ATMOSPHERIC CHEMISTRY

A new player in climate change

Land-use change from pre-industrial times to the present day has altered Earth's surface energy balance. Until now, the role of volatile hydrocarbons, emitted by plants, in controlling this balance and driving climate change has been overlooked.

Kirsti Ashworth

Even though their atmospheric lifetimes are measured in seconds to minutes and they have no direct role as greenhouse gases, highly reactive hydrocarbons have the capacity to affect the climate. Writing in *Nature Climate Change*, Nadine Unger[1] shows that altered emissions of these volatile chemicals, resulting from human-driven land-use change, have had an effect on the global climate of comparable magnitude to the other dominant climate impacts of land-use change over the same period.

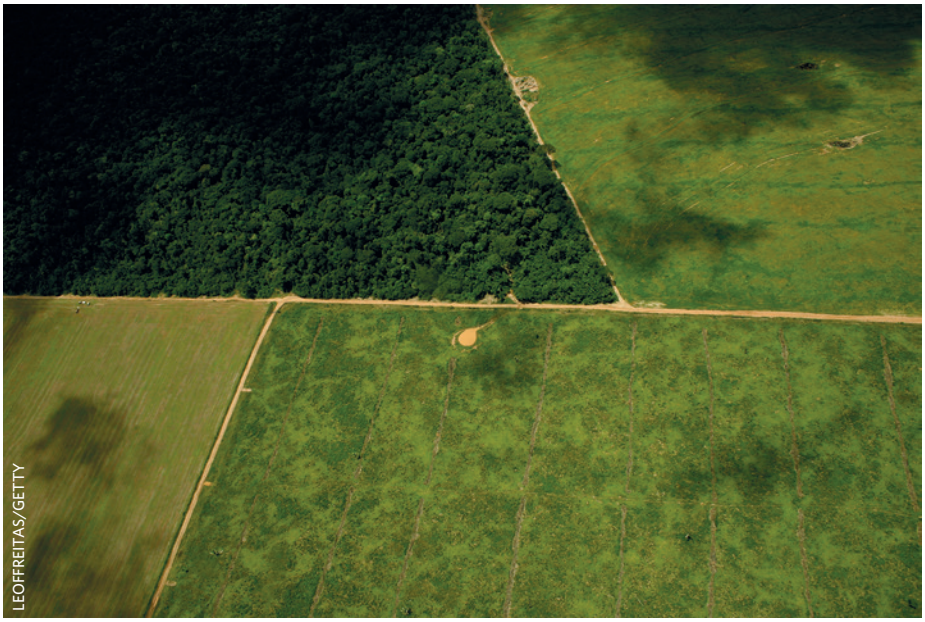
It has been estimated that over the past 500 years around 50% of Earth's land surface has been converted for human use[2]. Most of this change in land use has been driven by the expansion of agriculture into areas that were previously forested, resulting in the loss of around 25% of the world's original forestland. It is well established that such changes in land use and land cover have the potential to affect Earth's surface energy balance through both physical and chemical feedbacks[3]. Of these, changes in surface albedo (the reflectivity of the land surface to incoming solar radiation), and the capacity of the vegetation to act as a sink for CO_2 dominate[3,4]. Replacing dark, carbon-storing trees with lighter crops increases albedo, cooling the climate, while reducing the land carbon sink results in an increase in atmospheric levels of CO_2, warming the climate; the magnitude of these opposing effects are similar[4]. However, changes in chemical cycles, other than the carbon cycle, arising from altered vegetation have up until now been neglected in studies of climate change, in part due to the short atmospheric lifetimes (of the order of seconds to minutes) of the chemicals involved. It is this oversight that Unger[1] seeks to address.

It is well known that one group of chemicals released from vegetation, referred to collectively as biogenic volatile organic compounds (BVOCs), undergo photochemical oxidation in the atmosphere leading to the formation of two short-lived climatically active species: ozone and aerosols[5]. The high reactivity of BVOCs also reduces the oxidation capacity of the atmosphere, decreasing the sink for methane and thereby increasing the atmospheric lifetime of methane[6]. While the impact of BVOCs on climate has been previously assessed, their effect on the radiation budget has not been quantified, and the focus of recent research has shifted towards air pollution[7].

The expansion of agricultural land at the expense of forests is known to lead to substantial reductions in BVOC emissions[8], as trees tend to produce and emit such chemicals at far higher rates than crops and other herbaceous plants. Such reductions can affect atmospheric levels of ozone, aerosols and methane[9]. However, the effects on radiative forcing have not been directly quantified before.

Unger[1] uses a global integrated carbon–chemistry–climate model to simulate the changes in emissions of highly reactive hydrocarbons from vegetation between 1850 and 2000 that occurred due to conversion of forests to agricultural land over this period. On a global basis, the estimated ~35% reduction led to substantial decreases in the concentrations of both tropospheric ozone and organic aerosols, as well as a decrease in the atmospheric lifetime of methane[1]. As ozone and methane are both greenhouse gases, these reductions resulted in a cooling effect on global climate over the period of the study. In contrast, decreased aerosol levels led to less backscattering of incoming solar radiation, thereby warming the climate.

It is, however, the magnitude of the estimated impact on global climate that is most striking. The model simulations show that the combined effect of the altered concentrations of ozone, aerosols and methane is a global cooling of -0.11 W m^{-2}, a forcing on global climate that is of a magnitude comparable to that of the estimated changes due to CO_2 ($+0.17$ W m^{-2}) and surface albedo (-0.15 W m^{-2}) that have occurred due to the same land-use changes over the same period. The author rightly concludes that atmospheric chemistry, even that involving highly reactive species with atmospheric lifetimes too short to directly influence climate, must be considered in the context of its impact on Earth's radiation budget.



Mato Grosso, Brazil.

This study raises a number of intriguing questions that should be addressed by the chemistry–climate community. How, for example, do processes that occur on different spatial and temporal scales, such as changes in albedo and methane lifetime, interact to drive local or global changes in climate? How critical is the location of the changes in land cover in determining the magnitude and direction of the global impact? How would inclusion of the indirect effects of aerosols on climate affect the radiative forcing of BVOCs estimated here?

Projected future changes in land use are small compared with those modelled here[2], but with questions still surrounding the atmospheric oxidation of BVOCs and their emission rates under future climate, it remains unclear if the magnitude of their effect on the radiation budget would be proportionately smaller. It is also concerning that future land-use changes are projected to be in the opposite direction, with forest expansion and cropland diminution[2] suggesting that the future contribution of BVOCs could be a warming of the climate.

Unger[1] has demonstrated that the atmospheric reactions of highly reactive short-lived organic compounds from vegetation can have a substantial effect on the surface energy balance at both local and global scales. Changes in the atmospheric concentrations of ozone and aerosols, and the lifetime of methane due to reductions in these emissions, as a result of the expansion of agricultural land between 1850 and 2000 have resulted in a global cooling estimated at -0.11 W m^{-2}. The magnitude of the impact suggests that atmospheric chemistry should no longer be neglected in the modelling of future global change. ❐

Kirsti Ashworth works within the Biosphere–Atmosphere Interactions Group, Atmospheric, Oceanic and Space Sciences Research (AOSS), University of Michigan, Ann Arbor, Michigan 48109-2143, USA.
e-mail: ksashwor@umich.edu

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