Comments on “Review of San Joaquin Valley 2024 Plan for the 12 μg/m^3 Annual PM2.5 Standard” by CARB, June 14, 2024

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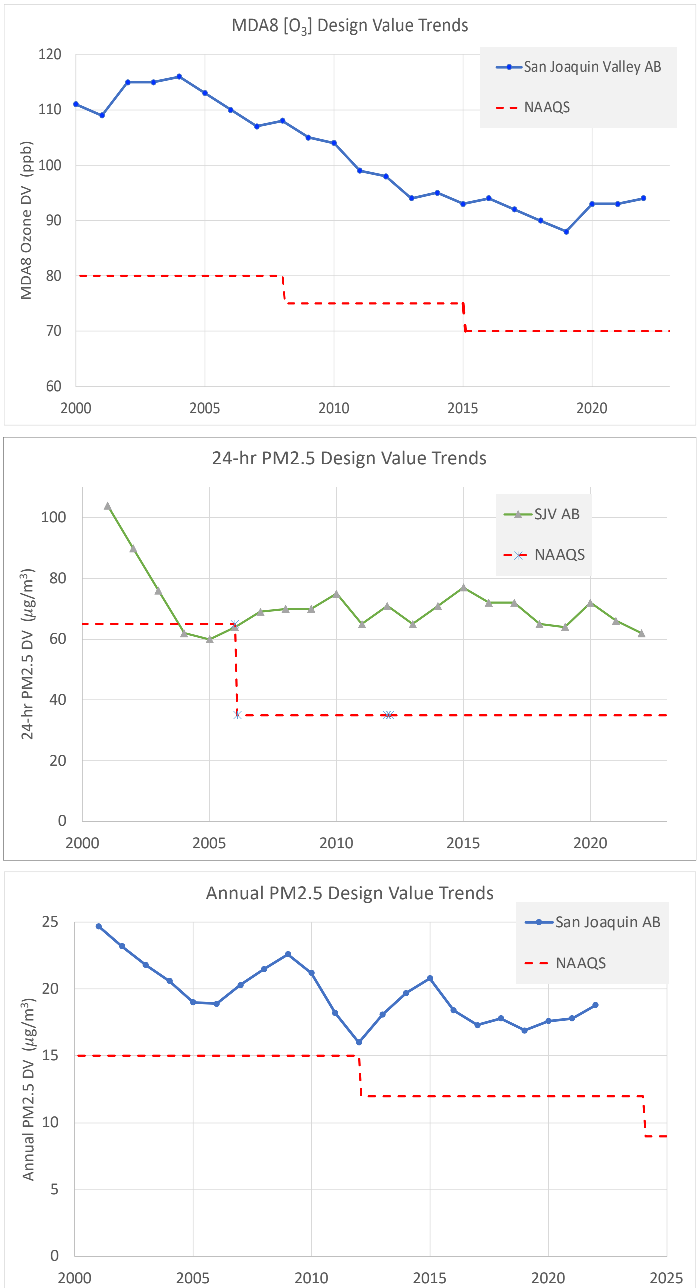
Introduction

Disadvantaged communities in rural agricultural areas throughout the San Joaquin Valley (SJV) disproportionately bear the impacts of poor air quality, despite years of regulatory efforts to reduce pollution from traditional combustion sources. In fact, the top 3 most polluted cities in the country by annual PM standards lie in the SJV [ALA, 2024]. Because no appreciable improvements have been seen in the design values of O_3 or PM2.5 (either the 24-hr or annual standard) over the past decade, we believe the State Implementation Plan (SIP) Modeling behind the targets to meet the NAAQS are fatally flawed. Mounting evidence suggests that there are likely overlooked, unregulated pollution sources affecting the San Joaquin Valley and other intensively agricultural regions of the state. The influence of soil NO_x emissions (both NO and HONO) on air pollution in agricultural regions has come under intense scrutiny in the past decade and the lack of any references to this growing body of literature in the SIP is troubling. However, despite many public comments and letters emphasizing the critical nature of this issue, little has been done towards investigating and regulating this putative source of air pollution save for the establishment of an expert panel. Here, we provide some of the evidence from peer-reviewed research that supports our claim that soil NO_x and wildfires are an important and growing source of PM2.5 air pollution to the SJV.

Nitrogen oxides ($NO_x = NO + NO_2$) serve as ***important precursors to both tropospheric ozone (O_3) and fine particulate matter ($PM_{2.5}$)*** and so that is why we mention the stagnation in improvement of the other standards (O_3 and PM2.5 24-hr) because we believe they are related through the stagnation in improvement in NOx concentrations throughout rural California [Wang et al., 2023]. Microbial emissions of NO (and HONO) from nitrification/denitrification processes in soils has been known about for several decades [Williams & Fehsenfeld, 1991; Yienger & Levy, 1995; Oikawa et al., 2015] and consequently have been in global atmospheric chemistry models for decades where they are believed to account for approximately 20% of global NO_x emissions [Jaeglé et al., 2005; Hu et al., 2017]. A recent modeling study by Silvern et al. [2019] for the continental US (CONUS) estimates the proportion of total emissions from anthropogenic fossil fuel combustion to be only 42% in 2017, with ~18% coming from US soil emissions. It is therefore very difficult to believe the results presented in Guo et al. [2020] which indicate that California, the number one agricultural state in the union, produces soil NO_x emissions that only amount to 1.1% of the total inventory.

Evidence of Stagnation in AQ Improvements



Parrish et al. [2017] developed an empirical model to investigate the asymptotic behavior of ozone improvements in air basins across southern California, finding that the San Joaquin Valley air basin stands out because the asymptote occurs at a much higher O_3 concentration than other air basins indicating the presence of sources that have not been decreasing under regulatory efforts (as is observed throughout the rest of California.) The authors suggest that this could be due to the intensive agricultural activities in these areas. Furthermore, several satellite NO_2 studies over the past decade have drawn attention to a rise in NO_x seen in rural regions across the US and have suggested the cause may be soil emissions [Russell et al., 2012; Miyazaki et al., 2017; Qu et al., 2021]. These studies are complicated by the various sources of "natural" NO_x emissions found across the continent (wildfire, lightning, and soil). More recently Wang et al. [2023] studied specifically California (where lightning sources of NO_x are negligible) using OMI satellite data and showed that cropland areas all over the state have experienced negligible changes in NO_2 columns overhead. They go on to argue that while wildfires are the principal cause of changes in forested regions, soils are an appreciable cause of this stagnation over agricultural regions. Furthermore, they found a strong relationship between satellite NO_2 amounts and underlying surface temperature and soil moisture strongly implying that soil emissions dominate in these regions.

Figure 1. *The long-term trends of ozone and PM2.5 design values in the San Joaquin Valley (SJVAB) indicating the absence of any appreciable trend in the last decade or more.*

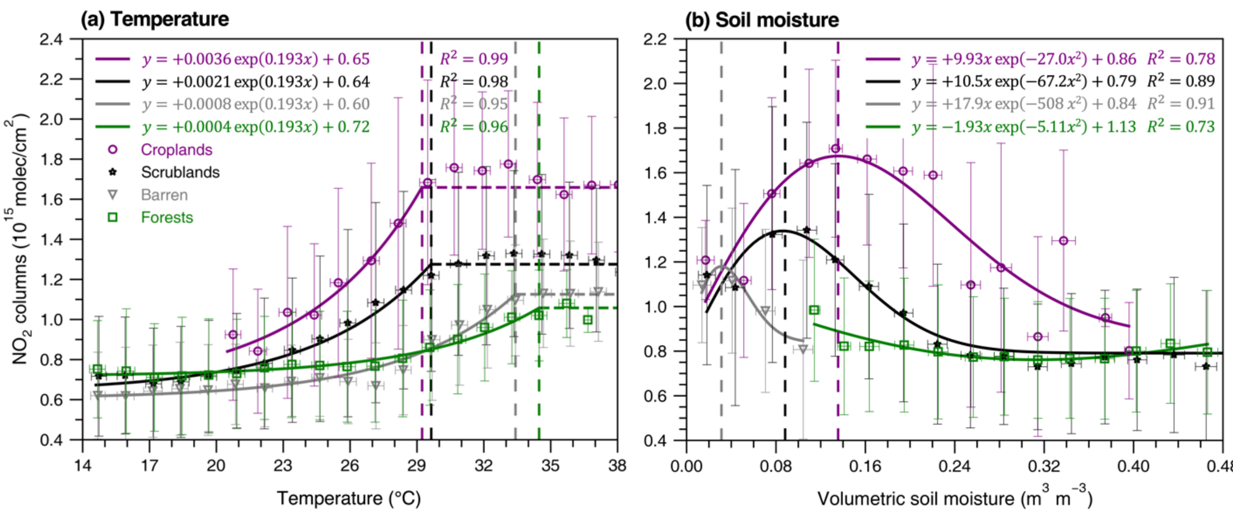


Figure 2. *Relationships between OMI satellite NO_2 columns and daily maximum temperature (a) and soil moisture (b) over different land covers across CA. The solid lines are fitted exponential and Poisson curves, respectively, common functional forms used in soil NO_x parameterizations.*

<u>Mounting Evidence of Soil Emissions Impacts on Air Quality in SJV</u>

Several independent studies support the hypothesis that soil NO_x emissions are underestimated by regulatory AQ models. These studies are summarized in Table 1, outlining key findings, including emphasis on the continual nonattainment of AQ standards in the SJVAB and SSAB, the impact of soil NO_x on AQ nonattainment, and various environmental factors and agricultural practices that may influence soil NO_x production. Overall, one study by CARB researchers, using a soil biogeochemical model (DNDC) that has not been extensively tested in air quality studies (that is, validated by observations of NO_2 by satellite or surface network NO_x/O_3), found soil NO_x emissions from agricultural systems across California to be negligible. Based on a study by Wang et al. (2021) this underestimate is likely to be, at least in part, due to their use of a default temperature coefficient for nitrification based on temperate meteorological conditions that may not accurately reflect the influence of extreme temperatures, like those observed in the SJVAB. This negligible (~1.1%) contribution from agricultural soils in California is conceptually hard to justify given that the global average of soil sources of NO_x is on average ~20%, similar to the contribution from the continental US (~17% according to Silvern et al., 2019). On the other hand, ten other studies, based on thoroughly tested models and observations, found emissions 2-50 times larger across California agricultural landscapes. The collective evidence strongly suggests that agricultural soil NO_x significantly aggravates AQ problems in rural California communities (and inland cities), making it urgent that policymakers and regulatory bodies consider these insights for effective AQ management strategies. There is a pressing need for continued research to refine simulated soil NO_x parameterizations and improve our understanding of the exact physio-chemical controls, which should emphasize collaborations between researchers, regulatory agencies, and local communities for comprehensive and sustainable solutions.

Table 1. A summary of recent literature that addresses agricultural soil NO_x and its impact on air quality in California, especially in the San Joaquin Valley and Salton Sea air basins.

Study	Key Findings
Oikawa et al. (2015)	- Reported record soil NO_x emissions (up to 280 kg N ha^{-1} yr^{-1}) in Holtville, CA (Imperial Valley). - Default soil NO_x parameterization in WRF-Chem model underestimates emissions by at least one order of magnitude. - Augmenting the default soil NO_x emissions (by factors of 10-64 to improve agreements with observations) increases modeled O_3 concentrations by 2-8.5 ppb throughout Imperial Valley in the SSAB.
Parrish et al. (2017)	- Observed dramatically curtailed O_3 improvements in the San Joaquin Valley and Salton Sea air basins, despite improvements in surrounding Southern California air basins. - Suggested that recalcitrant O_3 levels are linked to sources evading regulatory efforts most probably related to the intensive agriculture that characterizes these basins.
Almaraz et al. (2018)	- Suggested in 2018 that agricultural soils emit 20-32% of the state's total NO_x on average, with the average cropland NO_x flux around 20 kg N ha^{-1} yr^{-1}.
Trousdell et al. (2019)	- Top-down aircraft measurements of NO_x and O_3, estimated a total emission rate of 215 ± 33 tons/day around Fresno in the SJVAB, a factor of 2 larger than the CARB's CEPAM inventory - Rural SJV counties exhibited no observed O_3 decreases from 2006-2016.
Kleeman et al. (2019)	- Modified soil emissions in their model using the seasonal soil NO_x emissions from Almaraz et al. [2018]. - These modifications increased predicted $PM_{2.5}$ nitrate concentrations in January of three different years in the SJV, helping to correct a consistent underprediction by the model.
Guo et al. (2020)	- California Air Resources Board study using a soil biogeochemical model (DeNitrification-DeComposition, DNDC) that is largely untested against agricultural soil NO_x emissions in studies using satellite or network sensors. - Concluded that soil emissions contribute only 1.1% of total anthropogenic NO_x in CA, although larger than normal emissions were estimated for the Imperial Valley. - Suggested default temperature coefficient for nitrification may need revision to account for hot agroecosystems like SJVAB (and SSAB).
Sha et al. (2021)	- University of Iowa modified soil NO_x parameterization in WRF-Chem (Berkeley Dalhousie Iowa Soil NO Parameterization, BDISNP), e.g., enhanced land cover, soil temperature, emission pulses, and N fertilizer influences. - In July 2018, estimated soil emissions contributed ~40% of California's total NO_x, increasing rural O_3 concentrations by +23%.
Wang et al. (2021)	- Used a stronger, observation-based temperature response for soil NO_x.

	- Improved correlation between satellite NO_2 and modeled column NO_2 over the central US in the summer, suggesting soil emissions could be larger than expected at temperatures >30°C - Emphasized hotspots in the SJVAB and SSAB due to N fertilization and warm climates.
Luo et al. (2022)	- Simulated reactive N emissions across the contiguous US by county, estimating annual emissions from the 8 counties of the SJVAB to total about 100 tons/day, compared to CARB's CEPAM inventory of ~230 tons/day anthropogenic NO_x estimate (comparable deviation to that reported in Trousdell et al. [2019]). - Incorporated daily fertilizer application estimates from the Environmental Policy Integrated Climate (EPIC) agricultural model, based entirely on simulated idealized plant demands
Wang et al. (2023)	- OMI satellite NO_2 data over croplands revealed a soil-like temperature and soil moisture dependence, with no long-term trend over croplands as opposed to continued decreases (-3.7±0.3 $\%yr^{-1}$) over urban areas. - Illustrates similar dependence of observed NO_2 columns over a variety of non-urban land types across California, implying that soil NO_x is a significant source.
Lieb et al. (2024) in press	- A mixing model using CARB's CEPAM NO_x inventory and source-dependent $\delta^{15}N$-NO_x isotopic measurements revealed an underestimated soil contribution. - Our adjustments showed soil NO_x to be 30% of total NO_x in the Salton Sea AB, an order of magnitude larger than CEPAM's 3%.

In considering the long-term evolution of this problem, it is important to realize that according to CDFA data [CDFA, tonnage reports] fertilizer sales have risen on average by about 1%/year over the past 3 decades, and because this reactive nitrogen is the principal reactant in the soil microbial production of NO (and HONO) these sources are likely to increase over time. Furthermore, while the exact temperature dependence of the soil NO_x emissions is still uncertain, the rapidly warming state of California (approximately 1.0°C per decade), the exponential dependence on temperature means that this too will likely increase the overall emissions. All of these considerations of the time dependence of these sources of NO_x are not included in the current SIP modeling efforts that confidently predict attainment by 2030.

I would like to call attention to one element of the SIP report in particular, that is Table 14, which expects a generally linear RFP (reasonable further progress) targets for NO_x in the state of California. Estimates in that table show a projected 2030 NO_x emission rate in the SJV of 78 tons d^{-1}. This is likely to be highly unrealistic as one recent modeling study outlined in Table 1 above by Luo et al. (2022) using a state-of-the-art agroecosystem model - Fertilizer Emission Scenario Tool for the CMAQ (FEST- C) estimated soil emissions of NO_x in the SJV AB to be ~103 tons d^{-1} in 2011. It appears to be highly unrealistic to expect a total NO_x emission rate that is below that of the unregulated source from agricultural soils, particularly given the trends in warming and fertilizer use outlined above.

I would also like to mention that I have limited the survey above to studies that have included California agriculture specifically. However, there is a rapidly expanding literature on similar issues being discovered in the North China Plain where vast agricultural activities are contributing to degraded air quality and a similar recent deflation of regulatory improvements in air quality [Lu et al., 2021; Tan et al., 2023].

Wildfires as Exceptional Events

There is another problematic flaw in the SIP report as it stands, and that is of the treatment of wildfire emissions as “abnormal”. For example, Section IIIA of the weight of evidence document states, “due to the historic wildfire impacts to California in 2020-2022, the summer (July to September) PM2.5 levels appear to be abnormally higher than typical levels.” This seems to imply that ‘typical’ is when there are no wildfire impacts in the SJV and that 2020-2022 was an exceptionally high wildfire period. Although it is indisputable that 2020/2021 were, in fact, record years, trends in burned area across California presented by Wang et al. [2023] indicate that the trend is exponentially growing with a doubling time scale of 10 years in the warm season (and 20 years for the annual total burn area.) Furthermore, Iglesias et al. (2022) show that not just the burn areas are rising across the Western US, but with wavelet analysis they show that the frequency is increasing as well, with an exceptional wildfire year occurring once every 5 years since about the turn of this century. Moreover, a recent study by Pan & Faloona [2022] on the impacts of wildfires on PM2.5 in the Central Valley warm season found that from June-Sept, 2016-2020, wildfires impacted 1 in 5 days of the study, and that on average the 24-hr PM2.5 in the SJV was elevated by 8.2 $\mu g\ m^{-3}$ during these days. One in five days is already likely to tax the ability of the regulatory system to allocate exemption days due to wildfires, and this problem is only going to get worse. Therefore, forecasting PM2.5 air quality into the next decade is going to require realistic considerations of the rapidly increasing wildfire impacts, in addition to the soil sources outlined above.

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