Wetland Soil Organic Carbon Stocks of the Conterminous United States:

Utilizing Data from the National Wetland Condition Assessment (NWCA) 2011

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Soil Organic Carbon and Wetlands

Wetland soils play an important role in global carbon cycles because they represent a large carbon pool and have potentially high carbon sequestration and/or emission rates. This study uses data collected in the National Wetland Condition Assessment to estimate wetland soil carbon stocks across the conterminous U.S.

The National Wetland Condition Assessment

The National Wetland Condition Assessment (NWCA) is the first national evaluation of the ecological condition of the nation's wetlands. The NWCA is part of a broader effort by EPA and state, tribal, and federal partners to conduct national scale assessments characterizing the ecological condition of the nation's waters. Under the National Aquatic Resource Survey (NARS) program, studies have been completed for lakes, rivers and streams, coastal waters, and wetlands. The NWCA is designed to answer basic questions about the condition of our nation's wetlands and the prevalence of key stressors at national and regional scales.

NWCA 2011 Survey Design and Sampling

NWCA target wetlands include tidal and nontidal wetlands within the conterminous U.S. with rooted vegetation, and when present, shallow open water <1.0 m deep, that are not currently being used for crop production. Sites were selected using the same digital map of wetland locations used by the U.S. Fish and Wildlife Service (FWS) Wetlands Status and Trends Program in 2005.

Using a Generalized Random Tessellation Stratified (GRTS) survey design, 967 wetland points were selected for sampling. The NWCA estimated there are 95 million acres of wetlands in the target population. The probability sites sampled by NWCA 2011 represent 62 million acres of wetlands in the conterminous U.S. (Table 1).

In order to assess wetland condition for distinct wetland types at national and regional scales with an acceptable degree of statistical certainty, Omernik Level III Ecoregions (Omernik 1987) were combined into four NWCA Aggregated Ecoregions. Within each ecoregion, NWCA grouped wetlands into one of four NWCA Aggregated Wetland Types.

Table 1. Wetland area assessed in NWCA 2011 by ecoregion and wetland type.

Ecoregion	NWCA Wetland Type	Sampled Sites in Target Population	Area Represented		Sites with Soil Organic Carbon data 0-50 cm	Area Represented by Soil Sampling	
			acres	% of Target Population		acres	% of Target Population
National	All	967	62,156,199	100	633	40,062,044	65
	Estuarine Herbaceous	258	4,987,824	8	174	2,971,663	5
	Estuarine Woody	69	497,821	1	50	471,112	0.8
	Inland Herbaceous	302	13,599,611	22	196	8,888,327	14
	Inland Woody	338	43,070,943	69	213	27,730,942	45
Coastal Plain	All	513	30,893,305	50	330	19,770,666	32
	Estuarine Wetlands	288	5,283,489	9	197	3,305,604	5
	Inland Herbaceous	62	3,750,551	6	33	2,447,072	4
	Inland Woody	163	21,859,265	35	100	14,017,990	23
Eastern Mountains & Upper Midwest	All	152	19,956,668	32	107	12,130,327	20
	Estuarine Wetlands	14	29,173	0.04	12	27,057	0.04
	Inland Herbaceous	55	3,762,089	6	39	2,413,476	4
	Inland Woody	83	16,165,406	26	56	9,689,794	16
Interior Plains	All	156	7,659,166	12	116	5,554,756	9
	Estuarine Wetlands	0	0	0	0	0	0
	Inland Herbaceous	115	4,598,831	7	88	3,203,672	5
	Inland Woody	41	3,060,335	5	28	2,351,084	4
West	All	146	3,647,060	6	80	2,606,294	4
	Estuarine Wetlands	25	172,985	0.3	15	110,113	0.2
	Inland Herbaceous	70	1,488,139	2	36	824,107	1
	Inland Woody	51	1,985,936	3	29	1,672,074	3

NWCA 2011 Soil Sampling and Laboratory Analysis

At each sampling point, field crews described four soil profiles to a depth of 60 cm. Soil pit locations were based on the assessment area layout and generally associated with vegetation plots. A representative pit was selected for further description and sampling. Soils were sampled by horizon to a depth of 125 cm in the representative pit. Bulk density samples from each horizon (to 60 cm) were collected using a 3 in. diameter stainless steel core.

Soil samples were analyzed at the Natural Resources Conservation Service Kellogg Soil Survey Lab, Lincoln, NE. Total carbon was measured by dry combustion using a elemental analyzer (Soil Survey Staff, 2014). When present, inorganic carbon (measured as $CaCO_3$) was subtracted from the total carbon to determine organic carbon concentrations. Samples from approximately 43 sites in North Dakota were analyzed by the NDSU state soil testing lab. For these samples, organic matter was measured by loss on ignition; organic carbon was estimated using the equation:

$$Organic\ Carbon\ (\%) = \frac{Organic\ Matter\ (\%)}{1.72}$$

Data Analysis and Calculation of Soil Organic Carbon Stocks

Due to difficulties sampling under inundated or saturated soil conditions, soil could not always be collected at each site or for every horizon to 125 cm. For some horizons (approximately 30%), bulk density was estimated using a regression model developed from available NWCA soil data. Bulk density was estimated as function of organic carbon content (Fig. 1).

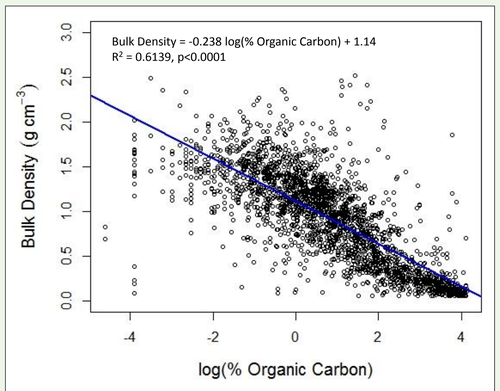

Fig. 1. Bulk density of NWCA 2011 soil samples as a function of organic carbon.

Acknowledgements

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Carbon density was calculated for each horizon using organic carbon concentration and bulk density values. The Algorithms for Quantitative Pedology (aqp) package in R was used to divide soil profiles into 1 cm thick "slices", with each slice assigned the carbon density value of the horizon (Fig. 2).

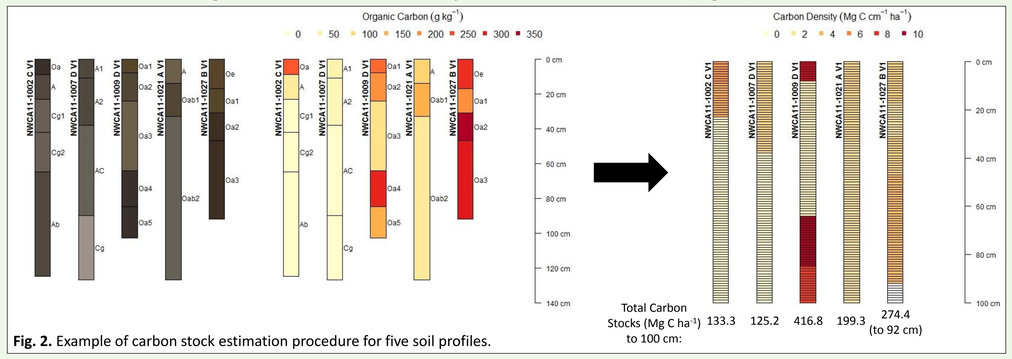

Fig. 2. Example of carbon stock estimation procedure for five soil profiles.

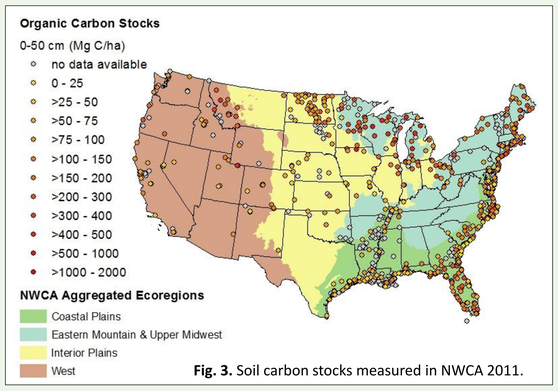

Fig. 3. Soil carbon stocks measured in NWCA 2011.

By summing the carbon densities of the "slices", carbon stocks were calculated to depths of 5, 10, 20, 30, 50, and 100 cm. Carbon stocks were only calculated when soil data was available for every horizon from 0 cm to the depth of interest, so complete soil carbon stocks data is not available for the entire population (Table 1 shows the proportion of the population represented by sites where soil carbon stocks could be calculated to 50 cm). Sample point locations and soil carbon stocks calculated to 50 cm are shown in Fig. 3.

Assessing Soil Carbon Stocks Using Wetland Population Estimates

The NWCA (along with the other NARS assessments) is designed to assess water bodies as groups or populations, rather than as individual waters. Data collected cannot be used to represent or evaluate a specific wetland, but instead can be used to assess populations of wetlands nationally or within ecoregions. Each sample point represents a known wetland area based on survey design adjusted weights. The site weights were used to estimate the cumulative distribution of soil carbon stocks for each of the NWCA Ecoregions and Aggregated Wetland Types. The distribution of carbon stocks (0-50 cm) for wetland area nationally and for each of the NWCA reporting groups is shown in Fig. 4.

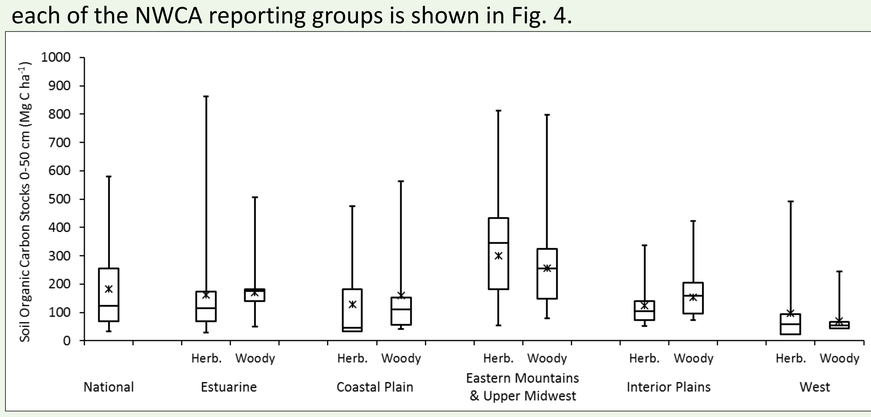

Fig. 4. Distribution of soil carbon stocks to 50 cm for wetland acres nationally and in each of the NWCA reporting groups. The boxes display the interquartile range, 25% to 75% of wetland area within the group, and the error bars show the 5th and 95th percentiles. The mean carbon stock value for the population of wetlands within a reporting group is shown with an asterisk.

Average carbon stock for wetland area nationally was estimated to be 182.0 ± 10.6 Mg C ha^{-1} (based on 65% of the target wetland area). As might be expected, carbon stocks vary widely within each of the reporting groups, likely due to differences in hydrology, soil parent material, and climate within these groups. However, there are apparent differences in the ranges and average carbon stocks between reporting groups.

Organic carbon accumulations in wetland soils often extend much deeper than 50 cm, and these values likely underestimate the total soil carbon pool. Based on a more limited data set (43% of wetland area assessed by NWCA), average soil organic carbon stock to 100 cm was estimated to be 293.1 ± 24.4 Mg C ha^{-1} for wetland area nationally. For comparison, average carbon stock to 50 cm for this same (smaller) data set was 172.7 ± 10.9 Mg C ha^{-1}.

The probability based survey design of the NWCA makes the measured stock values particularly useful for estimating soil carbon stocks at national and regional scales. However, the proportion of unassessed area may introduce a bias to the estimates. At some sites, thin buried surface horizons were not sampled and it was often difficult to sample soils at inundated sites. As a result, carbon stocks could not be estimated for wetland area represented by these sample points. It may not be appropriate to assume that carbon stocks of sampled sites are reflective of wetland areas not assessed.

Next Steps and Future Research Areas

The NWCA will be conducted on a five year schedule, with the next survey occurring in 2016. Efforts are being made to improve soil sampling protocols to obtain a more complete soil data set. Research will continue to investigate how site weights can be used to make more precise national and regional estimates of total soil carbon stocks, and data from future surveys will be used to evaluate trends in wetland soil carbon stocks. Additionally future research efforts will focus on using soil organic carbon (and other soil properties) as indicators of wetland ecological condition.

The draft Public Report and data from NWCA 2011 have been published for public comment and are available online. For more information on NWCA and the NARS program, visit: http://www2.epa.gov/national-aquatic-resource-surveys.