Carbon Sequestration from Biosolids Land Application

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Human actions have drastically increased the amount of carbon dioxide in the atmosphere

Data Source: Mauna Loa Observatory, Scripps Institute
Mitigating climate change requires diverse solutions, including enhancing carbon storage in soils.

Concentrations are expected to continue to rapidly rise.

Reducing emissions slows the rate of change.

Managing ecosystems for carbon storage pulls CO₂ out of the atmosphere.

Data Source: Mauna Loa Observatory, Scripps Institute
Soils store a lot of the world’s carbon – more than the atmosphere and all the plants, combined!!

1 Pg = $10^{15}$ g
= 1 Gt = $10^9$ tonnes
Soil carbon stocks vary globally and are a function of soil type, climate, vegetation, and management
A large portion of the world’s soils are directly managed for the production of food, fuel, fiber, and forest products. Improved stewardship of the world’s agricultural lands, grazing lands, and forests can restore and increase soil carbon stocks.
Soil Carbon Sequestration:
Increasing the capacity of ecosystem to store C by increasing C inputs, decreasing C outputs, or increasing stability of C in soil.
Soil carbon is key to soil health

Biological functions
- Energy for microorganisms
- Reservoir of nutrients
- Contributes to plant production

Physical functions
- Improves structure
- Increases water retention
- Reduces erosion

Chemical functions
- Nutrient holding capacity
- Buffers changes in pH
- Improves fertility
Known natural climate solutions can achieve 1/3 of cost-effective climate mitigation.
Organics in the California Context: Lessons from the Marin Carbon Project

- A one-time application of compost to grazed rangelands:
  - Increased ecosystem C storage by 0.5 - 1.2 Mg C ha\(^{-1}\) yr\(^{-1}\)
  - New soil carbon was stored in physically protected soil pools
  - Forage increased by 50 – 70%
  - Soil moisture increased
  - Did not increase soil greenhouse gas emissions

Silver et al. 2010. *Rangeland Management*
Ryals and Silver. 2013. *Ecological Applications*
DeLonge et al. 2013. *Ecosystems*
Ryals et al. 2014. *Soil Biology & Biochemistry*
Ryals et al. 2015. *Ecological Applications*
Ryals et al. 2016. *Ecosphere*
Marin Carbon Project – Scaling and Implications

• Applying compost to 5% of CA grasslands would offset emissions from state’s forestry and agriculture sector

• Ecosystem modeling suggested the effects will last several decades

• Inspired Carbon Farming Planning, Carbon Offset Protocol, Climate-beneficial textiles, and access to CA Healthy Soils Program funding
Drivers and Opportunities for Biosolids Reuse

- Application restrictions on number of acres, timing, and certain crop types
- New organics policies and regulations will change how we manage biosolids (e.g. SB 1383)
- There is untapped potential to repair the broken agricultural nutrient cycles and mitigate climate change
- ...but additional research is needed in California to quantify the benefits and opportunity to ultimately inform policy and local practices
The beneficial reuse of biosolids on agricultural land has been demonstrated

- Improvements in soil fertility
- Boost in plant production
- Phosphorus recycling
- Boost in plant production

Washington State University, 25 year old research plots
Human organic amendments increase crop yields, and benefits carry over in time.

Fertilizers/Amendments applied only once

Ryals et al. in prep
Carbon sequestration from biosolids application has been observed in mine reclamation studies.

Long term carbon sequestration potential of biosolids-amended copper and molybdenum mine tailings following mine site reclamation

Paul M. Antonelli^a,^, Lauchlan H. Fraser^a, Wendy C. Gardner^a, Klaas Broersma^b, John Karakatsoulis^a, Michelle E. Phillips^a
What is the potential for carbon sequestration from biosolids application in California agricultural ecosystems?
We identified three ranches in California where biosolids were applied for ~ 20 years

20+ years of application
Unamended control comparisons

3 ranches in CA
3 sets of paired-transects at each ranch

<table>
<thead>
<tr>
<th>Ranch</th>
<th>Transect #</th>
<th>Frequency of Application</th>
<th>Total Amount Applied From T=0 (Dry Tons/Acre Applied)</th>
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<td>Sacramento</td>
<td>1</td>
<td>Yearly</td>
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<td>2</td>
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<td>Merced</td>
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<td>Every 5 Years</td>
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<td>Every 5 Years</td>
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</tbody>
</table>
Three paired transects were sampled within each of the ranches.

- Web Soil Survey
- thorough documentation of biosolids application
- no fertilizer
- Control vs Biosolids
Soils were sampled to 1 m depth

10-30, 30-50, 50-75, 75-100 cm
10 replicates/ 100 m transect
900 total soil samples
Samples represent a range of soil conditions found within California’s agricultural ecosystems

We are measuring...

- Total soil carbon & nitrogen
- Physical and chemical carbon stability

...and several factors that control rates of C sequestration

- Water retention
- Microbial biomass
- Soil properties – pH, texture, mineralogy
The potential for biosolids to increase soil carbon is significant across all sites. Soil carbon increases are observed in deep soil layers, where it is likely to be stored for longer periods of time.
Biosolids increase the pool of biological active carbon, a key indicator of soil health.
How do biosolids fit within current and future soil carbon sequestration efforts?

- **Methodologies for carbon accounting**
  - Baseline sampling and monitoring
  - Modeling

- **Incentives for adopting biosolids application**
  - Soil Health Policies
  - Voluntary carbon offset markets
  - Private investment
  - Realization of co-benefits
  - Opportunities in urban, ag, and restored land
Multi-stakeholder partnerships are critical to:

- develop locally-relevant and data-driven best management practices
- to quantify environmental benefits and tradeoffs
- provide technical training
- educate the public
Take home messages

• Biosolids are a resource for carbon sequestration and soil health.
• Benefits are vary across agroecological contexts. Local studies are important.
• In California, long-term biosolids application increased carbon storage.
• Biosolids increase crop production, but could have a greater impact if composted.
• Soil nitrous oxide emissions must also be considered.
THANK YOU!
QUESTIONS?