ISSUE BRIEF

CLIMATE-READY SOIL: HOW COVER CROPS CAN MAKE FARMS MORE RESILIENT TO EXTREME WEATHER RISKS

Appendix: Analysis Methodology

ANNUAL CARBON SEQUESTRATION AND GHG EMISSIONS REDUCTIONS

To calculate the amount of greenhouse gas (GHG) emissions that could be captured annually in the soil by planting cover crops, we obtained county-level data from the National Agricultural Statistics Service's *2012 Census of Agriculture* on the total acres of corn (grain and silage) and soybeans harvested in the top 10 U.S. agriculture states.[1] These are California, Iowa, Texas, Nebraska, Minnesota, Illinois, Kansas, Wisconsin, North Carolina, and Indiana.[2] We selected corn and soybeans for our analysis because they are the most commonly planted and harvested crops in the country, and cover crops can be easily incorporated into this crop rotation.[3] However, cover crops can also be incorporated into other crop production systems, such as vegetables, cotton, and cereals.[4] Consequently, our estimate of the potential for cover crop adoption is conservative because it does not take into account the use of cover crops on fields planted with other commodity crops.

We then determined the acreage for each county if 50 percent of the total corn and soybean acres harvested in 2012 were planted with cover crops. After consulting with agricultural conservation experts, we chose an adoption rate of 50 percent because we believe this to be a reasonable goal for cover crop use in commodity cropping systems.

County-level estimates of carbon dioxide (CO_2) and nitrous oxide (N_2O) emissions reductions and capture were derived using the COMET-Planner tool, which was developed by the Natural Resources Conservation Service (NRCS) of the U.S. Department of Agriculture (USDA) and Colorado State University to evaluate potential carbon sequestration and greenhouse gas reductions from the use of various NRCS conservation practices.[5] We selected the relevant state/county and the cover crop (CPS 340) conservation practice and entered the acreage value previously calculated to obtain an estimate of carbon sequestration and GHG emissions reductions in total CO_2 equivalent for each county.

The tool uses an average CO_2 emissions reduction value of 0.21 Mg CO_2 equivalent per acre per year for dry/semiarid climate zones and 0.32 Mg CO_2 equivalent per acre per year for moist/humid climate zones. Each county is automatically classified into one of these two climate zones by the tool. Nitrous oxide emissions reductions are estimated at 0.05 Mg CO_2 equivalent per acre per year for both climate zone types. The tool does not estimate methane emissions reductions.[6] However, research studies suggest that the use of no-till and cover crop practices in some farming systems can reduce methane emissions from soil to a small degree.[7] A total GHG emissions reduction value for each state was calculated by adding the individual county-level estimates. These values also were translated into "cars removed from the road" using the U.S. Environmental Protection Agency's Greenhouse Gas Equivalencies Calculator.[8]

In California, the existing cover crop acreage already exceeds half of the total corn and soybean acres harvested in 2012. Accordingly, the values presented for California in Table 3 of the Executive Summary are calculated using the above methodology for the total acres currently planted with cover crops. Because the *2012 Census of Agriculture* reports cover crop use only at the state level (and not the county level), we calculated carbon sequestration/GHG emissions reductions estimates using the more conservative average CO_2 emissions reductions value (0.21 Mg CO_2 equivalent per acre per year), which is for dry/semiarid climate zones. The average nitrous oxide emissions reductions value is the same for both climate zones so we used this single value in the calculation.

Additional information on this topic is available for download at www.nrdc.org/water/climate-ready-soil.asp

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NOVEMBER 2015
IB:15-11-B

ADDITIONAL SOIL WATER-HOLDING CAPACITY

The estimates of additional soil water-holding capacity assume a 1 percent increase in soil organic matter (SOM) from the use of cover crops and other conservation practices. While there are local and regional variations in soil's ability to build organic matter, and while improvements in soil quality may not be detectable in the first few years after cover crop adoption, research shows that cover crops and other conservation practices, like no-till, can have long-term effects on SOM. SOM is composed of approximately 50 percent carbon, and numerous studies have shown increases in SOM or soil organic carbon of 7 to 85 percent after 4 to 48 years of cover crop adoption.[9,10] As evidenced by these wide ranges, there is no guarantee that cover crops will increase SOM in all locations within a specified time period, as the precise influence of cover crops, no-till, and other conservation practices is critically dependent on many factors (e.g., soil type, precipitation, land use history). We assume that a 1 percent increase in SOM allows an additional 20,000 gallons of water to be stored to a depth of 6 inches (0.1524 m) per acre of soil. This value was derived from the calculations shown below.[11]

Soil mass per acre	= volume x density
	= $(4046.86 \text{ m}^2 \times 0.1524 \text{ m}) \times 1330 \text{ kg/m}^3$*
	= 820,264.2 kg
1% of soil mass per acre	= 820,264.2 kg × .01
	= 8,202.642 kg

Assuming that organic matter can hold 10 times its weight in water,[12] 82,026 kg of water can be held in 1 percent of the soil mass in one acre.

Water held in 1% of soil mass per acre	= 82,026 kg x 2.20462 (lbs/kg)
	= 180,836.16 lbs / 8.3454 (lbs/gal)
	= 21,668 gallons

* In this equation, we used the bulk density of a medium-textured soil with 50% pore space, which is 1.33 g/cm^3 or 1330 kg/m^3. See USDA-NRCS, *Soil Quality Indicators* (2008), www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_053256.pdf.

To err on the conservative side, we rounded down to a value of 20,000 gallons of additional water stored per acre of soil for use in our analysis. We multiplied this value by the county acreage estimated if 50 percent of total corn and soybean acres harvested were planted with cover crops (see discussion above) to obtain an estimate of additional gallons of water stored in the soil for each county. A total value of additional water that could be stored for each state was calculated by adding the individual county-level estimates. These values were also translated into an equivalent estimate of how many people's per capita annual water demand could be met with these savings, using the national average residential water consumption of 88 gallons per person per day and multiplying by 365 days per year.[13]

ENDNOTES

1 National Agricultural Statistics Service (NASS), U.S. Department of Agriculture (USDA), "Quick Stats," http://quickstats.nass.usda.gov/results/F4FB7A00-BB17-33A2-A0A2-33E3582D213C.

2 Top 10 states based on 2014 agricultural sector value production from Economic Research Service, USDA, "Farm Income and Wealth Statistics," available at http://www.ers.usda.gov/data-products/farm-income-and-wealth-statistics/farm-finance-indicators-state-ranking.aspx#Pedc8f8f45c564539be57c0fa0c892c95_5_186iT0R0x3, accessed September 3, 2015.

3 Kenneth Olson, Stephen A. Ebelhar, and James M. Lang, "Long-Term Effects of Cover Crops on Crop Yields, Soil Organic Carbon Stocks and Sequestration," *Open Journal of Soil Science* 4, no. 8 (2014): 284-292. M.B. Villamil et al., "No-Till Corn/Soybean Systems Including Winter Cover Crops: Effects on Soil Properties," *Soil Science Society of America Journal* 70, no. 6 (2006): 1936-1944.

4 Sustainable Agriculture Research & Education (SARE), *Managing Cover Crops Profitably*, 3rd edition, 2007, 37-43, www.sare.org/Learning-Center/Books/Managing-Cover-Crops-Profitably-3rd-Edition.

5 COMET-Planner is available at comet-planner.nrel.colostate.edu.

6 Additional technical support documentation for COMET-Planner is available at comet-planner.nrel.colostate.edu/COMET-Planner_Report_Final.pdf.

7 *See* Cimélio Bayer et al., "Methane Emission from Soil Under Long-Term No-Till Cropping Systems," *Soil & Tillage Research* 124 (2012): 1-7. *See also* A. Sanz-Cobena et al., "Do Cover Crops Enhance N_2O, CO_2 or CH_4 Emissions from Soil in Mediterranean Arable Systems?" *Science of the Total Environment* 466, no. 46 (2014): 164-174.

8 U.S. Environmental Protection Agency, Greenhouse Gas Equivalencies Calculator, www2.epa.gov/energy/greenhouse-gas-equivalencies-calculator, accessed Sept. 28, 2015.

9 Laura F. Overstreet and Jodi DeJong-Huges, "The Importance of Soil Organic Matter in Cropping Systems of the Northern Great Plains," University of Minnesota–Extension, www.extension.umn.edu/agriculture/tillage/importance-of-soil-organic-matter/#effect.

10 *See* T.C. Kaspar and J.W. Singer, "The Use of Cover Crops to Manage Soil," in *Soil Management: Building a Stable Base for Agriculture*, 2011, American Society of Agronomy and Soil Science Society of America. *See also* E.B. Moore et al., "Rye Cover Crop Effects on Soil Quality in No-Till Corn Silage-Soybean Cropping Systems," *Soil Science Society of America Journal* 78, no. 3 (2014): 968-976. *See also* M.D. McDaniel, L.K. Tiemann and A.S. Grandy, "Does Agricultural Crop Diversity Enhance Soil Microbial Biomass and Organic Matter Dynamics? A Meta-analysis," *Ecological Applications* 24, no. 3 (2014): 560-570).

11 A more thorough discussion of this calculation can be found at Lara Bryant, "Organic Matter Can Improve Your Soil's Water Holding Capacity," *Switchboard*, Natural Resources Defense Council, May 27, 2015, switchboard.nrdc.org/blogs/lbryant/organic_matter.html.

12 This is a conservative assumption of the ability of organic matter to hold water. Some estimates suggest it has the potential to hold up to 20 times its weight in water. *See* Natural Resources Conservation Service, USDA, "Soil Health: Key Points," February 2013, www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1082147.pdf. *See also* Alexandra Bot and José Benites, *The Importance of Soil Organic Matter: Key to Drought-Resistant Soil and Sustained Food and Production*, Food and Agriculture Organization of the United Nations (FAO), 2005, 37, www.fao.org/docrep/009/a0100e/a0100e.pdf.

13 The national average residential water use of 88 gallons per person per day comes from Molly A. Maupin, et al., *Estimated Use of Water in the United States in 2010*, U.S. Geological Survey, 2014, 21, http://pubs.usgs.gov/circ/1405/pdf/circ1405.pdf.