failures or other issues?

SOIL OPTIMUM LEVELS BASED ON CEC

https://www.alcanada.com/pdf/Tech_Bulletins/Soil/Optimum_Levels/553-Soil_O

Soils w/ higher CEC (more clay and OM) can normally supply sufficient P @ lower soil test P levels

Soil testing should be viewed as a tool to help solve problems

CEC

		0-6	7-15	16-25	26+
PPM SOIL					
P	POOR	0 - 25	0 - 23	0 - 18	0 - 13
	MED	26 - 55	24 - 43	19 - 33	14 - 23
	GOOD	56 - 93	44 - 83	34 - 55	24 - 43
	HIGH	94 +	84+	56 +	44+
K	POOR	0 - 45	0 - 60	0 - 80	0 - 100
	MED	46 - 90	61 - 120	81 - 160	101 - 200
	GOOD	91 - 180	121 - 240	161 - 320	201 - 400
	HIGH	181+	241 +	321+	401+
Ca	POOR	0 - 200	0 - 400	0 - 600	0 - 1000
	MED	201 - 400	401 - 800	601 - 1200	1001 - 2000
	GOOD	401 - 800	801 - 1600	1201 - 2400	2001 - 6000
	HIGH	801+	1600 +	2400+	6000+
Mg	POOR	0 - 25	0 - 50	0 - 75	0 - 100
	MED	26 - 50	51 - 100	76 - 150	101 - 200
	GOOD	51 - 100	101 - 200	151 - 300	201 - 600
	HIGH	101+	201+	301+	601+

higher (P) / lower (P)

lower (K, Ca, Mg) / higher (K, Ca, Mg)

Soils w/ higher CEC normally need higher soil test K, Ca and Mg levels to provide sufficient availability

% SATURATION OF CATIONS

Lower cation saturation %s are normally sufficient in soils w/ higher CEC

% K Saturation	4 - 6	3 - 5	2 - 4	2 - 3
% Mg Saturation	10 - 20	8 - 20	5 - 20	5 - 20
% Ca Saturation	60 - 80	60 - 80	60 - 80	60 - 80

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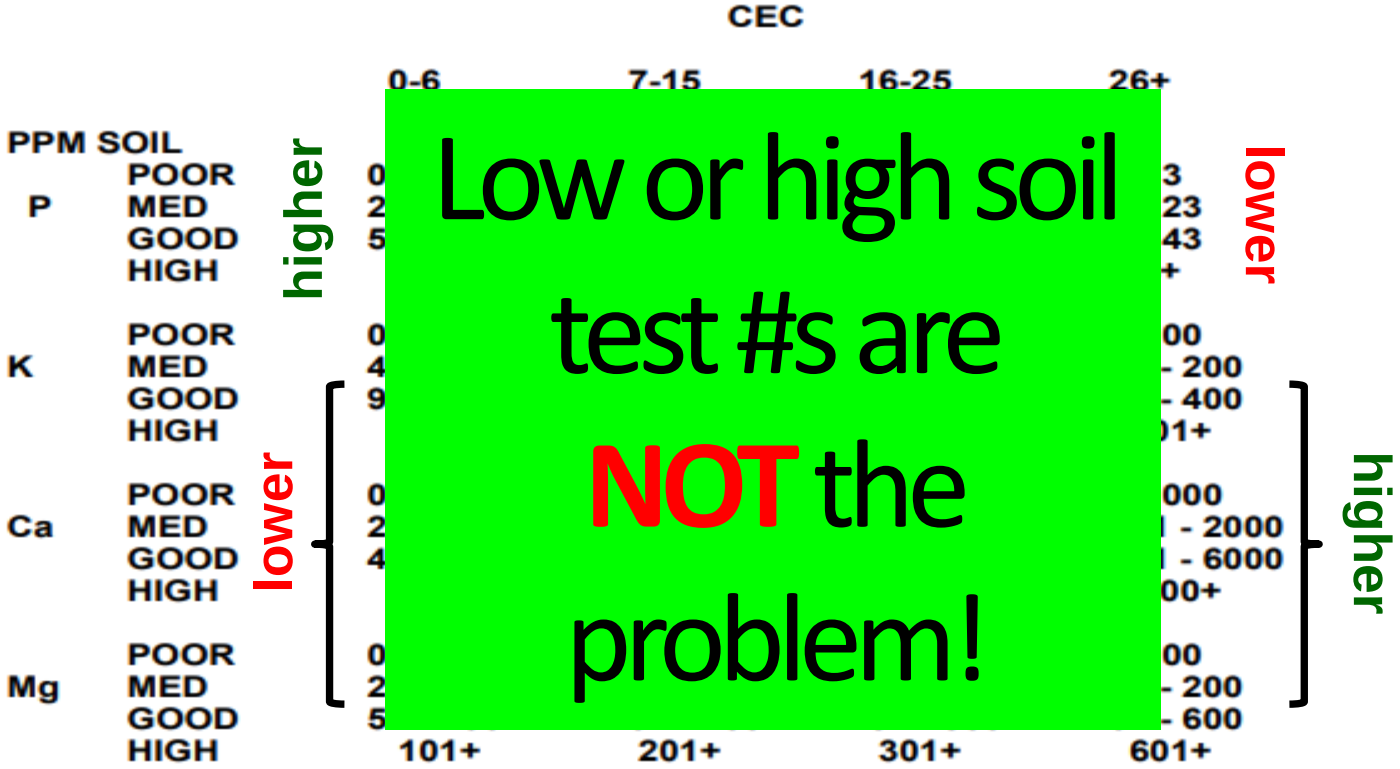

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SOIL OPTIMUM LEVELS BASED ON CEC

https://www -
Soil_OSoils w/ s

Soil testing should be viewed as a tool to help solve problems

Poor crop performance & inefficient use of nutrient resources are problems!

PPM SO

P	P M G H
K	P M G H
Ca	P M G H
Mg	P M G H

higher

Soils w/ bility

% SATURATION OF CATIONS

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Why do some soils have more SOM?

The amount of organic matter in soil is the result of two processes: additions and losses. **5** main factors affect both additions and losses.

Soil texture - Fine-textured soils can hold much more organic matter than sandy soils for two reasons. First, clay particles form electrochemical bonds that stabilize organic compounds. Second, decomposition occurs faster in well-aerated sandy soils. Sandy loams rarely have more than 2% organic matter.
Historical vegetation - In prairies, much of the organic matter that dies and is added to the soil each year comes from grass roots that extend deep into the soil. In forests, the organic matter comes from leaves that are dropped on the surface of the soil. Thus, farmland that was once prairie will normally have higher amounts of organic matter deep in the soil than land that was previously forest.
Climate - High temperatures speed up the degradation of organic matter. In areas of high precipitation (or irrigation) there is more plant growth and therefore more roots and residues entering the soil.
Landscape position - Low, poorly-drained areas have higher organic matter levels, because less oxygen is available in the soil for decomposition. Low spots also accumulate organic matter that erodes off hill tops and steep slopes.

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So what is the 5th factor?

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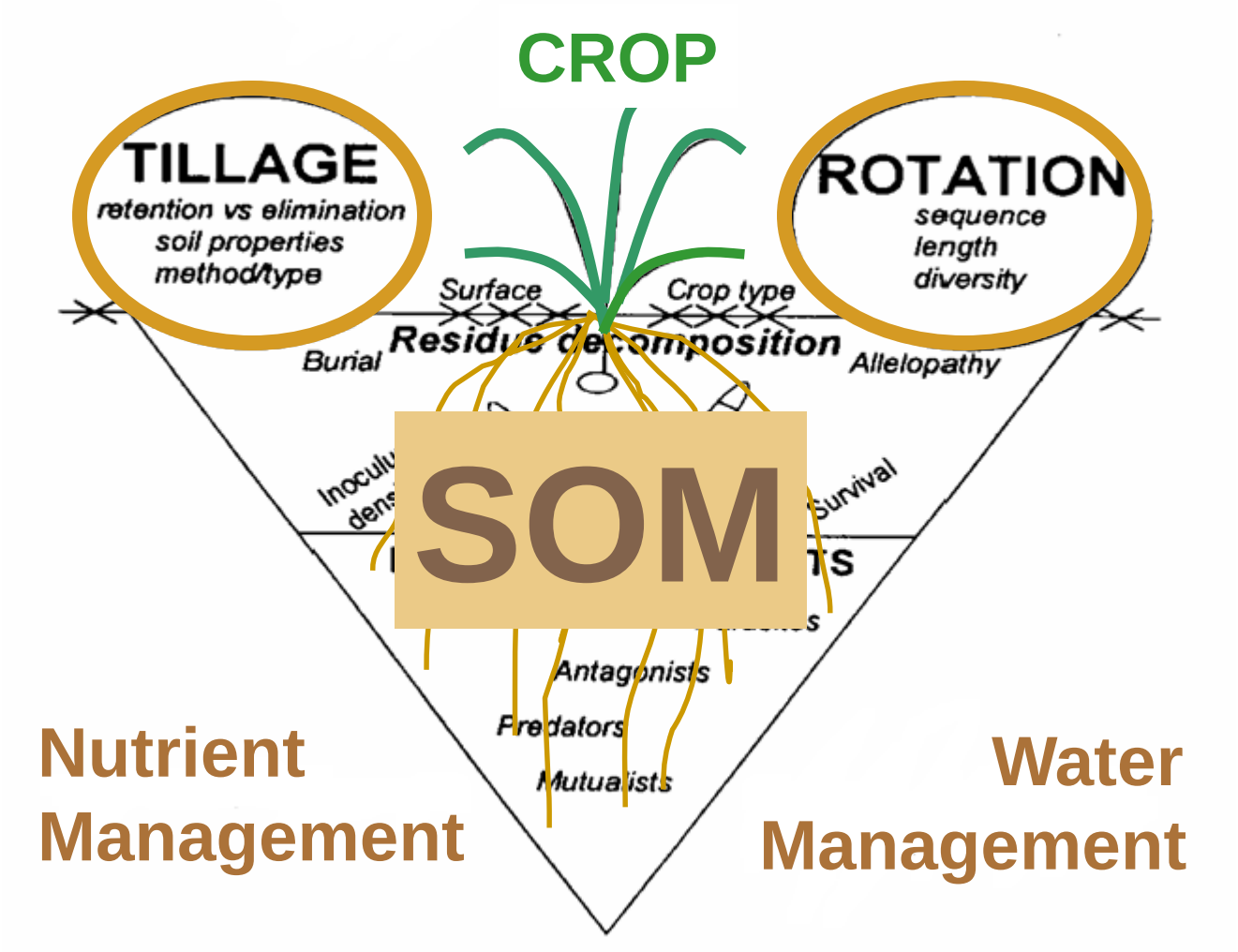
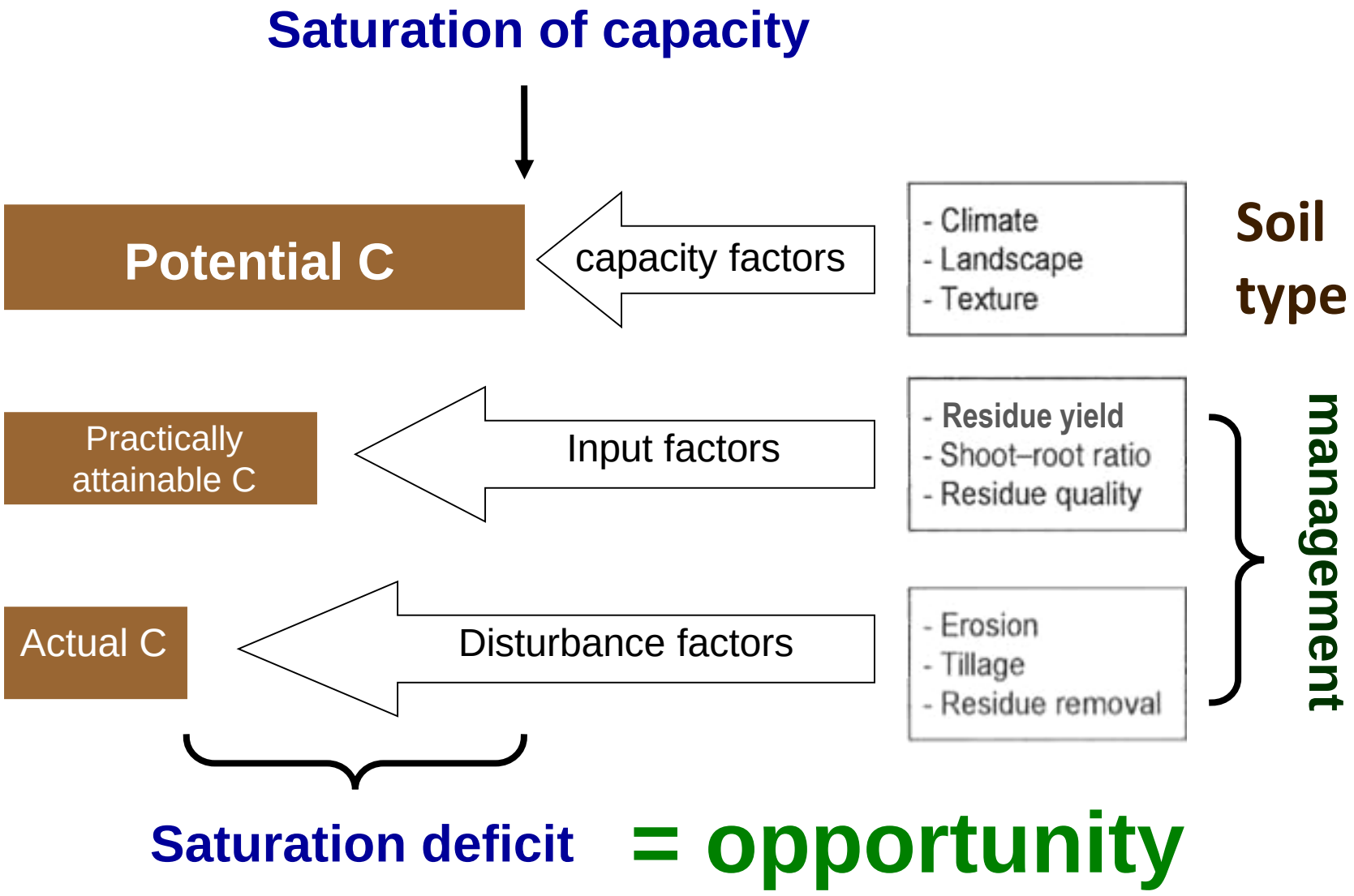
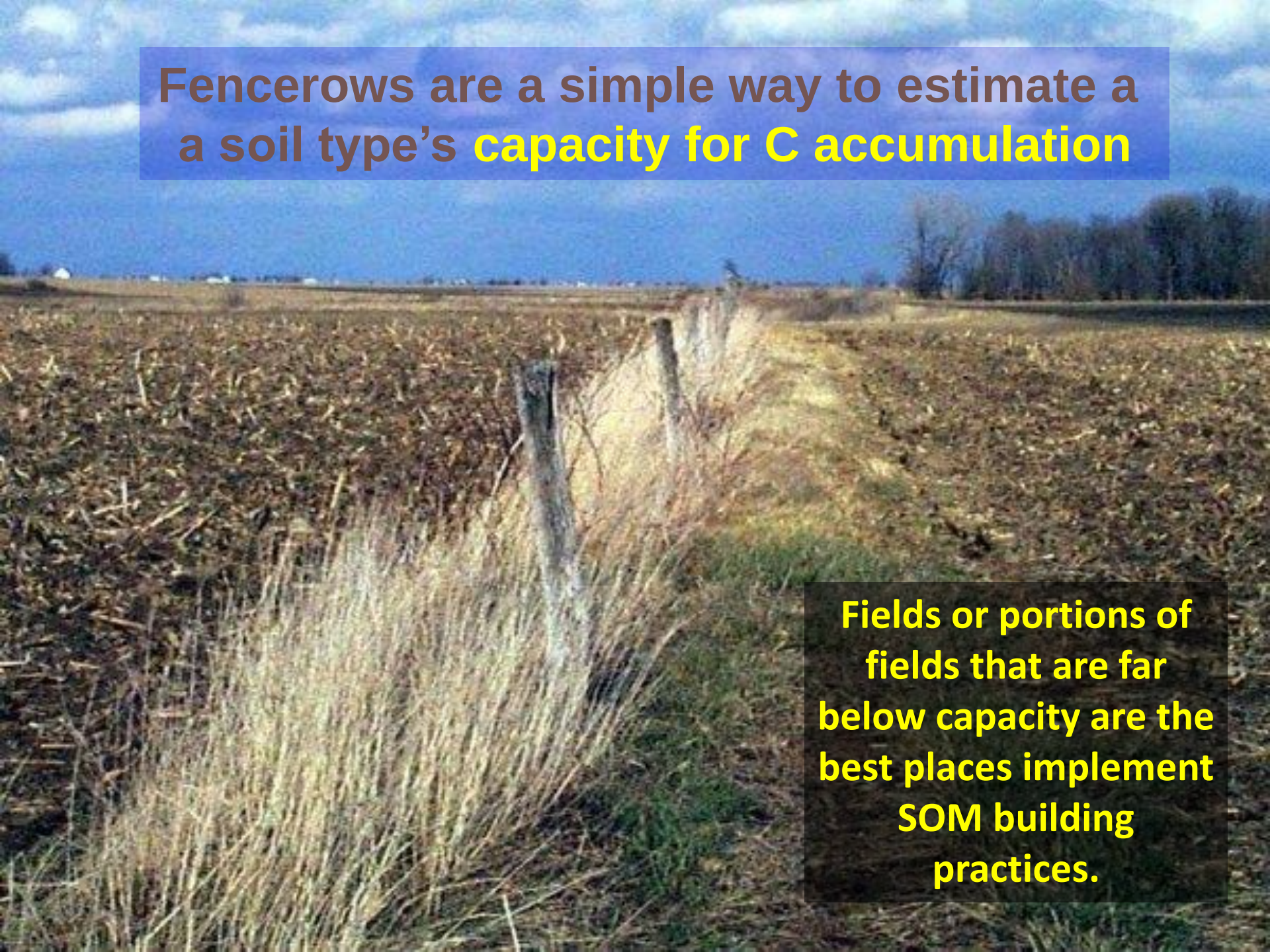
Landscape position - Low, poorly-drained areas have higher organic matter levels, because less oxygen is available in the soil for decomposition. Low spots also accumulate organic matter that erodes off hill tops and steep slopes.

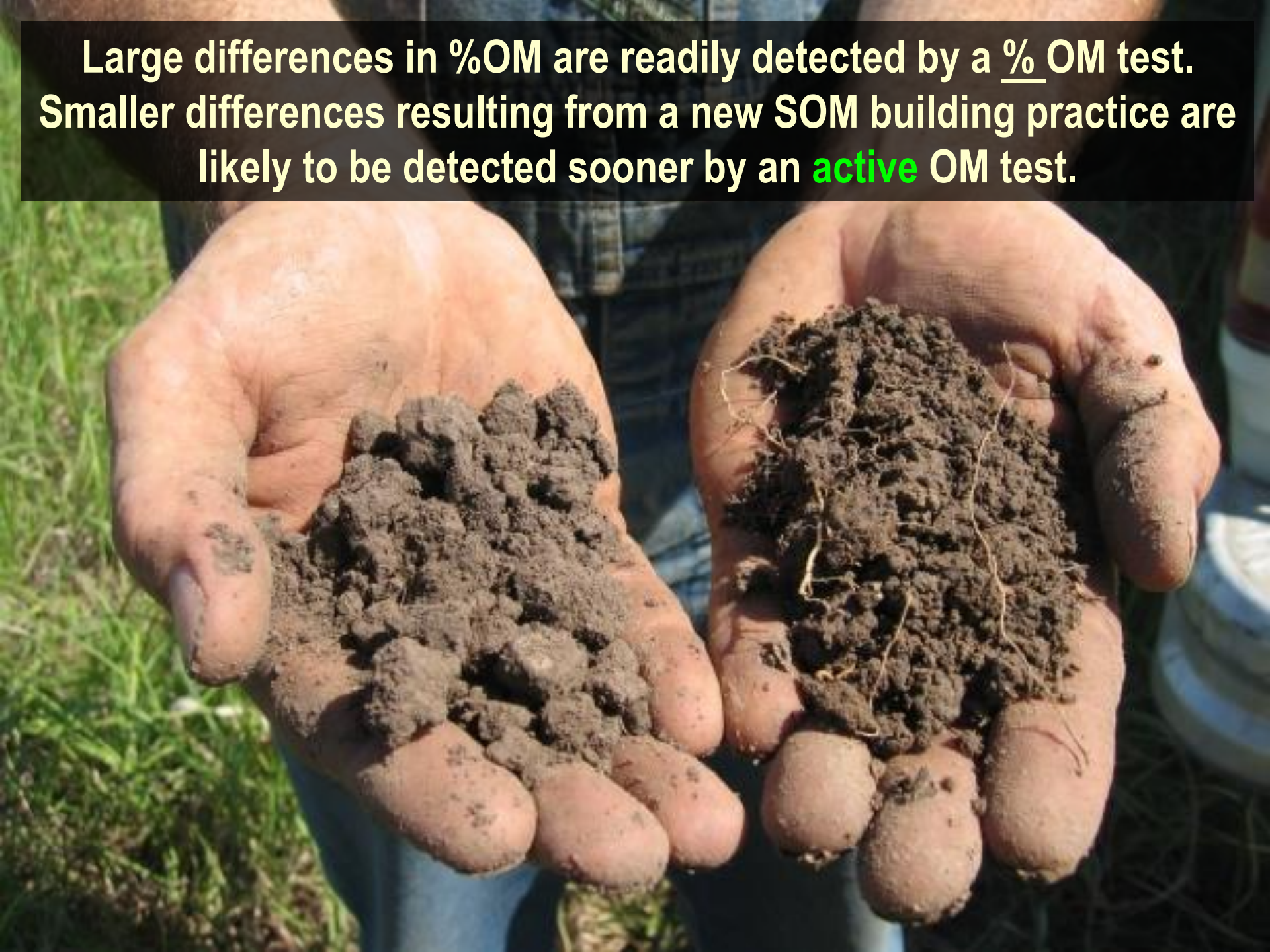
5th factor = MANAGEMENT





(Dick and Gregorich, 2004)


Fencerows are a simple way to estimate a a soil type's capacity for C accumulation
Fields or portions of fields that are far below capacity are the best places implement SOM building practices.


Large differences in %OM are readily detected by a % OM test.
Smaller differences resulting from a new SOM building practice are likely to be detected sooner by an active OM test.

Estimating active carbon for soil quality assessment: A simplified method for laboratory and field use

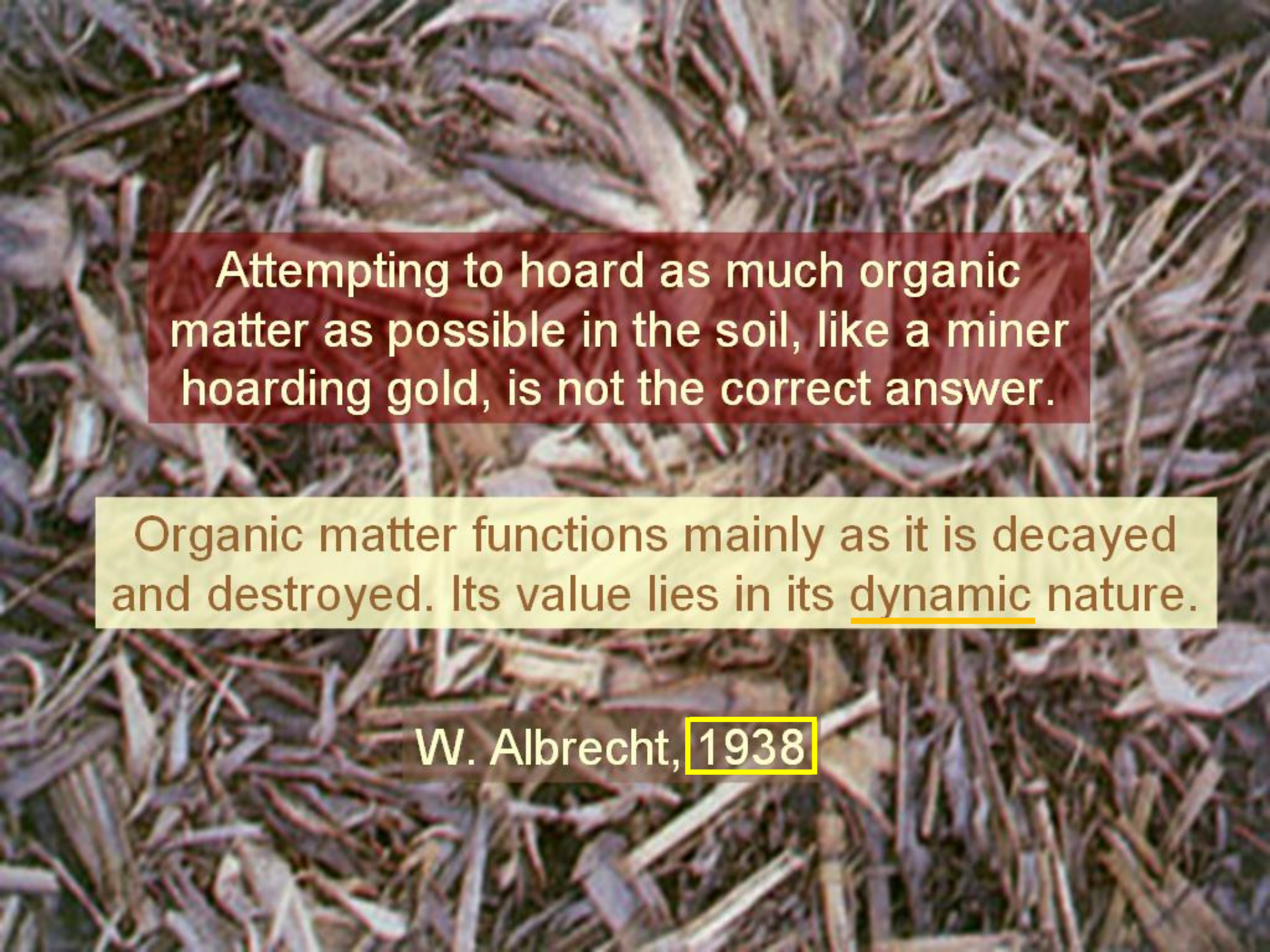
Ray R. Weil, Kandikar R. Islam, Melissa A. Stine, Joel B. Gruver and Susan E. Samson-Liebig

Abstract. *A simple method of estimating changes in biologically active soil carbon (C) could help evaluate soil quality impacts of alternative management practices. Most reports of permanganate for active C determination use highly concentrated solutions (0.333* M*) that are difficult to work with and tend to react with a large fraction of soil C that is no* ... *te, slightly alkaline* ... *Mn(II), and proportio* ... *ntration of* $KMnO_4$ *u* ... *king (1–15 minutes).* ... *nagement-sensitive* ... *1* M $CaCl_2$ *to the pe* ... *tion in the field kit.* ... *e from an inter-laboratory sample exchange (R^2 = 0.91). The active soil C measured by the new procedure was more sensitive to management effects than total organic C, and more closely related to biologically mediated soil properties, such as respiration, microbial biomass and aggregation, than several other measures of soil organic C.*

The active soil C measured by the new procedure was more sensitive to management effects than total organic C, and more closely related to biological and physical soil properties, such as respiration, microbial biomass and aggregation than several other measures of soil organic C.

Permanganate oxidizable C

a routine test for “active” soil C ??


Attempting to hoard as much organic matter as possible in the soil, like a miner hoarding gold, is not the correct answer.
Organic matter functions mainly as it is decayed and destroyed. Its value lies in its dynamic nature.
W. Albrecht, 1938

This classic commentary provides good food for thought

Journal of Soil and Water Conservation - 1995

COMMENTARY

Conventional row crop agriculture: Putting America's soils on a white bread diet ???

T. H. DeLuca

An analysis of the soils of the great plains will reveal their incredible wealth of native fertility, tilth, and rich dark color. Even after 100 years of cultivation, these soils retain much of their attractive appearance. On closer observation, however, conventionally managed soils reveal their massive structure, few roots, and little life compared to their virgin counterparts. What has caused this change? Is it simply because of the use of synthetic fertilizers and pesticides, or is there a greater overall problem with the way that we have approached agriculture?

It appears that the demand for synthetic fertilizers and pesticides may be a symptom of the poor diet that the soils have been given over the last 100 years, a diet that has only worsened with the advent of synthetic fertilizers.

have a single crop of corn or soybeans grown in a linear pattern with the majority of the proteins, fats, and vitamins removed at the end of the growing season during harvest. Even if the straw isn't removed for baling, the food actually returned to the conventional row crop soil is primarily cellulose (a polymer of glucose), hemicellulose, and lignin. Thus the soil is fed a scant diet of "white bread" devoid of protein, complex carbohydrates, nutrient storage compounds, vitamins, or nucleic acids.

To take the above mentioned analogy a bit further, imagine yourself living on a diet of commercial white bread and water. You would look pretty sick within few weeks. Based on the vitamin revolution of the 1960s, humans eating such a diet would be told to "take a vitamin pill" or "eat bread

human immune system and result in chronic illness including anemia, colds, flu, and numerous secondary bacterial and even fungal infections. The medical profession might prescribe a heavy dose of antibiotics to eliminate the bacteria and as a side effect reduce beneficial microflora in digestive organs. Likewise, the "immune system" of the soil on the white bread diet will begin to fail and the plants growing in this soil will be faced with unchecked outbreaks of aggressive antagonistic and pathogenic organisms. In this case the prescribed cure would be to apply fungicides, nematicides, insecticides, or antibiotics to control the pathogens, but this would ultimately result in the further demise of beneficial organisms, thus worsening the health of the soil.

So what's wrong here? We are well aware that a poorly balanced diet for humans spells disaster in the form of dead looking skin, hair, and nails, bad teeth, immune system failure, cancer, heart disease, etc.... Why can't we look at the soil in a similar light? Soils need a well balanced diet of proteins, cofactors, minerals, and carbohydrates. Our conventional agricultural practices are silently killing our soils nation wide by feeding the soil nothing but white bread and vitamins.

This classic commentary provides good food for thought

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T. H. DeLuca

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What are the symptoms of a "white bread diet"?

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DEGRADED SOIL STRUCTURE

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of proteins, cofactors, minerals, and carbohydrates. Our conventional agricultural practices are silently killing our soils nation wide by feeding the soil nothing but white bread and vitamins.

This classic commentary provides good food for thought

Journal of Soil and Water Conservation - 1995

COMMENTARY

Conventional row crop agriculture: Putting America's soils on a white bread diet ???

T. H. DeLuca

An analysis of the soils of the great plains will reveal their incredible wealth of native fertility, tilth, and rich dark color. Even after 100 years of cultivation, these soils ret their attractive appearance. C servation, however, convent aged soils reveal their mass few roots, and little life com virgin counterparts. What h change? Is it simply because synthetic fertilizers and pes there a greater overall prob way that we have approached

It appears that the deman ic fertilizers and pesticid symptom of the poor diet that the soils have been given over the last 100 years, a diet that has only worsened with the advent of synthetic fertilizers.

have a single crop of corn or soybeans grown in a linear pattern with the majority of the proteins, fats, and vitamins removed at the end of the growing season would look pretty sick within few weeks. Based on the vitamin revolution of the 1960s, humans eating such a diet would be told to "take a vitamin pill" or "eat bread

human immune system and result in chronic illness including anemia, colds, flu, and numerous secondary bacterial and even fungal infections. The medical profession might prescribe a heavy dose of antibiotics to eliminate the bacteria and as a side effect reduce beneficial microflora in digestive organs. Likewise, the "immune system" of the soil on the white bread diet will begin to fail and the plants growing in this soil will be faced with unchecked outbreaks of aggressive antagonistic and pathogenic organisms. In this case the prescribed cure would be to apply fungicides, nematicides, insecticides, or to control the pathogens, but ultimately result in the further beneficial organisms, thus worsening health of the soil.

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slower infiltration resulting in more erosion

This classic commentary provides good food for thought

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Less efficient retention of **SOM**

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Pump up Organic Matter – Feed Your Soil Like a Cow

https://www.youtube.com/watch?v=mXwh4JN6c6M

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Precision Cover Cropping

for organic farms

This was my main focus for about 5 years

Joel Gruver
WIU- Agriculture
j-gruver@wiu.edu
(309) 298 1215

Precision planted CCs = more management but fewer benefits than expected

Diverse cover crop mix planted mid-August at the Allison Farm


Nodulation on a sunn hemp root


Soil Surface!

Review: Endophytic microbes and their potential applications in crop management

James F White, Kathryn L Kingsley, Qiuwei Zhang, Rajan Verma, Nkolika Obi, Sofia Dvinskikh, Matthew T Elmore, Satish K Verma, Surendra K Gond, Kurt P Kowalski

First published: 22 June 2019, Abridged by JB Gruver

https://doi.org/10.1002/ps.5527

Reading for this week

Abstract

Endophytes are non-pathogenic microbes (mostly bacteria and fungi) active inside plants. Endophytic microbes have been shown to: (i) obtain and transfer nutrients to plants in the rhizophagy cycle and other nutrient-transfer symbioses; (ii) increase plant growth and development; (iii) reduce oxidative stress of hosts; (iv) protect plants from disease; (v) deter feeding by herbivores; and (vi) suppress growth of competitor plant species. Because of the effective functions of endophytic microbes, we suggest that endophytic microbes can significantly reduce use of agrochemicals (fertilizers, fungicides, insecticides, and herbicides) in crop production. The loss of endophytic microbes from crop plants during domestication and long-term cultivation could be remedied by transfer of endophytes from wild relatives of crops to crop species.

Cool Science!
Rhizophagy: A New Understanding of Plant Nutrition

Karen Stever, Ph. D.
GGSPro Technical Specialist
ggsprotech@griffinmail.com
1-800-888-0054 ext. 89129

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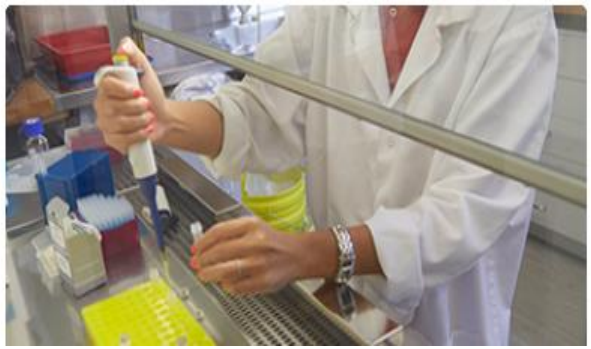
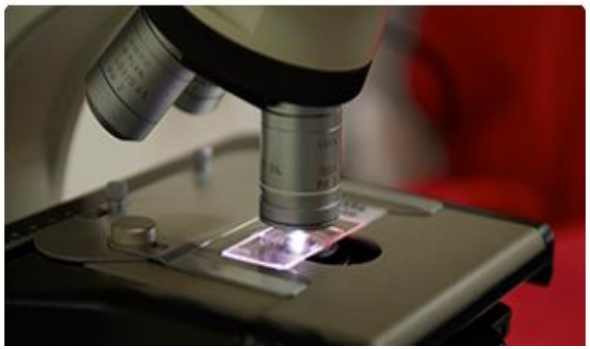
BioConsortia is developing highly effective microbial consortia for increasing agricultural yields.

We have developed a revolutionary Advanced Microbial Selection (AMS) process, which uses directed selection to discover beneficial teams of microbes. This novel, patented model works by controlling the seed genetics and the environment while changing the microbial community in order to shift trait performance in the crop toward improved targeted phenotypes.





https://youtu.be/2f5aru4103I

BioAg Facility in Augusta IL for production of compost teas & extracts

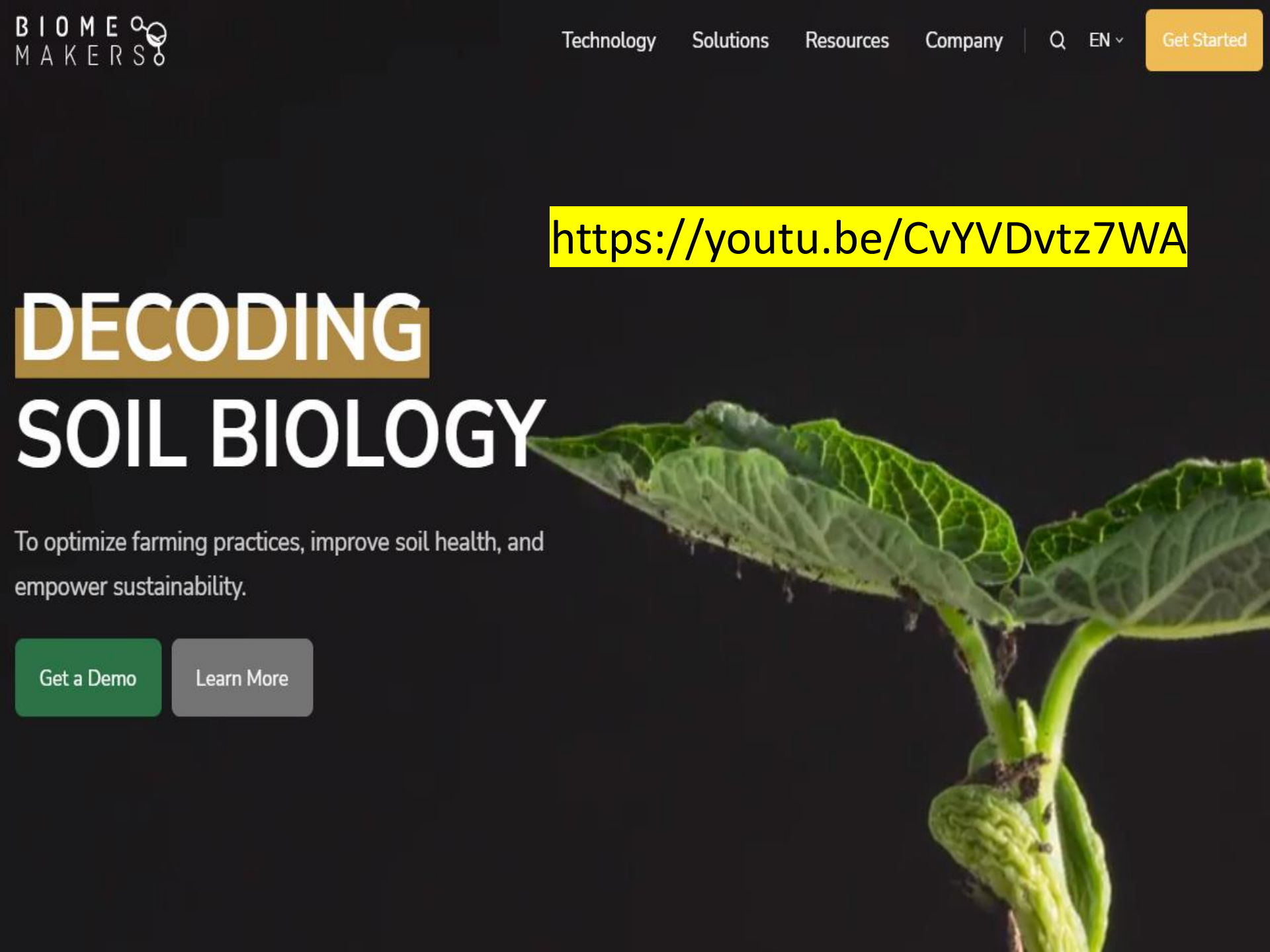
MICROBIAL DYNAMICS AND INTERACTIONS IN THE SPERMOSPHERE

= zone of high microbial activity in, on and near seeds

Eric B. Nelson
Department of Plant Pathology, Cornell University, Ithaca, New York 14853; email: ebn1@cornell.edu

Key Words seed microbiology, seed exudation, *Pythium*, *Fusarium*, plant-microbe interactions

■ **Abstract** The spermosphere represents a short-lived, rapidly changing, and microbiologically dynamic zone of soil surrounding a germinating seed. It is analogous to the rhizosphere, being established largely by the carbon compounds released into the soil once the seed begins to hydrate. These seed exudations drive the microbial activities that take place in the spermosphere, many of which can have long-lasting impacts on plant growth and development as well as on plant health. In this review, I discuss the nature of the spermosphere habitat and the factors that give rise to its character, with emphasis on the types of microbial activities in the spermosphere that have important implications for disease development and biological disease control. This review, which represents the first comprehensive synthesis of the literature on spermosphere biology, is meant to illustrate the unique nature of the spermosphere and how studies of interactions in this habitat may serve as useful experimental models for testing hypotheses about plant-microbe associations and microbial ecology.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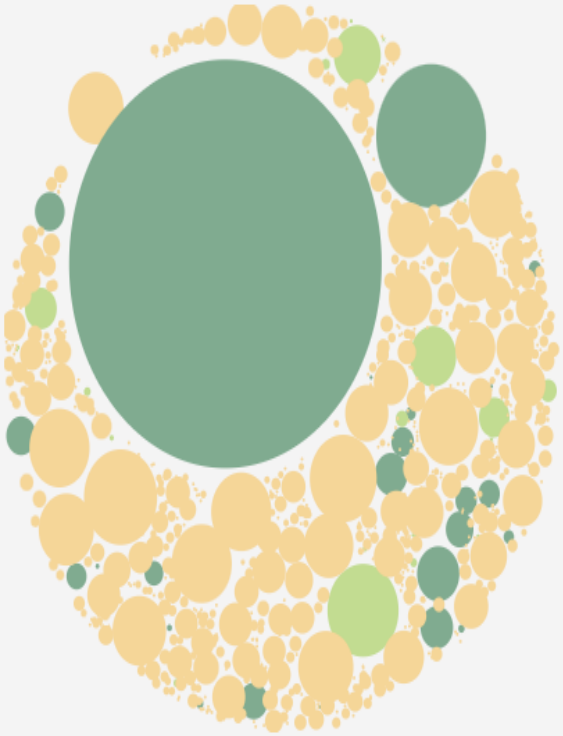


Why BeCrop®?

Largest Global Database

Our database contains over **14M taxonomic references** using DNA Next Generation Sequencing (NGS) techniques.

Patented Technology

We use proprietary **DNA Sequencing workflow and Intelligent Computing** to monitor the most relevant bio-indicators.

Functional and Ecological

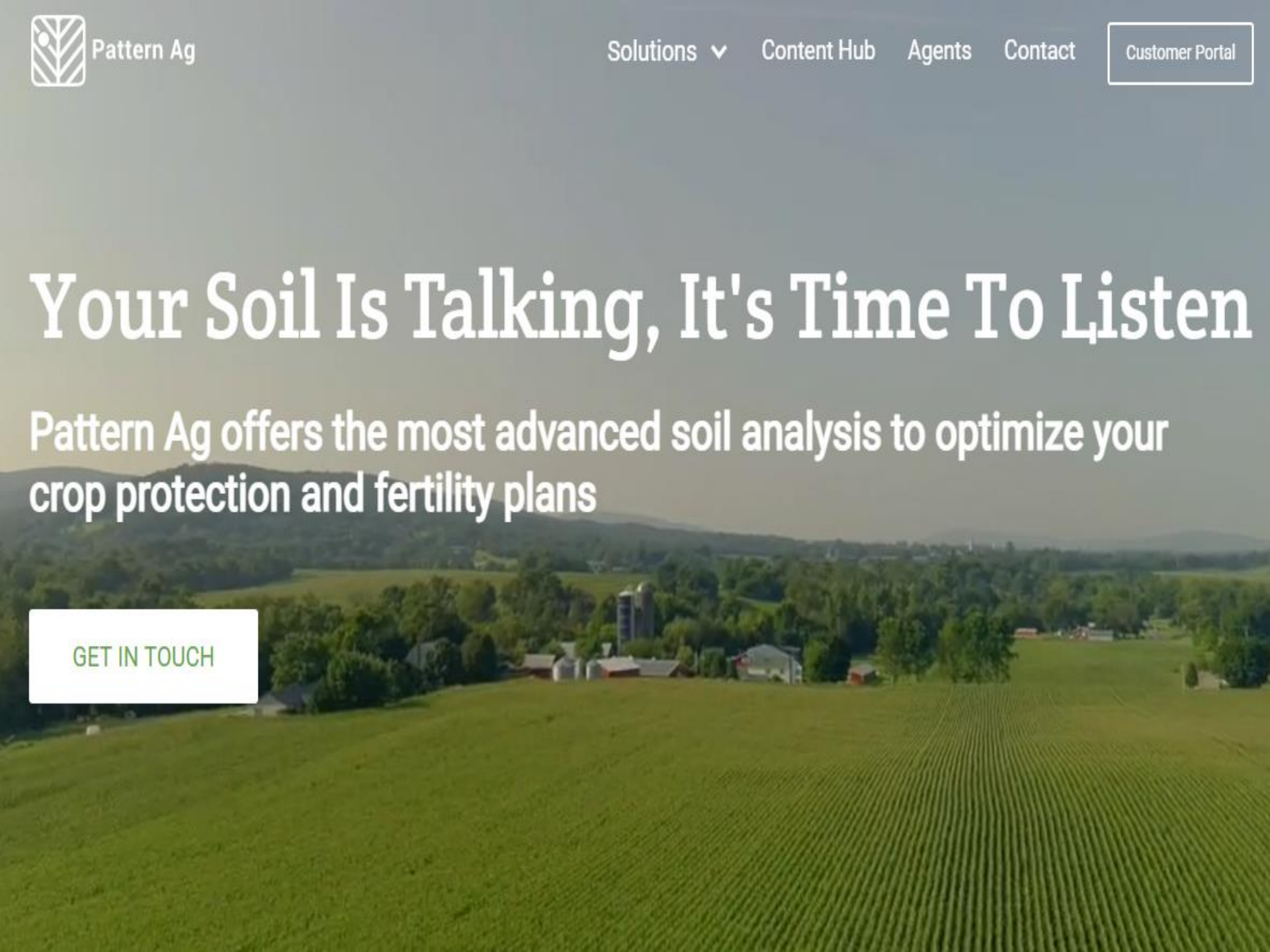
Our technology analyzes the functional dimensions of the existing microbe network, contains ecological insights, and advances knowledge about the soil microbiome.

170 Crops Analyzed

Our technology is the first Intelligence Computing System (ICS) based in Artificial Intelligence (AI), with a proprietary database of more than **170 crops analyzed from 40+ countries** worldwide of ag-soil microbial profiles.

Providing unmatched soil analysis with industry-leading metagenomics sequencing.

BIOLOGY AND CHEMISTRY INSIGHTS. ACTIVATED.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Case Study: Corn Rootworm

Farm:
Olson Farms

Location:
Amboy, Illinois

Soil Sample Date:
Fall 2021

Crop Planted Last Season:
Soybeans

Result:
Savings of $20/ac on 75% of fields sampled (savings ~$49K)

BACKGROUND

Planning on rotating their crop for the spring 2022 planting season, Olson Farms sampled 3,333 acres of soybeans in the fall of 2021. Ordering Pattern Ag's Corn Root Pressure Panel, the operation wanted to determine the level of economic risk they were facing, along with which input costs (traits and insecticides) were going to be necessary.

Corn Yield Target: 250 bu/ac

Corn Price: $5.50/bu

OLSON FARM DECISION DASHBOARD RESULTS

Microbial seed banks: the ecological and evolutionary implications of dormancy

Jay T. Lennon & Stuart E. Jones

Nature Reviews Microbiology **9**, 119–130 (2011) | Cite this article

Cutting edge science

Key Points

- Dormancy is a bet-hedging strategy used by a wide range of taxa, including microorganisms. It refers to an organism's ability to enter a reversible state of low metabolic activity when faced with unfavourable environmental conditions.

- Dormant microorganisms generate a seed bank, which consists of individuals that are capable of being resuscitated following environmental change. Seed banks can prolong the persistence of genotypes and populations, and also have important consequences for community- and ecosystem-level processes.

BUILD IT AND THEY WILL COME
is the most important strategy for managing soil biology!