Modelling Global Land-Use and Land-Cover Impacts on Soil Physical Properties and Water-Holding Capacity

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Soil as A Bucket

Soil water-holding capacity (WHC)

Reduced WHC
Decreased Global AE and Increased Deficit and Surplus due to Soil WHC Changes under Human Land Uses

- Thornthwaite-type water balance model (Feddema, 2005)
- Areas of moist climates (but not constantly wet) and with high seasonality are most affected.
Soil WHC Changes by Human Land Uses
Estimating Soil WHC from Soil Properties

Soil Water-Holding Capacity (WHC)

Pedotransfer Functions modified from Saxton & Rawls (2006)

Soil organic carbon (SOC) content

Soil bulk density

Soil texture

Sand  Silt  Clay
How We Model Human-Induced Soil Property Changes

- How human land uses alter each soil property?
- How environmental conditions affect soil change?
- What’s the vulnerability of soil?
- How the impacts change with depth?
Meta-Analysis of Human-Induced Soil Property Changes

- **Soil properties:**
  pair observations (primary vegetation & disturbed)
  140 Papers with 737 paired observations

- **Environmental Factors:**
  NPP, slope, rainfall intensity, soil texture, moisture index, moisture index range
Estimating LULC Impacts along Depth
Soil Degradation Models

For each soil property of SOC, sand, silt, clay, BD:

$$\Delta\text{soil} = f (\text{LULC factors, NPP, slope, rainfall intensity, moisture index, moisture index range, clay content, depth factors})$$
Global Environmental Factors

- Moisture index (IM)
- Moisture index range (IMRange)
- Rainfall erosivity (R)
- Slope
- Soil depth
- NPP
Dominant LULCs on 4 Soil Groups of 2015

(Wang & Feddema, 2020)

+ Global Soil Datasets: SoilGrids250m (Hengl et al., 2017) → SOC, sand, silt, clay, bulk density
Potential SOC% Change under Global LULCs of 2015

- Increase SOC: pasture (4%) and light grazing (2%)
- Other human LULCs decrease SOC
Potential Soil Texture Change (%) under Global LULCs of 2015
Potential Soil Bulk Density Change (%) under Global LULCs of 2015

- All human LULCs increase soil bulk density (mean 6%) except grazing under dry environments
Soil WHC Changes under Different Land-Use Intensities

**Undisturbed Soil WHC**

**High intensity**
Agriculture = conventional tillage
Grazing = heavy intensity

**Low intensity**
Agriculture = no-till
Grazing = light intensity
Water Balance Change under Different Land-Use Intensities

Undisturbed

High intensity - Undisturbed

Low intensity - High intensity
## Global Mean Soil WHC Change (%) by Individual LULCs

<table>
<thead>
<tr>
<th>Land use</th>
<th>A: sandy</th>
<th>B: loamy</th>
<th>C: Sandy clay loam</th>
<th>D: clayey</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>annual cropland = conventional tillage</td>
<td>-14.06</td>
<td>-14.22</td>
<td>-14.30</td>
<td>-14.73</td>
<td>-14.34</td>
</tr>
<tr>
<td>annual cropland = no-till</td>
<td>-1.93</td>
<td>-6.43</td>
<td>-4.60</td>
<td>-8.68</td>
<td>-6.23</td>
</tr>
<tr>
<td>perennial cropland (no-till)</td>
<td>-2.37</td>
<td>-12.41</td>
<td>-5.46</td>
<td>-14.02</td>
<td>-10.66</td>
</tr>
<tr>
<td>grazing land = low intensity</td>
<td>4.23</td>
<td>0.54</td>
<td>-0.15</td>
<td>-4.33</td>
<td>1.15</td>
</tr>
<tr>
<td>grazing land = heavy intensity</td>
<td>-7.58</td>
<td>-6.07</td>
<td>-7.07</td>
<td>-5.80</td>
<td>-6.74</td>
</tr>
</tbody>
</table>

- Largest impact: conventional tillage
- Positive impact: low-intensity grazing
- Clayey soils show higher impacts by high intensity human LUs
Summary and Future Work

• Conventional tillage has the largest impact on soil WHC
• Water balance: moist climates with high seasonality are most affected by changed soil WHC
• Land use management such as rotating light and heavy land uses can potentially recover/improve soil WHC

Future work:
• Including soil erosion
• Constructing historical soil property datasets
• Applying in Earth system models
Thank You!

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