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How can we make biofuels more climate-friendly?

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Abstract

Wouldn't it be great to find a fuel that powers our cars and planes without polluting the environment or warming up our planet? Fuels made from plants, like corn or sugarcane, called "*biofuels*," appeared to be more climate-friendly than burning *fossil fuels*. Unfortunately, it turns out that many biofuels are no better, if not worse, than their fossil fuel counterparts in their impact on our climate. This is because they use up more fossil fuels in their production than they were meant to save! We wanted to see if we could change that and find a more climate-friendly way to produce biofuels. And we did! We found two promising candidates that we tested in field experiments in Hawaii. We showed that a conservation-oriented production method (no *tillage*, less water, less fertilizer) and good *crop* selection are crucial for producing better biofuels.

Introduction

Biofuels are made out of modern-day plants, whereas fossil fuels like gasoline and diesel are made from *crude oil* - ultimately, fossils! Biofuels still release *carbon* when used in cars or planes, just like fossil fuels. However, the plants or crops that are made into biofuels take carbon out of the atmosphere while they grow, whereas fossil fuels release carbon that would otherwise remain stored in the earth.

So why would these new fuels be any better? Well, what's important is the *net carbon balance*: the amount of carbon released into vs. taken out of the atmosphere. Ideally, we want this balance to be zero, or even negative. This means the amount of carbon taken up by the biofuel plants while growing should be equal to or more than the amount of carbon released when the biofuel is burned.

Plants and their soil emit greenhouses gases when they are grown on the field, but careful practices can limit how much - and even help contain more carbon than is released!

Unfortunately, a lot of fossil fuels are used to grow these biofuel crops on a big scale - for instance, running farm machinery and producing fertilizer. That means, in the end, the biofuels can release more carbon than the plants take up. Moreover, the plants and soil emit greenhouse gases when grown in the field.

We wanted to test if we could grow biofuel crops in a way that reduces overall greenhouse gas emissions and makes them a more climate-friendly option than current fuel sources.

Figure 1:
Sugar cane (left) and napiergrass (right) growing in the field

Methods

We set up a couple of experiments on former sugarcane plantations on the island of Maui in Hawaii. We wanted to compare the greenhouse gas emissions of two potential biofuel crops under two different production methods: conventionally grown sugarcane compared with less *intensive production* of napiergrass. Both are *perennial* tropical grasses, so they build up their root systems over several years. This takes more carbon out of the atmosphere and stores it in the soil.

We tested two levels of irrigation for both grasses: normal watering (no water stress) and 50% reduced watering. Furthermore, for napiergrass we opted for a more climate-friendly production practice: following the initial planting, harvesting the biomass requires no disturbance of the soil (also called *no-tillage* management) by using a special type of *ratoon harvest* that leaves stubs of the plants on the field to regrow (like cutting your lawn) and the belowground root system undisturbed. To distribute fertilizer more efficiently, we applied it via buried drip irrigation tubes.

We grew both crops for a 2-year period and kept track of the amount and type of gas released from the soil. At the end of year 1 and year 2, we measured how many roots the plants grew underground and analyzed whether the amount of soil carbon had changed. We also harvested the crop's above-ground *biomass* (*yield*) at regular intervals to see how much could be turned into biofuels.

Figure 2:
Roots on young napiergrass plant

Figure 3:
Setup to measure greenhouse gas emissions in the field

Results

To our delight, we found that both ratoon harvested grasses stored more carbon underground than they released into the atmosphere, which makes them promising candidates for biofuel production. The overall greenhouse gas emissions of napiergrass were less than those of conventionally grown sugarcane. But even for conventional sugarcane, our greenhouse gas emission values were much lower than those of previous studies because of new, efficient fertilization techniques. The amount of carbon that plants took up from the atmosphere and built into the roots, as well as added to the soil, was critical to the negative carbon balance of both crops when ratoon harvested.

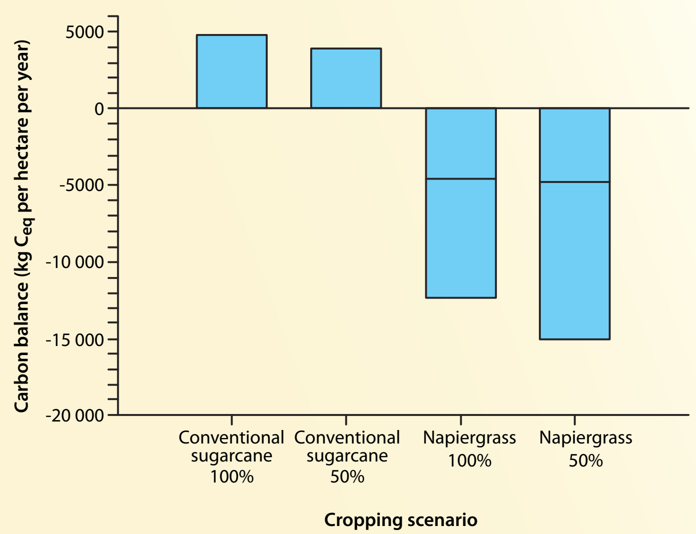

Figure 4:
Carbon balance for the 2 different biofuel crops that we tested in our study. The most suitable crops (and production methods) have the lowest carbon balance. The % describes how much water has been applied to the crops.

Which crop and watering scenario was the most climate friendly in our study?

Discussion

Our study shows that conservative management strategies for biofuel crops – using less water and more efficient ways to apply fertilizer together with no tillage and an efficient harvest – can reduce their net carbon balance significantly. An efficient way to apply fertilizer is crucial because it reduces the outgassing of greenhouse gases that usually occur after crops are fertilized. Ensuring the soil is not unnecessarily disturbed (no tillage or plowing) also minimizes the release of greenhouse gases. Using these techniques didn't give quite as a high yield as conventional production, but they help rebuild healthy, climate-smart soils that can increase yield over time.

Perennial crops like our two tropical grasses seem well suited for biofuel production because they grow strong root systems, which take carbon out of the air and store it in the ground. In a no-tillage system, this also helps to build up the amount of carbon in the soil, which is very important for overall soil health. A healthier soil allows crops to grow with less water or less fertilizer, which improves the carbon balance. The soils in which we grew our test-crops had formerly been used for intensive sugarcane production for many years, and consequently were very depleted of carbon. Our climate-friendly way of growing biofuel crops led to a faster buildup of carbon in the soil.

Conclusion

An idea that sounds "green" does not necessarily help the environment. Early biofuels made from corn or conventionally grown sugarcane are actually as bad or sometimes even worse than fossil fuels when you account for the amount of greenhouse gases released during their production. However, we can minimize negative effects on the climate by carefully choosing our biofuel crops as well as managing their production, as we did with napiergrass in our study. That might allow us to eventually develop more climate-friendly biofuels.

Check your understanding

1. What is the difference between biofuels and fossil fuels?
2. Why are the most commonly used biofuels not very climate-friendly?
3. Why are the grasses we tested better candidates for biofuel production? What did we do different than other growers of biofuel crops?
4. What other problems can you imagine for fuels made from plants (most of them food plants)?
5. Can you think of ways toreduce this problem and also make biofuels more environmentally friendly?
6. Can you think of other examples where the term "bio" or "green" makes a product sound more environmentally friendly than it actually is? (This process is called "greenwashing").

Glossary of Key Terms

Biofuels – fuels made out of modern-day plants (as opposed to fossil fuel from ancient fossilized material).

Biomass – the amount of organic matter (part of a plant or animal).

Carbon – a common element on Earth, stored in the atmosphere as CO2 (2%), in plants and soils (5%), in fossil fuels (8%, which is carbon that got buried from long-dead plants and animals), and in the oceans (85%). By burning fossil fuels and cutting down forests, humans are putting more carbon into the atmosphere and making the world warmer.

Crop – a cultivated plant that is grown as food, or in our case, for biofuel.

Crude oil (or petroleum) – a naturally occurring liquid found in geological formations beneath the Earth's surface, which can be turned into various types of fuels. It's also the base to make plastic. It is called a fossil fuel because it is formed by millions of dead organisms (fossils) that have been buried under rocks for a long time and under heavy pressure.

Fossil fuel – a natural fuel such as crude oil, coal or gas, formed in the geological past from the remains of living organisms.

Greenhouse gases – gases that contribute to global warming by trapping heat from the sun in the atmosphere close to the Earth, including carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O).

Intensive production – agriculture (or farming) that involves higher levels of input (water, fertilizer, pesticides) and output (yield) per unit of agricultural land area.

Irrigation – the supply of water to a crop. In drip irrigation, a slow supply of water is delivered to the crops.

Perennial – plants that live for several years (as opposed to "annuals" which only live for a year or less).

Ratoon Harvest – a method of harvesting a crop that leaves the roots and the lower parts of the plant uncut to give the ratoon or the stubble crop. The main benefit of ratooning is that the crop matures earlier in the season. Here, it allowed us to use less water and fertilizer to grow our biofuel crop.

Net Carbon Balance – the sum of carbon taken out of the atmosphere versus released into it.

Tillage – the preparation of land for growing crops, usually by digging, overturning, or stirring. This practice releases greenhouse gases from the soil, that's why no-tillage management practices are more climate-friendly.

Yield – the amount of agricultural product/crop that can be harvested in a given area and time.

REFERENCES

Pawlowski MN, Crow SE, Meki MN, Kiniry JR, Taylor AD, Ogoshi R, et al. (2017) *Field-Based Estimates of Global Warming Potential in Bioenergy Systems of Hawaii: Crop Choice and Deficit Irrigation*. PLoS ONE
http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0168510

National Geographic: Biofuels
https://www.nationalgeographic.com/environment/global-warming/biofuel/

Biofuel digest: Viable biomass for Hawaii
http://www.biofuelsdigest.com/bdigest/2017/03/12/viable-biomass-for-hawaii/