Inconsistencies undermine the conclusion that agriculture is a dominant source of NO$_x$ in California

Tai McClellan Maaz1*, Sarah Waldo2*, Tom Bruulsema1*, Rob Mikkelsen1*

Almaraz et al. reported that agricultural soils are a dominant source of NO$_x$ pollution in California (20 to 32% of total statewide NO$_x$ emissions). However, this conclusion may be undermined by the lack of agreement between their modeled estimates and previously reported empirical measurements, the extrapolation of NO$_x$ fluxes during hot moments to derive annual estimates, and the overestimation of nitrogen fertilizer consumption in California.

However, three potential issues arise from this argument. First, 45% of the modeled values were more than twofold greater than these averaged empirical measurements, and 31% were at least an order of magnitude larger. The paper cites a study that included 2850 NO$_x$ measurements at 26 sites in 10 different cropping systems and reported average peak (noon-time) and diel (adjusted for lower night-time temperature) fluxes of 4.0 and 1.9 kg of N ha$^{-1}$ year$^{-1}$, respectively, if hourly summer fluxes are extrapolated to annual emissions. Even the agreement between the top-down and bottom-up estimates reported in Almaraz et al. is difficult to assess without an analysis of model uncertainty; and even when canopy exchange is considered, the bottom-up modeled flux for July and August is 32 to 47% greater than the top-down estimate based on airborne measurements collected in July and August.

Second, too much weight has been given to the hot moments of measured emissions when scaling up temporally. The best agreement between modeled and observed high-magnitude NO fluxes reported in Almaraz et al. occurs in the Imperial Valley, CA. The fluxes modeled by Almaraz et al. appear to agree with chamber-based measurements published in Oikawa et al. (4), which was reported by Almaraz et al. as 21 kg of N ha$^{-1}$ year$^{-1}$ in table 1. Almaraz et al. derived this estimate by extrapolating an average flux of 66 ng of NO$_x$-N m$^{-2}$ s$^{-1}$ to represent annual emissions. This extrapolation is inappropriate because the NO measurements by Oikawa et al. were largely designed to characterize emission pulses following summer fertilization. Because of the aims of that research, the measurements are weighted toward high-emission periods. Furthermore, Oikawa et al. reported integrated emission factors of 1.8 to 6.6%, less than the emission factor if the annual average emission rate were 21 kg of N ha$^{-1}$ year$^{-1}$ (~11%, if averaged across both small and large field measurements). Excluding or down-adjusting the Oikawa et al. “Observed NO” from table 1 limits the range of the empirical data and further challenges the quantitative coherence between modeled and observed values.

Third, the perception that state-wide N fertilizer consumption in agriculture has increased since the 1990s is not supported by the available data. California fertilizer N sales plateaued in the early 2000s (5). According to the Association of American Plant Food Control Officials, annualized mineral N fertilizer sales have declined to pre-2000 levels (6). The California Department of Food and Agriculture reports the sales of Home and Garden fertilizer blends and compost for organic agriculture under code 0 (“Identified by Grade”). Following reporting changes in 2012, 44% of total fertilizer sales have fallen in this category, resulting in a tonnage increase by more than 300,000 metric tons (7). However, Almaraz et al.
did not assess nonagricultural fertilizer inputs, such as for Home and Garden fertilizer use, in urban areas. Future nitrogen modeling groups using these data should be aware of these reporting differences, as well as the need to differentiate among the uses and sources of nitrogen fertilizers (agricultural versus nonagricultural uses) to properly interpret the model outputs.

The impact of these inconsistencies is difficult to assess because Almaraz et al. did not present their N budget for California. The N rate and total emission data estimated in this study infer an agricultural area of 6,423,737 ha and a natural ecosystem area of 33,810,000 ha. The total annual N fertilizer inputs to agriculture would thereby amount to 848,000 metric tons. This estimate exceeds fertilizer N sales in California from 1980 to 2007, a period for which Almaraz et al. used crop-specific data to generate N inputs, by almost 50% (6). It also well exceeds total nitrogen fertilizer sales in 2016, even when additional sources of nitrogen fertilizers are included (7). It is unclear whether this estimate includes other sources of reactive N (that is, N from biological fixation and deposition), although the authors state that manure N was not included. Is it possible that the authors overestimated fertilizer N inputs? Or are the authors using the term “fertilizer” when they actually meant “reactive” N?

We ask that the authors upload their complete N budget and assumptions for water-filled pore space, along with an uncertainty analysis, for California as supplemental data. This will help the reader properly compare and otherwise address the apparent inconsistencies in emission factors and allow for an improved assessment of the role of agriculture as a source of NOₓ in California.

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