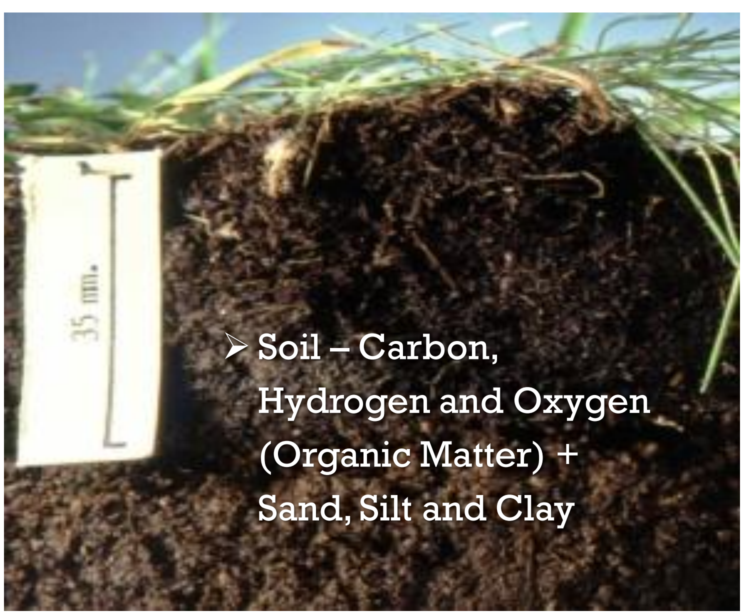
Food Water Wellness Foundation

ALBERTA REGENERATIVE LIVING LAB

Soil Carbon Measurement and Monitoring to Enable Landscape Level Change

1

RECARBONIZATION



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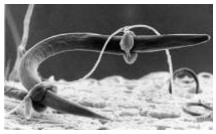
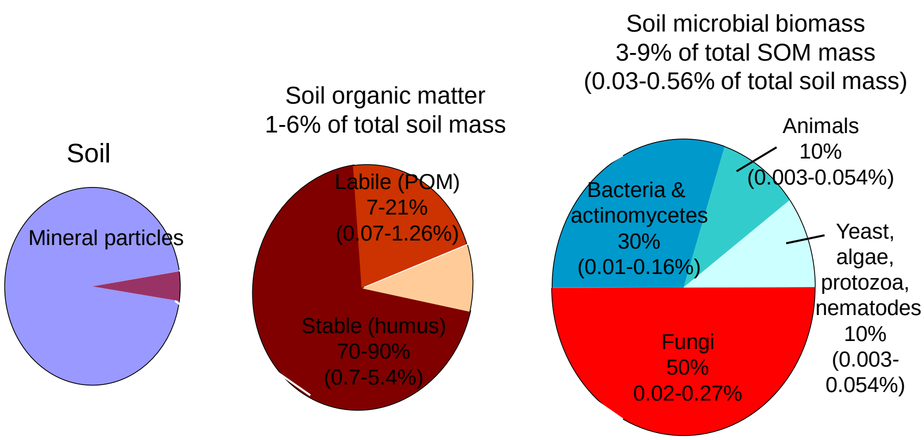


WHY CARBON?

- Almost all life is carbon based
- Almost all the carbon in all this life comes from photosynthesis

3

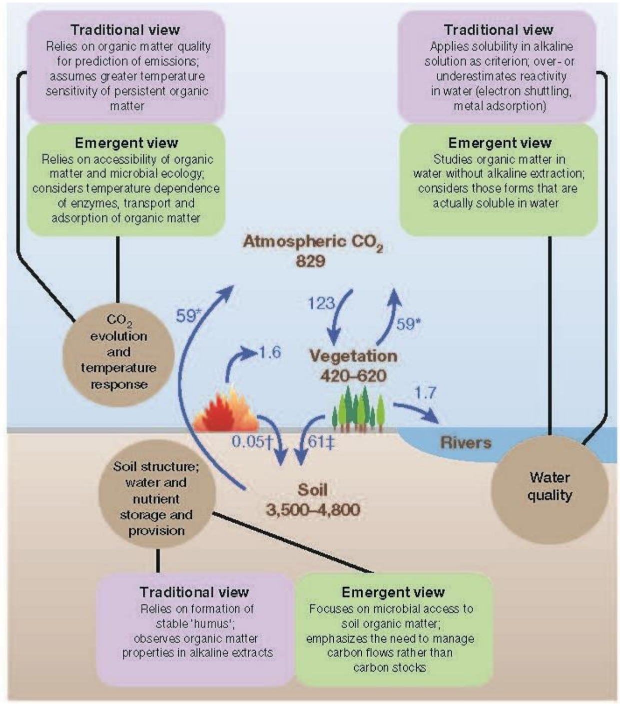
SOIL ORGANIC MATTER COMPOSITION



- Modified from Building Soils for Better Crops, Magdoff and van Es, 2000

4

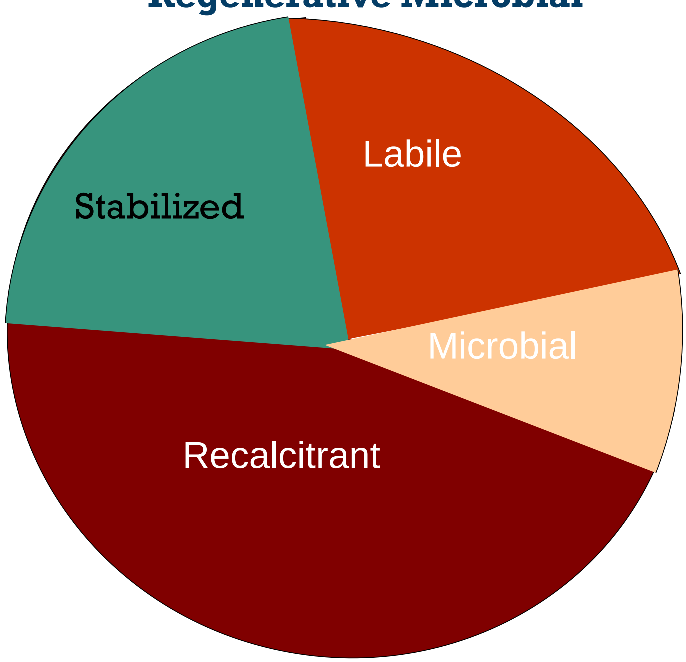
Emerging view of SOM supports Regenerative Ag – We can build SOM in our lifetime!



Lehmann and Kebbler, 2015

5

Regenerative Microbial



6

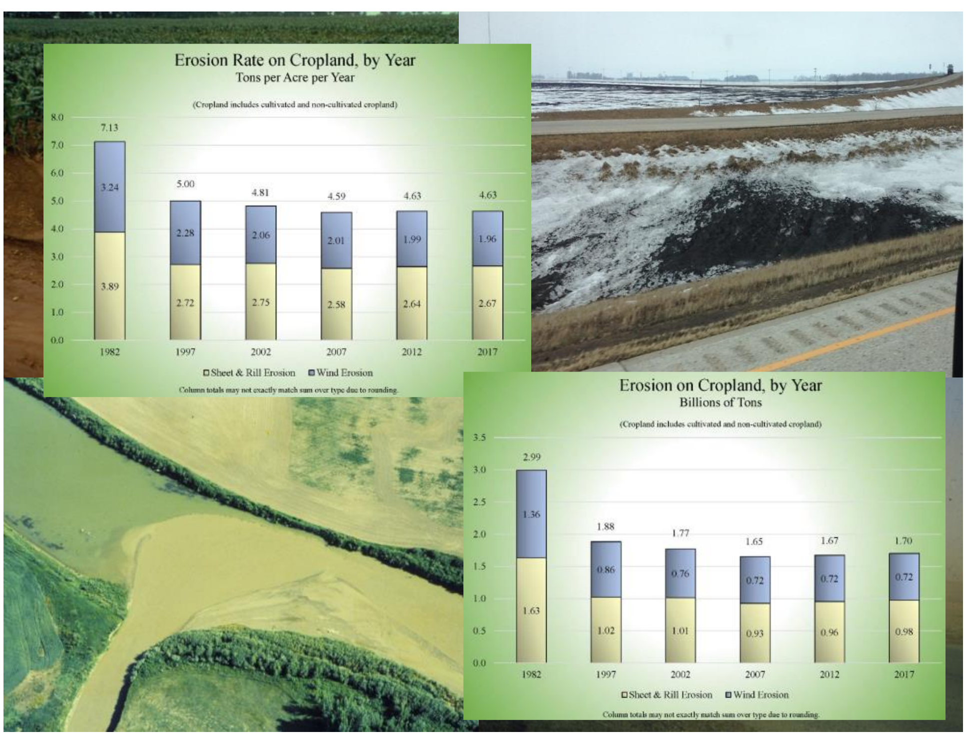
Land use	Depth	Chemical shift (ppm)			
Romero et al., in process	(cm)	Carboxyl-C 220-160 carbs & proteins	Aromatic-C 160-110 benzene rings	O-alkyl-C 110-45 cellulose	Alkyl-C 45-0 hydrocarbons
Irrigated Cropland (C_{RP})	0 – 15	14.1 ± 0.4	22.4 ± 0.1	38.0 ± 0.0	25.4 ± 0.5
	15 – 30	13.3 ± 0.4	22.2 ± 0.4	38.3 ± 0.2	26.0 ± 0.6
	30 – 60	12.5 ± 0.2	21.1 ± 0.2	38.6 ± 0.0	27.7 ± 0.5
	60 – X	12.6 ± 0.3	21.1 ± 0.2	38.5 ± 0.1	27.6 ± 0.2
Rotationally Grazed (R_{GZ})	0 – 15	13.3 ± 0.1	21.7 ± 0.1	38.9 ± 0.2	25.9 ± 0.3
	15 – 30	13.9 ± 0.2	22.5 ± 0.1	38.1 ± 0.1	25.4 ± 0.3
	30 – 60	12.7 ± 0.3	21.5 ± 0.2	38.4 ± 0.3	27.2 ± 0.4
	60 – X	12.8 ± 0.3	20.8 ± 0.2	38.4 ± 0.1	27.9 ± 0.4
Adaptive Multi-Paddock Grazing (A_{MP})	0 – 15	14.0 ± 0.2	22.6 ± 0.3	37.9 ± 0.2	25.2 ± 0.5
	15 – 30	13.8 ± 0.3	22.0 ± 0.1	37.8 ± 0.1	26.3 ± 0.3
	30 – 60	14.1 ± 0.3	22.0 ± 0.1	38.1 ± 0.1	25.6 ± 0.4
	60 – X	15.9 ± 0.8	22.7 ± 0.3	37.0 ± 0.3	24.2 ± 0.4

7

Dust Storms - When – 1900s or 2000s

8

9


Erosion Rate on Cropland, by Year
Tons per Acre per Year
(Cropland includes cultivated and non-cultivated cropland)
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
7.13
3.24
3.89
5.00
2.28
2.72
4.81
2.06
2.75
4.59
2.01
2.58
4.63
1.99
2.64
4.63
1.96
2.67
1982
1997
2002
2007
2012
2017
Sheet & Rill Erosion
Wind Erosion
Column totals may not exactly match sum over type due to rounding.
Erosion on Cropland, by Year
Billions of Tons
(Cropland includes cultivated and non-cultivated cropland)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2.99
1.36
1.63
1.88
0.86
1.02
1.77
0.76
1.01
1.65
0.72
0.93
1.67
0.72
0.96
1.70
0.72
0.98
1982
1997
2002
2007
2012
2017
Sheet & Rill Erosion
Wind Erosion
Column totals may not exactly match sum over type due to rounding.

10

Hendricks, MN 2022

West Side

East Side

BUSINESS

Study: Midwest topsoil 'being eroded 100 times faster than it's forming'

An eye-popping new report argues that soil erosion in the Midwest is happening at a far faster clip than previously estimated.

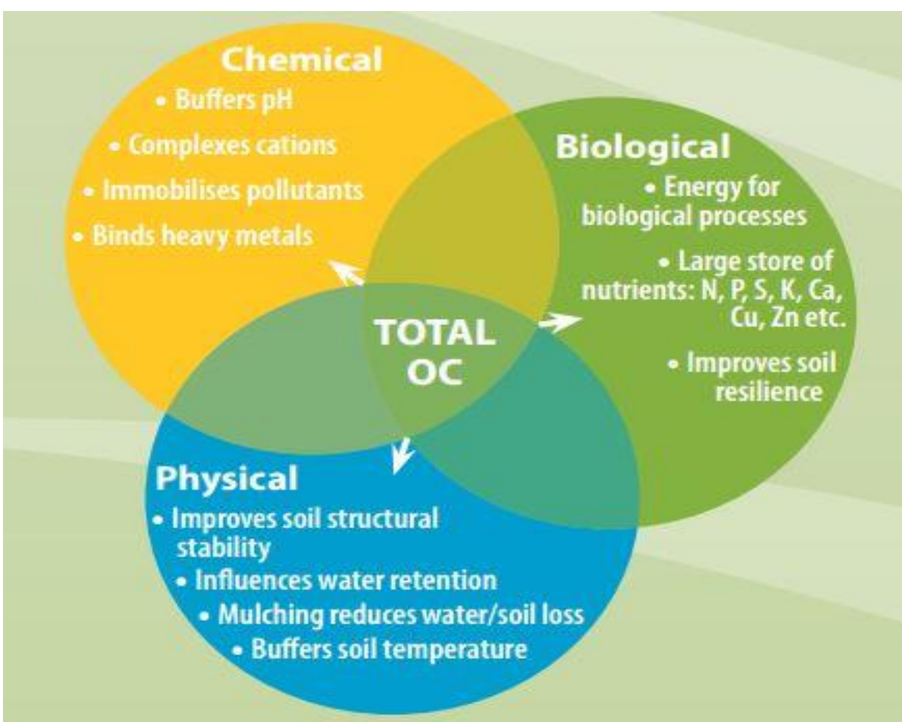
By Christopher Vondracek (https://www.startribune.com/christopher-vondracek/9173241/) Star Tribune

DECEMBER 28, 2022 — 12:31PM

Farmers might not know it — but something is stealing the land from under their feet.

It's erosion.

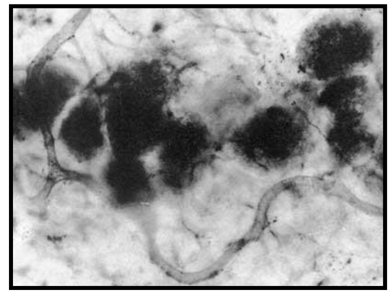
11

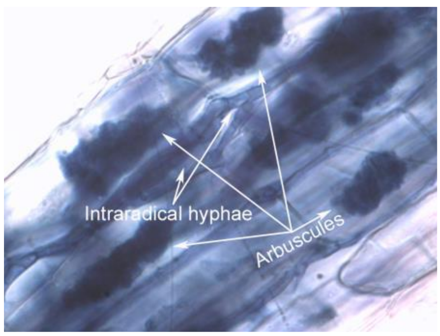


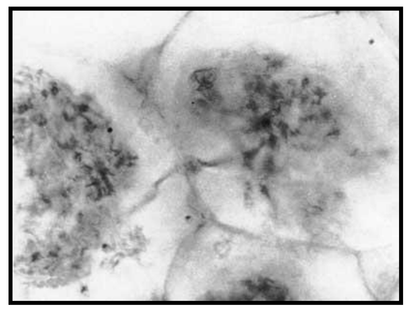
12

MYCORRHIZAL FUNGI MAKE SOIL

- Soil is organic – Carbon, Hydrogen, and Oxygen
- No soil without plants
- No land plants without fungi
  - 450-500 Myr - Taylor et al., 1995

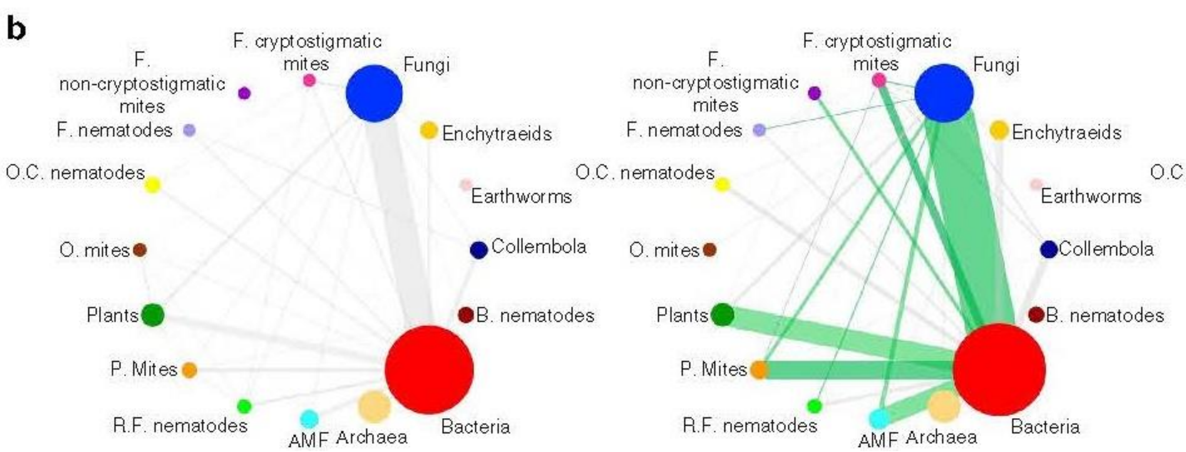






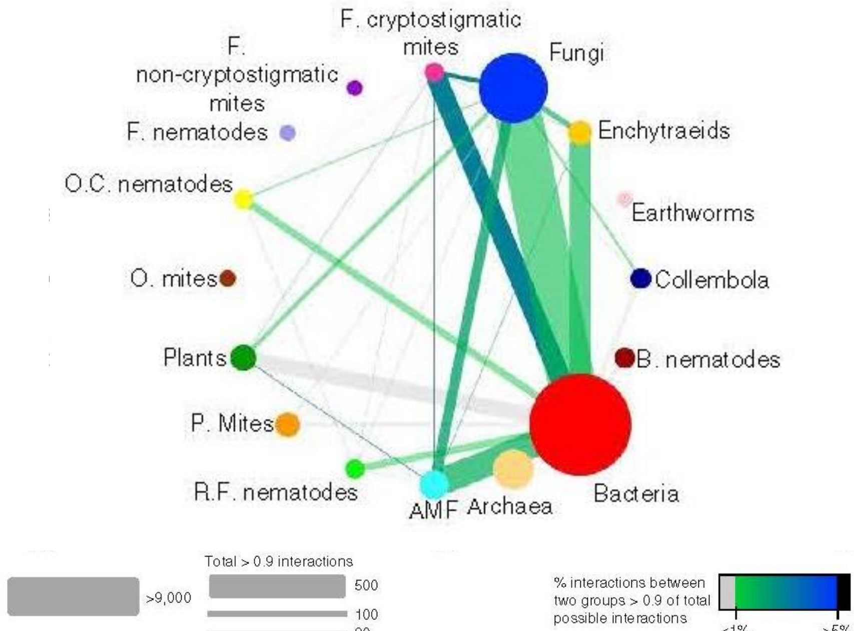
13

Compounding Principle of Consortia



Morriën et al., 2017

14

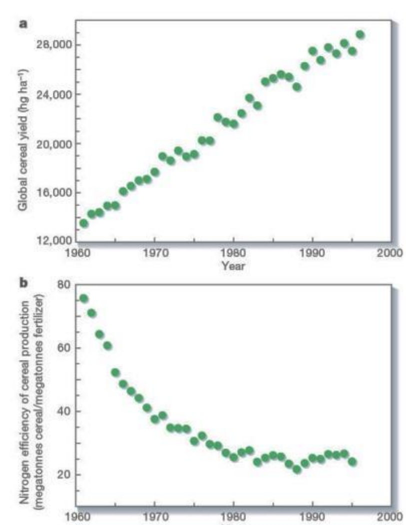


Morriën et al., 2017

15

Nutrient Use Efficiency

- Plant available – synthetic vs. biologic
- 30-50% of nitrogen fertilizer is used by the plant (Hirel et al 2011)
- 30% of phosphorus is used by the plant
- Availability, timing, water, and pH

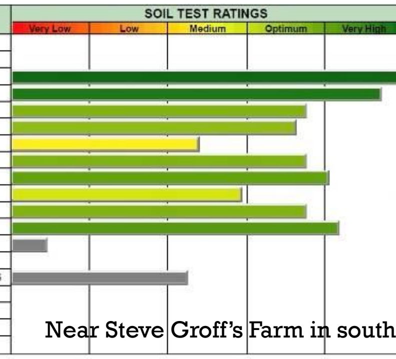


- Tilman et al., 2002

16

Test	Method	Results
Soil pH	1:1	7.3
Buffer pH		
Phosphorus (P)	M3	204 ppm
Potassium (K)	M3	324 ppm
Calcium (Ca)	M3	2119 ppm
Magnesium (Mg)	M3	218 ppm
Sulfur (S)	M3	14 ppm
Boron (B)	M3	1.4 ppm
Copper (Cu)	M3	4.1 ppm
Iron (Fe)	M3	100 ppm
Manganese (Mn)	M3	231 ppm
Zinc (Zn)	M3	11.4 ppm
Sodium (Na)	M3	34 ppm
Soluble Salts		
Organic Matter	LOI	3.6% ENR 116
Nitrate Nitrogen		

SOIL TEST RATINGS: Very Low | Low | Medium | Optimum | Very High



Calculated Cation Exchange Capacity: 13.4 meq/100g

%Saturation

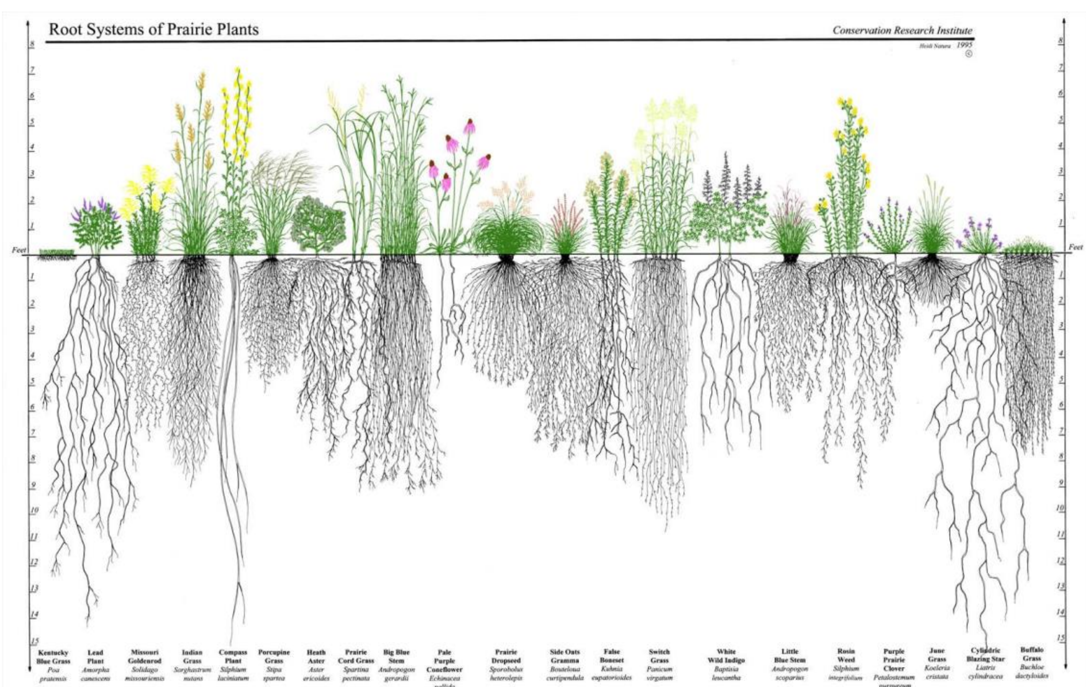
	%sat	meq
K	6.2	0.8
Ca	79.1	10.6
Mg	13.6	1.8
H	0.0	0.0
Na	1.1	0.1

K/Mg Ratio: 0.46

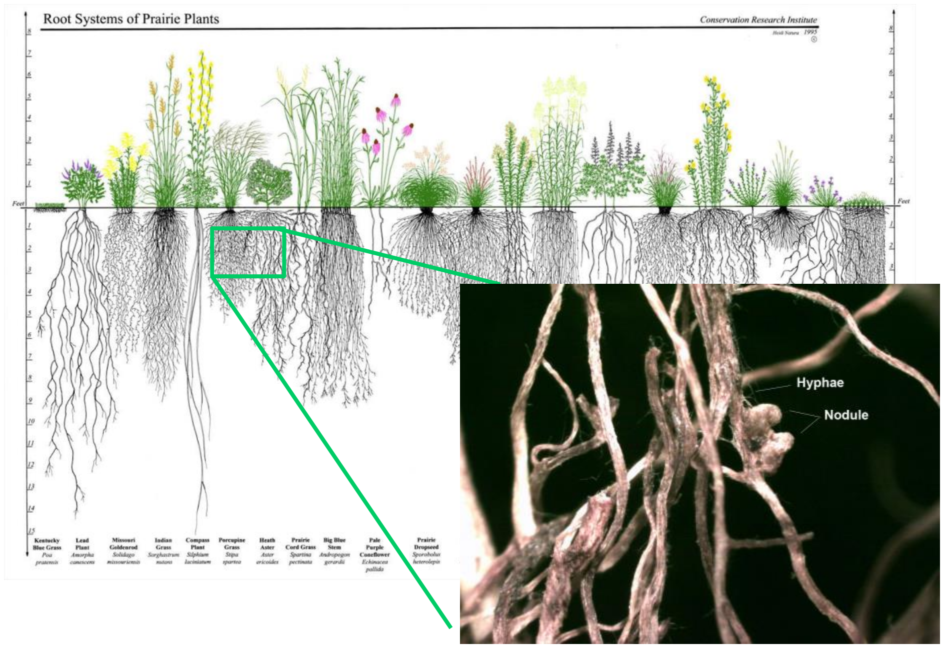
Ca/Mg Ratio: 5.82

Near Steve Groff's Farm in south central PA

17



18



19

Pilot Project Farm in SE Alberta near Taber

AMP Grazed Pasture

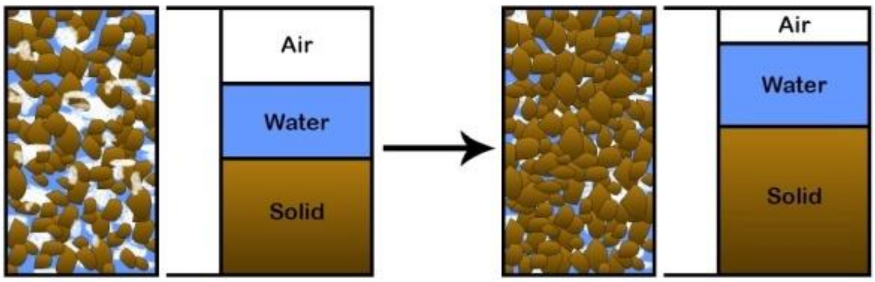
145.21 tonnes CO2e/acre

Irrigated Cropland

98.64 tonnes CO2e/acre

20

SOIL POROSITY



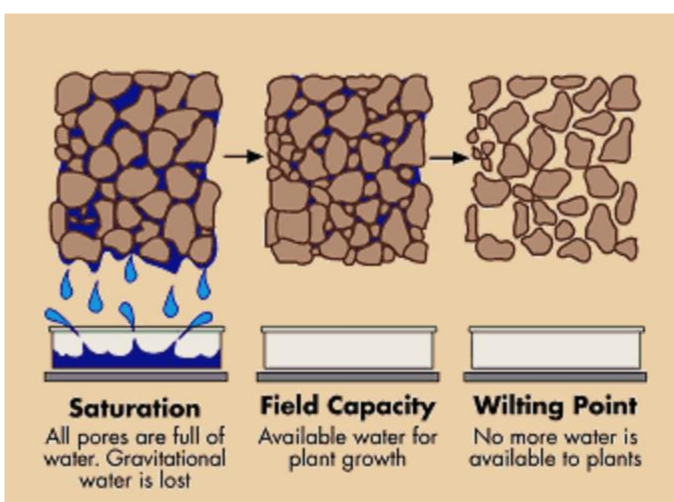
Healthy Soil **Unhealthy Soil**

- 45% greater porosity increases infiltration by 167% for the first inch and 650% for the second inch - Karlen et al., 1998

21

21

SOIL POROSITY



22

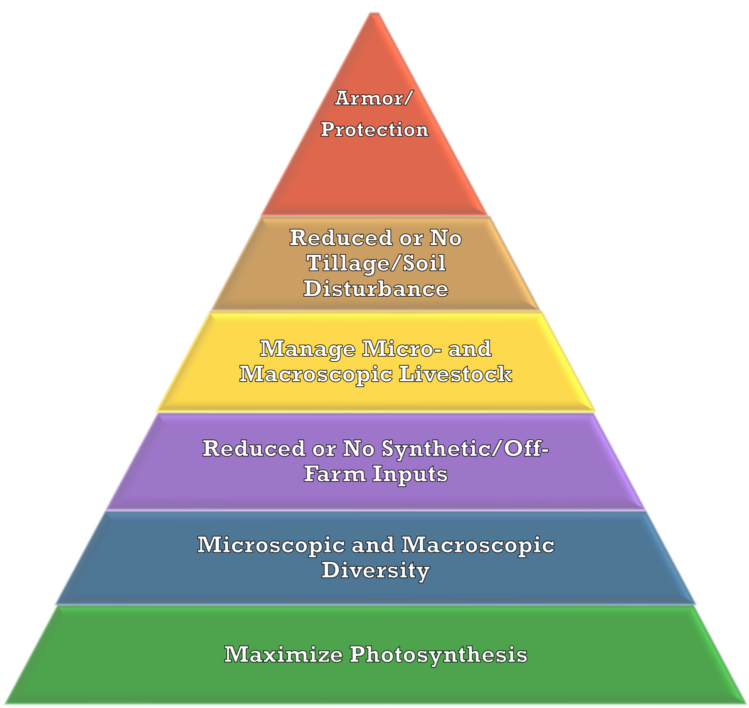
22

REGENERATIVE AGRICULTURE:

- Systems Approach
- Dynamic, Innovative, Integrated, Intensive
- Soil Regeneration via Recarbonization
- Photosynthesis – Carbon Flow/Costs

Photosynthesis – most efficient form of solar energy conversion to chemical energy in the bonds between carbon atoms or carbon atoms and other atoms.

23



24

Alberta Map

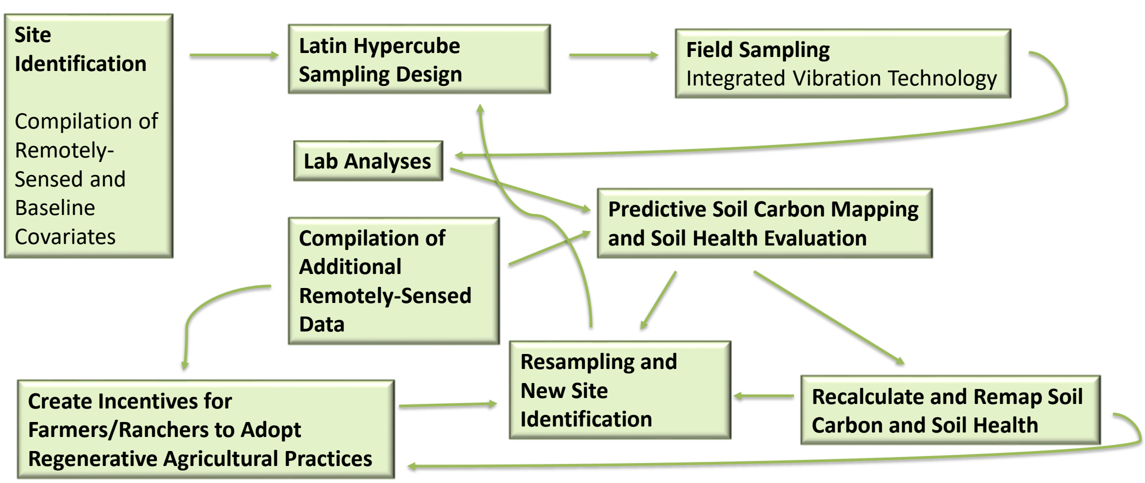
Project Goal: Enable farmers, ranchers and researchers to work together to understand how soil can mitigate climate change, drought and flood, increase biodiversity and, most importantly, produce healthy food by advancing the practices of Regenerative Agriculture.

- 4500 1-m cores collected on over 100 farms and ranches
- Annual Emissions:
  - Alberta 272 Megatonnes (MT)
  - Canada – 729 MT

- 50.5 Million Acres of Agricultural Land (White zone on map)
  - 1% increase in Soil Organic Matter by 2030 = 963 MT (120 MT per yr)
  - 2.5% Increase of Soil Organic Matter by 2030 = 2409 MT (300 MT per yr)

25

FWWF Predictive Soil Carbon Mapping Process



26

Covariates Used in Latin Hypercube Sampling Design

Climate related covariates, which include:
Temperature maps,
precipitation maps,
snow cover maps,
potential evapotranspiration,
cloud fraction and other atmospheric images,

Relief and topography-related covariates, which include:
standard window-based calculations e.g. slope, curvatures, standard deviation,
standard flow model outputs,
landform classes / landform class likelihoods,
hydrological / soil accumulation and deposition indices —
MRVBFI, Wetness index, height above channel,
height below ridge, horizontal distance to channel, horizontal distance to ridge,
climatic and micro-climatic indices determined by relief e.g.
incoming solar insolation and similar,

Human or Anthropogenic Influences, which include:
land use / land management maps,
probability / intensity of agricultural land use, probability / intensity of pasture or grazing use,
probability / intensity of forest land management,
probability / intensity of urbanization,
soil dredging, surface sealing,
night time illumination (nightlights) images,
probability of gullying or human-induced erosion,
soil nutrient fertilization, liming and similar maps,

Vegetation and living organisms, which include:
vegetation indices e.g. FAPAR (mean, median), NDVI, EVI,
biomass, Leaf Area Index,
land cover type maps,
vegetation types and communities (if mapped at high accuracy),
land cover,

Parent material / geologic material covariates, which include:
bedrock type and age,
bedrock mineralogy (acid, basic),
surface material type, texture, age, mineralogy, thickness,
volcanic activity, historic earthquake density,
seismic activity level,
gamma ray spectroscopy grids,
gravity measurements,
electrical conductivity/resistance,

Estimated geological age of surface, which include:
bedrock age / surface material age,
recent disturbance age,
Spatial position or spatial context, which include:
latitude and longitude,
distance to nearest large ocean
Northing — distance to north pole,
Southing — distance to south pole,
Easting — distance to east,
Westing — distance to west,
shortest distance in any direction,
distance to nearest high mountain,
distance to nearest moderate hill,
distance to nearest major river.

27

Innovative Sampling Tool

Capable of collecting 1-m deep cores in rocky soil

28

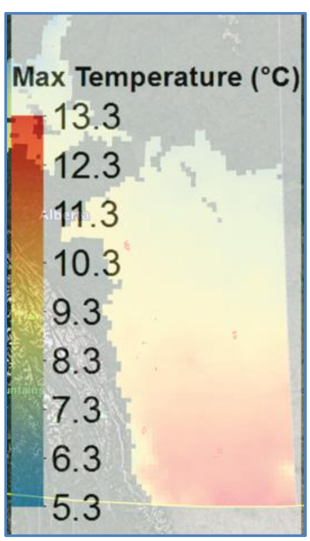
Innovative Sampling Tool

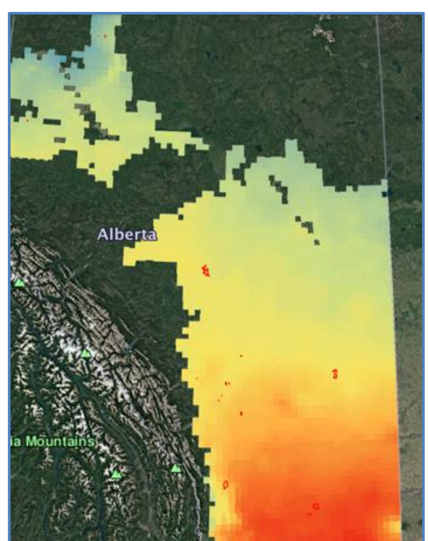
Capable of going onto remote sites and collecting 1-m deep cores on slopes

29

Latin Hypercube Sampling Design – Temperature (^oC)

Accounts for Widely Varying Temperatures throughout Alberta

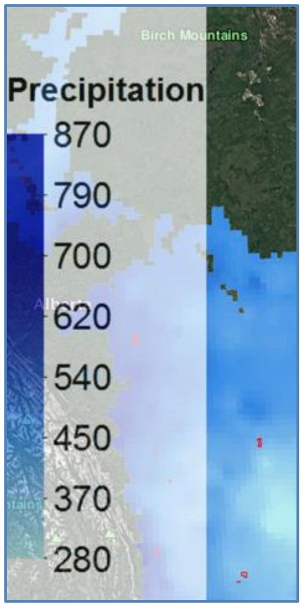


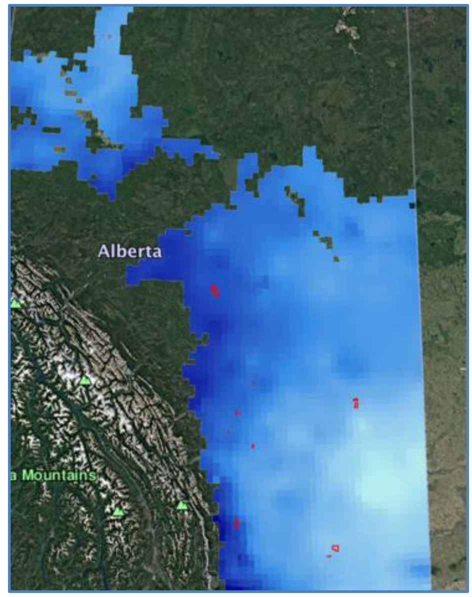


30

Latin Hypercube Sampling Design – Precipitation (mm)

Accounts for Widely Varying Annual Precipitation throughout Alberta





31

Latin Hypercube Sampling Design
Ecoregion Variation

Ecoregions	# sampling points
Central Parkland	118
Dry Mixedgrass	361
Dry Mixedwood	157
Foothills Fescue	67
Foothills Parkland	287
Northern Fescue	262
Peace River	16

NPAR
Dry Mixedwood

VALH
Peace River

TMHK
Dry Mixedwood

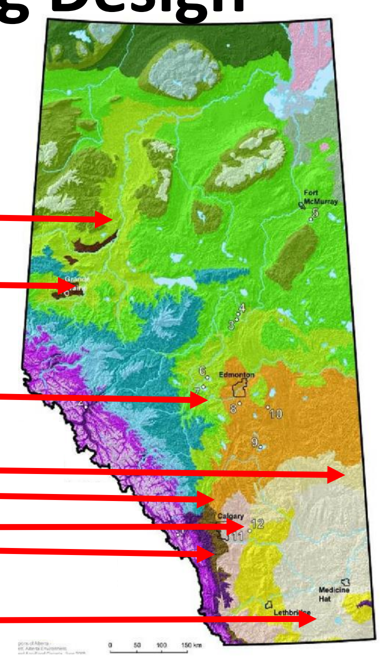
TKRH
Northern Fescue

OLDS
Central Parkland

WRAY
Foothills Fescue

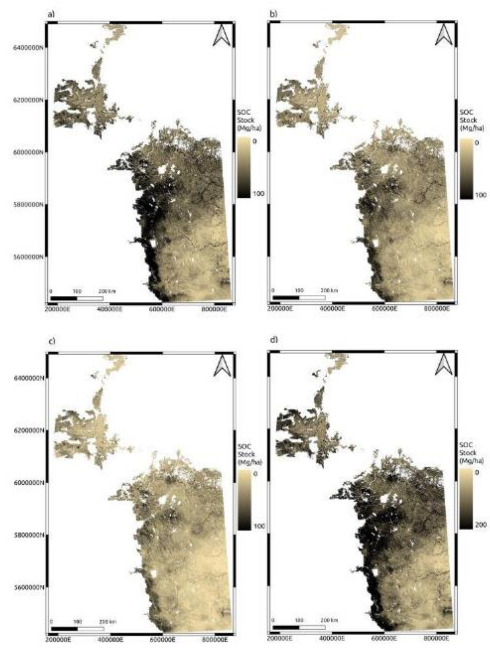
A7XS
Foothills Parkland

TABER
Dry Mixedgrass



32

Alberta Map



Sorenson et al., in process

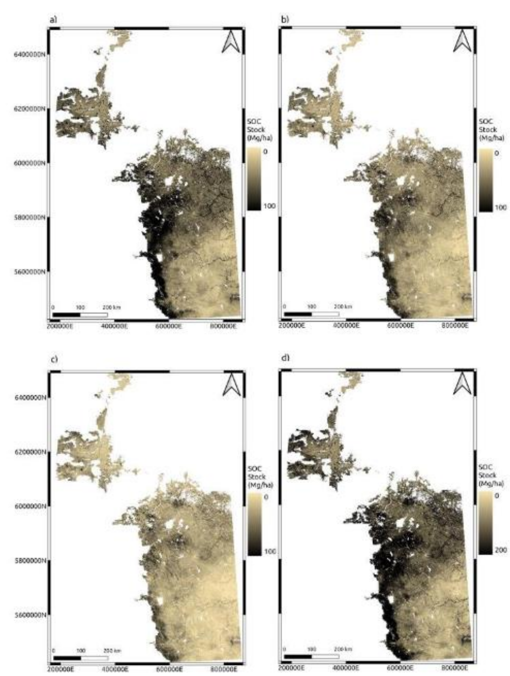
33

Soil organic CARBON concentrations ranged (1st to 99th percentiles) from:

- 0.4 to 6.1 percent for 0 to 30 cm,
- 0.2 to 2.8 percent for 30 to 60 cm,
- and 0 to 1.6 percent from 60 to 100 cm

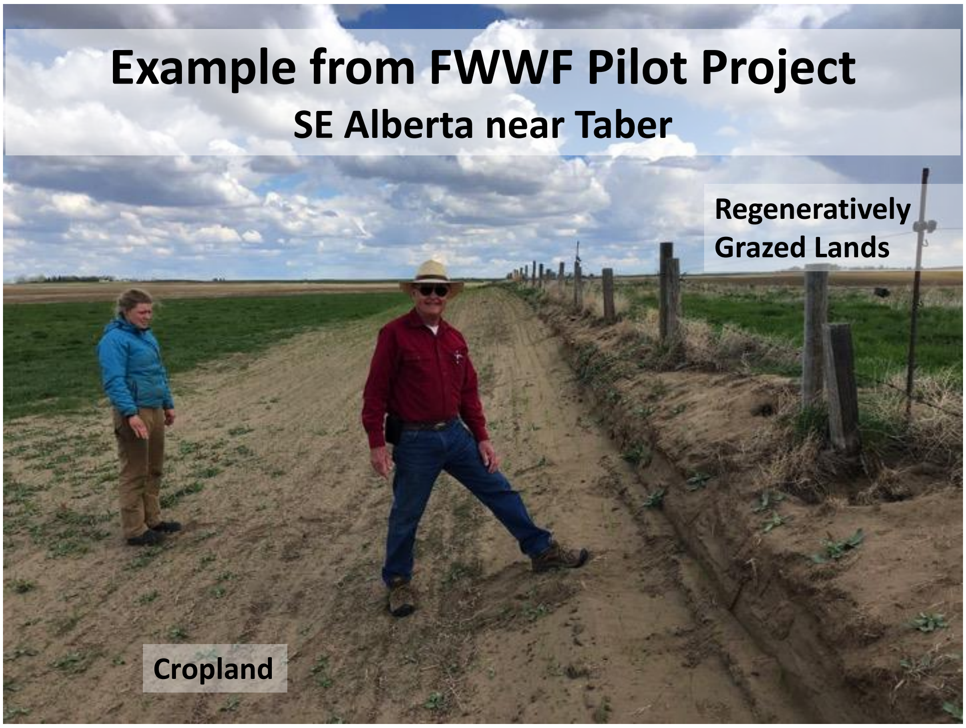
Soil organic MATTER concentrations

- 0.68 to 10.49 percent for 0 to 30 cm
- 0.34 to 4.8 percent for 30 to 60 cm,
- and 0 to 2.75 percent from 60 to 100 cm



Sorenson et al., in process

34



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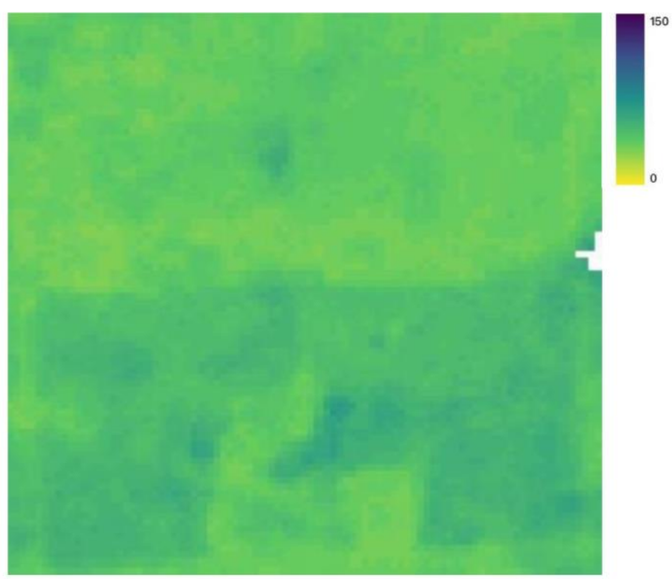


0-30cm tonnes/hectare

36

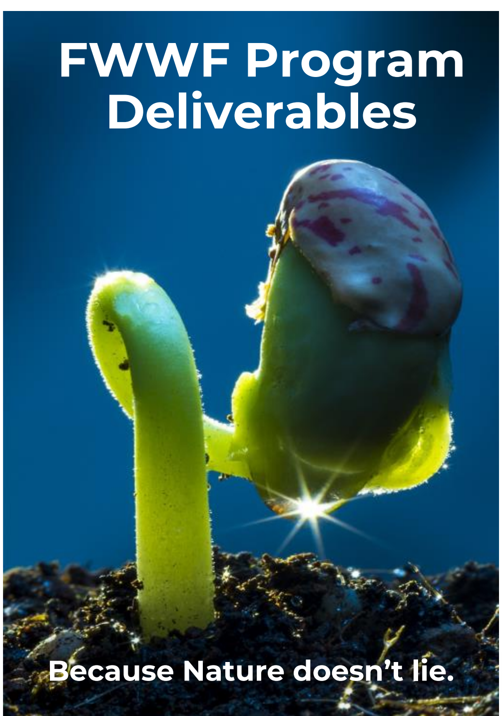
It really boils down to this: that all life is interrelated. We are all caught in an inescapable network of mutuality, tied into a single garment of destiny. Whatever affects one destiny, affects all indirectly.

Martin Luther King Jr., Christmas Eve Serman, 1967

Dr. Kris Nichols
Soil Scientist
Food Water Wellness Foundation
Alberta Regenerative Living Lab
KNichols@foodwaterwellness.org
glomalin1972@gmail.com

CANADIAN AGRICULTURAL PARTNERSHIP Innovate. Grow. Prosper. Alberta Canada

37



Back your story with data

Standard operating protocols for field sampling, for lab analysis provide global, high resolution, reproducible & robust geo-accounting of ecosystem services.

Each digital symbiont responds dynamically to each & every field, farm or country.

No more averages - cheaply test, track, prove each and every innovation in situ via an interactive and agile map that is producer accessible.

Optimise your agro-ecosystems

Whether realising increased farm profits; monetising eco-services restoring 10.7 billion tCO_{2e} into nature every year; contextualising the ~$150 trillion in standing ecological assets or satisfying global food production needs – it's all connected.

38

Lab Analyses

Holistic Picture of Carbon Dynamics + Soil Health

Bulk Density
Gravel Content
Texture
Aggregate Stability
pH
Root Depth
Soil Colour
Compaction
Soil Moisture
Soil Temperature
Available Water Capacity (AWC)

Carbon (TOC) + Organic Matter (% LOI)
Nitrogen (Total) EC
Nitrogen (Available) P available K available
- Water Extraction and Weak Acid Extraction
Micro Nutrients (Ca, Mg, Na, S04-S, Zn, Fe, Mn, Cu, B, Cl)
Spectral Data - Hyperspectral/NIR
Metagenomics
Transcriptomics

39