Charcoal takes some heat off global warming

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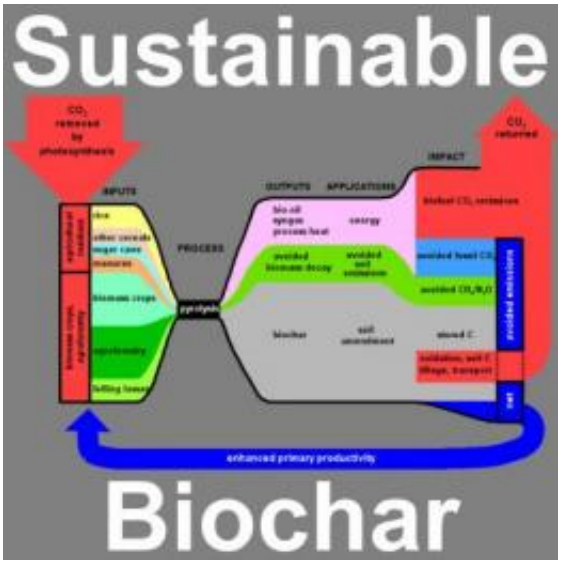

Carbon emissions can be sustainably offset by producing biochar from waste and residue biomass, as demonstrated in this schematic of the pyrolysis process to create biochar. Credit: Pacific Northwest National Laboratory

As much as 12 percent of the world's human-caused greenhouse gas emissions could be sustainably offset by producing biochar, a charcoal-like substance made from plants and other organic materials. That's more than what could be offset if the same plants and materials were burned to generate energy, concludes a study published today in the journal *Nature Communications*.

"These calculations show that biochar can play a significant role in the solution for the planet's climate change challenge," said study co-author

Jim Amonette, a soil chemist at the Department of Energy's Pacific Northwest National Laboratory. "Biochar offers one of the few ways we can create power while decreasing carbon dioxide levels in the atmosphere. And it improves food production in the world's poorest regions by increasing soil fertility. It's an amazing tool."

The study - by Amonette, Dominic Woolf and Alayne Street-Perrott from Swansea University in Wales, U.K., Johannes Lehmann of Cornell University in Ithaca, N.Y., and Stephen Joseph at the University of New South Wales, Australia - is the most thorough and comprehensive analysis to date on the global potential of biochar. The carbon-packed substance was first suggested as a way to counteract climate change in 1993. Scientists and policymakers have given it increasing attention in the past few years.

A farmer in India demonstrates what he described as vigorous root growth on one of the banana trees he planted in biochar, the black, powdery material in the soil. Credit: Rob Bryant, Swansea University

Biochar is made by decomposing biomass like plants, wood and other organic materials at high temperature in a process called slow pyrolysis. Normally, biomass breaks down and releases its carbon into the

atmosphere within a decade or two. But biochar is more stable and can hold onto its carbon for hundreds or even thousands of years, keeping greenhouse gases like carbon dioxide out of the air longer. Other biochar benefits include: improving soils by increasing their ability to retain water and nutrients; decreasing nitrous oxide and methane emissions from the soil into which it is tilled; and, during the slow pyrolysis process, producing some bio-based gas and oil that can offset emissions from fossil fuels.

Making biochar sustainably requires heating mostly residual biomass with modern technologies that recover energy created during biochar's production and eliminate the emissions of methane and nitrous oxide, the study also noted.

Crunching numbers and biomass

For their study, the researchers looked to the world's sources of biomass that aren't already being used by humans as food. For example, they considered the world's supply of corn leaves and stalks, rice husks, livestock manure and yard trimmings, to name a few. The researchers then calculated the carbon content of that biomass and how much of each source could realistically be used for biochar production.

With this information, they developed a mathematical model that could account for three possible scenarios. In one, the maximum possible amount of biochar was made by using all sustainably available biomass. Another scenario involved a minimal amount of biomass being converted into biochar, while the third offered a middle course. The maximum scenario required significant changes to the way the entire planet manages biomass, while the minimal scenario limited biochar production to using biomass residues and wastes that are readily available with few changes to current practices.

Amonette and his colleagues found that the maximum scenario could offset up to the equivalent of 1.8 petagrams - or 1.8 billion metric tons - of carbon emissions annually and a total of 130 billion metric tons throughout in the first 100 years. Avoided emissions include the greenhouse gases carbon dioxide, methane and nitrous oxide. The estimated annual maximum offset is 12 percent of the 15.4 billion metric tons of greenhouse gas emissions that human activity adds to the atmosphere each year. Researchers also calculated that the minimal scenario could sequester just under 1 billion metric tons annually and 65 billion metric tons during the same period.

But to achieve any of these offsets is no small task, Amonette noted.

“This can’t be accomplished with half-hearted measures,” Amonette said. “Using biochar to reduce greenhouse gas emissions at these levels is an ambitious project that requires significant commitments from the general public and government. We will need to change the way we value the carbon in biomass.”

Experiencing the full benefits of biochar will take time. The researchers’ model shows it will take several decades to ramp up biochar production to its maximum possible level. Greenhouse gas offsets would continue past the century mark, but Amonette and colleagues just calculated for the first 100 years.

Biochar and bioenergy work together

Instead of making biochar, biomass can also be burned to produce bioenergy from heat. Researchers found that burning the same amount of biomass used in their maximum biochar scenario would offset 107 billion metric tons of carbon emissions during the first century. The bioenergy offset, while substantial, was 23 metric tons less than the offset from biochar. Researchers attributed this difference to a positive

feedback from the addition of biochar to soils. By improving soil conditions, biochar increases plant growth and therefore creates more biomass for biochar productions. Adding biochar to soils can also decrease nitrous oxide and methane emissions that are naturally released from soil.

However, Amonette and his co-authors wrote that a flexible approach including the production of biochar in some areas and bioenergy in others would create optimal greenhouse gas offsets. Their study showed that biochar would be most beneficial if it were tilled into the planet's poorest soils, such as those in the tropics and the Southeastern United States.

Those soils, which have lost their ability to hold onto nutrients during thousands of years of weathering, would become more fertile with the extra water and nutrients the biochar would help retain. Richer soils would increase the crop and biomass growth - and future biochar sources - in those areas. Adding biochar to the most infertile cropland would offset greenhouse gases by 60 percent more than if bioenergy were made using the same amount of biomass from that location, the researchers found.

On the other hand, the authors wrote that bioenergy production could be better suited for areas that already have rich soils - such as the Midwest - and that also rely on coal for energy. Their analysis showed that bioenergy production on fertile soils would offset the greenhouse gas emissions of coal-fired power plants by 16 to 22 percent more than biochar in the same situation.

Plantations need not apply

The study also shows how sustainable practices can make the biochar that creates these offsets.

“The scientific community has been split on biochar,” Amonette acknowledged. “Some think it’ll ruin biodiversity and require large biomass plantations. But our research shows that won’t be the case if the right approach is taken.”

The authors’ estimates of avoided emissions were developed by assuming no agricultural or previously unmanaged lands will be converted for biomass crop production. Other sustainability criteria included leaving enough biomass residue on the soil to prevent erosion, not using crop residues currently eaten by livestock, not adding biochar made from treated building materials to agricultural soils and requiring that only modern pyrolysis technologies - those that fully recover energy released during the process and eliminate soot, methane and nitrous oxide emissions - be used for biochar production.

“Roughly half of biochar’s climate-mitigation potential is due to its carbon storage abilities,” Amonette said. “The rest depends on the efficient recovery of the energy created during pyrolysis and the positive feedback achieved when biochar is added to soil. All of these are needed for biochar to reach its full sustainable potential.”

More information: Dominic Woolf, James E. Amonette, F. Alayne Street-Perrott, Johannes Lehmann, Stephen Joseph. “Sustainable biochar to mitigate global climate change,” Nature Communications, Aug. 10, 2010. www.nature.com/ncomms/journal/ … full/ncomms1053.html

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