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Carbon Sequestration in Agricultural Systems

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Word Association:

Carbon Sequestration?

- Building Soil Organic Matter
- Receiving Carbon Credit Payments
- Mitigating Climate Change
What does soil C accomplish?

• Soil C (and organic matter, OM)
  – Positively correlated with
    • Aggregate stability - AS
    • Biological activity (micro and macro)
    • Cation exchange capacity – CEC
    • Available water holding capacity - AWC
    • Hydraulic conductivity (usually) - Ksat
Distribution of SOC in the U.S.

Source: A New High-Resolution National Map of Vegetation Ecoregions Produced Empirically Using Multivariate Spatial Clustering by William W. Hargrove and Robert J. Luxmoore
A crew takes a break from digging in Edison in fall 1910.
Loss of SOC following cultivation

- Best estimate:
  - 20 to 30% loss of SOC

Some view this as a reservoir that can potentially be refilled

Carbon Credits
Payments for sequestered C or avoided emissions

- Who pays? Entities with PR issues
- Who’s in the middle? Broker (CCX) Aggregator (e.g. NDFU)
- What practices qualify? Conservation tillage, permanent grass planting, methane capture/destruction
Current C price $1.60/t
Benefits of reduced tillage

• Reduced soil erosion
• Reduced production costs
• Reduced fossil fuel use
• Increased SOC?
Field-scale Gas Exchange
How strong is the evidence?

- Major literature review by West and Post, 2002
  - global extent
  - 67 long term experiments
  - 276 treatment pairs
  - 0.25 tons C/ac/yr
- Only 50% sampled more than 8” deep
- None sampled more than 12” deep
- What are we missing?

NRCS photo
Fig. 9.—Root system of corn on September 2.
Roots and carbon

- Crop roots often extend well below 12”
- 30 to 50% of the C plants take in may be initially moved below ground
- The ratio of SOC derived from below-ground C to that derived from stover was nearly 2:1 in long-term corn plots
- No-till results in lower soil temperature and can lead to less rooting at depth
What if we dig deeper?

- VandenBygaart et al. (2003) reviewed Canadian data
  - 62 studies
  - NT gains C near surface
  - NT neutral or losing C when sampled >12” deep
- Does shallow sampling bias the results?
More studies with deep sampling where NT did not increase SOC

- **Minnesota** - Dolan et al. (2006); Venterea et al. (2006)
- **OH, WV,KY** – Blanco & Lal (2008)
- **UK** - Powlson and Jenkinson (1981)
- **Switzerland** - Hermle et al. (2008)
- **Brazil** - Sisti et al. (2004)
Summary of evidence

- No-till increase SOC near the soil surface
  - a potentially beneficial effect in its own right
- This surface increase can be offset by less SOC at depth
- The evidence for C sequestration under conservation tillage is not compelling
Practical implications

• Adopt (or promote) conservation tillage for its proven benefits

• Support (or do) long-term experiments with deep soil sampling to monitor SOC

• Don’t rely on SOC storage from conservation tillage to stabilize CO$_2$

• Look for other ways to build SOC
Use more of the growing season
Alfalfa
“We analyzed the impact on SOC of four N fertilization rates (0–270 kg N ha\(^{-1}\)) and four cropping systems: continuous corn (CC); corn–soybean; corn–corn–oat–alfalfa (CCOA), and corn–oat–alfalfa–alfalfa (COAA)…. Cropping systems that contained alfalfa had the highest SOC stocks, whereas the CS system generally had the lowest SOC stocks.”

1793 June 28. (TJ to GW) "Good husbandry with us consists in abandoning Indian corn and tobacco, tending small grain, some red clover following, and endeavoring to have, while the lands are at rest, a spontaneous cover of white clover. I do not present this as a culture judicious in itself, but as good in comparison with what most people there pursue.[1]
Drain no more than necessary

...But there are better approaches

Controlled Drainage

Controlled drainage
- conserves water
- reduces nitrogen and phosphorus loads
- increases yields

Research shows 50% reduction of nitrogen
10% increase in yield

ADMC image
Better utilization of manure
Soil C on Dairy Farm

Terra Preta

Oxisol

Photosynthesis

FARM

1100 Tg Biomass
451 Tg C

220 Tg Biochar
139 Tg C

CO₂ - C

LOCAL PYROLYZER

224 Tg C

61 Tg CO₂

660 Ta Bio-oil
285 Tg C

CONSUMERS

Bio-oil displaces
261 Tg of fossil fuel
224 Tg C credit

CENTRALIZED REFINERY

Sequester
139 Tg C

224 Tg CO₂

821 Tg CO₂

220 Tg Syngas
27 Tg C
Other ways to help mitigate climate change in agricultural systems

- Plant trees
- Reduce CH$_4$ and N$_2$O emissions
Living snow fence at Lamberton, MN along the north side of Hwy 14
C “sequestration” through better N use efficiency

- 3-5 % of N applied in fertilizer returns to atmosphere as N₂O
- In terms of GWP, 1 N₂O = 310 CO₂

So, with current efficiency, applying 200 lb-N/acre ≈ release of 3400-5700 lb CO₂/acre
Strategies for Reducing N2O Loss

• Avoid fall N application
• Better synchrony between N application/availability and N demand
• Precision agriculture- match rates to soil types and landscape position
Conclusions

C-sequestration strategy depends on goals

Increase Soil O.M.?
Manure; alfalfa in rotation; controlled drainage
Participate in CCX program?
Conservation tillage; pasture; methane capture
Help mitigate climate change?
Improve N efficiency; plant windbreaks & living snow fences; reduce other GHG emissions
What about bio-energy?