Chapter 5: Ecosystem services and human well-being

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Section 5.4: Climate regulation

Box 5.4.X. Nitrous oxide: a greenhouse gas and an ozone depleting substance

Nitrous oxide (N_2O) contributes to two distinct global environmental issues: climate change and stratospheric ozone depletion. As a greenhouse gas, N_2O is 298 times more potent than carbon dioxide and is the third most abundantly emitted greenhouse gas (after carbon dioxide and methane) (Forster et al. 2007). Overall, N_2O is responsible for approximately 8% of global anthropogenic greenhouse gas emissions (Forster et al. 2007). While N_2O is a relatively long-lived greenhouse gas, solar radiation eventually degrades the molecule to form the free radical nitric oxide (NO). Free radicals such as NO catalyze secondary reactions that convert ozone (O_3) and a single oxygen atom (O) into two molecules of oxygen gas (O_2) (e.g., $O + O_3 \rightarrow 2\ O_2$). Consequently, increased N_2O emissions ultimately lead to a buildup of NO in the stratosphere and a subsequent depletion of the Earth's ozone layer. At present, N_2O is the most abundantly emitted ozone depleting substance, and will be for the remainder of the 21st century if emissions continue at their current pace (Ravishankara et al. 2009).

N_2O is not the only substance to have these dual properties. Many ozone depleting substances, including chlorofluorocarbons (CFCs), methyl bromide and several other gas species are also highly potent greenhouse gases. And yet N_2O and CFCs are controlled under two different treaties: CFCs under the 1987 Montreal Protocol and N_2O under the 1997 Kyoto Protocol. The Montreal Protocol is considered a model of global environmental cooperation. Under the Montreal framework, the production and commercial use of ozone depleting substances (with the notable exception of N_2O) have

been reduced by approximately 97% globally (Velders et al. 2007). This success in reducing the emissions of other ozone depleting substances is the main reason that N_2O is now the dominant remaining ozone depleting substance. In contrast, the Kyoto Protocol significantly undershot its first phase targets and the parameters of its second commitment period (with a diminished membership) remain unclear. Kyoto's uneven track record has motivated some to explore how the Montreal Protocol might be expanded to include N_2O and thus maximize the duel ozone and climate benefits of the existing policy framework (Kanter et al. 2013).

In California, the use of N fertilizers and livestock manure in agriculture are the largest sources of anthropogenic N_2O emissions. Other sources of N_2O include fossil fuel combustion, nitric and adipic acid production, biomass burning and wastewater. Chapters 7 and 8 of this assessment evaluate a range of technical and policy strategies for mitigating N_2O emissions from these economic sectors. Practices to improve fertilizer use efficiency by optimizing N rates, split applications, controlled release fertilizers, nitrification inhibitors, fertigation technologies and other types of precision agriculture have the potential to reduce N_2O emissions without adverse effects on crop yields (Robertson and Vitousek 2009). In particular, a recent review of 35 studies found that nitrification inhibitors and controlled release fertilizers on average can reduce N_2O emissions by approximately 38% and 35% respectively (Akiyama et al. 2009) and are steadily increasing their market share (USDA ERS 2012). Catalytic reduction technologies exist for N_2O reduction in nitric and adipic production, as well as stationary and mobile combustion, with the added benefit of also often reducing NO_x emissions (Wiesen 2010). Likewise, any of the agricultural strategies for reducing N_2O are also likely to have positive environmental co-benefits by reducing other forms of nitrogen pollution that diminish California's water and air quality.

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