Maryland’s Healthy Soils Initiative:
Developing a program for sequestering carbon in agricultural soils

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Maryland’s Healthy Soils Initiative

2016: MDA proposed Initiative to Maryland Commission on Climate Change

2016: Healthy Soils Consortium established by MDA
* Diverse stakeholder advisory group

2017: Maryland Healthy Soils Legislation
* Improve health, yield & profitability of MD soils
* Increase carbon sequestration in agricultural soils in Maryland
* Promote more widespread use of healthy soils practices by Maryland’s farmers
* Bipartisan
Maryland’s Healthy Soils Initiative

2017: Healthy Soils Workshops

2017: Begin work on carbon sequestration program
* Comprehensive review of scientific literature
* Synthesis and determination of practices likely to be successful in Maryland
* Input and feedback from stakeholders
* Development of incentive program
* US Climate Alliance Learning Lab/Challenge

2018-19: Include program in next Greenhouse Gas Reduction Act Plan
* Will help MD reach 40% reduction by 2030
Agriculture is part of the climate change solution

Reducing emissions is not enough

- Land-based carbon sequestration is the most practical and effective strategy
  - forests
  - farms
- Maryland already a leader in healthy soils practices, key for Bay water quality
- Build on & expand current incentives based on water quality to increase practices that sequester carbon
Sequestering Carbon in Healthy Soil

Plants absorb atmospheric C during photosynthesis and make sugar

- In healthy soil, up to 40% of this carbon is passed on to microbes.
- Most stored carbon comes from roots and has been processed by microbes.
- Healthy soil practices that boost microbes should increase carbon storage

Natural Resources Conservation Service (NRCS) principles: All about the microbes

- Feed & Diversify the Soil Biota*
- Protect Soil Aggregates & Organic Matter
- Maximize Continuous Living Roots
- Minimize Disturbance
- Maximize Soil Cover
- Maximize Biodiversity

modified from Dennis Chessman NRCS Kentucky
Natural Resources Conservation Service (NRCS) principles: All about the microbes

“Soil biology ... seems to resonate with producers unlike anything NRCS has promoted in the past”

Dennis Chessman, NRCS Kentucky
Natural Resources Conservation Service (NRCS) principles: All about the microbes

“Soil biology ... seems to resonate with producers unlike anything NRCS has promoted in the past”

Dennis Chessman, NRCS Kentucky

But if we boost the microbial population won’t more SOM be eaten, releasing CO$_2$ rather than storing it?
How is carbon protected from hungry microbes?

- Held tightly within microaggregates
- Adsorbed onto clay & minerals

Weil & Brady 2017, Fig. 4.25
Goals of Carbon Sequestration Project

1. Identify research-based practices for sequestering C on Maryland’s farms.
2. Estimate potential GHG reduction from each.
3. Determine costs/benefits for each.
4. Explore ways to build on current incentive programs to increase use of key practices.
Identifying research-based practices for sequestering C in soils

- Reviewed recent scientific reports on carbon sequestration & primary literature

- Consolidated results, evaluated support

- Aligned with NRCS conservation practices
  - Many already used in MD for water quality*
  - Incentives established
  - CA Healthy Soils program uses NRCS practices
  - COMET-Planner estimates GHG reduction for each practice (moist & humid environment)
GHG reductions from carbon-sequestering practices already used in Maryland for water quality

<table>
<thead>
<tr>
<th>NRCS Conservation Practices</th>
<th>(CO₂) Mean</th>
<th>(N₂O) Mean</th>
<th>Sum</th>
<th>acres 2017</th>
<th>CS in 2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional Tillage to No Till (CPS 329, s)   *</td>
<td>0.42</td>
<td>-0.11</td>
<td>0.31</td>
<td>1,079,000</td>
<td>334,490</td>
</tr>
<tr>
<td>Conventional Tillage to Reduced Tillage (CPS 345, s)</td>
<td>0.13</td>
<td>0.07</td>
<td>0.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nutrient Management - N Fertilizer Management (CPS 590, s,r)</td>
<td>0</td>
<td>0.11</td>
<td>0.11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conservation Crop Rotation (CPS 328, s)</td>
<td>0.21</td>
<td>0.01</td>
<td>0.22</td>
<td>304625</td>
<td>67,018</td>
</tr>
<tr>
<td>Cover Crops (CPS 340, s),</td>
<td>0.32</td>
<td>0.05</td>
<td>0.37</td>
<td>559000</td>
<td>206,830</td>
</tr>
</tbody>
</table>

Two practices > 200,000 Mt each

These agronomic practices have significant research support
No-Till or Not??

- No-till a key element of soil health
- **Co-benefits:** better water infiltration and storage, less erosion, less compaction, less fuel use
- **BUT** some studies in which C measured to 1m claim to show more C at surface but less at depth (& overall) in no-till
  
* Scrutiny of primary literature:
  - many cited papers are low quality
  - recent papers show slightly more C in the top 1m in no-till
* **CA & COMET Planner include** no-till as a sequestration practice
### Cropland to Herbaceous or Woody Cover

<table>
<thead>
<tr>
<th>Activity</th>
<th>CO₂</th>
<th>N₂O</th>
<th>Sum</th>
<th>#acres 2017</th>
<th>GHG red. 2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retiring marginal soils ==⇒ permanent grass cover (CPS 327,s)</td>
<td>0.98</td>
<td>0.28</td>
<td>1.26</td>
<td>27555</td>
<td>34,719</td>
</tr>
<tr>
<td>Insert forage planting into rotation (CPS 512,s)</td>
<td>0.21</td>
<td>0.01</td>
<td>0.22</td>
<td>13416</td>
<td>2,952</td>
</tr>
<tr>
<td>Convert cropland strips to permanent herbaceous vegetation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Riparian herbaceous cover (CPS 390)</td>
<td>0.27</td>
<td>0.28</td>
<td>0.55</td>
<td>13113</td>
<td>7,212</td>
</tr>
<tr>
<td>Contour buffer strips (CPS 332)</td>
<td>0.27</td>
<td>0.28</td>
<td>0.55</td>
<td>8.5</td>
<td>5</td>
</tr>
<tr>
<td>Field border (CPS 386)</td>
<td>0.27</td>
<td>0.28</td>
<td>0.55</td>
<td>703</td>
<td>387</td>
</tr>
<tr>
<td>Filter Strip (CPS 393)</td>
<td>0.27</td>
<td>0.28</td>
<td>0.55</td>
<td>30837</td>
<td>16,960</td>
</tr>
<tr>
<td>Grassed Waterway (CPS 412)</td>
<td>0.27</td>
<td>0.28</td>
<td>0.55</td>
<td>6237</td>
<td>3,430</td>
</tr>
<tr>
<td>Convert cropland to Farm Woodlot (CPS 612)</td>
<td>1.98</td>
<td>0.28</td>
<td>2.26</td>
<td>1928</td>
<td>4,357</td>
</tr>
<tr>
<td>Windbreak/shelterbelt establishment (CPS380)</td>
<td>1.81</td>
<td>0.28</td>
<td>2.09</td>
<td>120</td>
<td>251</td>
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<tr>
<td>Riparian Forest Buffer Establishment (CPS (391)</td>
<td>2.19</td>
<td>0.28</td>
<td>2.47</td>
<td>19439</td>
<td>48,014</td>
</tr>
<tr>
<td>Hedgerow Planting (CPS 422)</td>
<td>1.42</td>
<td>0.28</td>
<td>1.70</td>
<td>15.4</td>
<td>26</td>
</tr>
<tr>
<td>Alley Cropping (CPS 311)</td>
<td>1.71</td>
<td>0.03</td>
<td>1.74</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multistory Cropping = Permaculture (CPS 379)</td>
<td>1.71</td>
<td>0.03</td>
<td>1.74</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase efficiency of farm equipment (CPS 372)</td>
<td>0.01</td>
<td>NE</td>
<td>0.01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mulching (CPS 585)</td>
<td>0.32</td>
<td>NE</td>
<td>0.32</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stripcropping (CPS 585)</td>
<td>0.11</td>
<td>0.13</td>
<td>0.24</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Best < 50,000 Mt*

**Significant or medium research support**
Possible but…
not quite ready for prime time

<table>
<thead>
<tr>
<th>Grazing</th>
<th>GHG red. Mt CO$_2$e/acre/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silvopasture on grazed grassland/pasture (data gaps)</td>
<td>1.34 0.00 1.34</td>
</tr>
<tr>
<td>Rotational grazing (from T-AGG, data gaps) *</td>
<td>range CO$_2$: -5.27 - 1.90</td>
</tr>
</tbody>
</table>

Other strategies from T-AGG with low research support

<table>
<thead>
<tr>
<th></th>
<th>possible, but data gaps</th>
</tr>
</thead>
<tbody>
<tr>
<td>improve irrigation management, e.g. drip</td>
<td>possible, but data gaps</td>
</tr>
<tr>
<td>Improve manure management for low N$_2$O</td>
<td>possible, but data gaps</td>
</tr>
<tr>
<td>manage farmed histosols</td>
<td>possible, but data gaps</td>
</tr>
<tr>
<td>agroforestry on grazing land</td>
<td>possible, but data gaps</td>
</tr>
<tr>
<td>Replace N Fertilizer with Soil Amendments <em>(CPS 590)</em> but life cycle</td>
<td>1.75 0.00 1.75</td>
</tr>
<tr>
<td>convert dryland to irrigated</td>
<td>life cycle problems?</td>
</tr>
<tr>
<td>biochar</td>
<td>life cycle problems?</td>
</tr>
</tbody>
</table>
Rotational grazing: High variation in success

A well-managed rotational grazing program requires “adaptive management”, ie constantly:
- evaluate the nutritional and forage needs of animals,
- assess forage quality & quantity for stocking rate,
- regulate the acreage of access

Consumption must be enough to stimulate roots but not too much that overgrazing occurs

Most successful w/ motivated & experienced farmer

Over many studies, evidence for benefit not compelling

Might be positive if integrated with cover crops, insertion of deep-rooted perennials into rotations
Replace N fertilizer with organic amendments

Idea—synthetic N is quick release, big carbon footprint

Replace with manure or compost—slow release, adds SOM

Current issues
- must apply manure & compost at very low rate to avoid P problems
- now hard to obtain manure on Eastern Shore
- adequate supply of compost not currently available,  
  BUT possible revisit if food waste composting, leaf composting were scaled up?
How much can agriculture contribute to Maryland’s GHG reduction goals?

Calculated using actual # acres in NRCS practices 2007-2017 w/ estimated GHG reduction for each.

With only the water-quality practices,

<table>
<thead>
<tr>
<th>GHG reduction from agriculture</th>
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</thead>
<tbody>
<tr>
<td>2007 - 2017 = 6.15 MMt</td>
</tr>
</tbody>
</table>

puts agriculture in the top four GHG-reducing programs in Maryland
How much scope is there for enrolling more acres in these practices?

- With new funding reflecting the carbon benefit?
- If some key equipment were made available?
- With increased outreach?
Questions for Ag Extension Personnel

- What would it take to get farmers to increase their use of these practices?

- Will farmers accept some of the practices not commonly used now, such as:
  - Alley cropping
  - Hedgerows
  - Silvopasture etc.

- Can we increase no-till and cover crops in vegetables?
Economic Benefits of Practices

- Increased soil health worth $40-140/acre (ecosystem services worth up to $3500/acre)
- It can take time to reap soil health benefits, but profits can grow despite short-term yield decline
- Allow reduced use of synthetic N, herbicides, pesticides, fuel, irrigation; save time & labor costs
- Less nitrate in water reduces water treatment costs
- Future addition of carbon trading= more $
Environmental/Health Benefits

- Improved water quality, Bay protection
- Healthy soil resilient to climate change
  ex: better infiltration ➔ flood reduction
  more water held ➔ drought resilience
- Reduced erosion, dust, sediment
- Reduction of future climate change, BUT
  - practices must be maintained each year
  - in 30-50 yrs, saturation may reduce sequestration
Most practices have multiple co-benefits

- Improved Aggregation
- Improved Infiltration
- Increased Soil Biota
- Increased Nutrient Cycling
- Increased pH buffering

Enhance Soil Structure

Increase Soil Organic Matter

Cover Crops
Maintain live roots, PLUS

CC diversity ➔ microbial diversity, more C storage

Environmental Quality

- Reduced N-leaching
- Reduced Erosion
- Reduced Run-off

Improve Pest Management

- Weed Suppression
- Pathogen Suppression
- Nematode Suppression
Monitoring carbon sequestration:
Verify that management practices increase SOC

- Establish a set of permanent sites for regular sampling by trained techs
  * range of soils, geography and cropping systems
  * standard sampling protocol to 50 cm (or 1m?)
  * standard analyses

- Farmers submit yearly soil tests with records of field management using recommended protocol

- Try to get retroactive reporting of SOM from tests used for WIPs, ask for field management data
We need increased research & outreach

- Integrate the practices into current strategies
- Identify ways to increase value of each practice
  (i.e., make cover crops work harder -- mixtures, interseeding, planting green, use in weed control)
- Outreach to increase farmer acceptance and use
  - corn/soybeans, hedgerows etc?
  - boost no-till and cover crops in vegetable and organic farming
- Technical assistance to guide farmers and verify carbon increase over time
Conclusions

Agriculture can play pivotal role in GHG reduction in Maryland

Incentivizing carbon-sequestering practices: a win for the environment, a win for farmers

email me anytime: svia@umd.edu
NRCS principles: All about the microbes

- Feed & Diversify the Soil Biota
- Protect Soil Aggregates & Organic Matter
- Maximize Continuous Living Roots
- Minimize Disturbance

But won’t more microbes eat more SOM, release more CO₂?
Soil Health Principles

Maximize biodiversity & Maintain living roots

*Increase aboveground diversity
- Boosts predators & pollinators
- More biomass in mixtures
- Increases soil organic matter

*Increase belowground diversity & provide continuous food
- Increase diversity & stability of microbial community
- Increase nutrient cycling
- Enhance plant growth
Soil Health Principles

Minimize disturbance & Keep the soil covered
* Maintain stable aggregates
* Reduce erosion
* Buffer temperature & moisture
* Maintain soil organic matter

These outcomes protect the microbial community
Soil Health Principles

Minimize disturbance & Keep the soil covered
* Maintain stable aggregates
* Reduce erosion
* Buffer temperature & moisture
* Maintain soil organic matter

These outcomes protect the microbial community

but don’t the microbes eat SOM and release CO$_2$??
2020-2030? Acreage increases 2007-2017 mostly linear:
Used slopes to estimate acreages 2020-2030
Water quality only—no carbon incentives

Cover crops 2007-17

Conservation crop rotation 2007-17

Insert forage into rotation

Cover crops 2011-17

Conservation crop rotation 2014-17

Cropland to woodlot

Riparian woody

Riparian herbaceous

Marginal soils to permanent grass cover

Year (2007-2017)

Acreage data provided by Alisha Mulkey, MDA
Maryland’s GHG reduction goal: 40% reduction by 2030

- Conservative b/c new practices will be added & existing practices will increase with incentives for carbon benefit

Could cover up to 56% of potential shortfall
Rotational grazing

Other issues

- trampling is a cost not a benefit
- success and stocking levels depend on type of grass, soil characteristics
- experience and motivation of manager key
Conclusions

Agriculture plays pivotal role in GHG reduction in Maryland

Time to incentivize farmers to increase use of carbon-sequestering practices and to formalize a program for the 2019 GGRA Plan
No-Till or Not??

- **No-till** a key element of soil health

- **Co-benefits:** better water infiltration and storage, less erosion, less compaction, less fuel use

- **BUT** some studies that measure C to 1m suggest more C at surface but less at depth in no-till

  * Mechanism still uncertain

  * California uses no-till as sequestration practice
Sequestering Carbon in Healthy Soil

How is carbon protected from hungry microbes?

- Held tightly within micro-aggregates
- Adsorbed onto clay & minerals
Table 6. Potential co-benefits and tradeoffs of agricultural GHG mitigation practices

<table>
<thead>
<tr>
<th>GHG Mitigation Practice</th>
<th>Biodiversity</th>
<th>Water conservation</th>
<th>Water quality</th>
<th>Air quality</th>
<th>Soil quality</th>
<th>Food security</th>
</tr>
</thead>
<tbody>
<tr>
<td>Switch to no-till or other conservation tillage</td>
<td>Improved habitat for ground-nesting birds and other animals</td>
<td>Increased water use</td>
<td>Reduced irrigation need</td>
<td>Reduced sedimentation and herbicide use</td>
<td>Increased SOM</td>
<td>Reduced erosion, increased SOM</td>
</tr>
<tr>
<td>Eliminate summer fallow</td>
<td>Improved habitat for ground-nesting birds and other animals</td>
<td>Increased water use</td>
<td>Reduced nitrate leaching, but increased fertilizer N needs</td>
<td>Increased emissions from tractor use</td>
<td>Increased SOM</td>
<td></td>
</tr>
<tr>
<td>Add winter cover crop</td>
<td>Increased biodiversity</td>
<td>Improved soil water holding capacity</td>
<td>Increased water use</td>
<td>Reduced nitrate leaching</td>
<td>Increased emissions from tractor use</td>
<td>Increased SOM</td>
</tr>
<tr>
<td>Diversify annual crop rotations, increase intensity</td>
<td>Increased biodiversity (native and crop species), possibly detrimental to wildlife (e.g., bird diversity)</td>
<td>Reduced or increased water use</td>
<td>Disease-suppressive soils reduce pesticide and herbicide use or increased inputs and erosion</td>
<td>Increased emissions from tractor use</td>
<td>Improved soil quality</td>
<td>Increased yields, improved disease resistance</td>
</tr>
<tr>
<td>Include or substitute perennial crops in rotations, SRWCs</td>
<td>Increased biodiversity</td>
<td>Decreased water use and increased soil water holding capacity or possible increase in water use</td>
<td>Potentially decreased sedimentation and herbicide/pesticide use</td>
<td>Reduced emissions from tractor use</td>
<td>Improved soil quality, reduced erosion, increased SOM</td>
<td>Decreased overall production of main grain crops</td>
</tr>
<tr>
<td>SRWCs, agroforestry, herbaceous buffers</td>
<td>Increased biodiversity</td>
<td>Flood control</td>
<td>Reduced sedimentation and improved filtration</td>
<td>Reduced emissions from tractor use</td>
<td>Reduced erosion, increased SOM</td>
<td>Land taken out of production</td>
</tr>
<tr>
<td>Irrigation improvements (e.g., drip, supplemental)</td>
<td>Improved water use efficiency</td>
<td>Reduced sedimentation and nutrient runoff</td>
<td></td>
<td></td>
<td></td>
<td>Increased yields</td>
</tr>
<tr>
<td>Application of organic materials, biochar</td>
<td>Increased soil microbiota</td>
<td>Improved soil water-holding capacity</td>
<td>Reduced or increased runoff</td>
<td>Possible reduction of trace gases, increased or reduced storage</td>
<td>Improved soil quality (e.g., structure), increased SOM</td>
<td></td>
</tr>
</tbody>
</table>