# Biochar and energy from pyrolysis can pave the way for carbon-neutral agriculture in China

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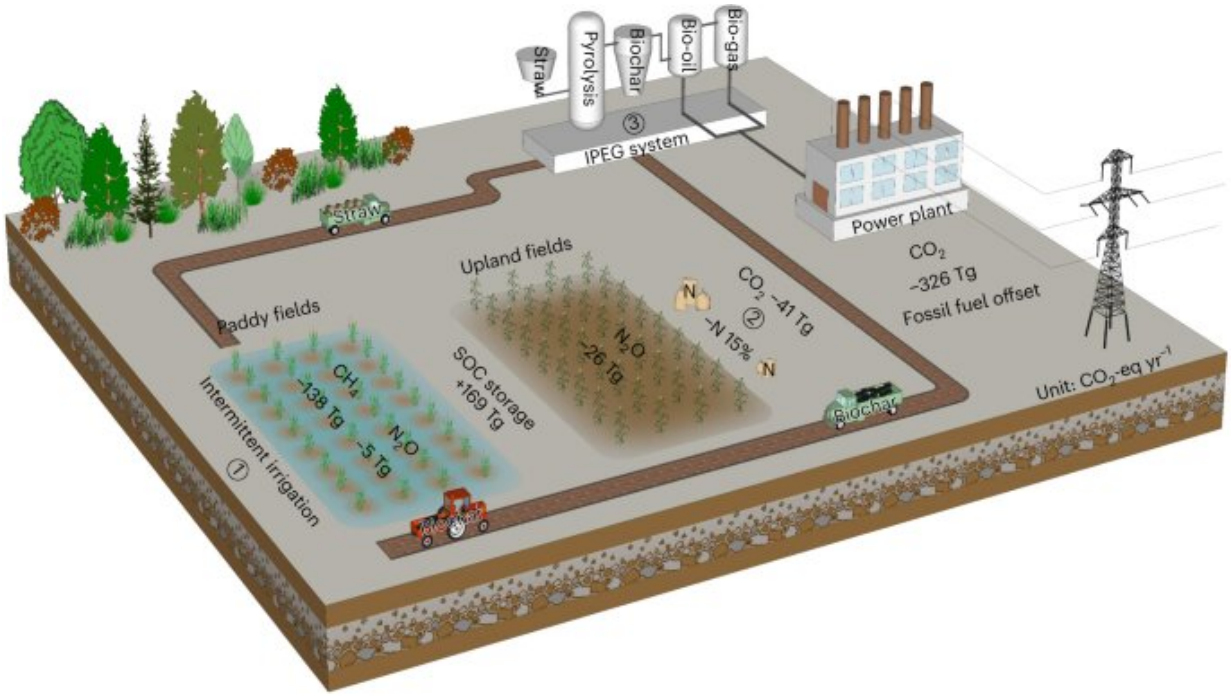


Overall effects of IPEG–CH4–N on mitigating GHG emissions from staple food production in China. Credit: *Nature Food* (2023). DOI: 10.1038/s43016-023-00694-0

Agriculture accounts for a large share of global greenhouse gas emissions, and the path to carbon neutrality is not straightforward.

Researchers from Land-CRAFT—Center for Landscape Research in Sustainable Agricultural Futures at Aarhus University and others have, through a comprehensive life cycle analysis of data from China, identified an integrated biomass pyrolysis and electricity generation system coupled with commonly applied methane and nitrogen mitigation measures that, together with the right management of agricultural land, can significantly reduce greenhouse gas emissions from Chinese staple crops.

Since the Paris Agreement to combat global warming was reached in 2015, many countries have committed to becoming climate neutral, i.e., achieving net-zero greenhouse gas emissions. The world's largest agricultural country, China, is also committed to join the green transition. As the largest agricultural country, China is also the world's biggest emitter of greenhouse gases, yet it has set itself a target of achieving carbon neutrality by 2060.

According to Professor and Head of Land-CRAFT at Department of Agroecology at Aarhus University Klaus Butterbach-Bahl, this places huge demands on agricultural systems. "Agriculture in China accounts for about 14% of the country's total greenhouse gas emissions, and the production of staple foods such as rice, wheat and maize take up about 70% of the country's cultivated land. This is a very large area, and the cultivation of these staple crops account for large emissions of methane and nitrous oxide because they are grown with intensive use of fertilizers and irrigation. So, it has been difficult to see how China's production of staple crops could achieve carbon neutrality by 2060."

## Management cannot do it alone

According to the researchers, several management methods have already been tested, all of which help to reduce greenhouse gas emissions from crop production in one way or another. Intermittent irrigation, for

example, has been tested to reduce methane emissions from rice fields. In addition, the use of nitrogen fertilizers has been reduced, and attempts have been made to improve the ability of crops to use nitrogen more efficiently, so that they need less and thus reduce nitrous oxide emissions. In addition, the focus has been on increasing soil organic carbon content by increasing the amount of straw returned to the soil.

"Although all these management methods work well, they are insufficient to achieve carbon neutrality," says Butterbach-Bahl, and points out that this is partly because the effect of one management method can be negated when they are used in combination.

"When you reduce one greenhouse gas, it can lead to an increase in another. For example, intermittent irrigation effectively reduces methane emissions from rice fields, but at the same time increases nitrous oxide emissions from those same fields. The same trade-off is seen with several of the other management practices; the increased emissions of either methane or nitrous oxide can completely outweigh the benefits of the management practices," he says.

## Biochar is the new black

So, management methods alone will not pave the way for climate-neutral food production. According to the researchers, more is needed, and pyrolysis of straw into biochar could prove to be part of the solution. It has the potential to reduce greenhouse gas emissions and at the same time increase the soil's organic carbon content.

"We can see that using biochar in rice fields significantly reduces methane emissions. This happens because the organic carbon in biochar decomposes much more slowly than in straw. The slower decomposition also means that the carbon from the biochar is sequestered in the soil for a longer time, it is a more long-term solution than straw," says

Butterbach-Bahl, who has been involved in a comprehensive life cycle analysis of, among other things, an integrated pyrolysis and energy system to find solutions that can help China towards climate-neutral agriculture.

The study shows that in addition to carbon sequestration and reduced methane emissions, biochar can also help reduce nitrous oxide emissions. This happens through complex microbial processes in the soil that inhibit denitrification, where nitrate is converted into nitrous oxide and other gases.

## Integrated pyrolysis and energy production lay the foundations for a greener future

"There is another advantage to pyrolysis. Pyrolysis of straw into biochar also produces biogas and bio-oil. These are by-products, but they can be used to generate electricity through an integrated pyrolysis and power generation system," says Butterbach-Bahl.

The energy produced by such a system can replace fossil fuels, further reducing greenhouse gas emissions.

"Our analysis shows that with this integrated pyrolysis and power generation system, combined with commonly used management methods to reduce methane and nitrous oxide emissions, we can achieve carbon-neutral production of staple crops in China," says Butterbach-Bahl. He stresses that when talking about carbon neutrality, the researchers are referring to a state where the sum of emissions of all greenhouse gases ($CO_2$, methane and nitrous oxide) from crop production is offset by $CO_2$ removal through carbon sequestration in the soil and $CO_2$ compensation through lower fossil fuel consumption.

The life cycle assessment included an analysis of the production of staple crops as it is today, as well as scenarios with different combinations of management methods, one scenario with biochar, and one with biochar and energy production from the integrated pyrolysis and energy system.

"Our analysis shows that only the combination of the integrated pyrolysis and energy system and different management methods can ensure carbon-neutral production of staple crops in China. In addition, this method can help reduce nitrate leaching into the aquatic environment and reduce emissions of air pollutants such as sulfur dioxide, that can cause acidic rain. And there is the added benefit of increasing yields too.

"Therefore, we conclude that this method can bring China, and perhaps other countries too, one step closer to the national goal of carbon neutrality and environmental sustainability in agriculture in 2060," says Butterbach-Bahl.

The study is published in the journal *Nature Food*.

**More information:** Longlong Xia et al, Integrated biochar solutions can achieve carbon-neutral staple crop production, *Nature Food* (2023). DOI: 10.1038/s43016-023-00694-0

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