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A Guide to Potential Soil Carbon Sequestration

Land-Use Management for Mitigation of Greenhouse Gas Emissions

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Terrestrial carbon sequestration has a potential role in reducing the recent increase in atmospheric carbon dioxide (CO_2) that is, in part, contributing to global warming. Because the most stable long-term surface reservoir for carbon is the soil, changes in agriculture and forestry can potentially reduce atmospheric CO_2 through increased soil-carbon storage. If local governments and regional planning agencies are to effect changes in land-use management that could mitigate the impacts of increased greenhouse gas (GHG) emissions, it is essential to know how carbon is cycled and distributed on the landscape. Only then can a cost/benefit analysis be applied to carbon sequestration as a potential land-use management tool for mitigation of GHG emissions.

For the past several years, the U.S. Geological Survey (USGS) has been researching the role of terrestrial carbon in the global carbon cycle. Data from these investigations now allow the USGS to begin to (1) "map" carbon at national, regional, and local scales; (2) calculate present carbon storage at land surface; and (3) identify those areas having the greatest potential to sequester carbon.

Ongoing efforts of the USGS to achieve these objectives are:

- compilation and synthesis of site-specific data needed to estimate carbon storage and inventory in soils, reservoir sediments, wetlands, and lakes of the conterminous United States;
- characterization of present-day carbon storage by landscape feature and environment; and
- prediction of potential carbon storage for land areas identified as possible reservoirs for carbon sequestration.

Black Mountain Range, western North Carolina—an area of high carbon soils—looking north from summit of Mount Mitchell, highest peak in eastern United States. (Photograph by Alan M. Cressler, USGS, 1996.)

The initial task required to accomplish the objectives outlined above is to determine current levels of terrestrial soil organic carbon (SOC) storage, and thus enable estimates to be made of net changes in SOC storage related to land use and climate change. Although there may be a sufficient density of site-specific data to spatially distribute SOC storage values in selected geographic areas, the most readily available method to estimate SOC inventory for the surface meter of any land area in the United States is to (1) calculate site-specific SOC storage for mineral soils (not including surface-organic matter or organic soils such as peat); and then (2) link these data to one of two U.S. Department of Agriculture–Natural Resources Conservation Service (USDA–NRCS) soil geographic databases (U.S. Department of Agriculture, 2001b,c)—the State Soil Geographic database (STATSGO, 1:250,000) or the Soil Survey Geographic database (SSURGO, 1:24,000). These databases provide a powerful GIS framework for calculating SOC inventories at scales ranging from national (STATSGO) to county (SSURGO).

U.S. Department of the Interior
U.S. Geological Survey

Open-File Report 01-374

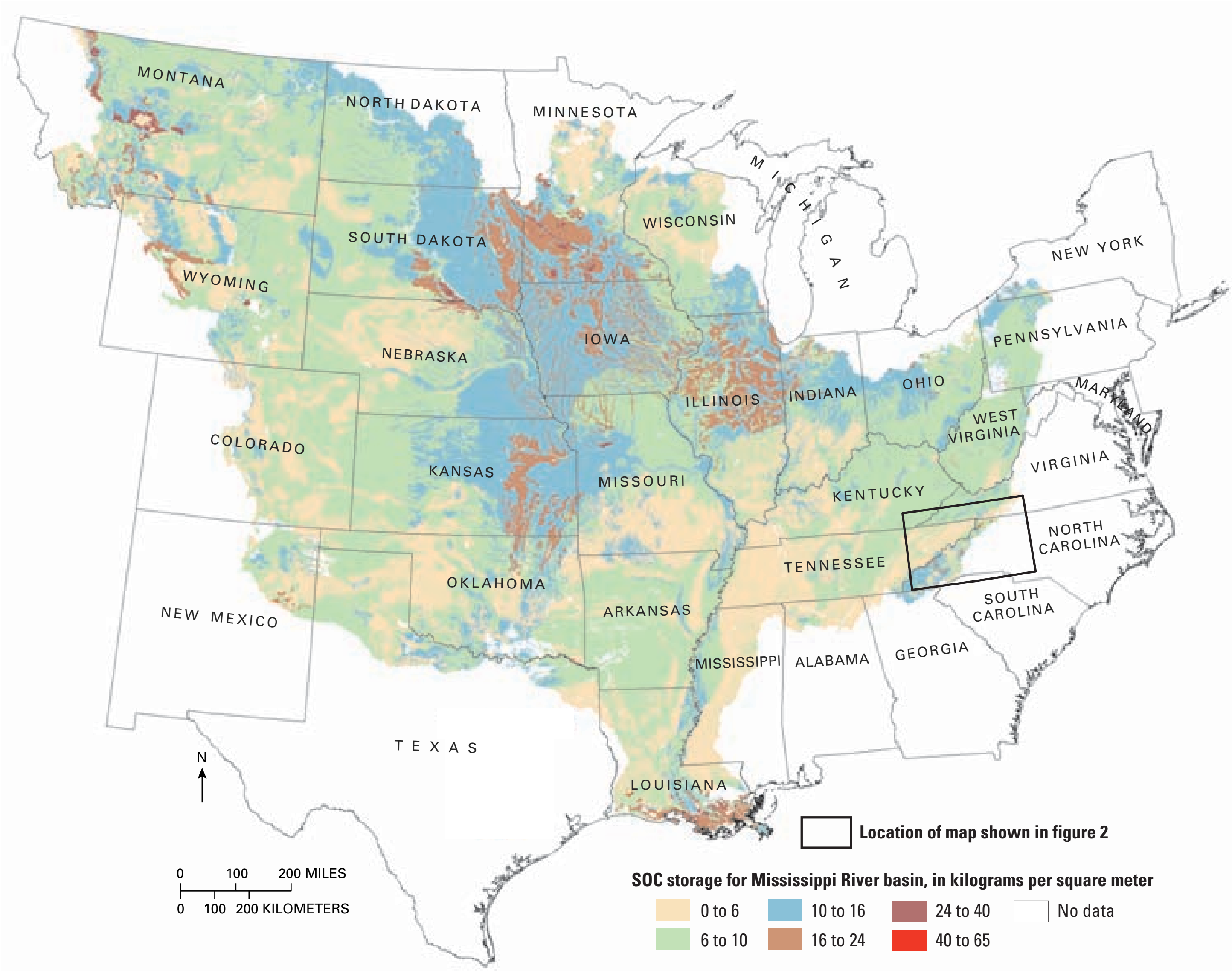

Figure 1. The above map shows regional patterns in SOC storage for the surface meter of mineral soil/parent material within the Mississippi River basin (STATSGO, 1:250,000 map units). SOC inventory for the surface meter of the entire Mississippi River basin is approximately 33 Petagrams (33×10^{15} grams). SOC storage values were calculated for about 10,000 mineral soils linked to STATSGO map units by soil series. Data are from the USDA–NRCS National Soil Survey Center Soil Survey Laboratory Characterization Database (U.S. Department of Agriculture, 2001a); state databases for Arkansas (E.M. Rutledge, University of Arkansas, Fayetteville, Arkansas, unpub. data, 2001), Illinois (University of Illinois, 2001), Louisiana (Schumacher and others, 1988); and numerous small databases provided by individual researchers.

In the Mississippi River basin (fig. 1), the southern Appalachian region (fig. 2), and individual counties—such as Mitchell and Yancey, North Carolina—within the Appalachian region (fig. 3), SOC storage data indicate distinct associations between spatial patterns in SOC distribution and regional variation in parent material (rock type), climate (latitude/elevation/aspect), and vegetation. Data analyses also suggest that SOC inventory estimates may vary widely, depending both on the scale of the map to which the data are linked and on the source of the linked data. For example, SOC inventory estimates for Mitchell and Yancey Counties in the Blue Ridge physiographic province of western North Carolina (figs. 2 and 3), range from 10.1 terragrams (Tg; 1 Tg=1,012 grams) using STATSGO data linked to STATSGO map units to 13.3 Tg using site-specific data linked to STATSGO map units. SOC inventory estimates for the same counties range from 14.5 Tg using SSURGO data linked to SSURGO map units to 13.4 Tg using site-specific data linked to SSURGO map units. These differences in SOC inventory estimates are partially explained by (1) the representativeness of data used to describe the component soil series, (2) the availability of sufficient data to represent an entire map unit, and (3) differences in the composition of SSURGO map units as compared with STATSGO map units that represent the same land area. The first step in identifying land areas having the greatest potential for SOC sequestration requires an understanding

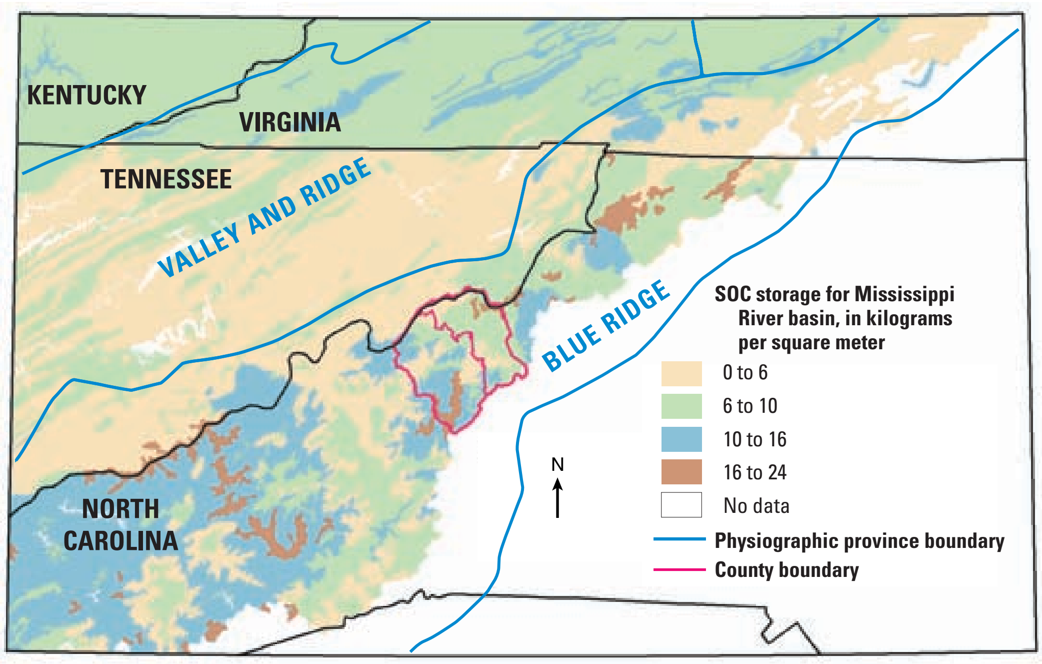

Figure 2. SOC storage values for site-specific data linked to STATSGO, 1:250,000, map units showing the regional pattern of SOC storage within the Blue Ridge and Valley and Ridge physiographic provinces (Fenneman, 1938) for part of the southern Appalachian region in North Carolina, Tennessee, Virginia and Kentucky (location shown in fig. 1).

of the controls on SOC storage and knowledge of the reliability of the SOC inventory data. These areas then can be given the highest priority for targeted efforts in land restoration/protection.

The Mississippi River basin (fig. 1) encompasses an area of 3.3 x 10^6 square kilometers (km^2), and includes a wide range of climate, vegetation, land use, and agriculture. Site-specific data for 10,000 mineral soils located within the Mississippi River basin were linked to the USDA–NRCS STATSGO, 1:250,000 database. Results show that soils that cover large areas of eastern South Dakota, southern Minnesota, Iowa, northern Illinois, and eastern Kansas store up to twice as much SOC (10–24 kilograms per square meter, kg/m^2) as soils in adjacent areas to the west and east (0–10 kg/m^2). Similarly, soils in the alluvial valley of the Mississippi River in Arkansas, Mississippi, and Louisiana store more SOC than soils in adjacent areas to the east. The highest SOC storage values in the Mississippi River basin (24–65 kg/m^2) are associated with wetland soils of the Mississippi River delta in southeastern Louisiana; and with soils in the cooler temperature climes of southern Minnesota, Montana, North Carolina, and Tennessee that receive higher precipitation than surrounding areas.

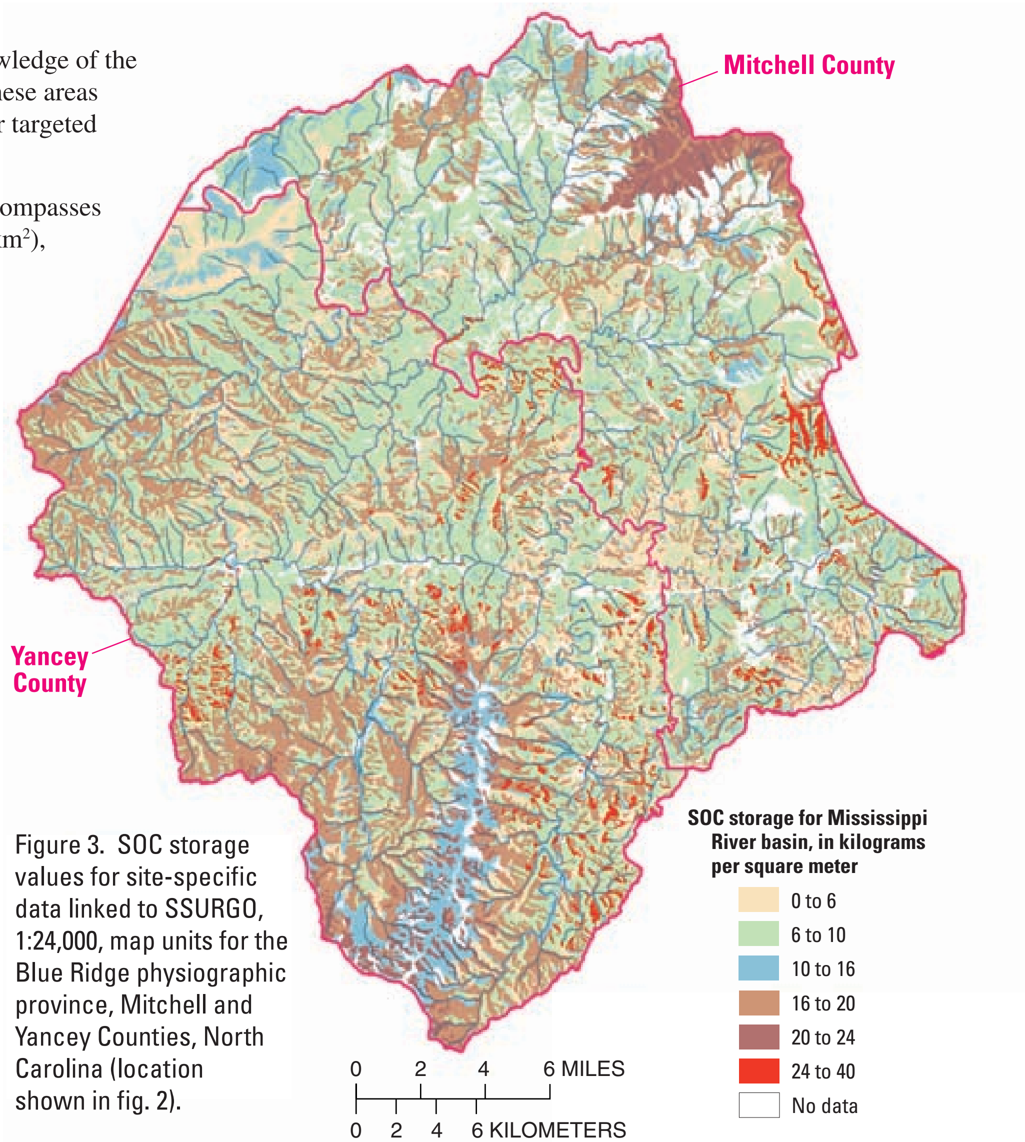

Figure 3. SOC storage values for site-specific data linked to SSURGO, 1:24,000, map units for the Blue Ridge physiographic province, Mitchell and Yancey Counties, North Carolina (location shown in fig. 2).

STATSGO map units in figure 2 show regional patterns in SOC storage for soils within the Blue Ridge and Valley and Ridge physiographic provinces (Fenneman, 1938), but do not capture local variations—especially those related to slope aspect—that are apparent in figure 3. The USDA–NRCS SSURGO 1:24,000 map units for Mitchell and Yancey Counties, North Carolina (fig. 3), capture variations in SOC storage related to slope aspect and elevation. What is particularly evident is the relatively higher SOC storage for soils on north-facing slopes. Throughout this two-county area, SOC storage values of 16–20 kg/m^2 are associated with north-facing side slopes; whereas, SOC storage values between 6–10 kg/m^2 are associated with south-facing side slopes. SOC storage values higher than 24 kg/m^2 are located in relatively small areas on the steepest and highest of the north-facing side slopes.

In some areas, there are obvious discrepancies between the STATSGO and SSURGO maps. SSURGO map units indicate SOC storage values of 20–24 kg/m^2 for the triangular-shaped area in northern Mitchell County, and SOC storage values of 10–24 kg/m^2 for the north-south trending area in south-central Yancey County, North Carolina. Each of these areas have high mountain ridges with elevations ranging from 1,500 to 2,037 meters. STATSGO map units indicate that these areas have the same range in SOC storage (16–24 kg/m^2). Differences between the STATSGO and SSURGO maps need to be resolved before predictions of potential SOC sequestration can be made for targeted land areas.

Initial comparisons of SOC storage estimates based on different data sources and map scales show that STATSGO map units are suitable for small-scale/regional analyses (figs. 1 and 2). However, STATSGO has limited use in identifying specific areas having high carbon-sequestration potential. SSURGO map units—which delineate the smallest mappable unit of a soil series or association—provide data needed for the large-scale/county-level analyses required to identify those areas having a higher potential for SOC sequestration (fig. 3). Identification and delineation of these areas will be of particular interest to the local governments and regional planning agencies responsible for implementing changes in land-use management for carbon sequestration. These efforts will most likely be implemented at local levels, although increasing GHG emissions is a global problem.

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Acknowledgements

Funding by U.S. Geological Survey Earth Surface Dynamics Program as part of the U.S. Global Change Research Program

Graphic design by Caryl J. Wipperfurth

Editing by Carloyn A. Casteel

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