Study confirms contribution of bioenergy to climate change mitigation

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A cross-border team of researchers refute arguments that carbon debt, opportunity cost and indirect land-use change prevent greenhouse gas mitigation by biofuels. Credit: Oak Ridge National Lab

That biofuels can contribute to a cleaner global energy mix is widely accepted, but the net benefits of bioenergy in terms of mitigating greenhouse gases (GHG) are moot. Some argue, for example, that biofuels are not sustainable because the conversion of non-agricultural land to grow energy crops could lead to a significant initial decrease in carbon storage, creating what is known as a "biofuel carbon debt".

A study by a cross-border group of researchers published in *Proceedings of the National Academy of Sciences (PNAS)* could help refute this argument.

The study showed that the GHG mitigation potential of switchgrass cultivation for cellulosic ethanol production in the US was comparable on a per-hectare basis to that of reforestation and several times greater than that of grassland restoration. Switchgrass (Panicum virgatum) is a widely grown North American native grass proposed as biomass for the biobased economy.

More advanced technology and integration of carbon capture and storage (CCS) could further increase the per-hectare mitigation potential of bioenergy systems by a factor of six, according to the study, which was supported by São Paulo Research Foundation—FAPESP via a project led by John J. Sheehan.

Sheehan is affiliated with the University of Minnesota in the US and is currently a visiting fellow at the University of Campinas's School of Agricultural Engineering (FEAGRI-UNICAMP) in the state of São Paulo, Brazil, under the aegis of the (São Paulo Excellence Chair (SPEC).

Co-lead author of the study, Lee R. Lynd, a professor at Dartmouth College in Hanover, New Hampshire (USA), began a project in February at UNICAMP's Center for Molecular Biology and Genetic Engineering (CBMEG), with funding from FAPESP under the SPEC program.

"The study highlights in detail the factors and strategies that are important to the implementation of biofuel production in a way that helps stabilize the climate," Lynd told.

Questions answered

According to the authors, critics of bioenergy question whether feedstock crops can be sustainably sourced without causing self-defeating reductions in ecosystem carbon storage.

Besides the "carbon debt" resulting from the conversion of non-agricultural land into energy crop plantations, the use of existing productive agricultural land with low carbon stocks can also be counterproductive if food production is displaced and GHG emissions increase elsewhere.

This effect, known as indirect land-use change, can be minimized or avoided by growing biofuel feedstocks on low-yield or abandoned cropland, or land spared from continued agricultural use through future agricultural intensification or changes in diet.

Reforestation offers an alternative use of such land for GHG mitigation. However, it is often claimed that assessment of bioenergy production in these areas should consider their "opportunity cost", i.e. the carbon sequestration foregone when land is used for feedstock production instead of reforestation.

"The main studies published to date suggest zero net land-use change, but indirect land-use change continues to be invoked as a key criticism of biofuels," Lynd said.

These arguments were initially directed at first-generation biofuels—obtained from sugar, starch or vegetable oil in food crops grown on farmland—but questions focusing on carbon debt, indirect land-use change, and opportunity cost have since been raised regarding the production of cellulosic biomass for use in advanced biofuel production or electricity generation.

Based on these and other arguments, recent studies suggest that using land to produce bioenergy feedstocks has a less-than-ideal impact in terms of mitigating the climate crisis, and recommend research and policy be refocused toward land-based biological carbon management.

However, those studies are often based on secondary estimates of bioenergy system performance and mitigation opportunity costs. Furthermore, they generally exclude consideration of CCS or future technology improvements, the authors note.

"Each of the critiques we discuss in the study has some legitimacy in terms of pointing to factors that can cancel out the beneficial impact of biofuels on the climate, but they shouldn't be taken as proof that biofuels can't or don't have any beneficial impact at all," Lynd said.

To refute the arguments presented by critics of biofuel sustainability, the researchers used ecosystem simulation combined with models of cellulosic biofuel production and CCS, estimating the potential of biofuel from energy grass to replace fossil fuels and sequester carbon directly compared with other land-based mitigation schemes, such as reforestation and grassland restoration.

They calibrated the ecosystem model to perform temporally explicit simulations of atmosphere-biosphere carbon exchange under different land-use choices at three case study sites in the US.

The analysis showed that where farmers transitioned from switchgrass to cellulosic ethanol the per-hectare mitigation potential was comparable to that of reforestation and several times greater than that of grassland restoration.

It also showed that the mitigation potential of plausible future improvements in energy crop yields and biorefining technology, together with CCS, could be four times greater than that of reforestation and 15 times greater than that of grassland restoration.

"In addition, we found that natural land cover and the technological maturity of the supply chain make a significant difference when it comes to estimating the relative benefits of GHG mitigation by biofuels and restoration of natural vegetation," Lynd said.

Switchgrass cultivation can be particularly useful in parts of the US where the natural plant cover consists of grass rather than trees, according to the study.

In future, the researchers plan to use the same modeling approach to discuss these issues for the US on a nationwide scale. "An important direction in which the study points is an analysis of a broader range of sites, energy crops, and conversion processes, including those designed to include biofuel production in a manner consistent with the circular economy," Lynd said.

The methodology could also be used to analyze the production of biofuel from sugarcane in Brazil, he added.

More information: John L. Field et al, Robust paths to net greenhouse gas mitigation and negative emissions via advanced biofuels, *Proceedings of the National Academy of Sciences* (2020). DOI: 10.1073/pnas.1920877117

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