



# *Prologue for the on-line version*

This slide show accompanied a lecture by Dr Brinton in Asilomar, Monterey CA.

NOTES: Soil Health is a popular “new” movement gaining ground with farmers and promising renewed hope for real soil building - regardless of farming preferences and organic status.

Yet, soil health is not new, and is fully and completely an organic creation that has taken 40 years to gain a footing. The presenter will show that the science underlying health was conceived by early organic/bio-dynamic scientists in Europe. That soil health has jumped the border of organic farming is no surprise. Based on current science assessments, organic farming continues to lead conventional farming in virtually all soil health metrics.

*Will Brinton*





# Healthy Soil is ....

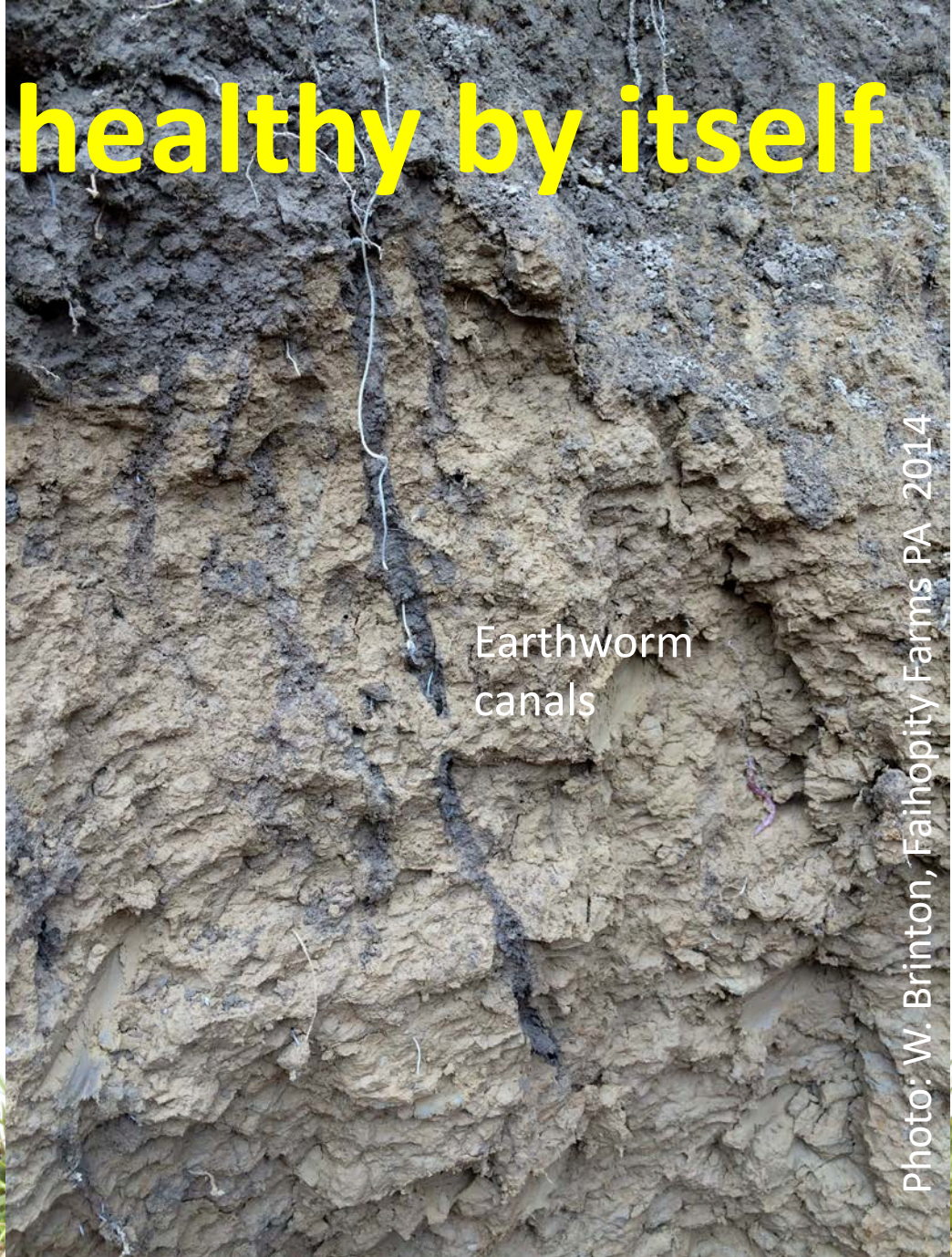
- A world *including* roots, microbes, animals
- A complicated trait that's hard to quantify!
- The *road not taken* for modern ag science
- The *brainchild* of early organic farming
- Nature's Plan





# Soil can't be healthy by itself

- Worms/roots/microbes interact, react, transport
- Hard to say what comes first: what are causes vs effects!
- Plants+microbes/animals are working together to improve their habitat.



Earthworm  
canals



Soil “health”  
created  
at least half  
of this yield.

**Soil Lab Report**

P 27

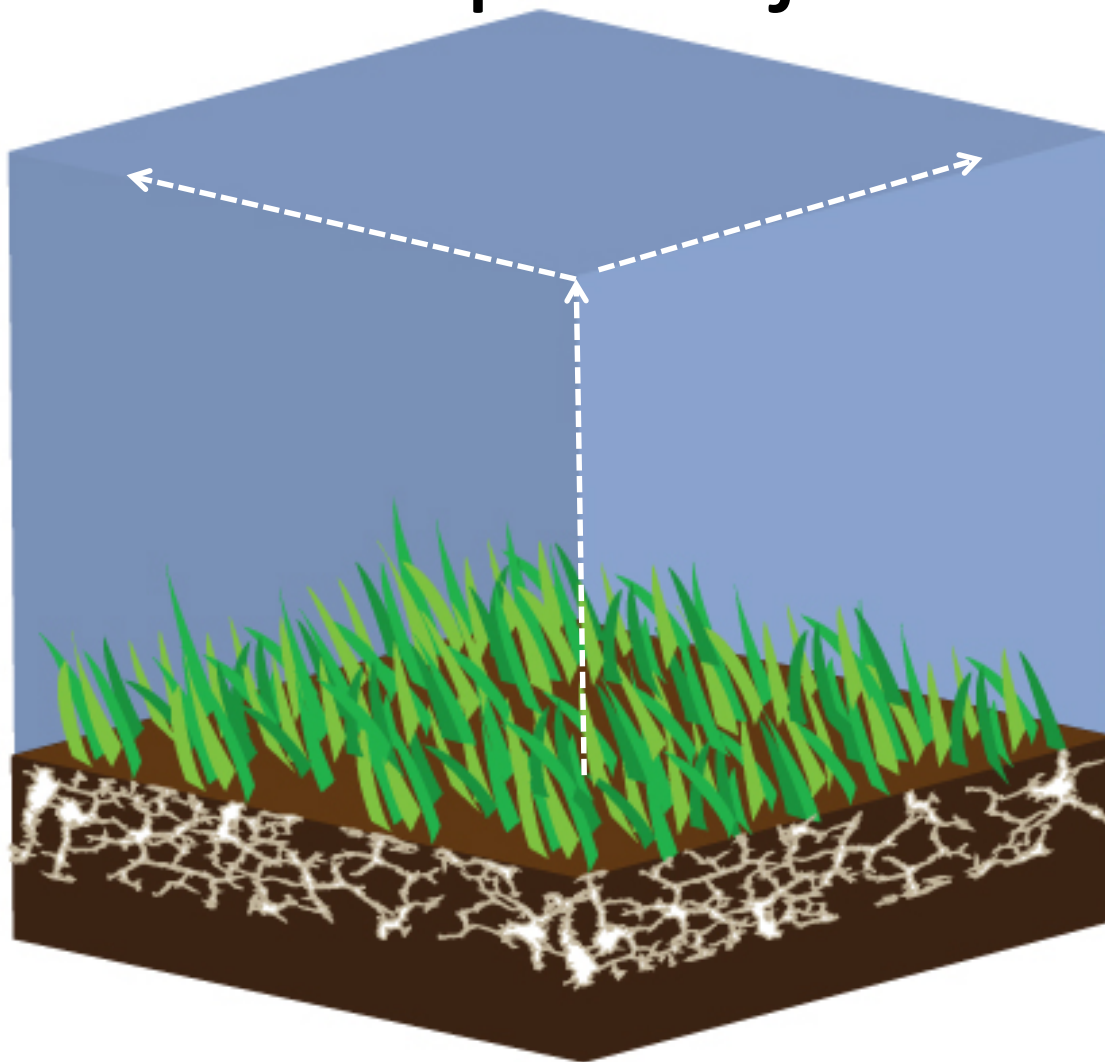
K 175

pH 6.5

**soil life ?**

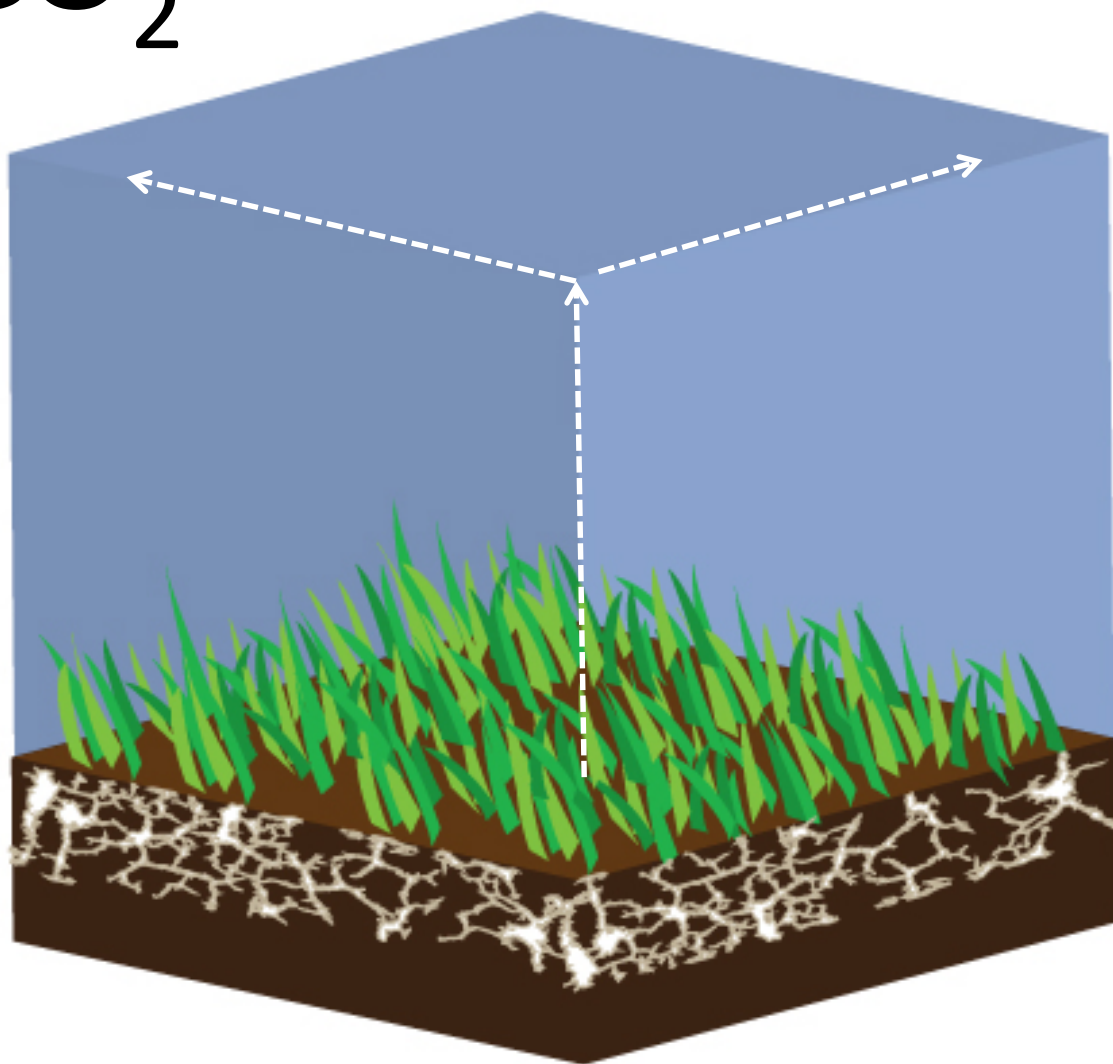


# What's the Crop's major nutrient ?





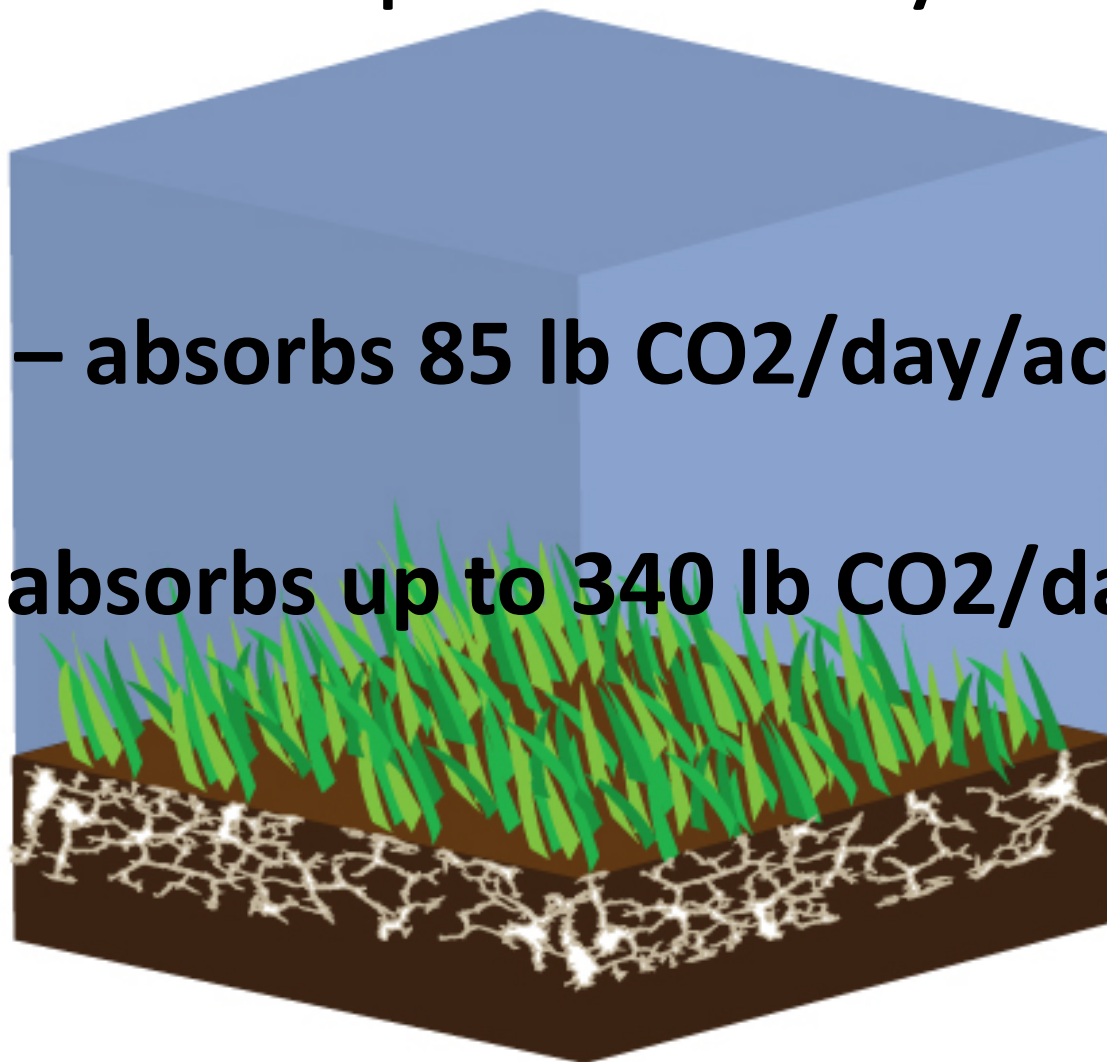
CO<sub>2</sub>



In order to produce dry matter;

**Wheat – absorbs 85 lb CO<sub>2</sub>/day/acre<sup>‡</sup>**

**Corn – absorbs up to 340 lb CO<sub>2</sub>/day/acre**



<sup>‡</sup> assuming ≈60 days to accumulate 50 bushels of dry wheat grain or 200 bu. corn



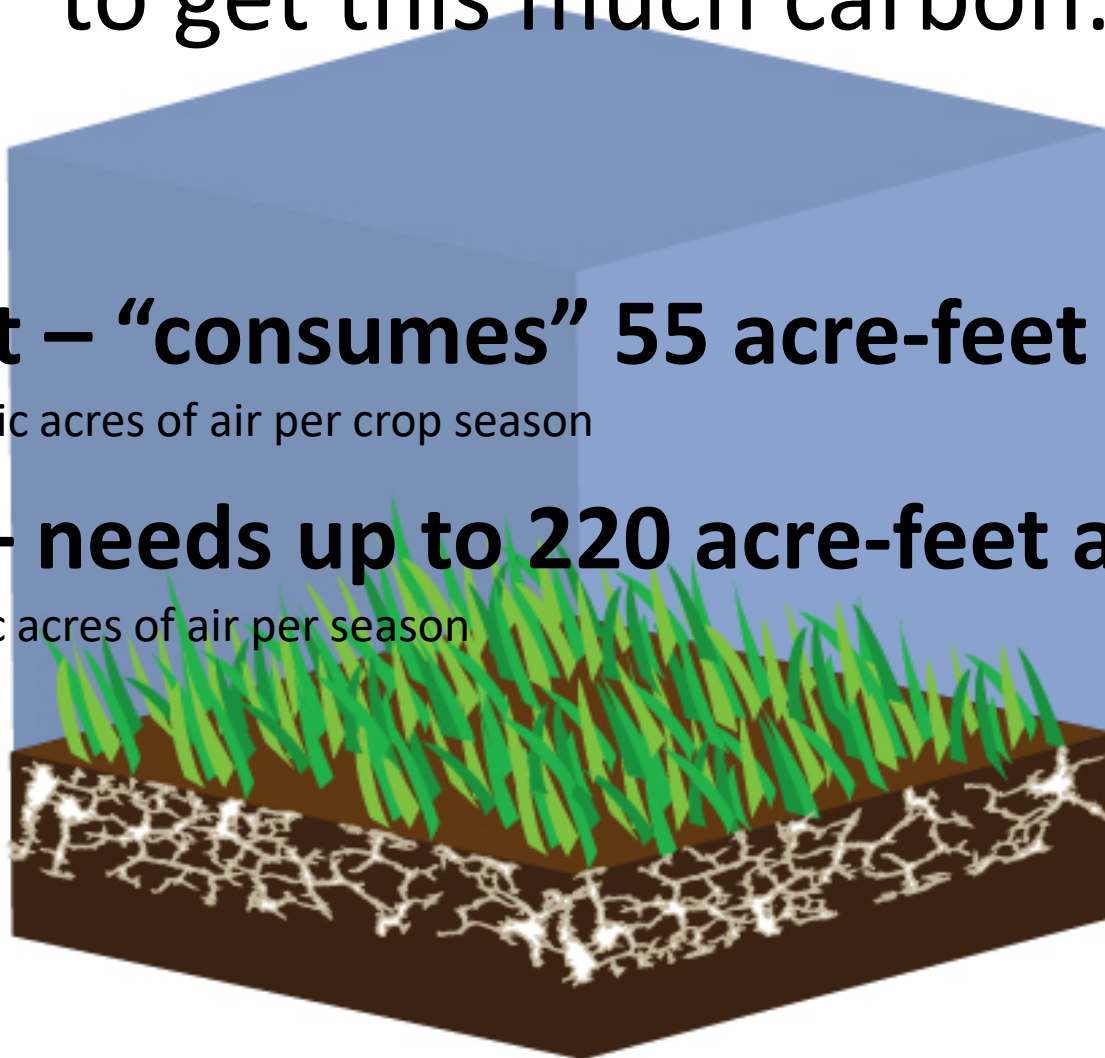
At 400\* ppm CO<sub>2</sub> in air,  
to get this much carbon:

**Wheat – “consumes” 55 acre-feet air/day<sup>‡</sup>**

- or 15 cubic acres of air per crop season

**Corn – needs up to 220 acre-feet air/day<sup>‡</sup>**

- or 60 cubic acres of air per season



As per the Ideal Gas Law, at STP, 1 cubic foot of air has 0.016 g CO<sub>2</sub> or 700 g / acre-foot

Living Soil raises the CO<sub>2</sub> concentration in and above the soil, reducing plants dependency on free air for its photosynthesis needs

ppmv:  
≈400  
(ambient)

≈800

≈1,500

≈4,000

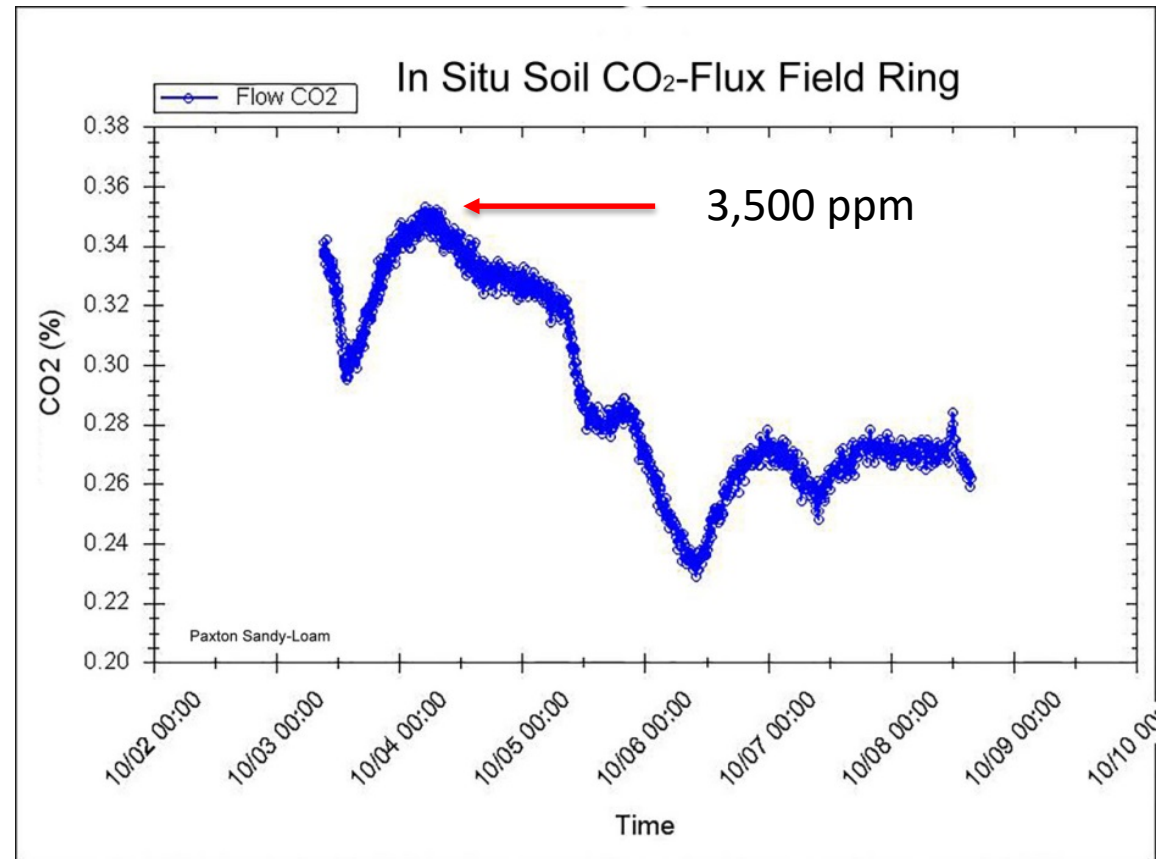




# Validation of *In Situ* Soil Pulsating-Breathing Respiration

CO<sub>2</sub> Infiltration Ring Chamber  
(Doran & Brinton 1995)

2" Over soil surface CO<sub>2</sub> Flux



# Where's the Soil CO<sub>2</sub> Going?

**BARE SOIL**



**COVERED SOIL**

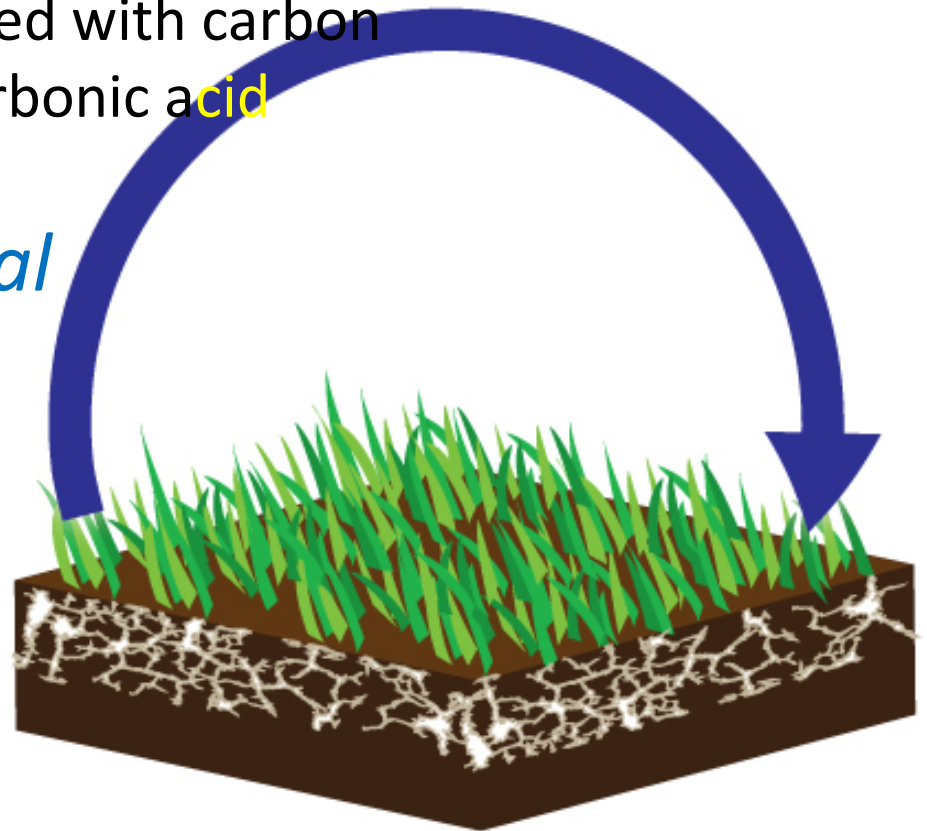




# Therefore, living soil biology is:

1. Helping meeting plants' nutrient requirement for CO<sub>2</sub>
2. Sequestering AND relinquishing CO<sub>2</sub>
3. Releasing available N associated with carbon
4. Dissolving soil minerals via carbonic acid

*Nature is balancing several equations simultaneously*





# Activity and mass is what counts

100 lb/d  
CO<sub>2</sub> Photo-synthesis

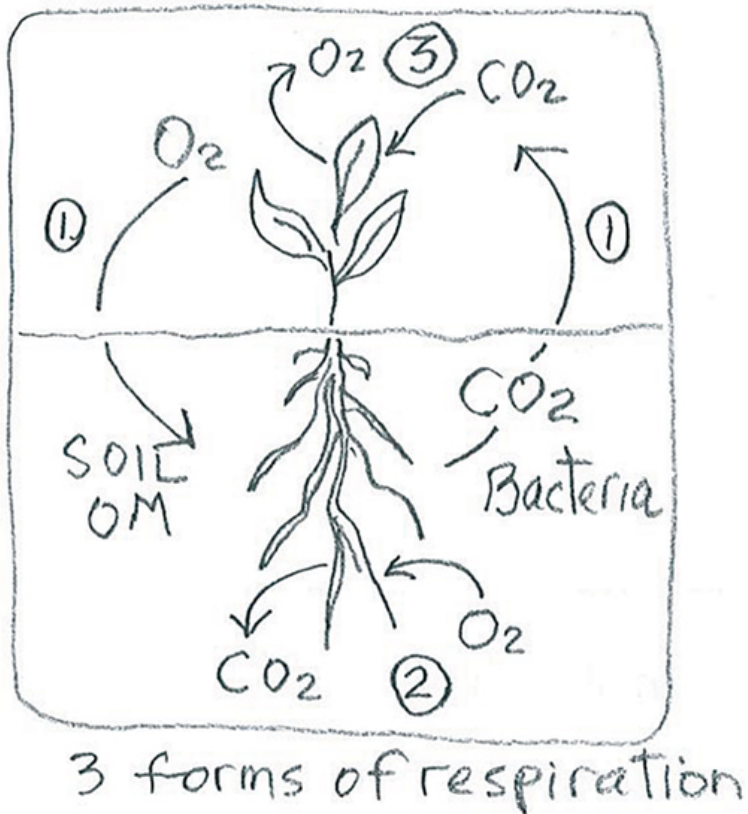
100 lb/d  
Soil CO<sub>2</sub>

1-5 lb/d  
Nutrient Release

2,000 lbs/acre  
Microbes

50,000 lbs/acre  
Organic Matter





1. Soil biological food web: consumes soil organic matter, requires  $O_2$  and produces  $CO_2$
2. Plant root metabolism requires  $O_2$  and releases  $CO_2$
3. Plant above-ground photosynthesis absorbs  $CO_2$  and produces  $O_2$





# Notice the roots

- Root mass often similar to above-ground mass
- Roots explore up to 200ft<sup>3</sup>/plant\*  
(Soil test models assume ~10ft<sup>3</sup>)
- Root length may be > 1,000 miles
- Root surface area >35 ball fields

\* Liebhardt W (2014) Moving beyond the soil test. RAFS Cambridge Press





# Validating Microbial/CO<sub>2</sub> induced natural soil mineral weathering

Soils are being constantly “mined” by microbes whose CO<sub>2</sub> as a weak acid releases geologic nutrients into biological cycles



Source: Canadian Jnl Soil Sci 1998

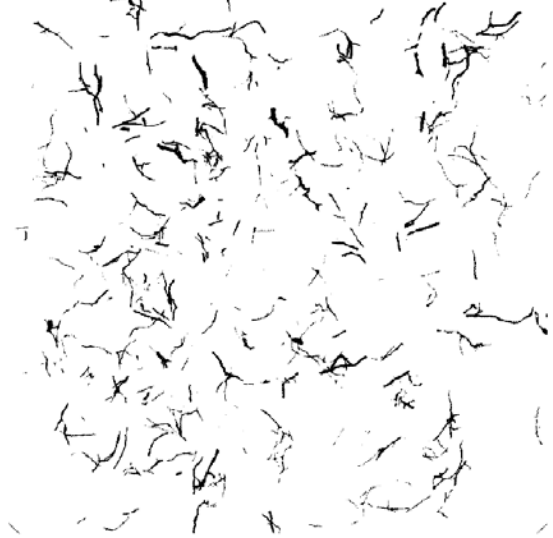
# Unseen world of roots

46

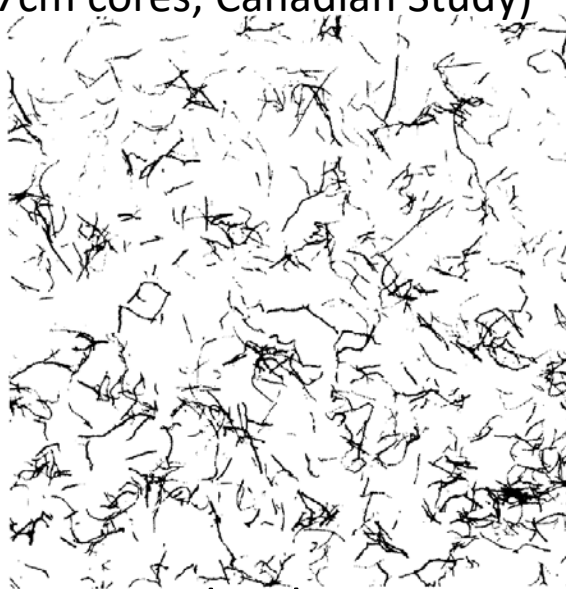
495

852 ft<sup>2</sup> / cubic foot

(Barley Roots extracted from 7cm cores; Canadian Study)



Unhealthy Soil /  
Stressed roots



Improved soil  
Moderate growth



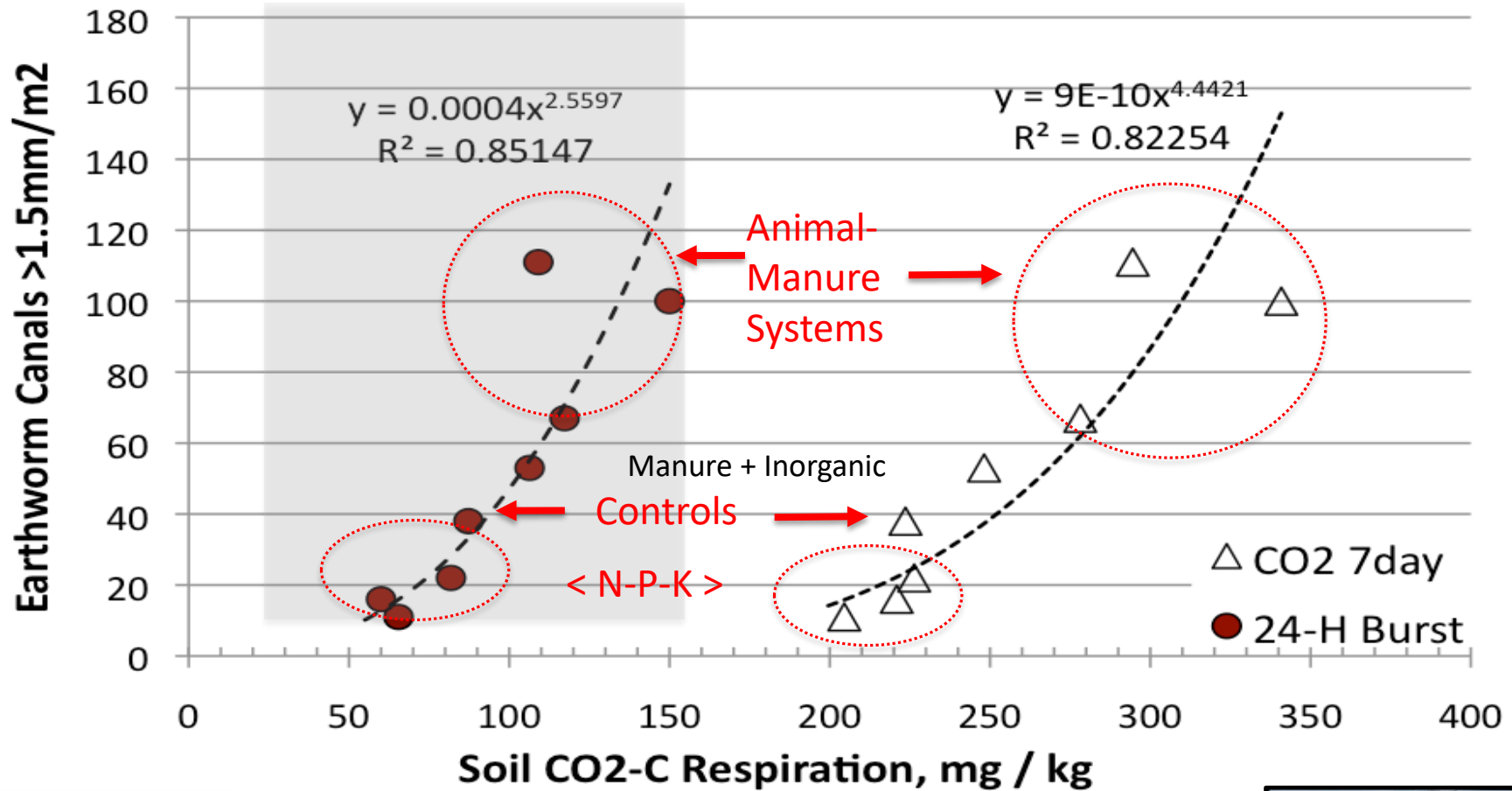
Healthy Soil  
Vigorous roots





# LONG TERM STUDIES SHOW CROP ROTATION AND MANURING VITAL TO SOIL HEALTH

## Earthworm Canals in Long Term Field Studies



**Source:** Brinton et al. (1981) Swedish 17-yr Field Plot Studies: CO<sub>2</sub> Rates vs Earthworm Canals.





# Social Insects may be your earthworms!

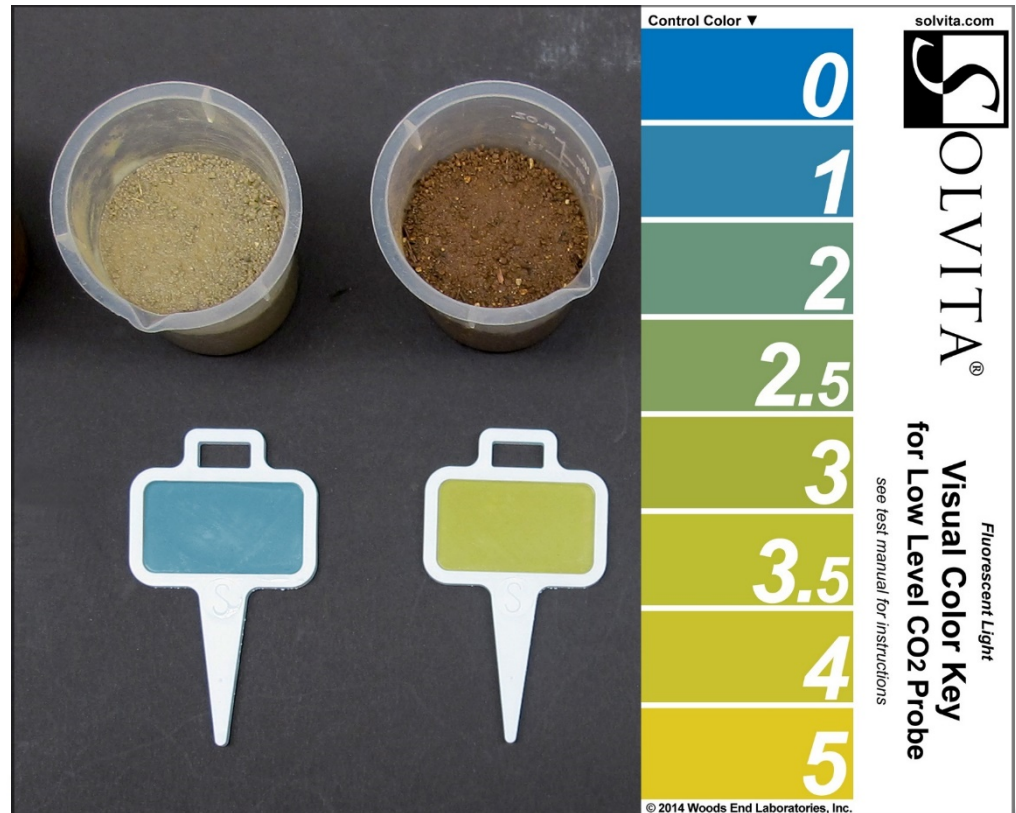


Hymenoptera species in Tuscany soil

Tuscany, Italy



# Validation Methods: Solvita Soil Respiration Test





# Field CO<sub>2</sub> Respiration Research 2017



## As found in Organic Growing Systems

Two long-term trials with 4-6 reps



**Permanent Bed Tillage Trial Plots (since 2014) – *How is soil respiration influenced by soil management?***

**High-Tunnel Organic (compost since 2013) *How does compost influence soil carbon mineralization changes***

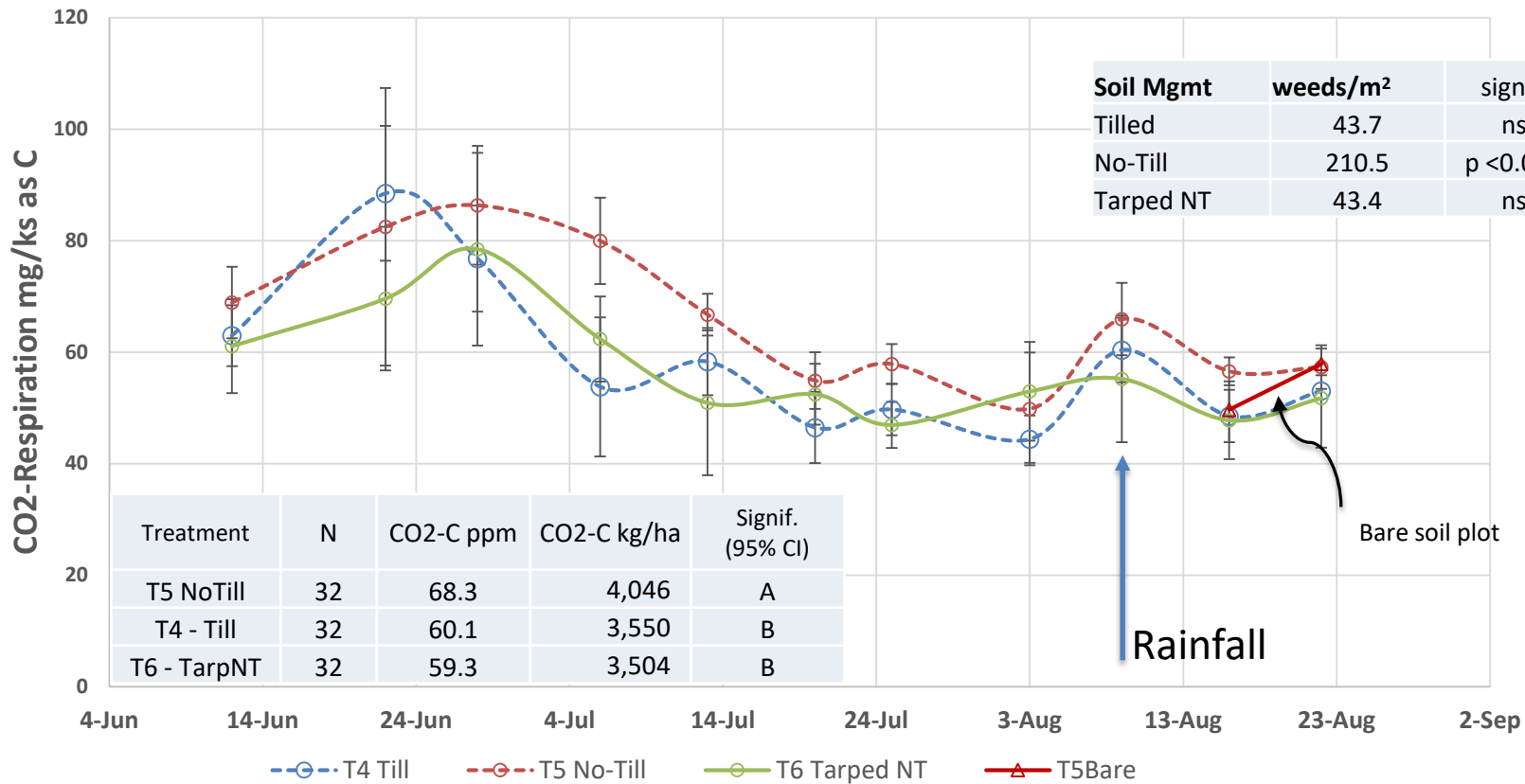




# Results: CO<sub>2</sub>-C release as influenced by organic tillage vs No-Till plots



Tillage Plots  $\pm$  SD ( 4 -6 reps) During the Season



Ref: Brinton, W., J. Vallotton, M. Hutton, M. Hutchinson. 2017. ASA-SSSA-CSA Tampa FL  
 This study was conducted using the field-version of the Solvita field kit with 5 replicates per treatment

## Details on CO<sub>2</sub> METHOD

Tests started within 3 hrs of sampling; all samples weighed.

Solvita® CO<sub>2</sub>-sensitive probes employed in basal mode (fresh, as-is soil), No drying or grinding

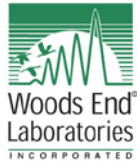
Two jar sizes (¼ and 1-liter) in case very high CO<sub>2</sub> concentration

Ambient room temp during measuring: ranged 19-26°C avg. 22 °C

Results quantified by Solvita DCR as CO<sub>2</sub>-C mg kg<sup>-1</sup>  
= kg ha fresh weight



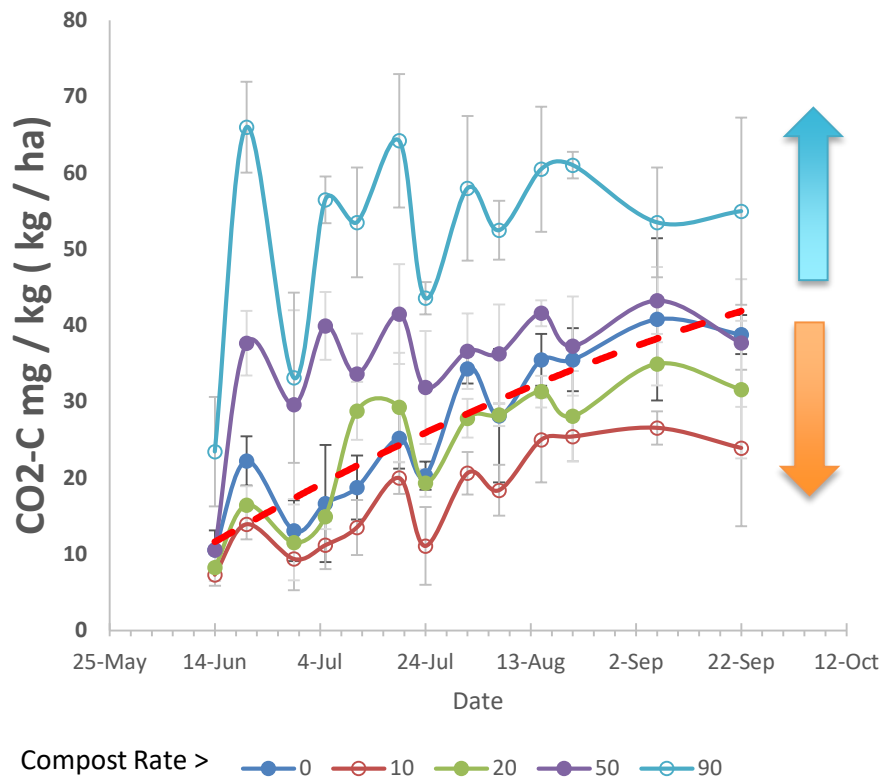




# Season compost-soil effects observed with basal Solvita CO<sub>2</sub> respiration



CO<sub>2</sub>-Emissions Per Compost Plots



## Overall Effects of CO<sub>2</sub>-Rate

Treatment Rate t/a (MG/ha)	P, Difference from Control
10 (22)	0.016* (- reduction!)
20 (45)	0.55 (ns)
50 (112)	0.003*** (+)
90 (200)	0.003*** (+)

Source	DF	SS	MS	F	P
DATE	11	6293.41	572.13	16.91	0.000
RATE	4	28791.33	7197.83	212.76	0.000
DATE*RATE	44	3021.80	68.68	2.03	0.001

# Assessment of Organic soil health status as revealed by research

Source: Research Institute for Biological Husbandry, Switzerland

	Total	Microbial biomass carbon	Microbial biomass nitrogen	Total PLFA	Basal respiration	Dehydrogenase activity	Metabolic quotient	Protease activity	Urease activity
<b>Number of studies</b>	56 studies	42 studies	21 studies	8 studies	29 studies	17 studies	22 studies	3 studies	7 studies
<b>Number of paired comparisons</b>	149	100	49	22	66	40	40	7	18
<b>Experimental field comparisons</b>	75	54	28	11	42	18	26	2	5
<b>Farm comparisons</b>	74	46	21	11	24	22	14	5	13
<b>Experimental duration in years (Mean / Median)</b>	16.1 / 10.0	17.2 / 10.0	11.0 / 10.0	25.9 / 10.0	12.6 / 10.0	8.8 / 5.5	12.3 / 8.0	6.6 / 6.0	7.9 / 7.0
<b>Coverage of climatic zones<sup>+</sup></b>	A, B, C, D	A, B, C, D	A, B, C, D	A, C, D	A, B, C, D	A, B, C, D	A, B, C, D	C	A, B, C
<b>Coverage of continents<sup>*</sup></b>	6 of 6	6 of 6	5 of 6	4 of 6	6 of 6	5 of 6	6 of 6	3 of 6	4 of 6

\* all except Antarctica

<sup>+</sup> A = Tropical/mega thermal climates, B = Dry climates, C = Temperate/mesothermal climates, D = Continental/Microthermal climates, E = Polar climates

<https://doi.org/10.1371/journal.pone.0180442.t001>





# 149 paired scientific studies:

- Location of Studies Used



Source: [Lori et al. \(FibL\) 2017 Plos One](#)

- **ORGANIC FARMED SOILS HAD:**

41% more biomass carbon

51% more microbial N

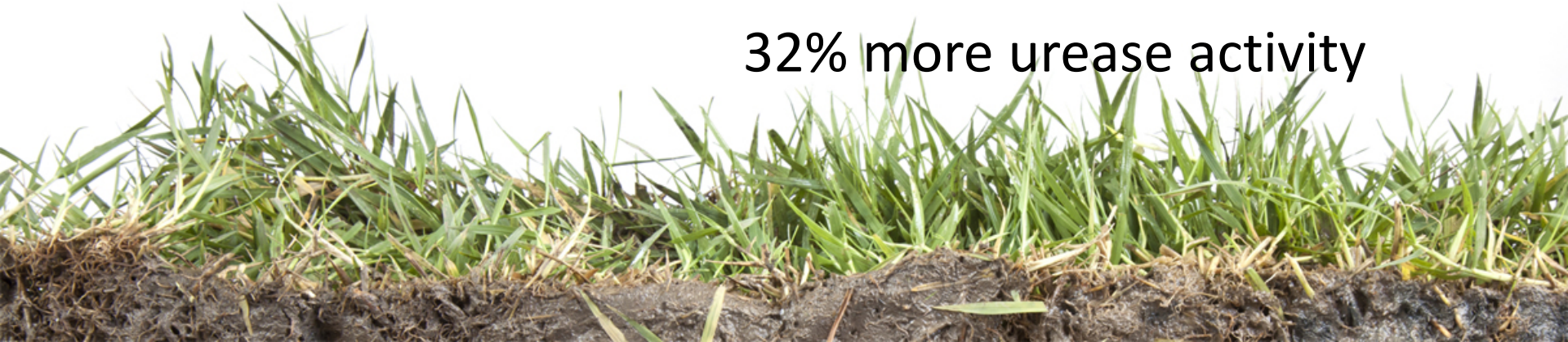
59% more PLFA count

74% more dehydrogenase

4% more efficient CO<sub>2</sub> cycle

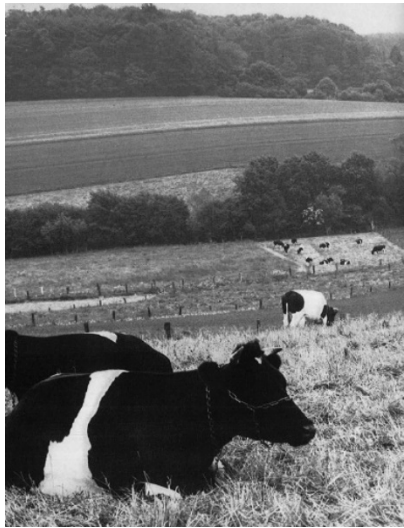
84% greater protease

32% more urease activity



# Compared to first EU Soil Health Study\*

- Location of Studies: 9 paired dairy farms on same soil types
- **Organic-Bio-Dynamic Farms had:**
  - 10-50% more CO<sub>2</sub> respiration
  - 14% higher N-mineralization
  - 40% more dehydrogenase enzymes
  - 76% more urease enzymes
  - 400% more azotobacter
  - 390% greater earthworm counts



\* Source: [German Ministry of Agriculture 1977](#)  
*Baden-Württemberg*





# Soil Labs worldwide integrating Solvita biology into lab process....



**SOIL FERTILITY & HEALTH REPORT**

Powered by **SOLVITA**

William Brinton  
Woods End Farm  
290 Belgrade Rd. P.O. Box 297  
Mt Vernon, ME 04352  
United States

Sample Identity: 9878.0  
Act Number: 100  
Sample: Soil: North Carolina VAST Reference Soil

Sample Date: 6/22/2016  
Intended Crop: General Crops

Nutrients:	Available,	Crop Need,	Deficit,	Value
N	30	7	125	\$ 70
P205	75	37.5	37.5	\$ 71
K2O	45	31	0	\$ 36

EST AVAIL: 30 7 125 \$ 70  
CRDP USE: 75 37.5 37.5 \$ 71  
DEFICIT: 45 31 0 \$ 36

**OVERALL FERTILITY SCORE: 33**

**SOIL HEAL**

Notes and Recommendations:  
General Cover Crop Guidelines  
Types of Cover Crop Blends: 50% Legume 40% Grass/No  
Lime Requirement for pH 6.5: 2.6 tons/acre

**SOIL HEALTH REPORT**

Steffsburg 20.10.2017

Report No.: 31106  
Sample No.: 200825  
Sample Ref.: SOIL HEALTH REP TEST  
Date Received: 20/04/2014

Client: College of Ag. and Nat. Sciences  
Field Area: 22 ac  
Date Reported: 21/08/2014

**Soil Chemical Analysis**

Element	Index	Result	Target
pH	1	5.27	5.5 - 6.5
Organic Matter (%)	1	1.13	2.0 - 4.0
Soil Moist. (%)	1	13.0	10.0 - 20.0

**Microbial Activity**

CO<sub>2</sub> Burst: 2.4 (Very Low)

**Textural Classification**

Soil Health Index: 29 (Very Low)

**Water Erosion Risk**

Very Low

**Bericht zur Bodenfruchtbarkeit und Nährstoffversorgung**

Steffsburg 20.10.2017

Vorbürger, Niklaus  
Weidweg 53  
9470 Buchs

Probe: Bodenprobe "gut" Nr. 8242301  
Prüfzeitraum: 18.09.17 bis 04.10.17  
Kultur: Zwetschgen

**Solvita Bodenfruchtbarkeit**

Biologie (CO<sub>2</sub>-Test): 127 (gute Bodenaktivität)  
Chemie (Humus-N): 115 (mittlere N-Nachlieferung)  
Physik (Aggregate): 84.4 (kaum Erosionsgefahr)

**Bodenkenngrößen**

Ton (%): 16 Schluff (%): 41  
Humus (%): 2.0 Salzgehalt: 37.2 mg KCl/100g  
pH: 6.8

**Nährstoffe**

Nitrat-N: 1.72 mg/100g  
Nachlieferung N-Min aus Corg: 0.46 ppm  
Stickstoffpotential: 86 kg N/ha

**Nährstoffverhältnisse**

Mg : Ca: 0.85 mg/100g (Reserve erhöht)  
K : Ca: 3.25 mg/100g (Reserve tief)  
K : Mg: 16.22 mg/100g (Reserve erhöht)  
K : P: 1.18 mg/100g (Reserve erhöht)

**Spurenelemente**

Natrium: 0.71 mg/100g  
Eisen: 0.19 mg/100g  
Bor: 0.03 mg/100g  
Mangan: 0.03 mg/100g

**Soil Health-Complete**

AgSource Laboratories

Notes on the Report: Soil Health Score = Overall Fertility Co.

**REPORT OF SOIL ANALYSIS**

Soil Health Score: 8.6

**COVER CROP RECOMMENDATION**

COVER CROP RECOMMENDATION: 80 ppm

**WATER SOLUBLE**

Element	ppm
Ammonium-N	389.9
Orthophosphate-P	87.1
Phosphorus	32.9
Calcium	245.7
Potassium	441.5
Iron	580.3
Aluminum	5.9
Potassium Ratio	14.1%
P-Ca Ratio	1.4%
Cu:Mg:Fe Ratio	2.1%

**Midwest Laboratories**

DAVIDSON ENTERPRISES

REPORT NUMBER: 16-344-0002  
DATE RECEIVED: Dec 13, 2016  
DATE REPORTED: Dec 9, 2016

**SOIL HEALTH ASSESSMENT**

Soil Health Score: 19.1

**ANALYTICAL LABORATORY FINDINGS**

Element	ppm
Nitrate-N	1.72
Ammonium-N	389.9
Orthophosphate-P	87.1
Phosphorus	32.9
Calcium	245.7
Potassium	441.5
Iron	580.3
Aluminum	5.9
Potassium Ratio	14.1%
P-Ca Ratio	1.4%
Cu:Mg:Fe Ratio	2.1%



- Soil Health mostly about *context*.
- Healthy soil is not a thing to be “precisely” measured.
- The organic community first created the vision for soil health
- A broad, growing movement to “restore soil” may require the organic community to rephrase some arguments.

### Soil Lab Report

P 27

K 175

pH 6.5

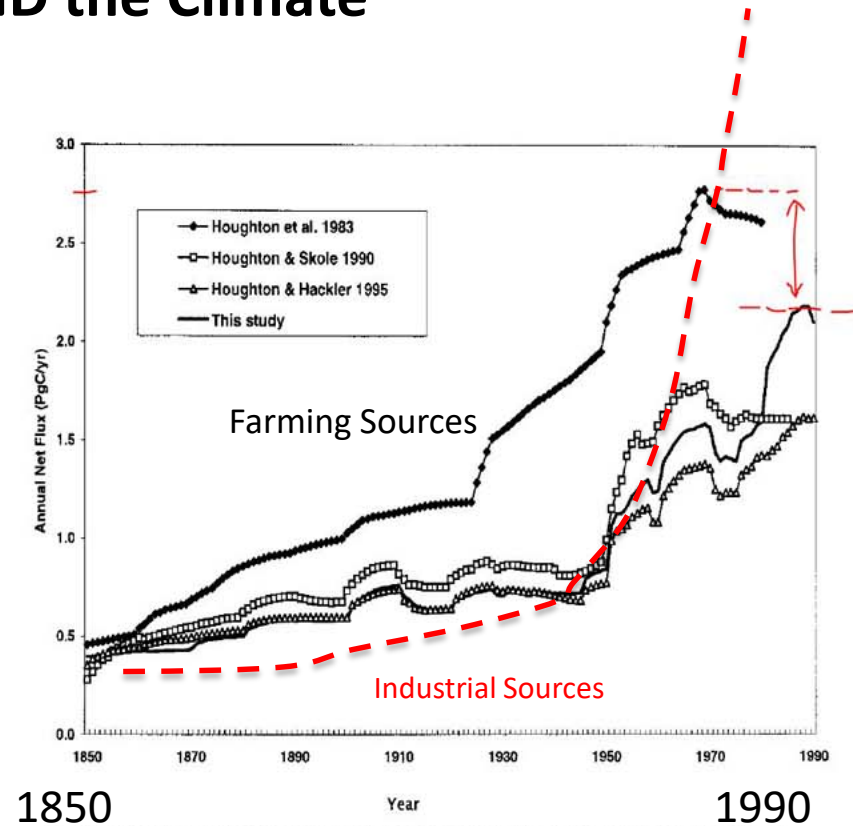
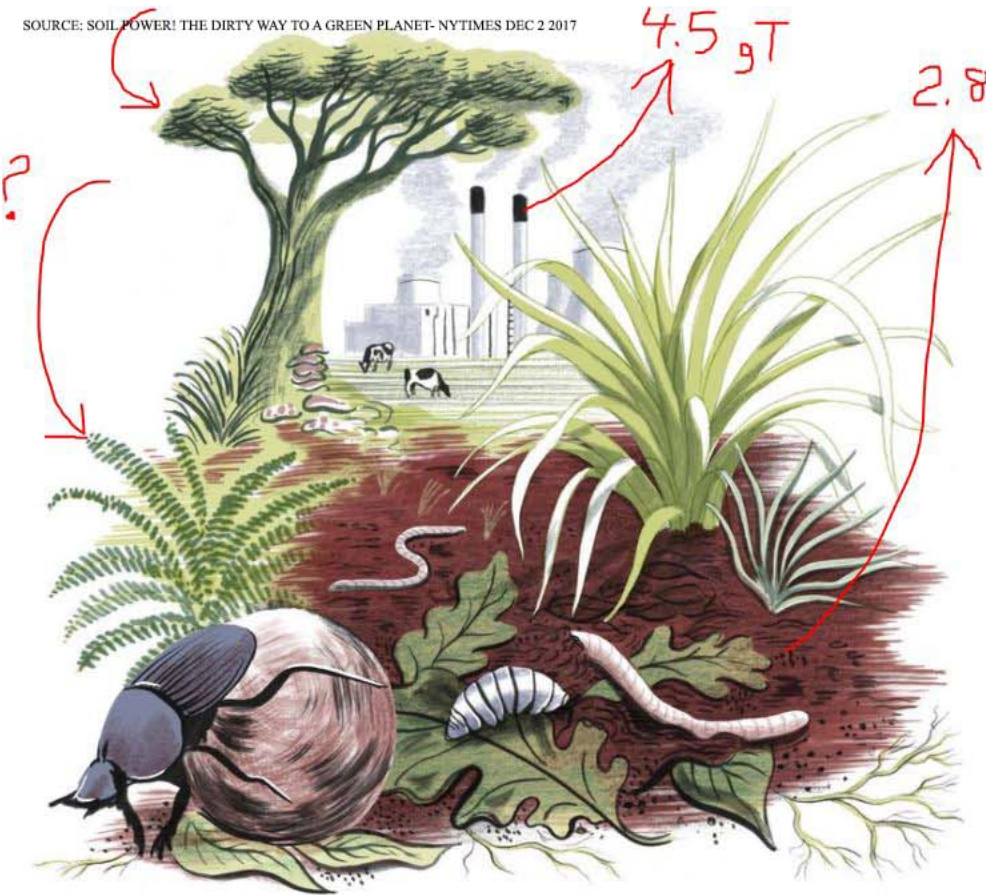
soil life



# Carbon & Farming: *A difficult Problem*

## Understanding Relinquishing vs Sequestering Carbon vs The Plight of Soil AND the Climate

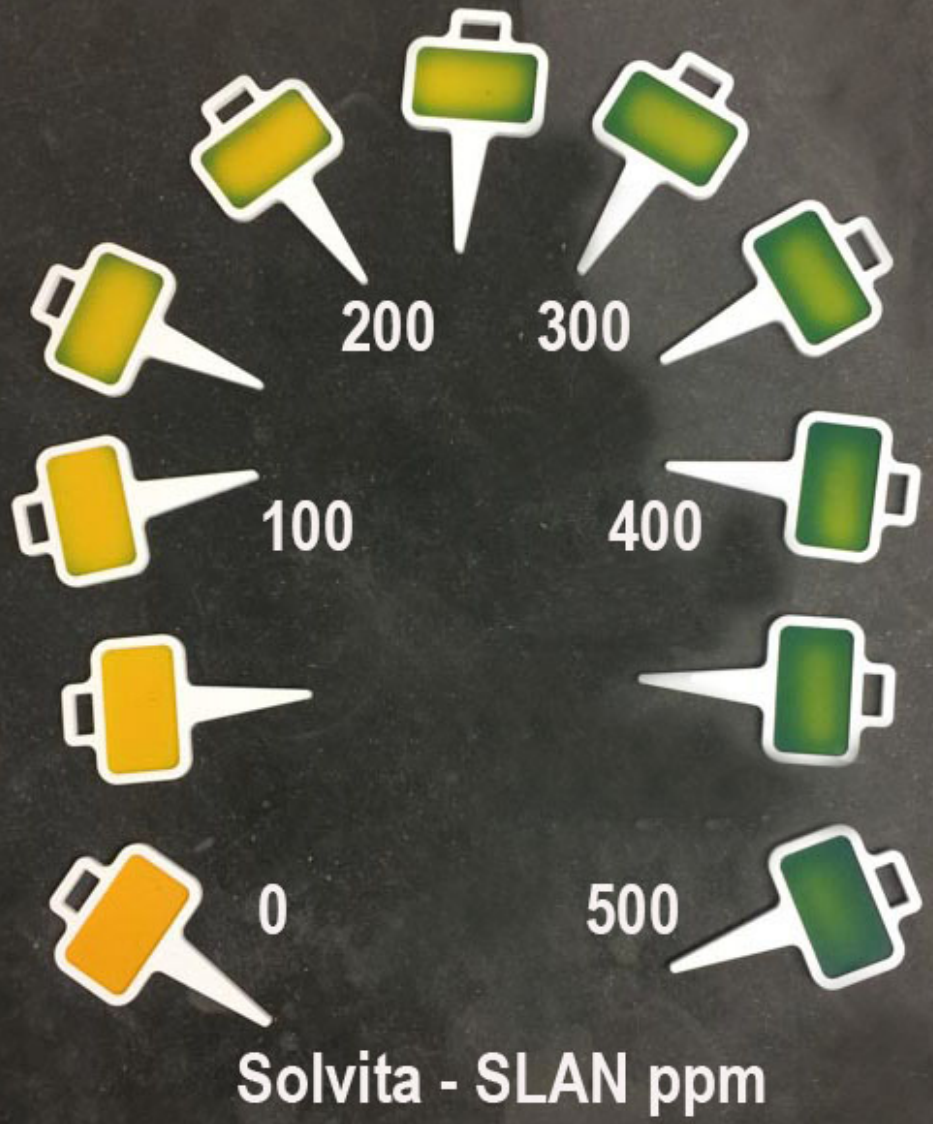
SOURCE: SOIL POWER! THE DIRTY WAY TO A GREEN PLANET- NYTIMES DEC 2 2017



SOURCE: THE ANNUAL NET FLUX OF CARBON TO THE ATMOSPHERE FROM CHANGES IN LAND USE 1850-1990\*  
R. A. HOUGHTON, THE WOODS HOLE RESEARCH CENTER, PO BOX 296, WOODS HOLE, MA 02543, USA

In pre industrial era, farming abuse of soils was the main contributor to global CO<sub>2</sub> rise.





For information on Solvita tests and Soil Health:  
visit [woodsend.com/soil](http://woodsend.com/soil)  
Author's email: [will.brinton@woodsend.com](mailto:will.brinton@woodsend.com)



Thank  
you!



## RESOURCES:

- [Building your own soil health test system](#)
- [Obtaining test kits](#)
- [Get a soil-health test](#)
- [Articles and Reprints](#)

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