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Consequences of solar geoengineering on terrestrial carbon cycle and agricultural production

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Solar radiation management (SRM) has been proposed as a complementary mitigation strategy for offsetting the global warming effects of high atmospheric CO_2 concentration, if global emission cut cannot meet the Paris target in time. Several SRM methods have been devised and experimented with Earth system models such as stratospheric aerosol injections (SAI), marine sky brightening (MSB) and cirrus cloud thinning (CCT). They can be implemented on top of a high emission scenario such as the Representative Concentration Pathway 8.5 (RCP8.5) so as to reduce the radiative forcing to that comparable to a middle-of-the-road scenario like RCP4.5. Although these methods could effectively reduce the radiation budget and global mean temperature on Earth's surface to the same target, they could incur significant regional variations in precipitation and other meteorological patterns and thereby affect ecosystem and agrosystem functioning with varying regional significance. Moreover, the potential fertilization effect of high CO_2 concentration allowed in the SAI, MSB, CCT scenarios could add to the uncertainty in ecosystem response as compared to a lower CO_2 world in the RCP4.5 scenario. There have been many studies on the impact of climate change on ecosystem functioning but our understanding of the promises and caveats of such geoengineering for agricultural systems remain poorly understood.

Here, we present a study that assesses the impacts of three SRM methods on agricultural production of nine major crop types and explore potential consequences on terrestrial carbon and water cycles. Results show that none of the three methods consistently benefit or harm different ecosystem services across different regions. On the global scale, a general finding is that land ecosystems will increase gross primary production in a high CO_2 world compared to the moderate RCP4.5 pathway. Net primary production is less different among them. Crop yield generally increases in the 21st century with or without geoengineering, which are related to increasing temperature, precipitation and CO_2. Among the three SRM methods, the MSB benefits global crop yield more than SAI and CCT. In general, limiting global warming by enforcing solar radiation management could mitigate drought and land degradation which is particularly beneficial for the accumulation of soil carbon stocks for all land cover types. But the more intense land use under RCP8.5, SAI, MSB, CCT scenarios will severely destruct the vegetation carbon stock which exceeds soil carbon accumulation relative to RCP4.5. It is the interplay between climate change and land use change that decides the balance between the temperature target and maintenance of ecosystem services (carbon, water, food) in a changing world.