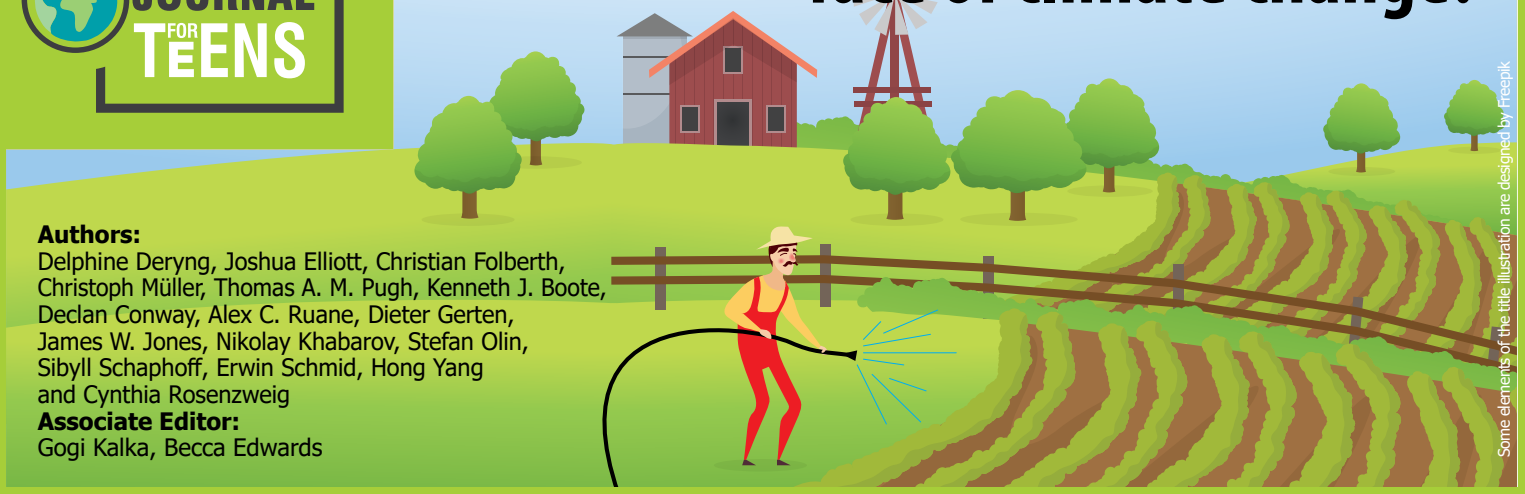
ENVIRONMENTAL SCIENCE JOURNAL FOR TEENS

AUGUST 2017

How can CO_2 help agriculture in the face of climate change?



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Abstract

Humans are increasing the amount of carbon dioxide (CO_2) in the air through *CO_2 emissions*. This is changing the climate, making life harder for many plants in areas that suffer from heat and drought. However, plants need CO_2 to grow, and more CO_2 can make them grow better. So will plants overall benefit from increased CO_2 level or suffer from it?

We wanted to test if the positive effect would offset the negative ones. To do so, we used scientific models to calculate future crop production and water use of four important *crops* all over the world under different *scenarios* of CO_2 emissions and climate change.

Our calculations show that although there will be large reductions in *crop yield* due to climate change over the next century, some crops will still be able to grow well. This is also because crops can grow with less water when CO_2 levels are raised.

Introduction

Many human actions, such as burning fossil fuels (like oil, coal, and natural gas) or cutting down forests, release carbon dioxide (CO_2) into our atmosphere. All the extra CO_2 acts like an insulating blanket, keeping heat on Earth instead of letting it escape into space. The trapped heat warms up our planet and changes the global climate and weather patterns. This can create periods of heat and water stress, damaging to humans, animals and plants.

However, plants develop by using energy from sunlight to convert CO_2 into plant tissue in a process called *photosynthesis*. So we wondered, could the increase in CO_2 in the atmosphere actually improve the growth of crops, and potentially offset the predicted negative effects of climate change? Some scientists say it can because more CO_2 makes crops grow better and use less water in the process. But how does this effect occur in the various regions of our planet that have very different weather conditions? (Fig. 1)

Most of our knowledge about how crops grow in high CO_2 environments comes from temperate regions: areas with four seasons and a moderate amount of rain. However, crops are grown in other parts of the world, including in dry and tropical climates. So we made sure to include them in our study.

We set out to answer the following specific questions:

1. **What effect do increasing *atmospheric CO_2 concentrations* and climate change have on *crop yield?***
2. **What effect do they have on crop water use?**
3. **What effect do they have on crop *water productivity?***
4. **Are there regions in the world where crops would actually grow better under future climate change because of the effects of CO_2?**

Please see Figure 1 on Page 2

Figure 1:
Fields of maize (aka corn) in different stages of growth

Methods

Because we cannot be sure how climate is going to change in the future, we used different computer models to calculate possible effects of climate change and atmospheric CO_2 concentrations on crop yield and plant water use (*evapotranspiration*) for many places all over the globe.

We focused our calculations on four common crops that are important for worldwide food supply: wheat, rice, soybean, and maize.

In order to separate the effect of increased CO_2 levels from effects of other *climate parameters* (such as increased temperatures or changing rainfall patterns), we made two separate calculations:

Calculation #1: We calculated crop yield and evapotranspiration in the future under a changing climate, but with current CO_2 levels.

Calculation #2: We calculated crop yield and evapotranspiration with changing climate and increased CO_2 concentrations.

Finally, we estimated how much *crop yield* is produced per unit of water use during the entire growing season, which is a quantity called *Crop Water Productivity* (CWP).

The two different calculations allowed us to see if changes in CWP were caused by the increasing CO_2 or just by the changes in climate. We also compared our calculated data with results from real-life CO_2 enrichment experiments where scientists grow crops in fields that are surrounded by increased CO_2 levels.

Results

As we expected, we got very different results for the two calculations:

1. When we changed climate parameters in our models, but kept CO_2 concentrations to today's level, we saw the yields of all our four crops decrease greatly all over the world. This shows us the effect of a changing climate alone.

2. However, when we also increased the CO_2 concentrations (to the expected future levels) in our models, some crops grew better and used less water at the same time. This means their Crop Water Productivity increased. This was especially true for *drier* areas, like parts of Africa and the Middle East (Fig. 2).

We compared our calculated results with results from field experiments where crops were grown in an enriched CO_2 environment. These show that the effects we calculated do actually happen in nature. We also found that well-fertilized crops respond better to the increased CO_2.

Our findings don't mean that climate change is great for crops. However, they can help farmers make smarter decisions about irrigating and fertilizing their crops in a world of changing climate.

Please see Figure 2 on Page 3

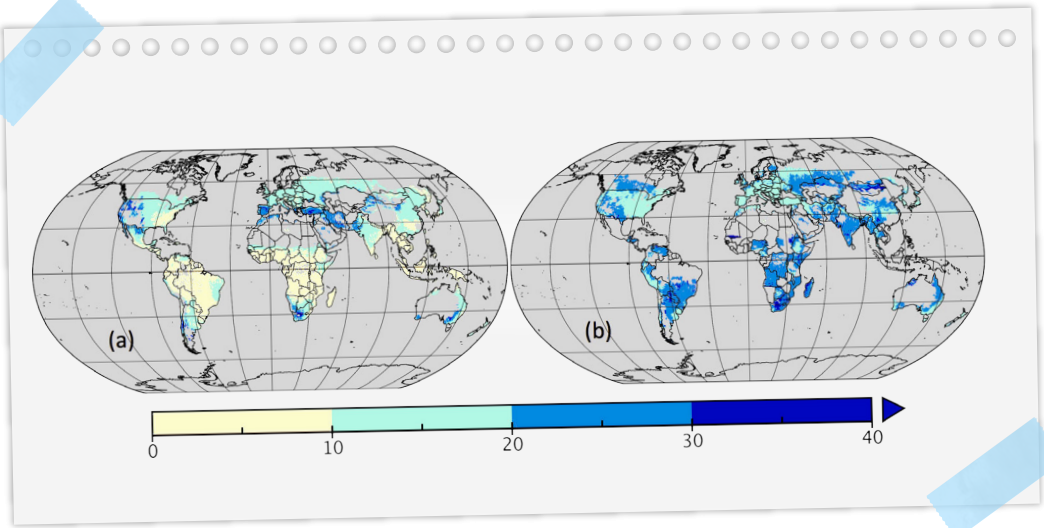

Figure 2:
World maps showing the **difference** in Crop Water Productivity (CWP i.e. crop yield/evapotranspiration) between the two main scenarios:

1. Climate change in combination with increased CO_2
2. Climate change **without** an increase in CO_2.

The left map shows results for maize, the right one for wheat, by the year 2050.

Can you notice how much higher CWP is when we account for the combination of warmer climate **and** higher CO_2 concentrations?

Discussion

The difference in the two outcomes of our simulations suggests that the positive effect of extra CO_2 on crop yield, especially when it comes to crop water productivity, offsets some of the negative effects of climate change on these crops. This is especially true for dry areas where lower water availability is already putting a strain on food production. The more water efficient a crop can grow, the better it can deal with a shortage of water.

So on the one hand, more CO_2 in the air changes the climate and makes life harder for a lot of plants, stressing them with higher temperatures. But on the other hand, our results suggest that there is at least one positive side effect for production of certain foods: CO_2 acts like a fertilizer for some crops, making them grow better, and most importantly, with less water. This could offset some of the negative effects of climate change that farmers will experience in the future.

Conclusion

Knowing how and where climate change and increasing atmospheric concentrations of CO_2 affects crops is important for farmers and planners preparing for a changing climate. If we know that crops will require less irrigation water, then we can have more water available, e.g. for irrigating other crops as well. This gives us hope that farmers will be able to adapt their practices to grow crops in a changing climate and continue to provide food.

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This contribution was supported by UKaid grant GB-1-202108 to the *Agricultural Model Intercomparison and Improvement Project* (AgMIP). The information presented does not necessarily reflect the views of DFID or the British people.

Glossary of Key Terms

Atmospheric CO_2 concentrations – The ratio of CO_2 to other gases in the atmosphere.

CO_2 emissions – The release of carbon dioxide into the atmosphere, caused by human activity like burning fossil fuels..

Climate parameters – factors that describe the climate, like temperature, amount and duration of rainfall, etc.

Crop – (a cultivated plant that is grown for human consumption (food, fiber).

Crop yield – agricultural output, such as grains; the amount of useful plant parts per unit of cultivated land.

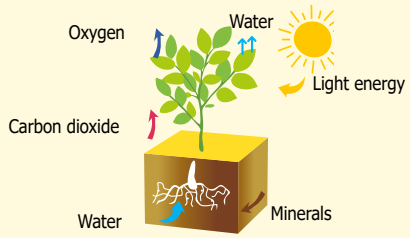
Crop Water Productivity (CWP) – the ratio between crop yield and evapotranspiration. It's a measure of how efficiently crops use water to produce grains.

$$\text{Crop Water Productivity} = \frac{\text{Crop yield (in kg/ha)}}{\text{Evapotranspiration (in mm)}}$$

Evapotranspiration – the process by which a plant releases water to the atmosphere.

Hectare (ha) – A unit of area equal to 10,000 square meters.

Photosynthesis – The process in which a plant uses energy from the sun to convert carbon dioxide from the atmosphere into plant tissue.



Scenario – A possible situation, based on certain assumptions and factors..

Check your understanding

1. You read above that crops can grow using less water when there is more CO_2 in the air. Any idea how this could be explained?

2. What crops do you eat? Do you know where they are grown? What is the climate like in that location? How might the climate there change in the future?

3. The article discusses how plants are projected to grow differently as a result of changing conditions like changing precipitation patterns, temperatures, and carbon dioxide concentration. How have growing seasons for various garden vegetables changed in the last few years?

4. Other than changes in precipitation patterns, what other factors might change the amount of water available to a plant? How might some of those factors change as a result of climate change?

5. The article talks about how plants grow differently in different regions of the world. Think of a movie you have seen that was set in a different region than where you live, or a time when you have traveled to somewhere far away. How were the plants and trees different in that location? What is it about that local climate that allows different sorts of plants to grow than the ones you are used to at home?