Soil carbon on forest land in the United States

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Importance of C in soils

- Largest terrestrial sink
- UNFCCC reporting
- Much is in forests
- Influences biological, chemical, and physical soil functions
- ...much uncertainty exists


Why the change in SOC methods?


NFI sampling frame

Prefield analysis

Core field
1 plot per 2,430 ha

Intensive field
1 plot per 38,880 ha

NFI plot design

NFI litter and soil sampling

\[ SOC_{FIA} = C_i \cdot BD_i \cdot t_i \cdot ucf \]


Belowground C without coarse roots but including fine roots and all other organic carbon not included in other pools, to a depth of 1 m.
## NFI and ISCN data

<table>
<thead>
<tr>
<th>SOIL_ORDER</th>
<th>FIA profiles</th>
<th>ISCN profiles</th>
<th>Measurements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfisol</td>
<td>840</td>
<td>558</td>
<td>5895</td>
</tr>
<tr>
<td>Andisol</td>
<td>135</td>
<td>154</td>
<td>1256</td>
</tr>
<tr>
<td>Aridisol</td>
<td>129</td>
<td>9</td>
<td>281</td>
</tr>
<tr>
<td>Entisol</td>
<td>234</td>
<td>127</td>
<td>1190</td>
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<tr>
<td>Gelisol</td>
<td>0</td>
<td>10</td>
<td>63</td>
</tr>
<tr>
<td>Histosol</td>
<td>58</td>
<td>171</td>
<td>1203</td>
</tr>
<tr>
<td>Inceptisol</td>
<td>577</td>
<td>250</td>
<td>2614</td>
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<tr>
<td>Mollisol</td>
<td>588</td>
<td>200</td>
<td>2451</td>
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<tr>
<td>ORDER_NOT_FOUND</td>
<td>0</td>
<td>265</td>
<td>2254</td>
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<tr>
<td>Oxisol</td>
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<td>13</td>
<td>82</td>
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<tr>
<td>Spodosol</td>
<td>407</td>
<td>246</td>
<td>2583</td>
</tr>
<tr>
<td>Ultisol</td>
<td>686</td>
<td>311</td>
<td>3553</td>
</tr>
<tr>
<td>Vertisol</td>
<td>13</td>
<td>11</td>
<td>114</td>
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<tr>
<td><strong>TOTAL</strong></td>
<td><strong>3667</strong></td>
<td><strong>2325</strong></td>
<td><strong>23539</strong></td>
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</table>
NFI and ISCN data
\[
\log_{10} SOC = I + \log_{10} Depth
\]

<table>
<thead>
<tr>
<th>Soil order</th>
<th>Intercept</th>
<th>Slope</th>
<th>( r^2 )</th>
<th>F-statistic</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>1.1795</td>
<td>-0.8228</td>
<td>0.56</td>
<td>29646.79</td>
<td>&lt;0.001</td>
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<td>Alfisols</td>
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<td>0.64</td>
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<td>Andisols</td>
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<td>-0.8425</td>
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<td>Aridisols</td>
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<td>0.02</td>
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<td>0.011</td>
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<td>Entisols</td>
<td>0.9300</td>
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<td>0.39</td>
<td>752.34</td>
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<td>Histosols</td>
<td>1.6227</td>
<td>-1.0109</td>
<td>0.59</td>
<td>1724.22</td>
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<td>Inceptisols</td>
<td>1.1631</td>
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<td>Mollisols</td>
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<td>Spodosols</td>
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<td>4097.61</td>
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<td>Ultisols</td>
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<td>7450.16</td>
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<td>Vertisols</td>
<td>0.5145</td>
<td>-0.2427</td>
<td>0.08</td>
<td>9.58</td>
<td>0.002</td>
</tr>
</tbody>
</table>

From 3,667 plots to 127,325 plots...
Modeling approaches

LAT, LON, ELEV, SLOPE, ASPECT, WATERCD, FORTYPGRP, STDAGE, PHYSCLCD, SITECLCD, STDORGCD, DISTURB, TRTMNT, BALIVE, SDI, REL_DENS, AGLT_C_MGHA, PRISM_PPT, PRISM_TMAX, GMI, YSD, SOIL_ORDER (STATSGO2), SURF_NAME, SURF DEPTH

Ensemble Model: example for regression

Pruning and variable selection

\[ P(SOC) = f(lat, lon, elev, fortypgrp, ppt, t\ max, gmi, order, surfgeo) \]

RMSE: 34.9 on 1091 DF,
\[ R^2: 0.38, \]
F-stat: 536 on 1 and 1091 DF,
p-value: < 0.0001
Model comparisons

The estimates (MeanSOC100) and predictions (Mean P(SOC)) were statistically equivalent.

Cao et al. In prep. Spatial modeling of litter and soil carbon stocks with associated uncertainty on forest land in the conterminous United States. Outlet TBD.
Topsoil carbon in the US

Remote Sensing

Soil Profile

Topsoil carbon in the US

Understory invasion and soils

Understory invasions and soils


Understory invasion and soils

- Plant-fungal associations play critical roles in aboveground vegetation dynamics and belowground nutrient cycling.
- Litter and soil attributes were significantly associated with AM tree dominance.
- Higher AM dominance in saplings than adult trees in most part of USA forests.
- AM tree dominance may facilitate understory invasions by decreasing litter thickness and soil C:N ratio.

Take aways...

- The contribution of soil C in forests has been grossly underestimated in recent national inventory reports (NIRs) in the US
- New predictions represent an estimated 40 percent (42.52 ± 46.80 Mg C ha\(^{-1}\)) increase in C stocks per unit area relative to previous estimates used in UNFCCC reporting
- SOC accounts for more than 71 percent (65,244 Tg C) of the C stocks in forests of the US
- Great potential for continued C accumulation in soils on reforested lands
- Improvement but much variability and uncertainty remains...
Thanks!

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FIA carbon: http://www.fia.fs.fed.us/forestcarbon/

FIA program: www.fia.fs.fed.us