Soil Carbon Sequestration

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BIOSEQUESTRATION OF ATMOSPHERIC CO$_2$

Only 0.05% of the 3800 zettajoules ($10^{21}$J) of solar energy is absorbed annually as GPP

- Gross Primary Productivity (GPP) = 123 Gt C/yr
- Net Primary Productivity (NPP) = 63 Gt C/yr
- Net Ecosystem Productivity (NEP) = 10 Gt C/yr
- Net Biome Productivity (NBP) = 3 Gt C/yr

“If we control what plants do with carbon, the fate of CO$_2$ in the atmosphere is in our hands”

-Freman Dyson (2008), BioScience (10/10)
# Anthropogenic Emissions (Pg) by Carbon Civilization

<table>
<thead>
<tr>
<th>Category</th>
<th>1950-2010</th>
<th>2010-2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Land use</td>
<td>486</td>
<td>30</td>
</tr>
<tr>
<td>(i) Prehistoric</td>
<td>320</td>
<td></td>
</tr>
<tr>
<td>(ii) 1750-2010</td>
<td>136</td>
<td></td>
</tr>
<tr>
<td>(iii) 2010-2030</td>
<td></td>
<td>30</td>
</tr>
<tr>
<td>II. Fossil Fuel Combustion</td>
<td>200</td>
<td>190</td>
</tr>
</tbody>
</table>

These emissions have and will affect the ecosystems from which we derive food, feed, fiber, fuel and shelter.
WHY SOIL CARBON SEQUESTRATION?

1. It is the natural process,
2. It is the most cost effective option,
3. It has numerous co-benefits (e.g., food and nutritional security),
4. It is a bridge to future until no-C fuel sources take effect (e.g., H₂)
5. It is the essence of life through its effects on agriculture and biota,

And

Soil and agriculture must be on any agenda that addresses global climate change and the environment.
SOIL CARBON AND ECOSYSTEM SERVICES
THE ENGINE OF ECONOMIC DEVELOPMENT

WATER RESOURCES
- Quality
- Quantity

CLIMATE CHANGE
- Mitigation
- Adaptation
- Stabilization

RECARBONIZATION OF THE BIOSPHERE (IMPROVING SOIL QUALITY)

BIODIVERSITY
- Above ground
- Below ground

FOOD SECURITY
- Quantity
- Quality
The Short-Term Global Carbon Cycle

**Atmosphere**
- 840 Pg
- +4.0 Pg/yr
- Mean Residence Time (MRT) = 400Yr
- 10 Pg/yr Fossil fuel combustion
- 1.6 ± 0.8 Pg/yr Deforestation
- 120 ± 2.0 Pg/yr (photosynthesis)
- Plant respiration: 60 ± 1.6 Pg/yr

**Soils (3-M)**
- 4,000 Pg
- MRT = 25Yr
- 60 Pg/yr (soil respiration)
- 1.1 ± 0.2 Pg/yr (erosion)
- 0.6 ± 0.2 Pg/yr (deposition)

**Biota**
- 620 Pg
- MRT = 5Yr

**Fossil Fuels**
- 4,130 Pg
- (i) Coal: 3,510 Pg
- (ii) Oil: 230 Pg
- (iii) Gas: 140 Pg
- (iv) Other: 250 Pg
- 90 Gt/yr

**Ocean**
- 42,000 Pg + 2.3 Pg/yr
- (i) Surface layer: 670 Pg
- (ii) Deep layer: 36,730 Pg
- (iii) Total organic: 1,000 Pg
- MRT (Sea surface and deep layer): 25Yr

**Biofuel Offset?**

Mean Residence Time (MRT) = 400Yr
THE BRIGHT FUTURE OF AGRICULTURE

As an engine of economic development and being integral to any solution for improving the environment, agriculture has a bright future.

**Food Security:** Additional global demand by 2050 of grains by 1 billion ton/yr and meat by 200 million ton/yr.

- **Climate Security:** With the appropriate policy incentives, world soils and the terrestrial biosphere have a potential to reduce atmospheric \( \text{CO}_2 \) by 50-100 ppm by 2150.

- **Water Security:** Additional water demand of 40% by 2030 can be met by increasing the “green water” supply and water productivity of agro-ecosystems.

Soil C is a key determinant of these essential ecosystem services, which are intertwined with climate change.
With soil C pool of 2400 Pg, 4/1000

= 9.6 Pg C

= 4.5 ppm CO$_2$ Drawdown

- Reducing emissions in 2050 to half of 1990 levels in Europe implies offsetting a total if 20 Pg CO$_2$ (5.5 Pg C)

- Thus, 4 per 1000 initiative can be an important strategy to achieve this goal.
# Global Technical Potential of Carbon Sequestration in the Terrestrial Biosphere

<table>
<thead>
<tr>
<th>Activity</th>
<th>Technical Potential (Pg C/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>I. Forest</strong></td>
<td></td>
</tr>
<tr>
<td>1. Afforestation, Forest Successions Peatland Restoration</td>
<td>1.2-1.4</td>
</tr>
<tr>
<td>2. Forest Plantations</td>
<td>0.2-0.5</td>
</tr>
<tr>
<td><strong>II. Soils</strong></td>
<td></td>
</tr>
<tr>
<td>1. Croplands</td>
<td>0.4-1.2</td>
</tr>
<tr>
<td>2. Pasturelands</td>
<td>0.3-0.5</td>
</tr>
<tr>
<td><strong>III. Degraded Lands</strong></td>
<td></td>
</tr>
<tr>
<td>1. Salt-affected soils</td>
<td>0.3-0.7</td>
</tr>
<tr>
<td>2. Desertification Control</td>
<td>0.2-0.7</td>
</tr>
<tr>
<td><strong>Total Technical Potential</strong></td>
<td><strong>2.6-5.0 (3.8 Pg C/yr)</strong></td>
</tr>
</tbody>
</table>

Reducing emissions
Sequestering carbon

*Lal (2010)*
Creating Positive C Budget

Gains
- Biochar
- Compost
- Cover Crops
- Root Biomass
- Crop Residues

Losses
- Erosion
- Leaching
- Decomposition

Gains
- Residue
- Compost
- Root Biomass

Losses
- Erosion
- Leaching
- Decomposition

Soil Carbon Sequestration

Soil Carbon Depletion
VULNERABLE CARBON POOLS

Canadell et al. (2006)
Soil stewardship and care must be embedded in every fruit and vegetable eaten, in each grain ground into the bread consumed, in every cup of water used, in every breath of air inhaled, and in every scenic landscape cherished.
Soil is Life and Life is Soil

Lal (2014)