Technical Appendix 1

Methods for Assessing Soil Organic Carbon of Massachusetts Land Cover Classes in the 2021 Massachusetts Healthy Soils Action Plan

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Summary of the Process

In order to provide Soil Organic Carbon (SOC) estimates for all 20 major land cover classes in Massachusetts (2016 High Resolution Land Cover plus the HSAP forest class) the Healthy Soils Action Plan researchers combined two methods. The first method relied on weighted averages of SOC by land cover and drainage class. The landcovers calculated with this method consisted of Cropland, Pasture, Grasslands, and Forest. For all other land cover classes, soil organic carbon estimates were derived from a meta-analysis of peer-reviewed research describing SOC values by land cover type combined with SSURGO SOC averages for those areas.

Below is a detailed summary of the process and inputs used for each method.

Method One: Estimating SOC for Cropland, Pasture, Grasslands, and Forest Using RCA Data.

As part of the Massachusetts Healthy Soils Action Plan researchers from Regenerative Design Group and associates Eric Toensmier and Rafter Ferguson, in cooperation with the Soil Survey (Maggie Payne, Mass NRCS) and with input from the National Rapid Carbon Assessment investigators (NRCS, LIncoln NE) investigated the relationship between Soil Organic Carbon (SOC), land cover, and soil drainage class to better understand if the SOC estimates derived from NRCS SSURGO typical pedons could be refined. The SOC values found in SSURGO are based on a representative or typical soil pedon. However, these values do not reflect land cover or land use history of a particular area.

This study began in March 2020 with the hypothesis that soil organic carbon levels are affected by land cover/land use and influenced by the soil drainage class. An analysis of soil sample data within 100 mi of MA from both the Rapid Carbon Assessment and the National Cooperative Soil Characterization Database confirmed that landcover, when isolated by drainage class, plays a large role in SOC levels.

Our team identified two distinct data sets derived from real world soil samples with laboratory testing:

First we analyzed the National Cooperative Soil Characterization Database (SCDB). Collected by the Soil Survey of the NRCS over 50 years, our original data set began with 1,100 points within 100-mi of Massachusetts. After filtering for presence of vegetation descriptions and complete 100 cm SOC values this unfortunately yielded a small sample of only 48 complete points.

We then analyzed the Rapid Carbon Assessment (RCA) database that consisted of a total 166 points within 100-mi of Massachusetts' borders with a dataset that ended up with 154 points qualifying for inclusion. These points were collected and tested between 2010 and 2015 by the USDA-NRCS Soil Science Division.

Because the RCA had a larger dataset and it was focused on soil carbon, we decided to use it as our preliminary dataset. After determining that the SCDB data was compatible with the RCA data we included the 48 points filtered from the SCDB to create a composite dataset consisting of 202 sample points for analysis.

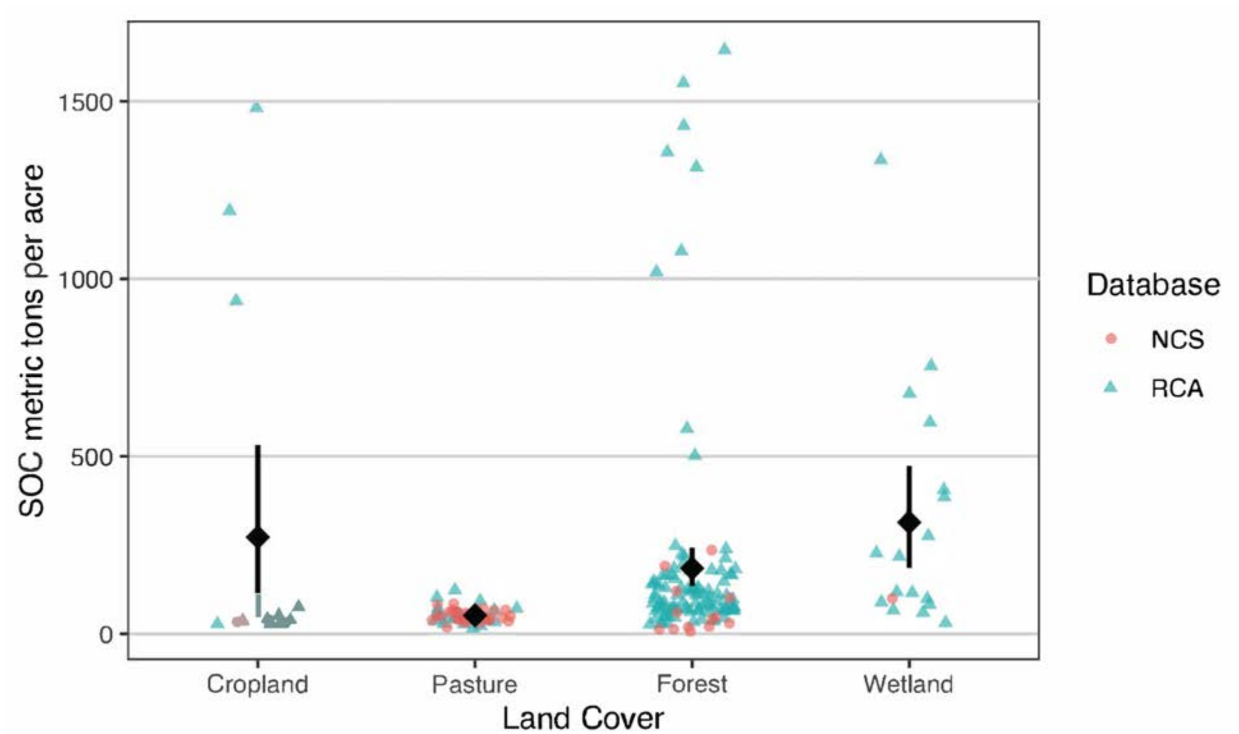

Figure 1: All the points plotted by land cover.

DRAINAGE CLASS

Examining the influence of drainage class on SOC concentrations within and between land cover classes was a significant objective of this project. While the RCA data does not record an associated drainage class for the sample points, we were able to assign the drainage class values from the SSURGO soil polygons dataset using the geographic location of RCA sample points obtained from RCA staff.

Once all points were classified by drainage class, the very poorly draining soils showed by far the highest concentration of SOC and made the relationship between land cover in the other drainage classes harder to see.

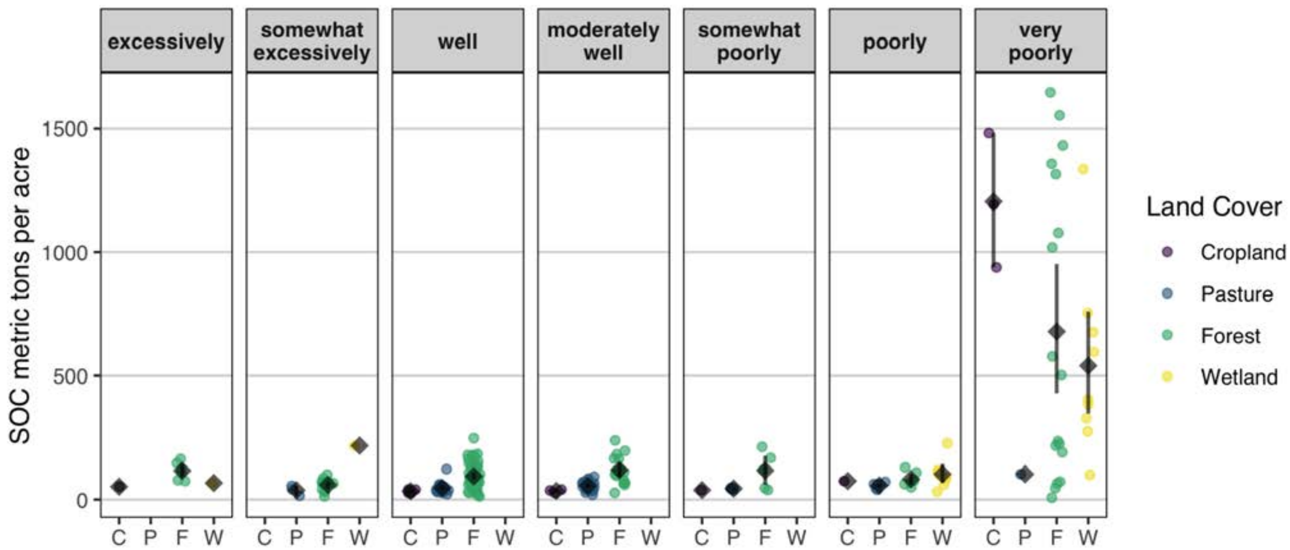

Figure 2: The analysis on the 154 valid RCA points within 100 miles of the MA border broken down by vegetation and drainage class.

Once points of the Very Poorly Drained Drainage Class were removed, land cover showed a clear trend in SOC concentrations. We looked for separation by comparing bootstrap means and confidence intervals.

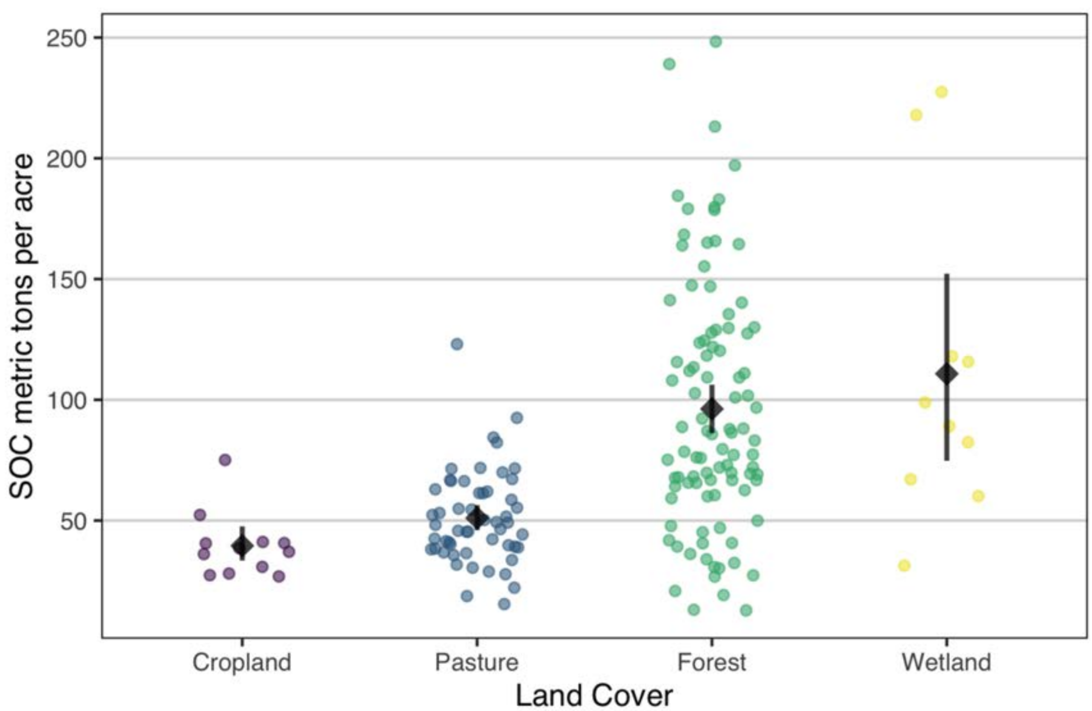

Figure 3: SOC by land cover with very poorly draining filtered out.

However the trends we saw in land cover alone persisted in most of the drainage classes when filtered by land cover and drainage class.

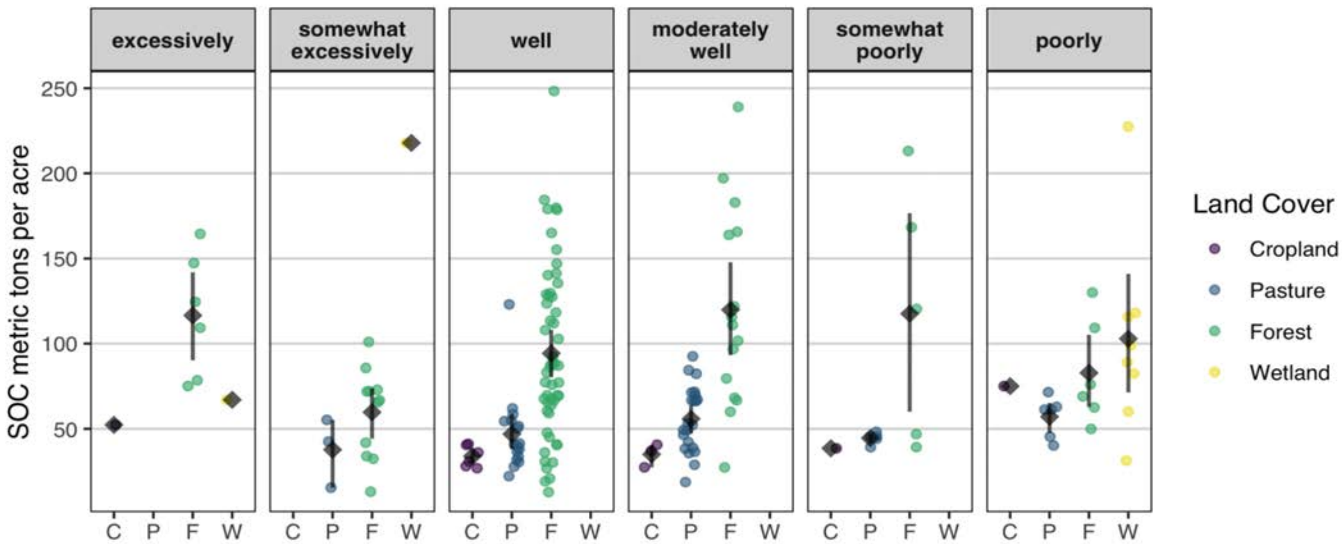

Figure 4: SOC by land cover and drainage class

We used the geometric mean of the land cover and drainage class to assign an SOC value for each land cover drainage class combination.

Taking the acres those areas represented we calculated a statewide weighted average for each of the following land covers;

- Cropland = 32.7 metric tons per acre
- Pasture = 51 metric tons per acre
- Grassland = 45.7 metric tons per acre
- Forest = 86.7 metric tons per acre
- Wetland = 334 metric tons per acre

Method Two: Meta-Analysis Derived SOC Estimates for All Other Land Covers Classes

Where land cover specific SOC data was not available in the National Rapid Carbon Assessment (RCA), SOC was estimated using values derived from two sources; 1. A meta-analysis of peer reviewed literature, led by Eric Toensmeier, on Soil Organic Carbon (SOC) stocks found in different land cover classes, and 2. SSURGO/STATSGO SOC averages by land cover.

The literature data points used were mostly from the Northeast US, but some were from global temperate climate resources. Some land covers did not have good data to derive a SOC value from. In those cases we used the very conservative value that was calculated for impervious surfaces. It is likely that this resulted in an underestimation of SOC for many of these land covers. These land covers included non-forest trees, unconsolidated shores, barren lands, open waters, and aquatic beds.

Final SOC Estimates by Landcover

The following table includes all of the final values and sources used to estimate the total stocks and fluxes of Soil Organic Carbon in the Massachusetts Healthy Soils Action Plan.

2016 High Resolution Land Cover Class	Metric Tons of SOC per Acre	Source of SOC Value
Impervious (2)	22	Meta analysis
Developed or Open Space (5)	40	Meta analysis
Cultivated Crops (6)	33	SOC Assessment
Pasture or Hay (7)	51	SOC Assessment
Grassland or Herbaceous (8)	46	SOC Assessment
Deciduous Trees- non forest (9)	22	Meta analysis
Evergreen Trees- non forest (10)	22	Meta analysis
Forest (11)	87	SOC Assessment
Scrub/Shrub (12)	49	Meta analysis
Palustrine Forested Wetland (13)	334	Meta analysis
Palustrine Scrub/Shrub Wetland (14)	334	Meta analysis
Palustrine Emergent Wetland (Persistent) (15)	334	Meta analysis
Estuarine Forested Wetland (16)	161	Meta analysis
Estuarine Scrub/Shrub Wetland (17)	161	Meta analysis
Estuarine Emergent Wetland (18)	161	Meta analysis
Unconsolidated Shore (19)	22	Meta analysis
Barren Land (20)	22	Meta analysis
Open Water (21)	22	Meta analysis
Palustrine Aquatic Bed (22)	22	Meta analysis
Estuarine Aquatic Bed (23)	22	Meta analysis

References

GIS Data Layers and Processing Notes

Soil Carbon

NRCS SSURGO/STATSGO SOC

- Inputs
  - We used the NRCS SSURGO valu1 table SOC_0-100cm SOC vlaues except in undefined areas in the SSURGO data such as urban areas, mines and water in those cases we used the numbers from the USDA carbonscapes STATSGO2 SOC 0-100cm.
- Processing
  - To fill in areas that were undefined in the SSURGO data such as urban areas, mines and water. We used the data from: Carbonscapes https://opendata.wvgis.wvu.edu/portal/home/item.html?id=cc3fff9716284a94af43c78678091713 Downloaded as a 100x100m raster and as a personal geodatabase that we extracted the table from and joined it to the layer STATSgdb and created a new raster file with the values from STATSGO2 SOC 0-100cm. A new attribute was created in the SSURGO value 1 table that was the average value in each soil polygon from the STATSGO2 SOC 0-100cm raster. We then created another attribute that used the values from STATSGO2 if they were missing in SSURGO.

2016 High Resolution Land Cover with Forests

- Inputs
  - Massachusetts 2016 High Resolution 1 meter Land Cover Data obtained through the NOAA data access viewer. Downloaded as multiple raster files.
- Processing
  - Preprocessing of the Massachusetts 2016 High Resolution Land Cover
    - The 2016 Landcover rasters were merged into one virtual raster (.vrt) using GDAL Build Virtual Raster in QGIS.
    - The resulting raster was clipped to the MA 25k state boundary GDAL Clip Raster by Mask Layer in QGIS.
    - Resampled to 3m resolution using the GDAL warp with nearest neighbor.
    - Saved as a packbits compressed unsigned 8bit raster tif file with 255 as nodata projected to EPSG 26986 NAD83 / Massachusetts Mainland Meters.
  - Isolating Forests from Trees
    - Reclassed the 2016 LC data to include only tree values (9,10,11,13,16).
    - Vectorized the resulting raster.
    - Removed any polygons less than 1 acre in size.
    - Did an internal buffer of -60 feet to remove any treed areas narrower than 120’.
    - Buffered the resulting layer by 60 feet to return any areas 0ver 120 wide back to their original size.
    - Removed any polygons less than 1 acre in size.

    - Buffered the resulting polygons by an additional 3m (the pixel size) to capture all of the original pixels.
    - Reclass LC to only include (9,10,11) Clip the original polygons by the +3 three polygons.
    - Rasterized the resulting layer. (forested areas not wetland)
  - Combining the Forest not Trees and the Massachusetts 2016 High Resolution Land Cover
    - Used the SAGA GIS **Patching** algorithm in QGIS to replace the tree areas (values 9,10) with Mixed Forest (value 11)
    - Saved as a packbits compressed unsigned 8bit raster tif file with 255 as nodata projected to EPSG 26986 NAD83 / Massachusetts Mainland Meters.

Meta-Analysis Works Cited

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