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"Reconcile land system changes
with planetary health"

Agricultural yield declines from the rapid removal of air pollutants under carbon neutrality

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Abstract

Human activities have increased greenhouse gas emissions since the 1750s, leading to increased climate warming and the risk of extreme weather. In the past, emissions of air pollutants like SO_2, NOx, and NH_3 through a net cooling effect on the Earth's temperature have kept warming under control. Stringent legislation and control measures have drastically reduced air pollutants in the developed world. This rapid reduction has already unmasked climate warming, which has led to increased extreme weather. In the global south countries, access to clean energy and clean cooking measures will soon reduce air pollutants, leading to an increasing rate of extreme events. In this study, we use simulations from the Detection and Attribution Model Intercomparison Project (DAMIP)—specifically aerosol-only, greenhouse gas (GHG)-only, and natural-only experiments—to investigate the drivers of crop yield variability. A hybrid modelling approach, combining the process-based crop model SIMPLACE(simplace.net) with machine learning (ML) regression techniques, is employed to explain observed yield variability for wheat and maize at a 0.5° spatial resolution. Key explanatory variables include extreme event indices such as heat wave duration, wet spell frequency, standardised precipitation index (SPI), and effective degree days. The ML models—comprising nonparametric tree-based methods, deep neural networks, and recurrent neural networks—are integrated with the dynamical crop model to assess the relationship between extreme climate events and crop yield variability under different forcing scenarios from DAMIP. Our results show that extreme weather events, as captured by the hybrid models, generally lead to a decline in crop yields across most regions and crop types. The hybrid crop modelling further confirms that the reduction of air pollutants propagates substantial agricultural losses, often exceeding those driven by GHG-induced warming alone. In most areas, these unmasking effects are more intense than the GHG-driven warming. Our study highlights the potentially severe consequences of unbalanced climate mitigation strategies. While reducing air pollution is crucial for public health, its unintended consequences for agriculture underscore the urgent need for coordinated carbon neutrality efforts. Without such actions, global food production systems may face escalating threats from climate extremes.

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