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Rapid Assessment of U.S. Soil Carbon (RaCA) for Climate Change and Conservation Planning

Summary of Soil Carbon Stocks for the Conterminous United States

May 24, 2013

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The Rapid Carbon Assessment (RaCA) project sampled for soil organic carbon across the conterminous United States.

This report is the initial summary of soil carbon stock data from the RaCA project. It is intended to describe, in general, the amounts and distribution of mean soil organic carbon stocks for the conterminous United States. Additional reports and other publications are being developed to provide similar overviews of other data derived from RaCA, including concentration of soil organic carbon, concentration of soil inorganic carbon, and bulk density for sampled horizons and concentration and distribution of soil carbon stocks by depth. Raw data are being made available to research cooperators for additional spatial and statistical analysis. These data and data summaries will also be available for NRCS personnel and external users.

The Rapid Assessment of U.S. Soil Carbon, RaCA, was initiated by the NRCS Soil Science Division in 2010 with the following objectives:

1. To develop statistically reliable quantitative estimates of amounts and distribution of carbon stocks for U.S. soils under various land covers and, to the extent possible, differing agricultural management.
2. To provide data to support model simulations of soil carbon change related to land use change, agricultural management, conservation practices, and climate change.
3. To provide a scientifically and statistically defensible inventory of soil carbon stocks for the United States.

To accomplish these objectives, NRCS collected 144,833 samples from the upper 1 meter of 32,084 soil profiles at 6,017 randomly selected locations. Measurements were taken of organic and inorganic carbon by visible and near infrared (VNIR) spectroscopy. Measurements were taken of bulk density by traditional methods. Sites from the National Resources Inventory (NRI) were used as the basis for random selection of sample sites stratified by soil group within RaCA region and by land use-land cover (LULC) classification within soil group. The RaCA regions were identical to the areas of responsibility of the NRCS Major Land Resource Area Regional Offices at the time of sampling (fig. 1). At each sample site, soil morphology and landscape characteristics were described and limited information regarding vegetation and agricultural management was collected. Sample

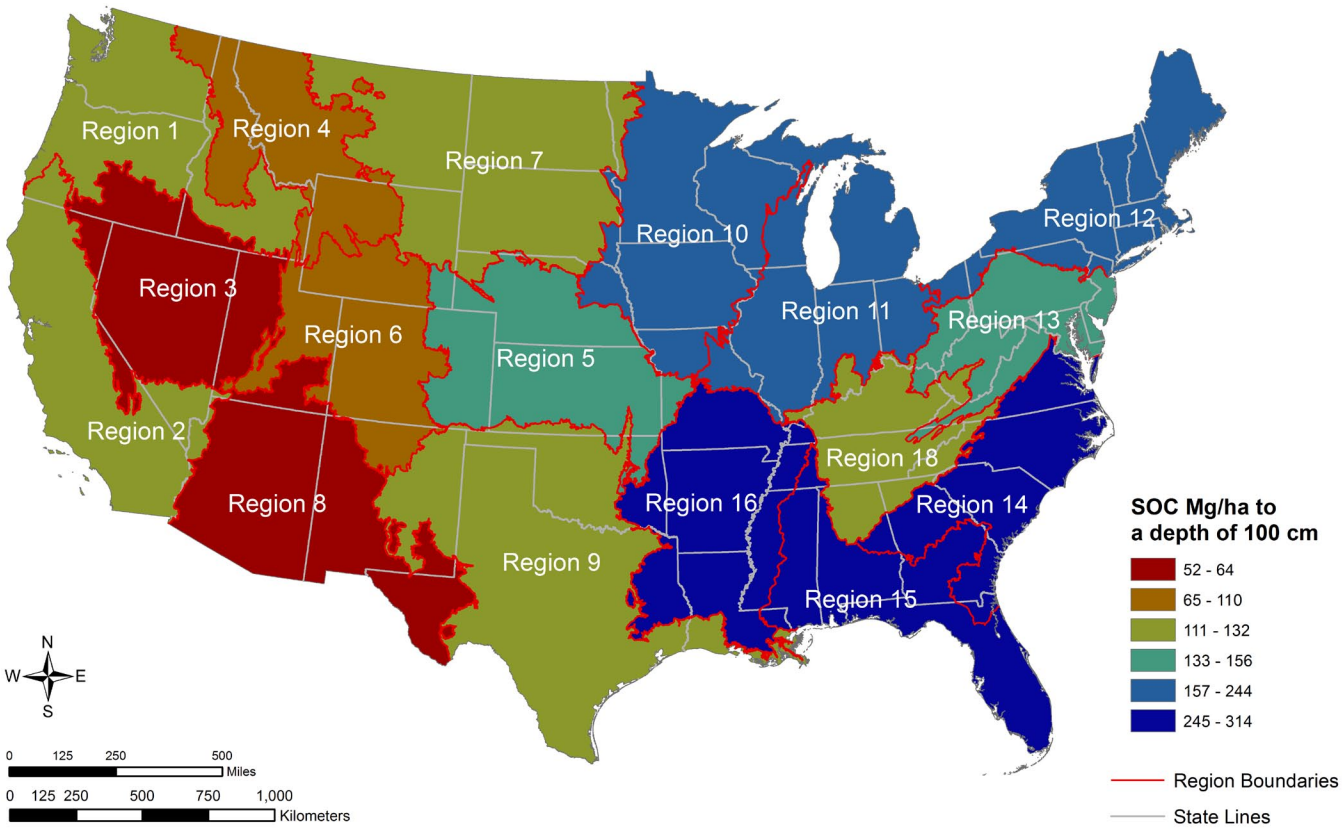

Figure 1.—Geometric mean of SOC stocks to 1 meter depth for RaCA regions.

collection and analysis involved more than 300 soil scientists and assistance from 22 universities. Details of the methods used in sample collection and analysis are available in a separate document (Wills et al., 2013).

A cluster-nested design incorporating RaCA region, soil group, LULC, and site allowed for estimation of uncertainty of soil organic carbon (SOC) at multiple scales. Monte Carlo simulation was used to assign uncertainty for SOC stocks by pedon, including sample SOC prediction uncertainty and bulk density error distributions. Average SOC stocks for combinations of soil group and LULC were mapped by linking the values to a January 2012 Soil Survey Geographic Database (SSURGO) raster that included map unit and National Land Cover Database (NLCD) classification. Only the geometric means of SOC stocks are reported here. Additional evaluation and interpretations that include uncertainty estimates will be forthcoming.

The estimated overall average of SOC stocks in the upper 1 meter of soil for the conterminous United States was 146 Mg/ha, which is higher than previous estimates. The previous estimates were based on data from the Soil Survey

Geographic Database (SSURGO) and the State Soil Geographic Database (STATSGO) without consideration of LULC classification (Bliss et al., 1995; Bliss, 2003; Waltman et al., 2010; West et al., 2010). Regional estimates of mean SOC stocks ranged from 53 Mg/ha in RaCA Region 3 (the arid southwestern U.S.) to 314 Mg/ha in RaCA Region 14 (southeastern U.S.) (fig. 1 and table 1). In general, the distribution of SOC stocks to a depth of 1 meter among the regions and across the nation was as expected with the exception of the amount of SOC in the southern U.S. (figs. 1 and 2 and table 1).

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Table 1.—Geometric Mean of SOC Stocks to 1 Meter Depth in the Conterminous United States

RaCA Region[1]	Land Use-Land Cover[2]						**Region Mean[3]**
	Crop-land	Forest-land	Pasture-land	Range-land	Wetland	CRP	
	----------Mg SOC/ha----------						
1	120	242	157	92	242	110	**130**
2	188	220	260	95	215	172	**133**
3	103	71	127	46	187	100	**53**
4	150	103	134	103	201	134	**110**
5	158	179	255	136	227	168	**154**
6	138	92	131	84	164	125	**89**
7	172	130	179	108	310	176	**132**
8	96	91	99	61	63	108	**64**
9	158	148	199	111	285	140	**131**
10	213	259	189	173	766	204	**244**
11	203	237	176	---	582	---	**220**
12	155	228	159	---	652	129	**224**
13	121	159	132	---	738	49	**156**
14	173	302	341	---	494	331	**314**
15	279	183	339	342	420	143	**269**
16	255	279	363	327	357	326	**302**
18	143	115	130	---	112	124	**120**
LULC mean[4]	**180**	**182**	**206**	**93**	**428**	**161**	**146**

[1] RaCA regions are identical to the MLRA Office regions prior to reorganization in 2012.

[2] Area weighted geometric mean based on proportion of LULC in each soil group within each region.

[3] Area weighted geometric mean based on proportion of region in each LULC.

[4] Area weighted geometric mean based on proportion of LULC in each region.

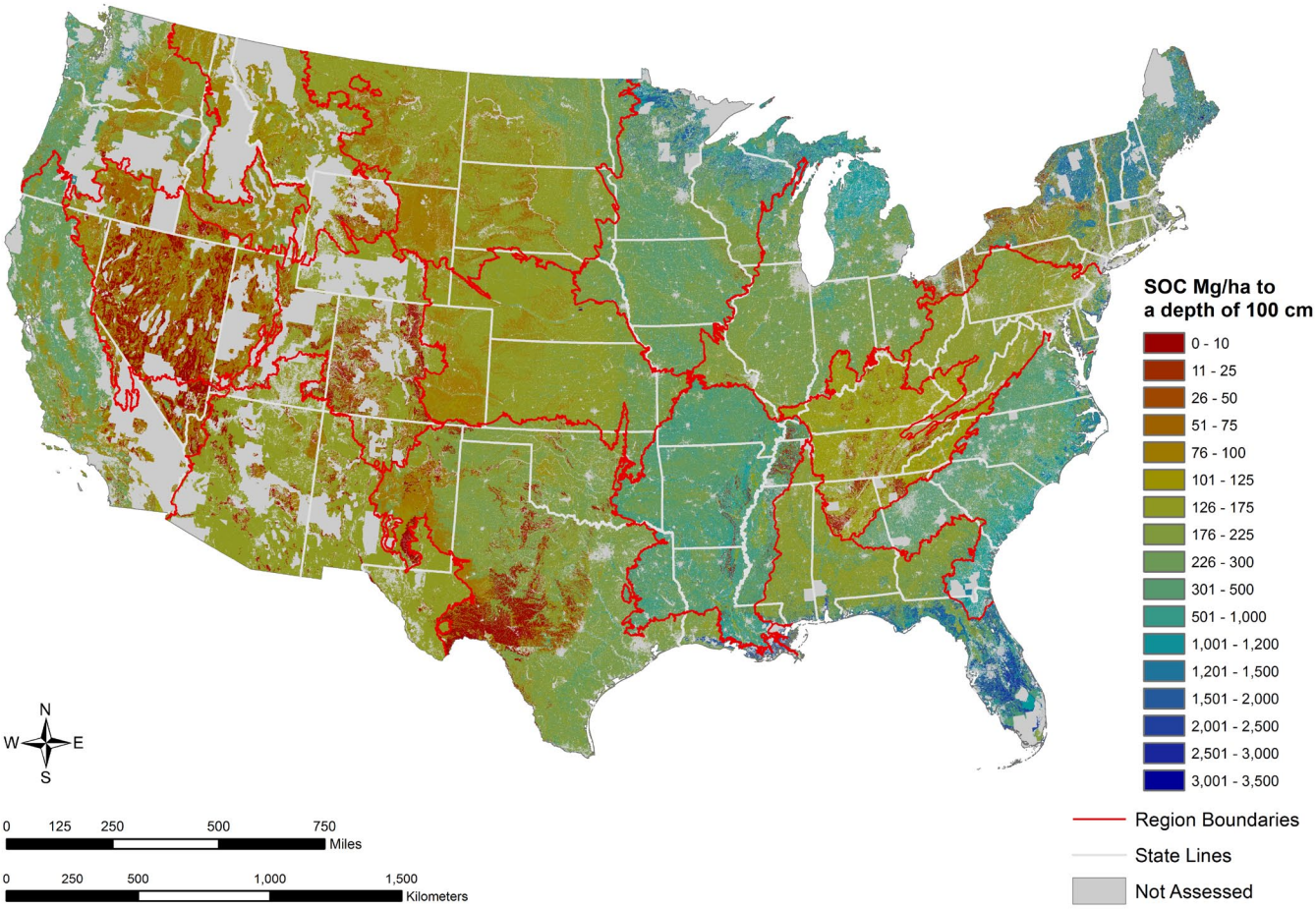

Figure 2.—Spatial distribution of geometric means of SOC stocks to 1 meter depth for the conterminous United States. Gray areas did not have SSURGO data as of December 2010 or were urban areas, roads, or other areas of development that were not included in the sampling plan.

Regions 1, 2, 4, 5, 7, and 9 had mean SOC stocks that ranged from 130 to 154 Mg/ha (table 1). These regions represent a wide variety of soil, landscape, and climatic conditions. Much of the area covered by these regions is semi-arid, but also included are more humid areas at high elevations and areas of desert, especially in Regions 1, 2, and 4. Regions 5, 7, and 9 include a major part of the semi-arid Great Plains in the central part of the country. Soils in these regions developed dominantly under grassland vegetation, and the current dominant land use-land cover classes are cropland and rangeland. Regions 1, 2, and 4 include forested mountain landscapes with common shallow and rocky soils, valleys with cropland and rangeland, and high deserts.

Regions 14, 15, and 16 were the only regions that had mean SOC stocks greater than 250 Mg/ha (table 1). This result was unexpected because surface horizons in

this part of the country have relatively low SOC concentrations. It should be noted that results presented here are for SOC stocks to a depth of 1 meter. Calculation of SOC stocks included, in addition to concentrations of SOC for each horizon to a depth of 1 meter, bulk density and content of coarse fragments for each horizon. Soil depth of less than 1 meter to bedrock also has an appreciable effect on SOC stock. Soils in Regions 14, 15, and 16 are generally deep and commonly have horizons with relatively high bulk density as compared to soils in other parts of the United States. Also, these regions have a high proportion of high-productivity forestlands, large areas of poorly drained soils in coastal areas and along major rivers, abundant organic soils (including the Everglades in Florida), and Spodosols with accumulation of organic carbon in the subsoil. This combination of conditions resulted in the relatively high mean SOC stocks for this part of the country.

Among land use-land cover classes, wetlands had the highest mean soil organic carbon stocks and rangelands had the lowest.

Regions 3, 6, and 8, which include a major part of the arid region of the United States, had the lowest mean SOC stocks among the regions. Regions 3, 6, and 8 had means of 53, 89, and 64 Mg/ha, respectively (fig. 1 and table 1). The relative mean quantities of SOC among the other regions generally followed a precipitation gradient. Regions 10, 11, 12, and 13, in high-latitude parts of the humid east, had mean SOC stocks that ranged from 156 to 244 Mg/ha (table 1). Regions 10 and 11 contain an appreciable part of the "corn belt" as well as large areas of poorly drained soils and forested landscapes in extreme northern latitudes. Regions 12 and 13 are dominated by the northern part of the Appalachian Mountains and have extensive forested areas in these mountains.

Among LULC classes, wetlands had the highest mean SOC stocks. The mean was about 428 Mg/ha. Rangelands had the lowest mean SOC stocks, 93 Mg/ha (table 1). Soils in the Conservation Reserve Program (CRP) also had relatively low nationwide mean SOC stocks, 161 Mg/ha. Relatively low SOC stocks for lands in the CRP is not surprising. Soils in these areas are considered erodible and may have lost all or part of their surface horizons through past erosion. Pastureland, forestland, and cropland had mean SOC stocks of 206, 182, and 180 Mg/ha, respectively. Greater differences among these LULC classes may have been expected, but these nationwide means include great variations in soil and climatic conditions that, at least partially, overshadow local and regional differences in SOC stocks related to differences in LULC classes.

Within regions, the relative amount of SOC stocks varied among LULC classes. Excluding wetlands and CRP, which are LULC classes with variable vegetative cover, forestland or pastureland were the classes that had the highest mean SOC stocks for 14 of the 17 regions. In the other three regions, 4, 6, and 18, cropland had the highest SOC stocks (table 1). Rangeland was identified as a LULC class

in 12 of the 17 regions. In 10 of these 12 regions, rangeland had the lowest SOC stocks of the LULC classes. These 10 regions (1, 2, 3, 4, 5, 6, 7, 8, 9, and 10) are all in the western part of the United States. Additional analysis will be required to fully evaluate the effects of LULC class on SOC stocks within regions.

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