CLIMATE CHANGE

Effects of climate engineering on agriculture

Climate engineering can alter the radiation budget in different ways than greenhouse gases and possibly benefit crop yields.

Ben Kravitz

Reducing greenhouse gas (GHG) emissions to halt climate change has thus far been slow and difficult. Worried about the rapidly worsening effects of climate change, scientists and policy makers have been increasingly discussing climate engineering technologies able to temporarily and deliberately modify the climate[1]. Ideas like injecting a layer of tiny sulfur droplets into the stratosphere, brightening low clouds over the ocean, or thinning heat-trapping cirrus clouds, have never been tested at climate-altering scales in the real world. Climate models indicate that climate engineering, if carefully done, could reduce the damaging effects of climate change for many[2] — but with possible side effects, some of which cannot be predicted. The risks of climate engineering need to be weighed against the risks of climate change to inform decision makers in the coming decades.

The potential effects of climate engineering on food supply are poorly understood. In simulations of future scenarios with increased GHG emissions, climate engineering might increase crop yields due to higher CO_2 and reduced heat stress[3], but reducing total available sunlight might negate the potential for those increases[4]. Stratospheric sulfate would scatter sunlight, increasing canopy-penetrating diffuse light and enhancing photosynthesis[5]. However, changes to cloud cover as a result of climate change or climate engineering may have important, nonlinear effects on crop yield[6]. The process of modelling temperature, radiation, and precipitation outcomes and then feeding them into agricultural models to determine effects on crops has numerous unknowns and uncertainties, some of which vary under assumptions about future scenarios of climate change; understanding how climate engineering might affect food supply seems daunting.

In *Nature Food*, Fan and colleagues[7] have used a common modelling setup to compare the effects on crops of different climate engineering methods with the effects of GHG reductions. While such a study won't reveal what will happen to agriculture under climate engineering, it does allow for a comparison of how different methods of addressing climate change might affect crop yield. The authors individually computed the effects of reduced heat stress, changes in direct and diffuse radiation, precipitation, relative humidity, and, in the case of emissions reduction, reduced CO_2 fertilization. They found that CO_2 fertilization is the dominant effect, resulting in reduced crop yields (that is, a reduction of approximately 5%) under the emissions reduction simulation despite reduced heat stress. In contrast, all of the climate engineering simulations that included no emission reduction showed a ~10% increase in crop yields — largely due to a combination of increased CO_2 and reduced heat stress (and, to a lesser degree, changes in relative humidity). Previous studies of stratospheric sulfate aerosol climate engineering[4] have indicated that reduced sunlight could offset yield gains from reduced heat stress. Fan and colleagues[7] found that incoming sunlight has much less importance for total crop yield changes, although the nonlinear relationship between sunlight and crop yield[6] suggests that more investigation surrounding this conclusion is needed.

There remain uncertainties regarding the climate and crop model's representations of the effects of climate change and climate engineering. For example, because of the potential variations in sensitivity of crop yields to incoming sunlight, results may have been affected by the model's aerosol and cloud parameterizations. Uncertainty quantification simulations to explore plausible parameter values or perturbed physics ensembles would be a useful follow-up to quantify the effects these parameterizations might have on crop yields. In addition, the models used don't capture all processes — and it is unclear how important those missing processes are for the study's conclusions. Comparing results from different climate or crop models, as is commonly done in model intercomparisons[8], can help quantify and/or reduce uncertainty.

Would climate engineering be beneficial or harmful to crops? The case is far from closed. While the study by Fan and colleagues[7] makes some important strides, there is still a robust debate regarding the net effects of climate engineering and climate change on agriculture. There are important uncertainties in modelled climate response and limited ability to validate those models with natural analogues. Those uncertainties may be compounded when climate output is passed onto crop models. Moreover, crop yield is not food supply; there could be numerous mediating effects on food availability due to change in transport, geopolitics (like food stockpiling), or fertilizer use to offset negative impacts of climate change. The effects of climate engineering on ecosystems also have numerous uncertainties, with important feedbacks on global food supply[9]; synergistic research on ecosystem impacts (agriculture could be viewed as an example of a managed ecosystem) could close knowledge gaps and identify important future areas of research.

Agriculture is one important piece in our understanding of the effects of climate engineering. Gaining a better picture of the impacts of climate engineering requires looking at numerous effects in addition to food supply, including water security, geopolitics, and environmental justice[10]. Many of these aspects, particularly the effects of climate engineering on biodiversity and ecosystems, are poorly understood, hampering thorough risk assessments of climate engineering. Progress on climate change through conventional mitigation strategies has been slow so far, and climate engineering may be the only way of rapidly reducing climate risks, while potentially introducing others. It is important to figure out whether climate engineering would ultimately be more or less risky than climate change (and to whom). Further research is needed so that society can make well-informed decisions about whether and how climate engineering should be used. ❐

Ben Kravitz[1,2] ✉

[1]*Department of Earth and Atmospheric Sciences,*

Indiana University, Bloomington, IN, USA.
[2]*Atmospheric Sciences and Global Change Division, Pacific Northwest National Laboratory, Richland, WA, USA.*
✉*e-mail: bkravitz@iu.edu*

Published online: 20 May 2021
https://doi.org/10.1038/s43016-021-00277-x

References

1. National Academies of Sciences, Engineering, and Medicine *Reflecting Sunlight: Recommendations for Solar Geoengineering Research and Research Governance* (National Academies Press, 2021); https://doi.org/10.17226/25762
2. Irvine, P. et al. *Nat. Clim. Change* **9**, 295–299 (2019).
3. Pongratz, J. et al. *Nat. Clim. Change* **2**, 101–105 (2012).
4. Proctor, J. et al. *Nature* **560**, 480–483 (2018).
5. Xia, L., Robock, A., Tilmes, S. & Neely, R. R. III *Atmos. Chem. Phys.* **16**, 1479–1489 (2016).
6. Proctor, J. *Nat. Food* **2**, 166–173 (2021).
7. Fan, Y. et al. *Nat. Food* https://doi.org/10.1038/s43016-021-00278-w (2021).
8. Kravitz, B. et al. *Atmos. Sci. Lett.* **12**, 162–167 (2011).
9. Zarnetske, P. L. et al. *Proc. Natl Acad. Sci. USA* **118**, e1921854118 (2021).
10. Irvine, P. J. et al. *Earths Future* **5**, 93–106 (2017).

Competing interests

The author declares no competing interests.