Modeling predicts which counties could store more carbon in soil by growing bioenergy crops

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Credit: AI-generated image (disclaimer)

To help stakeholders in government and business make smart decisions about the best types of land and local climates for planting bioenergy crops, researchers at the U.S. Department of Energy's (DOE's) Argonne National Laboratory are using computational modeling to predict which counties could see increases in soil organic carbon from cultivation of crops like switchgrass for biofuels. Increasing carbon stored in soil is one way to help mediate the amount of carbon dioxide released into the atmosphere.

In an effort to decrease greenhouse gas emissions from transportation by reducing the use of petroleum fuels, the U.S. Environmental Protection Agency's Renewable Fuel Standard calls for increased production of advanced biofuels. Fortunately, most bioenergy crops can grow on a range of crop and marginal lands across the country, taking advantage of land that may not be viable for traditional crops. Because Earth's soil stores about three times as much carbon as the atmosphere, these deep-rooted plants that return season after season might also help reduce greenhouse gas emissions before they are even harvested for fuel by increasing the amount of carbon stored in the soil.

In the Argonne study published in *Global Change Biology–Bioenergy*, researchers combined county-level crop yield and weather data and soil data at depths relevant to bioenergy crops. The team used a soil carbon model to calculate sequestration rates, or the rate at which carbon is transported in or out of the soil. This work was done in collaboration with Steffen Mueller at the University of Chicago, Michelle Wander at the University of Illinois at Urbana-Champaign and Ho-Young Kwon at the International Food Policy Research Institute.

Researchers modeled soil carbon sequestration rates for five crops: corn and four energy-dense crops including switchgrass, poplar, willow and Miscanthus, a tall drought-resistant grass. The production of each species was modeled on four types of land, including cropland, cropland pasture (which fluctuates between producing crops and serving as pastureland), long-standing undisturbed grassland and forest—totaling 20 land scenarios depicting different initial and final land uses or covers. Researchers also considered changes to soil carbon stocks when 30 percent of the corn stover remaining after corn harvest is collected, which is likely to contribute to future biofuel production and can also affect carbon stocks.

By modeling soil carbon at a depth of 100 centimeters rather than the standard 30, the study results represent the deeper root systems of crops like switchgrass and poplar trees that transport carbon below the topsoil, unlike more shallow-rooted row crops like corn. The team also collected detailed data on local weather patterns, soil conditions, historical land use and local crop yields for each county, as well as data from bioenergy crop field trials conducted by other agencies and national laboratories.

For bioenergy crops in particular, modeling land types and local climates at high spatial resolution is important because the yield of the crop and its impact on soil carbon stocks can vary significantly across the country.

"By doing this type of analysis we can find areas where bioenergy crops can have positive environmental effects—but also hotspots where growing bioenergy crops may cause a decline in soil carbon," said Argonne postdoctoral researcher Zhangcai Qin, who is examining the environmental effects of biofuel production.

Supported by local data, county-by-county modeling results confirmed that grasslands and forests generally have richer soil with larger carbon stocks and will contribute to greenhouse gas emissions if transitioned to bioenergy crop production. On the other hand, converting some cropland or cropland-pasture to bioenergy crops like switchgrass and Miscanthus can help reduce greenhouse gas emissions.

Results also revealed a trend for the tree species poplar and willow. Switchgrass and Miscanthus exhibited a higher rate of carbon sequestration than the tree species across the country, mainly because the tree species grow more slowly than cellulosic grasses and store less carbon in the soil. Notably, results show soil carbon on cropland can benefit from bioenergy crops in large areas of the country, particularly by planting Miscanthus in the Midwest and Pacific Coast and switchgrass in the Southeast.

To further understand the net carbon impact of biofuels from the farm to fuel emissions, the researchers incorporated soil carbon modeling results into Argonne's Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model, which evaluates the full life cycle of energy consumption and emissions of different transportation fuels, including biofuels. For example, when soil organic carbon changes were included in the GREET model, ethanol produced from deep-rooted Miscanthus showed the potential to sequester carbon on a life-cycle basis.

"By integrating high-resolution, soil organic carbon modeling with a life-cycle analysis model, we can holistically estimate the life-cycle greenhouse gas emissions of biofuels, including the influences of the life-cycle stages of feedstock planting, conversion to a fuel and fuel combustion," said Jennifer Dunn, Argonne Biofuels Life Cycle Analysis team lead. "These results could help decision-makers at all levels identify areas that are poorly or well-suited for biofuel crops."

The results are contributing to DOE's third Billion-Ton report. Updated every five years, the Billion-Ton report quantifies U.S. bioenergy feedstock potential. This year marks the first time the study will include a second volume with analyses on the potential environmental effects of select biomass production scenarios. Volume 2, expected later this year, will incorporate the Argonne team's work.

More information: Zhangcai Qin et al. Soil carbon sequestration and land use change associated with biofuel production: empirical evidence, *GCB Bioenergy* (2016). DOI: 10.1111/gcbb.12237

Zhangcai Qin et al. Influence of spatially-dependent, modeled soil carbon emission factors on life-cycle greenhouse gas emissions of corn and cellulosic ethanol, *GCB Bioenergy* (2016). DOI: 10.1111/gcbb.12333

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