“Carbonomics”
The Wonderful Economy of the Soil
Farming background

- No-tilling for 25+ years
- 2/3 dryland  1/3 irrigated
- Corn – Beans – Cereal rotation
- Added rye, triticale, oats, barley, vetch, sunflowers, buckwheat
- Cover crops for 8 years
- Green Cover Seed started in 2009
•Pride goeth before a fail...
Carbonomics – The Wonderful Economy of the Soil
Carbonomics – The Wonderful Economy of the Soil
7 Keys To A Healthy Economy

- Supply (Producers/ Sellers)
- Demand (Consumers/ Buyers)
- Currency
- Capital
- Energy and Resources
- Infrastructure
- Defense and Protection

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Supply (Producers/Sellers)

- Strong Economies are very productive
- High percentages of all entities involved in the economy are producing something
- Diversity is very important
Demand (Consumers/Buyers)

- Strong economies have a high demand for products
- Economies are strongest when majority are both Suppliers (producers) and Demanders (consumers)
- Diversity is very important
Currency

- Allows for quick, efficient and fair transactions or exchanges between Producers and Consumers
- Needs to be universally desired and accepted.
- Needs to have different forms and move (flow) easily
Capital

- Accumulated (stored or saved) currency
- Needed for Growth and Stability
Energy and Resources

- Energy drives the system but it is expensive
- Resources provide a base for growth and expansion
Infrastructure

- Allows economies to grow beyond subsistence
- Communication
- Transportation

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Defense and Protection

- Strong Economies will always be under attack by those who want to Consume without Producing
- Requires investments of Capital
7 Keys To A Healthy Economy

- Supply (Producers/ Sellers)
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7 Keys To A Healthy **SOIL**!

- Supply (Producers/ Sellers)
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- Capital
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The Soil Economy

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Keys To A Healthy SOIL!
The Soil Economy

Plants

Soil

Animals

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Keys To A Healthy SOIL!
Supply (Producers/ Sellers)

- Plants – Producing Carbon

![Diagram of photosynthesis]

CO₂ + H₂O → C₆H₁₂O₆ + O₂

Carbon dioxide + Water → Sugars + Oxygen

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**Keys To A Healthy SOIL!**
Supply (Producers/ Sellers)

- Soil – Provides Nutrients (Minerals)
- Soil – Provides Habitat for Roots and Biology
- Soil – Provides Water storage

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Keys To A Healthy SOIL!
Supply (Producers/Sellers)

- Soil Biota – Producing Nutrients (Fixation) (Cycling) (Availability)
- Soil Biota – Providing Defense and Protection

Keys To A Healthy SOIL!
Demand (Consumers/ Buyers)

- Plants – Need Nutrients and Water
- Plants – Need Services (Protection, Support, etc...)

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Keys To A Healthy SOIL!
Demand (Consumers/ Buyers)

- Soil – Needs Carbon
- Soil – Needs Services (Protection, etc.)
Demand (Consumers/ Buyers)

- Soil Biota—Needs Food and Habitat
Producers -(Sellers)   Consumers (Buyers)

- In a strong human economy, one of the leading indicators is low unemployment rate, where most people are both consumers AND producers and are actively engaged in making a contribution to the system.

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Keys To A Healthy SOIL!
Producers – (Sellers)  Consumers (Buyers)

- The soil economy is strongest when plants, soil, and animals are ALL producing and consuming.
- Diversity is very important.

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Keys To A Healthy SOIL!
Agricultural Welfare

- When we externally provide the plant with everything that it needs from the outside, we weaken the economy.
  - Fertility inputs
  - Crop protection inputs

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Keys To A Healthy SOIL!
Agricultural Welfare

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Keys To A Healthy SOIL!

You cannot help men permanently by doing for them what they could and should do for themselves.

Abraham Lincoln
We need to allow the system to work the way it was created to work!

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Keys To A Healthy SOIL!
Currency

- Currency is important because it allows goods and services to be exchanged more efficiently

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Keys To A Healthy SOIL!
Currency

- In the plant economy, the currency is Carbon

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Keys To A Healthy SOIL!
Currency

- Currency (Carbon) is important because it allows goods and services to be exchanged more efficiently with the soil economy.

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**Keys To A Healthy SOIL!**
The carbon and nutrients TRUTH

- Increased C → normalized pH, increased CEC
- Increased C → increased availability of P, Ca, K, S
- Increased C → increased availability of Cu, Zn, Fe, Mo, B
- Increased C → reduced availability of Na, Al
Carbon Currency

- Carbon is essential to all life
- People are 19% carbon
- Carbon can form over 10 million compounds
- Carbon is the most important but most overlooked of all plant nutrients
- Carbon is the main food source for soil biology

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Keys To A Healthy SOIL!
Carbon Currency

- Carbon can be: 
  - collected (photosynthesis)
  - spent (traded to soil organisms)
  - saved (soil organic matter)
  - desired by all members of the economy
Carbon Currency

- Carbon has different states
  - Gas – CO₂
Carbon Currency

- Carbon has different states
  - Gas – CO$_2$
  - Liquid – in plants and soils

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Keys To A Healthy SOIL!
Carbon Currency

- Carbon has different states
  - Gas – CO₂
  - Liquid – in plants and soils
  - Solid – in living organisms and Organic Matter

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Keys To A Healthy SOIL!
Carbon Currency

- Carbon has different states
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  - Liquid – in plants and soils
  - Solid – in living organisms and Organic Matter

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Keys To A Healthy SOIL!
Capital

- Accumulated (stored or saved) currency
- Needed for Growth and Stability

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Keys To A Healthy SOIL!
Biological Capital

• Long-term effects of having biodiversity
• Soil with high organic content
• Diverse and healthy populations of plants and animals both in and on the soil
• Wealth in the truest form
• Vital not only to agriculture but to society as a whole.
Biological Capital

When Biological Capital Is High

• Productivity and stability will be high

• Pest organisms will still be present but not in concentrations high enough to cause economic harm

• Ecological processes (water cycle, nutrient cycle and energy flow) function properly

Walt Davis

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Keys To A Healthy SOIL!
Soil Carbon Capital

- Organic Matter and Humus
- Accumulated (stored or saved) carbon currency
- Needed for Growth and Stability

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Keys To A Healthy SOIL!
Capital Rich Economies = High Organic Matter Soils

- Productive
- Stable
- Resilient
- Efficient

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Keys To A Healthy SOIL!
Soil organic matter generates and regulates every ecosystem service that sustains life on earth” – Rattan Lal

Capital Rich Economies = High Organic Matter Soils

- Productive
- Stable
- Resilient
- Efficient

- Productive
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- Efficient

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Keys To A Healthy SOIL!
Carbon Capital

- Capital (Savings) can’t be increased without an excess of cash income
- Soil Organic Matter can’t be increased without an excess of soil carbon currency
- Soil Carbon can’t be increased in most rotations without the use of cover crops

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Keys To A Healthy SOIL!
Energy and Resources

- Plant economy
  energy comes from
  the sun

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Keys To A Healthy SOIL!
Energy and Resources

- Plant economy energy comes from the sun
- Plant solar collectors (seeds) are MUCH cheaper and easier to install than man-made solar panels!
Energy and Resources

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- Plant solar collectors (seeds) are MUCH cheaper than man-made solar panels!
- A healthy soil economy should not need significant purchased energy inputs
Energy and Resources

- Plant economy energy comes from the sun
- Plant solar collectors (seeds) are MUCH cheaper than man-made solar panels!
- A healthy soil economy should not need significant purchased energy inputs
Energy and Resources

- Plant economy resources
- #1 is CARBON

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Keys To A Healthy SOIL!
Energy and Resources

- Plant economy resources
  - #1 is CARBON
  - #2 is NITROGEN

The Gases That Comprise Earth's Atmosphere

- 76.55% Nitrogen
- 20.54% Oxygen
- 1.96% Water Vapor
- 0.91% Argon
- 0.03% Carbon Dioxide
- 0.01% Misc. Gases

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Keys To A Healthy SOIL!
Energy and Resources

- Plant economy resources
- #1 is CARBON
- #2 is NITROGEN

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Keys To A Healthy SOIL!
Energy and Resources

- Nitrogen gets “fixed” or made plant available when combined with hydrogen or oxygen.

\[ \text{N}_2 + 3\text{H}_2 \rightarrow \text{NH}_3 \rightarrow (\text{dissolves}) \rightarrow \text{NH}_4^+ \]

(amide, ammonia)

(amide, ammonium)
Energy and Resources

- Nitrogen gets “fixed” or made plant available when combined with hydrogen or oxygen
- Very energy intensive process

\[ \text{N}_2 + 3\text{H}_2 \rightarrow \text{NH}_3 \rightarrow \text{(dissolves)} \rightarrow \text{NH}_4^+ \]

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Keys To A Healthy SOIL!
Energy and Resources

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Keys To A Healthy SOIL!

Rhizobia Bacteria
Nitrogen Factories

- Azosprillium
- Azotobacter
- Not limited to legumes

Keys To A Healthy SOIL!
Nitrogen Factories

- Azosprillium
- Azotobacter
- Rhizobia
- Must associate with a plant
- “Trade” nitrogen to the plant for carbon
- Will not happen if excess N is in the soil

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Keys To A Healthy SOIL!
Energy and Resources

- Plant economy resources
  - #1 is CARBON
  - #2 is NITROGEN
- Other mineral resources

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**Keys To A Healthy SOIL!**
Energy and Resources

- Plant economy resources
  - #1 is CARBON
  - #2 is NITROGEN

- Other mineral resources

- Employ tiny miners to extract the nutrients from the soil.

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Talaromyces flavus fungus extracting iron and magnesium from a mine. Credit Henry Teng
Earth and Space Science News

Keys To A Healthy SOIL!
Mycorrhizal Fungi run the Largest Mining Operation in the World

Up to 85% of plants depend on fungi to survive. Plants and fungi depend on each other for nutrient cycling and water absorption.

Image: Landeveert 2001
Thin-section micrograph of a tunneled feldspar
Scale bar = 100 micrometers

Photo: Amanita gemmata by Courtney Celley, US Fish & Wildlife Service

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Keys To A Healthy SOIL!
Arbuscular Mycorrhizal Fungi
Mycorrhizal fungi mine the soils not only for the basic food nutrients for plants we are familiar with like nitrogen, phosphorus, etc, but also those hard to come by trace elements (Zinc, Copper, Manganese, etc) which plants need for strong immune system health and survival against a potentially hostile world of pathogens. Oddly enough many soils are rich in important nutrients, but they are often locked up in a physical form which makes them unavailable to most plants.

(Source: Scientific American - Jennifer Frazer)
Infrastructure

*noun* | in-frac-ture | /in-fra-strık-chər, -frä-

**Simple Definition of INFRASTRUCTURE**

- the basic equipment and structures (such as roads and bridges) that are needed for a country, region, or organization to function properly

- **Transportation**
- **Communication**
- **Economies will be severely crippled or limited when these are lacking or disrupted (war strategies)**

**Carbonomic$ – The Wonderful Economy of the Soil**

**Keys To A Healthy SOIL!**
Infrastructure

- Transportation
- Communication

Economies will be severely crippled or limited when these are lacking or disrupted (war strategies)

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Keys To A Healthy SOIL!
Carbonomics – The Wonderful Economy of the Soil

Keys To A Healthy SOIL!
Mycorrhizal fungi transports:

- Phosphorus – one of the hardest to access
- Nitrogen, Potassium, Calcium, Magnesium, Iron
- Zinc, Boron, Manganese and Copper.
- In dry times they help transport and supply water.
Transportation Infrastructure

- A soil system without Mycorrhizal fungi is like a farming system without roads, rail lines or ports – huge potential but severely limited.

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Keys To A Healthy SOIL!
Transportation Infrastructure

- A soil system without Mycorrhizal fungi is like a farming system without roads, rail lines or ports – huge potential but severely limited.
Transportation Infrastructure

- A soil system without Mycorrhizal fungi is like a farming system without roads, rail lines, huge potential but severely limited.
Transportation Infrastructure

Earth worms help transport:

- Water
- Oxygen
- Surface carbon (residue)
- Other biota

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Keys To A Healthy SOIL!
Communication Infrastructure

Plants use liquid carbon root exudates to communicate to soil biota what they need.

Rhizophere Marketplace

The area right around the roots is where communication and commerce are occurring.

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Keys To A Healthy SOIL!
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Keys To A Healthy SOIL!
Communication Infrastructure

Mycorrhizal networks interconnect root systems and allow plants to communicate threats through chemical signaling.

When aphids infect the plant on the left a signal travels through the mycorrhizal network warning other (uninfected) plants that aphids are nearby. This induces defence responses that include the production of methyl salicylate, which repels the aphids and attracts the parasitoid wasp (an aphid predator).

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Keys To A Healthy SOIL!
Defense and Protection

The plant/soil economy needs protected from:

– Water (too much or too little)
– Wind
– Heat
– Cold
– Compaction
– Weeds
– Insects
– Diseases
Defense and Protection

The first line of defense is soil armor (cover)

Almost all advantages of the No-tillage system come from the permanent cover of the soil, and only few from not tilling the soil.

We should always aim at full soil cover.

Rolf Derpsch

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Keys To A Healthy SOIL!
Defense and Protection

The second line of defense is plant signaling - plants signaling each other and signaling insects and soil organisms to assist in defense.
The third line of defense is to call in the cavalry - beneficial insects and soil biota.

Aphids are highly destructive insects that feed on the sap of numerous plant species.

Plants under attack emit warning volatile organic compounds (VOCs).

Stressed-out plants release unidentified soluble compounds.

The receiving plant emits defense VOCs that attract aphid-hunting wasps and repel aphids.

Drought is a common stressor for many plants.
Defense and Protection

The third line of defense is symbiotic relationships between plants and organisms such as endophyte fungus.
Defense and Protection

- The fourth line of defense is Diversity - of plants, roots, types, seasons, insects, biota
- Most attackers will focus on only one or two things
Keys To A Healthy **SOIL!**

- Supply (Producers/ Sellers)
- Demand (Consumers/ Buyers)
- Currency
- Capital
- Energy and Resources
- Infrastructure
- Defense and Protection

Carbonomics – The Wonderful Economy of the Soil
Nine Take-Away Points

1. Economies are intricately interconnected and interdependent

The Soil Economy

- Plants
- Soil
- Animals

Keys To A Healthy Soil!
Nine Take-Away Points

2. Reduce the amount of welfare you are giving your economy - get everyone working!
Nine Take-Away Points

2. Reduce the amount of welfare you are giving your economy - get everyone working!
Nine Take-Away Points

3. Increase your “cash flow” of carbon currency

Less than 50% efficiency in collecting solar energy and producing liquid carbon

Carbonomic$ – The Wonderful Economy of the Soil

Keys To A Healthy SOIL!
Nine Take-Away Points

3. Increase your “cash flow” of carbon currency

Carbonomic$ – The Wonderful Economy of the Soil

Keys To A Healthy *SOIL!*

Less than 50% efficiency in collecting solar energy and producing liquid carbon
Nine Take-Away Points

4. Make capital investments of long term carbon (organic matter) and don’t sell off investments.
Nine Take-Away Points

4. Make capital investments of long term carbon (organic matter) and don’t sell off investments
5. Solar energy is free - use every opportunity to have plants capture it and boost your economy.
Nine Take-Away Points

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5. Solar energy is free - use every opportunity to have plants capture it and boost your economy.
Ten Take-Away Points

6. Take advantage of free tiny workers
   • Manufacturing
   • Mining
   • Transportation
   • Communication
   • Protection

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Biological Diversity

Keys To A Healthy SOIL!
Nine Take-Away Points

7. Build and do not destroy infrastructure - you will really see your economy grow!
Nine Take-Away Points

7. Build and do not destroy infrastructure - you will really see your economy grow!
Nine Take-Away Points

8. Protect your economy with soil armor
Ten Take-Away Points

9. Diversity is so very important for a healthy economy - plants, roots, and soil animals

The Soil Economy

Carbonomics – The Wonderful Economy of the Soil

Keys To A Healthy SOIL!
Nine Take-Away Points

1. Economies are intricately interconnected
2. Reduce the amount of welfare you are giving your economy - get everyone working!
3. Increase your cash flow of carbon currency for maximum production
4. Make capital investments of long term carbon (organic matter)
5. Solar energy is free - take advantage of every opportunity to capture it and boost your economy
6. Take advantage of the free resources you have in the air and the soil - nitrogen and other nutrients. Hire lots of tiny workers - miners, transporters, communicators, and protectors
7. Build and do not destroy infrastructure - you will really see your economy grow!
8. Protect your economy with soil armor
9. Diversity is so very important for a healthy economy - plants, roots, and soil biota

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Keys To A Healthy SOIL!