2025 Agricultural Mobile Equipment Emissions Inventory

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CALIFORNIA AIR RESOURCES BOARD

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1 Executive Summary

California is the nation's leader in agricultural production, producing over 400 different commodities that generate over $60 billion in annual sales[1]. The following technical report investigates total statewide agricultural emissions resulting from off-road mobile equipment used in agricultural goods production and supply processes. Diesel particulate matter (PM) and oxides of nitrogen (NOx) emissions from mobile diesel agricultural equipment significantly contribute to California's air quality issues, especially in the San Joaquin Valley (SJV). SJV has 56% of the state's harvested acres and its associated farming equipment.

The California Air Resources Board (CARB) developed a new 2025 mobile agricultural equipment emissions inventory covering all mobile agricultural equipment used primarily (over 50% of the time) in agriculture production or first processing, including all fuel types and horsepower. This 2025 emissions inventory replaces the previous 2021 emissions inventory using the latest available data on farm acreage and equipment population and activity. In conjunction with California Energy Commission (CEC), California Public Utilities Commission (CPUC), and with the support of the California agricultural community, CARB conducted a joint, anonymous, statewide survey to collect 2024 agricultural equipment trends. In addition to the survey, the inventory uses data from the 2022 USDA Agricultural Census[2], the 2022 County Agricultural Commissioners' Report[3], a report on the Sustainable Groundwater Management Act (SGMA)[4], and new load-dependent NOx emission methodology based on real-world emissions testing results[5].

In consultation with agricultural stakeholders, the anonymously reported survey data organizes responses according to twelve main commodity types and fifteen equipment categories. Further divisions include sorting farm size and commodity by acreage bins and equipment by horsepower bins.

Findings include a significant loss of small farms, those with less than 50 acres, with smaller losses in farms between 50 and 250 acres. The number of largest farms, those with greater than 250 acres, is increasing. This is also the first time the inventory forecast considers the anticipated reduction in harvested acres due to SGMA water use restrictions. Based on the

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[1] California Agricultural Production Statistics *https://www.cdfa.ca.gov/Statistics/*

[2] USDA Agricultural Census *https://www.nass.usda.gov/Publications/AgCensus/2022/Full_Report/Census_by_State/California/index.php*

[3] California County Agricultural Commissioners' Report *https://www.nass.usda.gov/Statistics_by_State/California/Publications/AgComm/index.php*

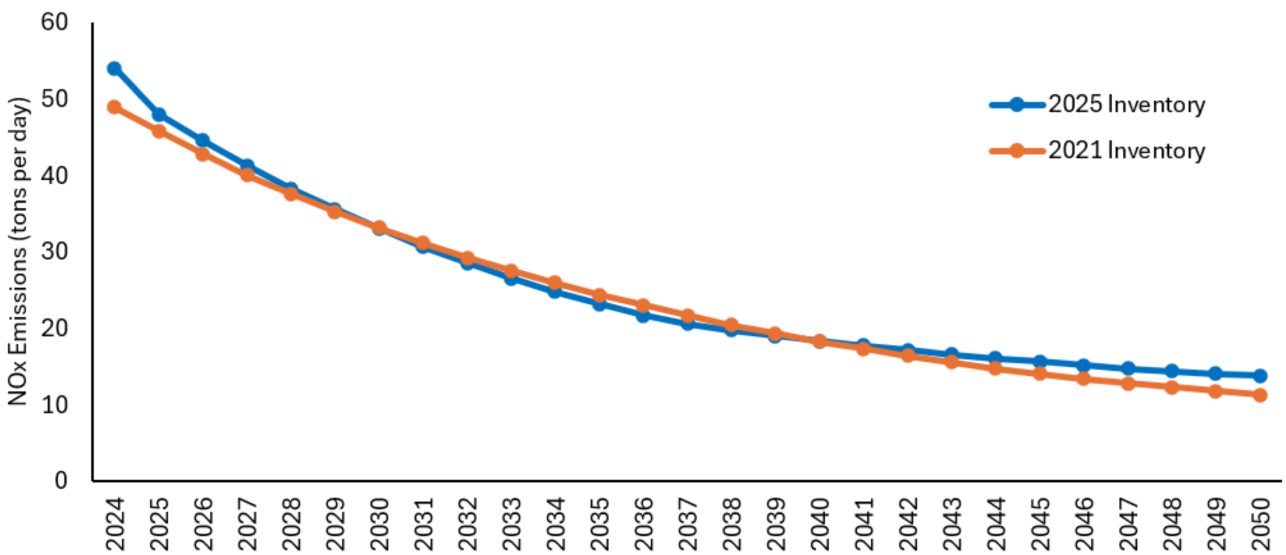
[4] Sustainable Groundwater Management Act *https://water.ca.gov/programs/groundwater-management/sgma-groundwater-management*

[5] CARB's 2025 Off-road Diesel Emission Factors. *https://ww2.arb.ca.gov/sites/default/files/2025-09/Tech%20Doc%20-%202025%20Emission%20Factors%20for%20Offroad%20-%202025%20ADA%20FINAL.pdf*

general loss of small farms, acreage, and water use restrictions, the emissions inventory forecasts that agricultural equipment population will decline over time. Overall, statewide NOx emissions are not substantially different than the previous 2021 inventory's projection, with the new 2025 inventory estimating slightly higher NOx emissions in 2024, dropping around 2030, and rising again around 2042.

Figure 1 summarizes statewide findings, demonstrating the 2025 inventory's statewide projected NOx emissions (blue line) are relatively close to the 2021 inventory (orange line). The decline in NOx emissions in historical and base years relates to equipment turnover to newer, cleaner engines, including both natural turnover as equipment ages and incentive projects designed to accelerate equipment replacement. Federal, state, and local investments have funded over $1.5 billion toward the replacement of over 19,000 agricultural tractors and over 12,000 other types of vehicles, equipment, or engines. The programs include the Carl Moyer program, Funding Agricultural Replacement Measures for Emission Reductions (FARMER) Program, the San Joaquin Valley Air Pollution Control District's Tractor Replacement Program, and Environmental Quality Incentives Program (EQIP) from the Natural Resources Conservation Service.

Figure 1 Previous and Updated Statewide Agricultural Equipment NOx Emissions



In the San Joaquin Valley, NOx emissions are projected to be slightly higher than the previous 2021 inventory (Figure 2), while PM emissions are projected to be lower (Figure 3). The primary drivers for these changes are updated emission factors and lower equipment populations.

Figure 2 Previous and Updated San Joaquin Valley NOx Emissions

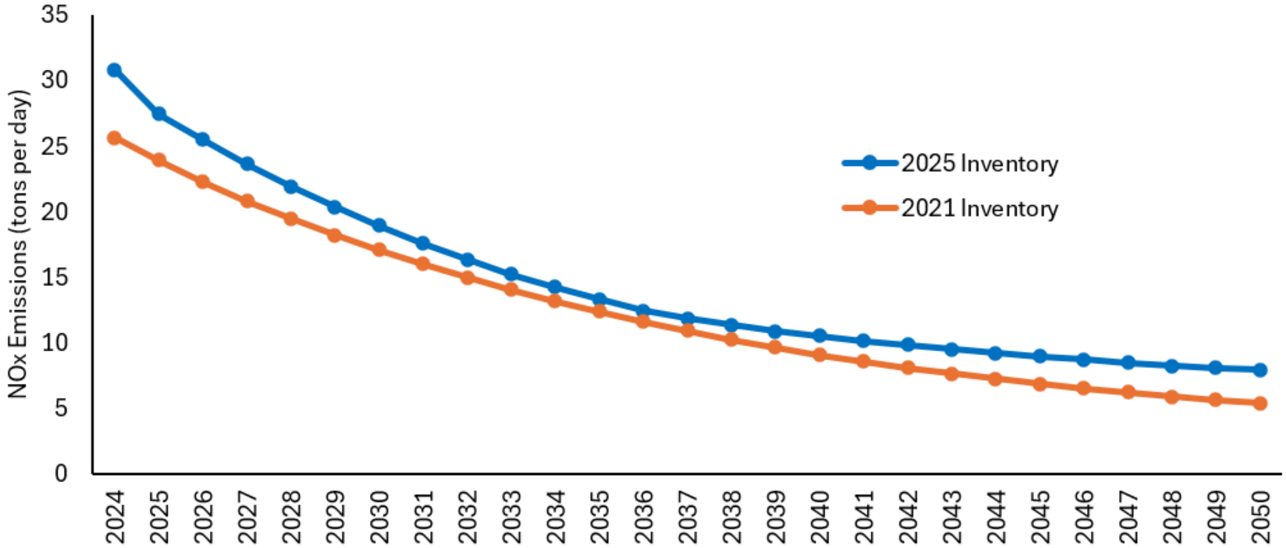
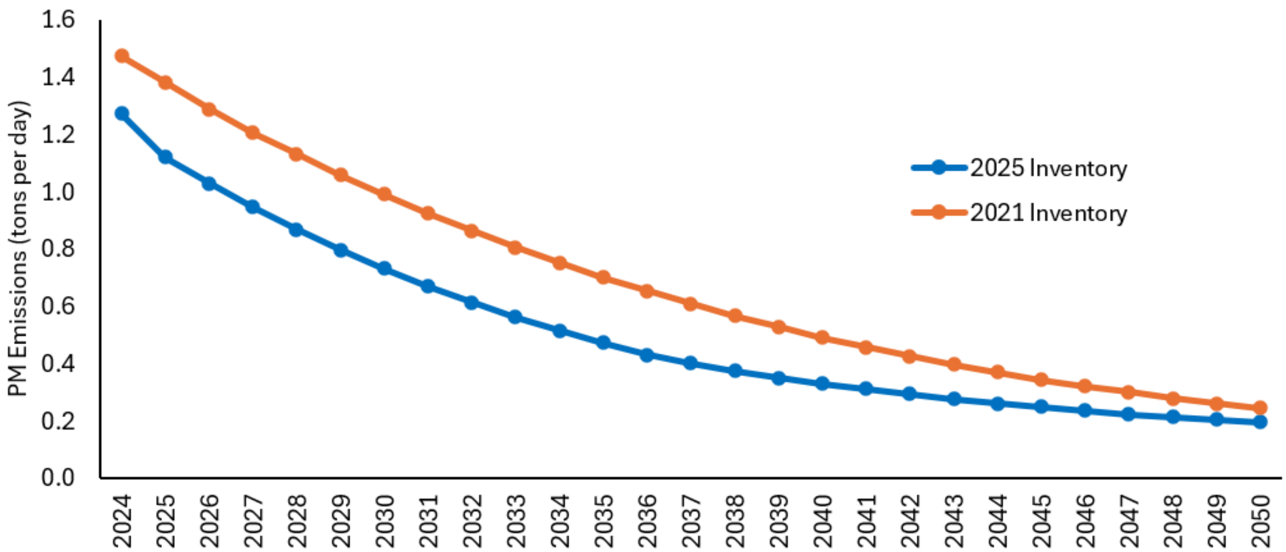


Figure 3 Previous and Updated San Joaquin Valley PM Emissions



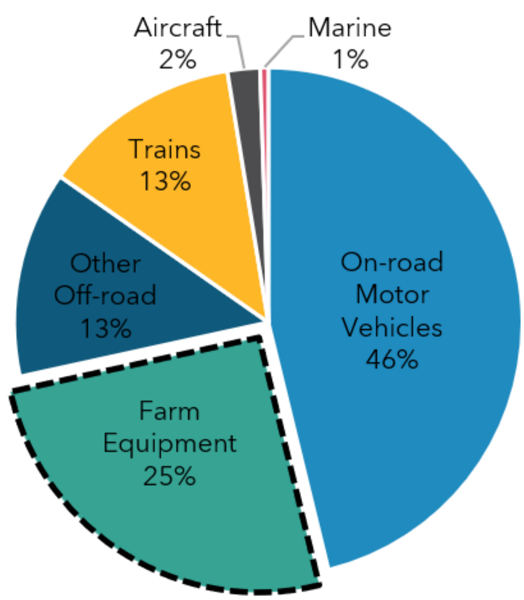
2 Agricultural Equipment Emissions Inventory

This technical report discusses all inputs and methodology used in developing the agricultural mobile off-road equipment emissions inventory. All data in this emissions inventory are specific to California farms, commodities, equipment, and overall agricultural operations. This 2025 emissions inventory replaces the previous 2021 emissions inventory using the latest available data on farm acreage and equipment population and activity.

An emissions inventory is an accounting of an industry sector's equipment population, how much the equipment is used (activity), engine characteristics such as model year and horsepower, and geographically where the equipment is used. This data is used to calculate the total equipment population's resulting emissions. Emission inventories are an important tool that help CARB understand where air pollution comes from and provide data necessary to create strategies for emission reductions, such as incentive funding for equipment replacement programs.

According to CARB's on-road (EMFAC2025 v2.1.0[6]) and sector-specific off-road mobile source emission inventories[7], farm equipment was responsible for 31 tons per day (tpd) NOx emissions in the San Joaquin Valley in 2024, or 25%. This is California's region with the largest amount of agricultural equipment (or 56%). Figure 4 shows the relative NOx emission contribution for all mobile source sectors in the San Joaquin Valley in 2024.

Figure 4 San Joaquin Valley Mobile Source NOx Emissions Contribution in 2024



[6] CARB's EMFAC emissions inventory *https://arb.ca.gov/emfac/*

[7] CARB's OFFROAD emissions inventory *https://arb.ca.gov/emfac/offroad/*

The statewide survey collected California-specific data on equipment use per acre of land for a sample of representative growers across the state. The survey successfully gathered information from almost 500 respondents and 1,350 pieces of equipment in different agricultural regions of California. Survey responses addressed such questions as equipment population, activity data, retirement and purchasing rates, and more. To develop a comprehensive statewide inventory, the survey responses were scaled up using acreage data from the 2022 County Agricultural Commissioners' report and the 2022 USDA Agricultural Census. The final inventory estimates that in 2024, there were approximately 112,500 mobile agricultural equipment operating in California, of which 63,000 were in the San Joaquin Valley.

2.1 Need for an Updated Inventory

An updated inventory is important when understanding where agricultural emissions occur and may inform potential approaches to reduce emissions. Here is a timeline of CARB's agricultural equipment inventories:

- New 2025 Agricultural Equipment Emissions Inventory – 2024 statewide survey on agricultural equipment of all fuel types and horsepower
- 2021 Agricultural Equipment Emissions Inventory[8] – 2018 statewide survey on agricultural equipment of all fuel types and horsepower
- 2018 Diesel Agricultural Equipment Emissions Inventory[9] – 2008 statewide survey on diesel agricultural equipment over 25 horsepower
- OFFROAD2007[10] - 2007 estimation based on equipment manufacturer sales reports

Updating the inventory captures shifts in the agricultural industry such as changes in total equipment population and usage, changes in farm size trends or commodities grown, and allows monitoring of equipment age due to incentive programs. Compared to the previous inventory released in 2021, the new 2025 inventory described in this report includes:

- Updates to the equipment survey data vintage from 2018 to 2024;
- Reflects the latest 2022 USDA Census of Agriculture and 2022 County Ag Commissioner's data on California acreage, reflecting changes in commodities and farm sizes;
- Reflects the large number of agricultural equipment incentive projects accomplished with the assistance of the San Joaquin Valley Air Pollution Control District (SJVAPCD)

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[8] 2021 Agricultural Equipment Emissions Inventory *https://ww2.arb.ca.gov/sites/default/files/2021-08/AG2021_Technical_Documentation_0.pdf*

[9] 2018 Diesel Agricultural Equipment Emissions Inventory *https://ww3.arb.ca.gov/msei/ordiesel/ag2011invreport.pdf*

[10] OFFROAD2007 *https://ww3.arb.ca.gov/msei/offroad/downloads/models/offroad2007_1215_exe.zip*

funds, NRCS funds, and Moyer funding sources from 2009 to 2024 in the baseline equipment population reported in the survey data; and

- Uses the latest off-road diesel emission factors, including new load-dependent NOx emission methodology.

2.2 Incentive Programs

Since 2009, a variety of federal, state, and local programs have invested over $1.5 billion in the San Joaquin Valley to replace older agricultural tractors and other equipment with newer, cleaner models. The agricultural community has either met or exceeded these incentive dollars by equal investment. The following incentive programs play a major role in funding the replacement of agricultural equipment: CARB's Funding Agricultural Replacement Measures for Emission Reductions (FARMER) Program[11], the Carl Moyer Memorial Air Quality Standards Attainment Program (Carl Moyer Program), the San Joaquin Valley APCD's Tractor Replacement Program, and NRCS's Environmental Quality Incentive Program (EQIP)[12].

CARB's agricultural incentive program, FARMER, facilitates distribution of state funds allocated by the California Legislature to incentivize turnover of agricultural equipment. The FARMER Program Guidelines, approved in March 2018 and updated in October 2024, detail the types of projects eligible for funding from the applicable allocations and specify the amount of funding distributed to various districts throughout the state. Over seven fiscal years (fiscal years 2017-18 through 2024-25), the FARMER Program has been appropriated $762 million for agricultural vehicle and equipment projects statewide, of which $603 million has been allocated to the San Joaquin Valley. In addition, the San Joaquin Valley APCD receives Carl Moyer Program and local funds to improve air quality from sources that can also be used to incentivize the accelerated turnover of agricultural equipment through their Tractor Replacement Program.

NRCS's EQIP funding originates from the 2008 Farm Bill, which amended Section 1240H of the Food Security Act of 1985, by authorizing payments for producers to implement practices and innovative technologies that address air quality concerns from agricultural operations and meets Federal, State, and local regulatory requirements. EQIP funding was reauthorized in the 2018 Farm Bill to address California's air quality concerns through 2023.

Through 2025, CARB's FARMER Program, the San Joaquin Valley APCD's Tractor Replacement Program, and NRCS's EQIP have provided over $1.5 billion for the replacement of more than 12,000 Tier 0, Tier 1, and Tier 2 tractors, plus other agricultural

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[11] CARB FARMER Program. *https://ww2.arb.ca.gov/our-work/programs/farmer-program*

[12] USDA NRCS EQIP. *https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/eqip/*

equipment, in California. The incentives targeted replacement of the largest and most used tractors, in addition to other types of farm equipment.

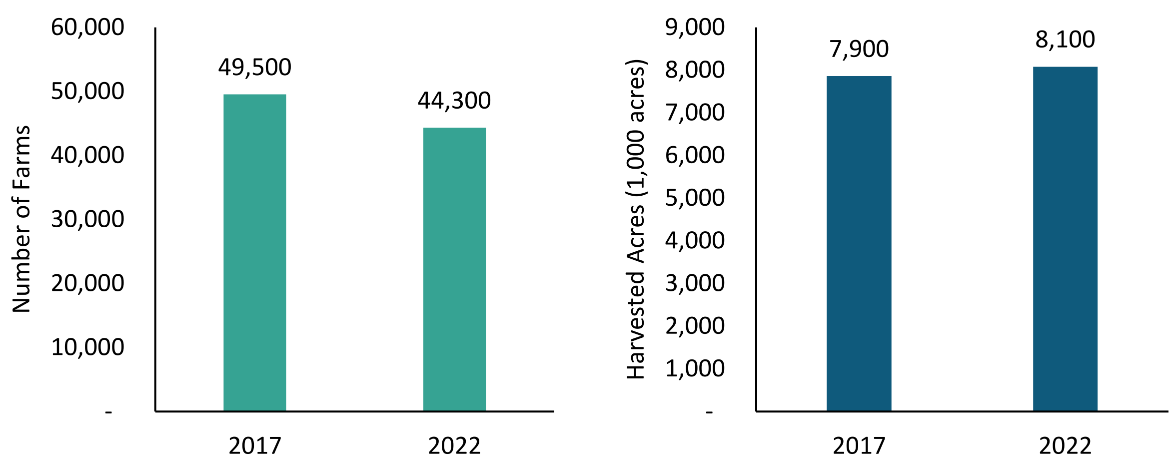
3 California Crop and Farm Data

The most recent 2022 USDA Agricultural Census provided farm size and harvest acreage data across the state. The 2022 County Agricultural Commissioners' report informed crop trends in the state. Additionally, the inventory accounts for loss of harvested acres due to Sustainable Groundwater Management Act (SGMA).

3.1 2022 USDA Agricultural Census

Figure 5 compares the 2017 and 2022 USDA Agricultural Census data. While the number of total California farms decreased (green bars on the left), the overall harvested land acres increased (blue bars on the right). There is a shift where smaller farms are disappearing while larger farms absorb the land.

Figure 5 USDA Agricultural Census, Comparing 2017 and 2022



The 2022 USDA Agricultural Census reports the loss of 4,200 farms under 50 acres and almost 1,200 farms between 50 and 250 acres since the 2017 census in Figure 6. The largest farms, those with 250 or more acres, show a slight increase in total farm count in 2022.

Figure 6 USDA Agricultural Census, Count of Farms by Farm Size

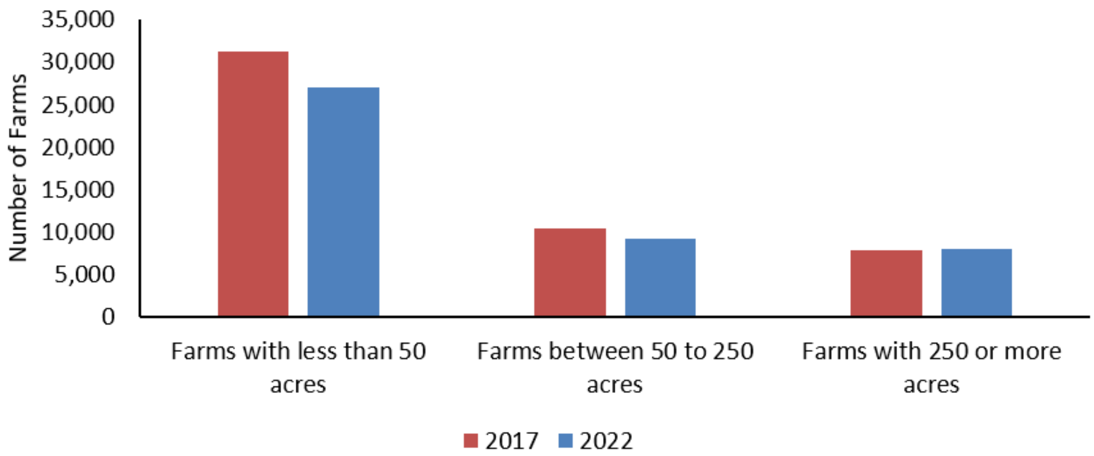
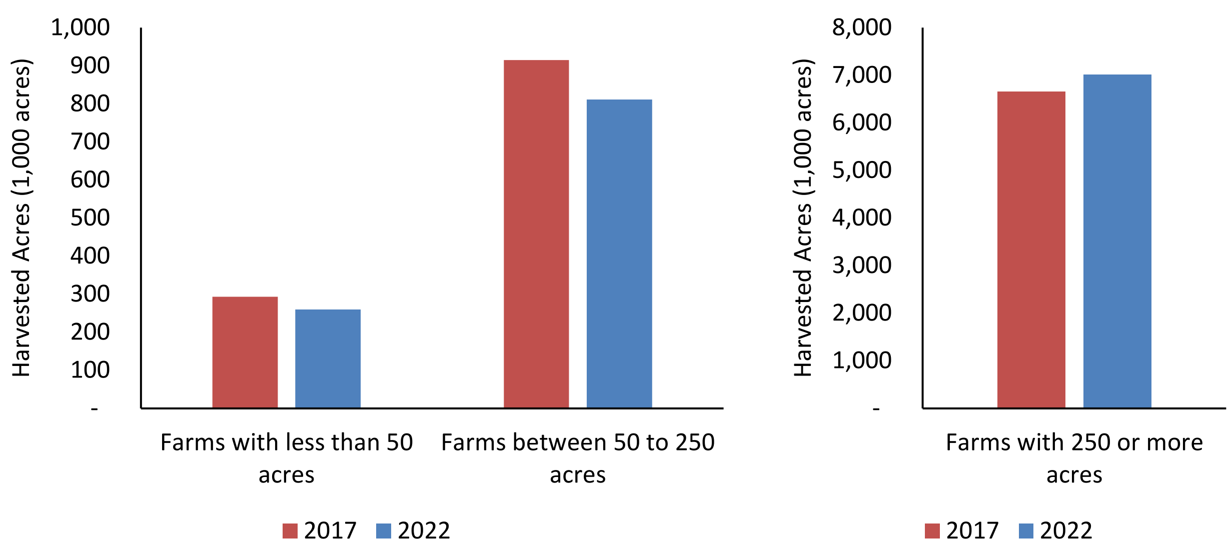


Figure 7 shows that farms with less than 50 acres and farms between 50 and 250 acres have lost harvested acres, at a rate of 12% and 11% respectively. The largest farms, those with 250 or more acres, have increased by 5%.

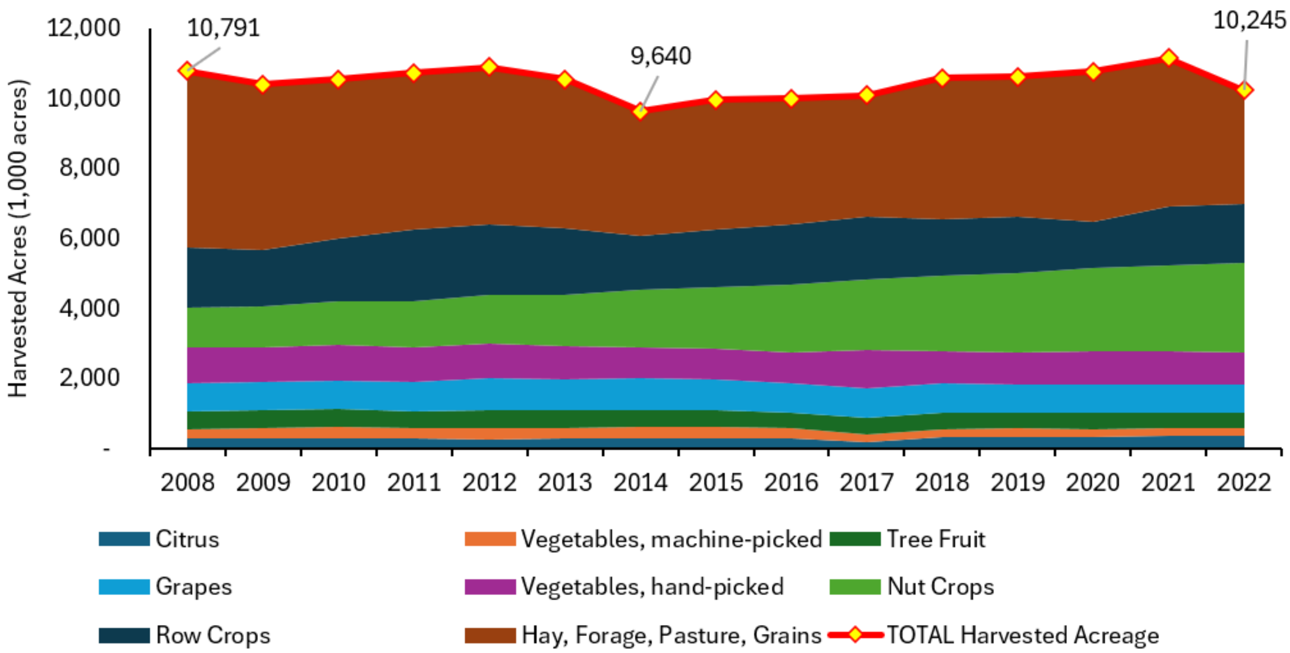
Figure 7 USDA Agricultural Census, Harvested Acres by Farm Size



3.2 2022 County Agricultural Commissioners' Report

The County Agricultural Commissioners' reports collect county level crop data. Figure 8 displays historical crop trends from 2008 through 2022. Total harvested acreage has remained constant, aside from a small dip in 2014, which then increased back to similarly previous levels. Reports show a shift in the quantity of crops harvested. Nut crops have grown substantially, with an average annual growth of 8% over the last 10 years, while hay, forage, pasture, and grains have declined at a rate of 3% over the last 10 years.

Figure 8 County Agricultural Commissioners' Data, Harvested Acres by Commodity



This data represents harvested crop acres, which includes some double cropping (the act of harvesting two separate crops grown on the same land within a single crop year) and explains why the total harvested acres appear to be greater than the total USDA harvested acres. USDA data represents harvested land acres, which counts a given land area only once even if it is harvested twice a year.

3.3 Sustainable Groundwater Management Act

The Sustainable Groundwater Management Act (SGMA) changes groundwater availability in California. Passed in 2014, SGMA helps protect groundwater resources and requires local Groundwater Sustainability Agencies in the state's high- and medium-priority basins to develop and implement Groundwater Sustainability Plans (GSP) or alternatives. Currently, 81 basins are operating under an approved GSP, representing 71% of statewide groundwater use in Water Year 2024 [13].

[13] SGMA *https://water.ca.gov/programs/groundwater-management/sgma-groundwater-management*

SGMA is projected to remove between 500,000 and 1 million acres of agricultural land out of production by 2040[14]. Discussion with agricultural stakeholders in 2025 revealed that individual water districts have already begun implementation ahead of schedule. Based on this information, the updated inventory assumes a loss of 750,000 harvested acres statewide by 2035. This represents, on average, a 0.60% decline in harvested acres each year until 2035. Starting in 2036, total statewide acreage is held constant with zero overall growth or decline, based on the lack of information suggesting agricultural land would continue to decrease following the impacts of SGMA.

Overall equipment populations and total fuel use are based on the total acreage and follow the same growth trends, as shown later in Section 5.1.

4 Emissions Inventory Development

Data inputs for the updated emissions inventory can be sorted into four groups:

1. Statewide Survey Data – 2024 statewide survey of all fuel types and horsepower type equipment, and crop and farm sizes across California
2. Crop and Farm Data – 2022 USDA Agricultural Census and 2022 County Agricultural Commissioners' Report
3. Sustainable Groundwater Management Act – projected decline of harvested acres
4. Other Inputs – CARB's new 2025 Emission Factors

The following sections describe a series of steps used to process the statewide raw survey data. Survey respondents reported commodities and corresponding acres which were sorted into farm size bins. Individual crop types are placed into larger commodity groupings. If, for example, only three pluot producers responded to the survey, that would not provide a representative sample size for scaling to statewide levels. Therefore, pluots are combined into a larger tree fruit grouping, thereby providing a larger number of survey responses that can be more accurately scaled to statewide levels.

Survey respondents also reported equipment type, including model year and usage. Equipment was sorted into bins to create equipment population and activity profiles. The same scaling actions apply for equipment. Assume there is only one 1950 model year tractor in the 100-horsepower bin, with a reported 1,000 hours of annual use. If this one piece of equipment is scaled to statewide levels, the inventory would report a significantly higher number of old tractors with the same characteristics, which is unlikely. Thus, grouping this tractor with others that have similar characteristics, creating profile bins, better represent the average agricultural equipment activity operating in California.

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[14] Land Transitions and Dust in the San Joaquin Valley *https://www.ppic.org/publication/land-transitions-and-dust-in-the-san-joaquin-valley/*

4.1 Statewide Agricultural Equipment Survey

The inventory's primary dataset on agricultural equipment comes from the 2024 statewide survey of California farms and equipment, an effort jointly conducted by CARB, California Energy Commission (CEC), California Public Utilities Commission (CPUC), and industry representatives through the California Polytechnic State University San Luis Obispo (Cal Poly). The survey ran from mid-December 2024 to the end of February 2025. Like in the previous 2018 survey, Cal Poly administered this survey online and anonymized all data, which includes removal of all identifying information. All responses are completely confidential.

Table 1 reports the number of survey participants and the number of pieces of equipment for the statewide surveys over the years. The 2024 survey had nearly 500 participants, reporting roughly 1,350 pieces of equipment. The lower response rate required more data aggregation, less specificity for equipment types and tractor horsepower bins, and further statistical comparison against previous surveys to fill gaps.

Table 1 Summary of Statewide Surveys

Survey Year	Number of Survey Participants	Number of Equipment
2008 Survey (2018 Inventory)	1,700	10,000
2018 Survey (2021 Inventory)	900	2,000
2024 Survey (2025 Inventory)	465	1,350

4.1.1 Commodity Groups

California grows hundreds of commodities, or types of agricultural goods. The USDA Agricultural Census identifies 55 common groups which were further sorted into 12 general commodity groups. For example, the commodity 'Romaine' is part of the 'Lettuce' grouping, which is then grouped into 'Hand-picked Vegetables'. These same groupings, created with the expertise of California's agricultural stakeholders, were used for the last two surveys. However, the most recent survey required respondents to use the 12 general commodity groups and eliminated the need to sort raw data.

The purpose of grouping commodities is to create statistically robust datasets that represent an average farm instead of many small, more detailed, commodity lists that may not represent average operations. Table 2 outlines the commodities within their larger commodity groups used to categorize agricultural production for the purposes of the emissions inventory.

Table 2 Commodity Groups

Commodity Group	Commodities
Citrus	• Citrus • Grapefruit • Lemons • Oranges (all)
Grapes	• Grapes • Raisins
Hay, Forage, Pasture, Grains	• Hay, Alfalfa • Oats, Rye • Pasture, Rangeland, Grass • Rice • Sorghum • Wheat, Silage Wheat, Grains, Seed crops, Barley
Nursery, Greenhouse, Floriculture	• Nursery, Flowers, Foliage • Sod, Seeds
Nut Crops	• Almonds • Other Nuts • Pecans • Pistachios • Walnuts
Other	• Forest, Lumber, Timber • Other (Beehives, Horses, Sheep, Swine, etc.)
Row Crops	• Beans • Corn, Silage Corn • Cotton (all) • Sunflower, Safflower
Tree Fruit	• Apples • Apricots • Avocados • Berries (all) • Cherries • Figs • Kiwis • Nectarines • Olives • Orchards, Tree Fruit, Stone Fruit • Peaches • Pears • Persimmons • Plums • Pluots • Pomegranates • Prunes

Commodity Group	Commodities
Vegetables, hand-picked	• Broccoli • Cabbage • Lettuce (all) • Melons (all) • Peppers • Tomatoes (fresh) • Vegetables
Vegetables, machine-picked	• Carrots • Onions • Potatoes, Sweet Potatoes • Tomatoes (processing)
Beef Cows	• Beef Cows
Milk Cows	• Milk Cows
Poultry	• Poultry

4.1.2 Farm Size Bins

The USDA Agricultural Census collects a variety of farm size characteristics such as farm size by acres, farm employment, and farm income. USDA census shows different farm size categories for different types of data. To scale the raw survey results to statewide levels, the inventory uses farm size characteristics that best match the USDA Agricultural Census data, specifically acres of production by farm size by county.

Table 3 lists farm size groupings by harvested acreage. In previous inventories, there were 7 farm size groupings. This inventory has three groupings due to a smaller survey size. For livestock categories, the USDA Agricultural Census groups farms by head.

Table 3 Farm Size Groupings

Farm Size Bin	Harvested Acres
50	< 50 Acres
250	≥ 50 acres and < 250 Acres
250+	250+ Acres

4.1.3 Equipment Horsepower Bins

Table 4 outlines the horsepower bins used for grouping equipment. Both U.S. EPA and CARB use these horsepower bins for off-road diesel engine emission standards.

Table 4 Horsepower Groupings

Horsepower Bin	Horsepower Range
11	< 11 horsepower
25	≥ 11 and < 25 horsepower
50	≥ 25 and < 50 horsepower

Horsepower Bin	Horsepower Range
75	≥ 50 and < 75 horsepower
100	≥ 75 and < 100 horsepower
175	≥ 100 and < 175 horsepower
300	≥ 175 and < 300 horsepower
600	≥ 300 and < 600 horsepower
750	≥ 600 and < 750 horsepower
750+	750+ horsepower

4.2 Equipment Profiles

As discussed in previous sections, equipment was sorted into smaller groups based on similar characteristics, whether by equipment type, horsepower bin, or farm size bin. Profile bins reflect population age distributions and average activity by equipment age within the bin. This step groups similar equipment to create averages that are applied to the statewide population following the scaling process. Table 5 describes the seven different equipment profile bins, reporting average age, population count, fuel type, and engine horsepower. Like the previous inventories, this analysis determined equipment type, farm size, and horsepower bin were the strongest factors influencing an equipment's age and activity. While commodity played a role, it was not as influential as other factors.

Table 5 Equipment Profile Bins

Bin ID	Equipment Type	Average Age	Count	Fuel Type
1	Equipment for livestock, all horsepower	20	208	Diesel, Gasoline, Propane, Electric
2	Tractors on farms with less than 50 acres, all horsepower	22	77	Diesel, Gasoline, Electric
3	Tractors on farms between 50 and 250 acres, all horsepower	23	134	Diesel, Gasoline
4	Tractors on farms with 250 or more acres, under 175 horsepower	19	272	Diesel, Electric
5	Tractors on farms with 250 or more acres, larger than 175 horsepower	16	136	Diesel
6	ATVs, under 100 horsepower	14	112	Diesel, Gasoline, Electric
7	Others: non-tractor, non-ATV equipment, all horsepower	21	309	Diesel, Gasoline, Propane, Hydrogen

4.2.1 Equipment Population and Activity Profiles

The age distribution of equipment populations and their corresponding activity levels are derived from survey data. For each bin described in the previous section, population and activity are combined to generate a smoothed profile by age. This smoothing process preserves overall trends observed in the survey data while reducing the influence of outliers introduced when scaling results to represent a statewide population.

Figure 9 plots raw survey data for equipment in Bin 1. Bin 1 contains a grouping with 208 pieces of equipment. This bin is a mix of equipment used for livestock of all horsepower engines. The blue dots in Figure 9 show the percentage of equipment by age, or the population distribution. The green squares in Figure 10 display the average activity by age, or the activity distribution, for the same profile bin. In both figures, the dashed purple line represents the best-fit polynomial for population and activity in this inventory, respectively. Other methods were evaluated, such as exponential, logarithmic, and power law, however the polynomial fits provided the best correlation to the observed data. The charts also show that very few units remain in operation as equipment approaches the end of its service life.

Figure 9 Bin 1 – Population Distribution by Age

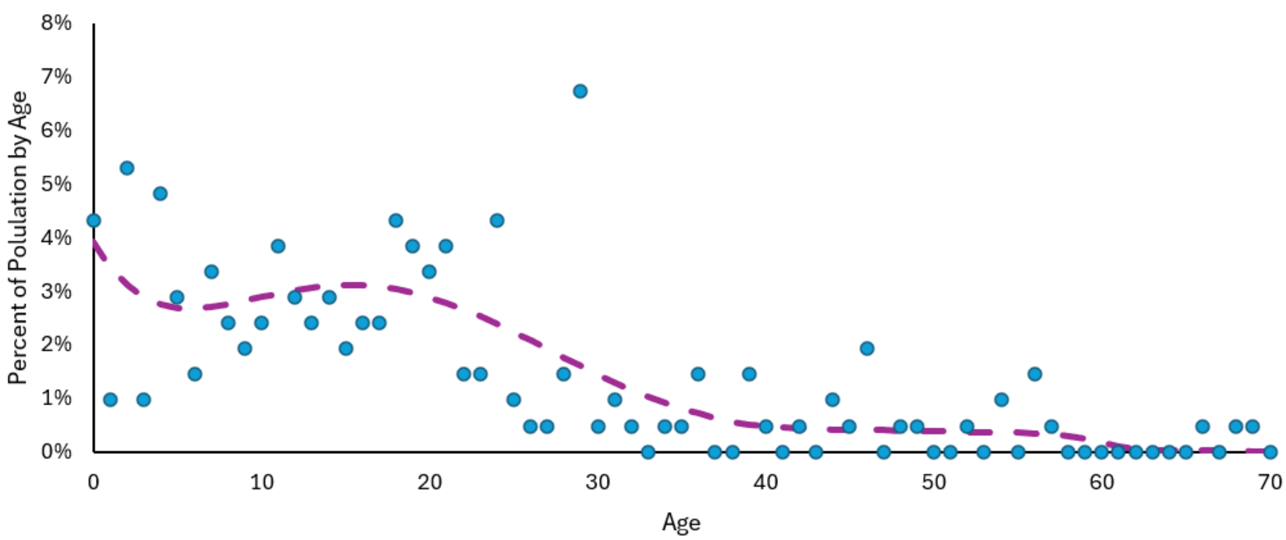
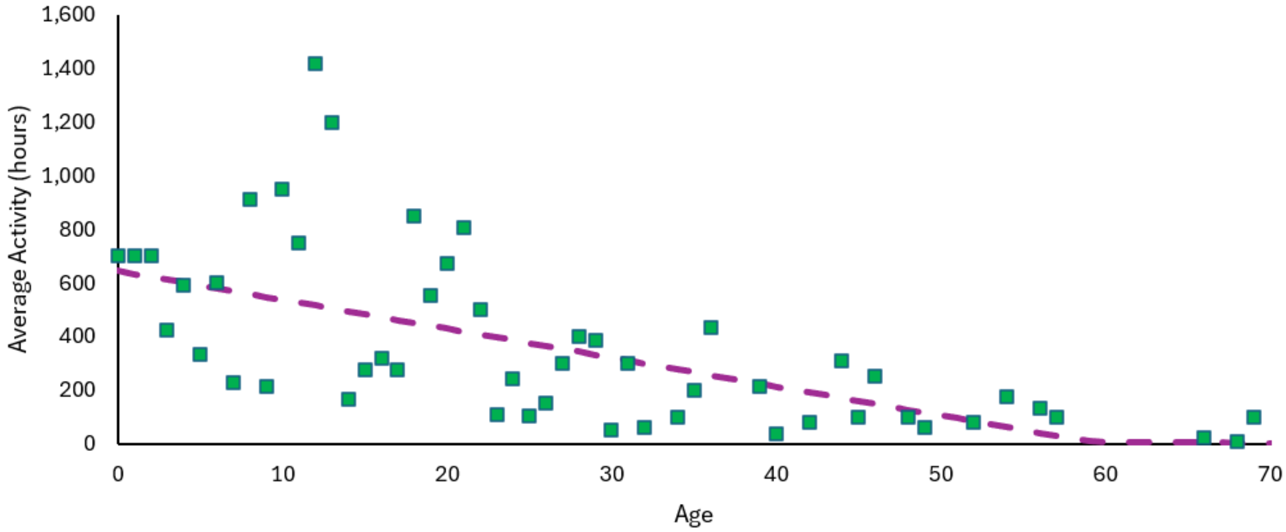


Figure 10 Bin 1 – Activity Distribution by Age



This same analysis was completed for the remaining six profile bins. They all exhibit similar age and activity trends, indicating that population declines with age as does average activity.

4.2.2 Equipment Purchasing and Attrition

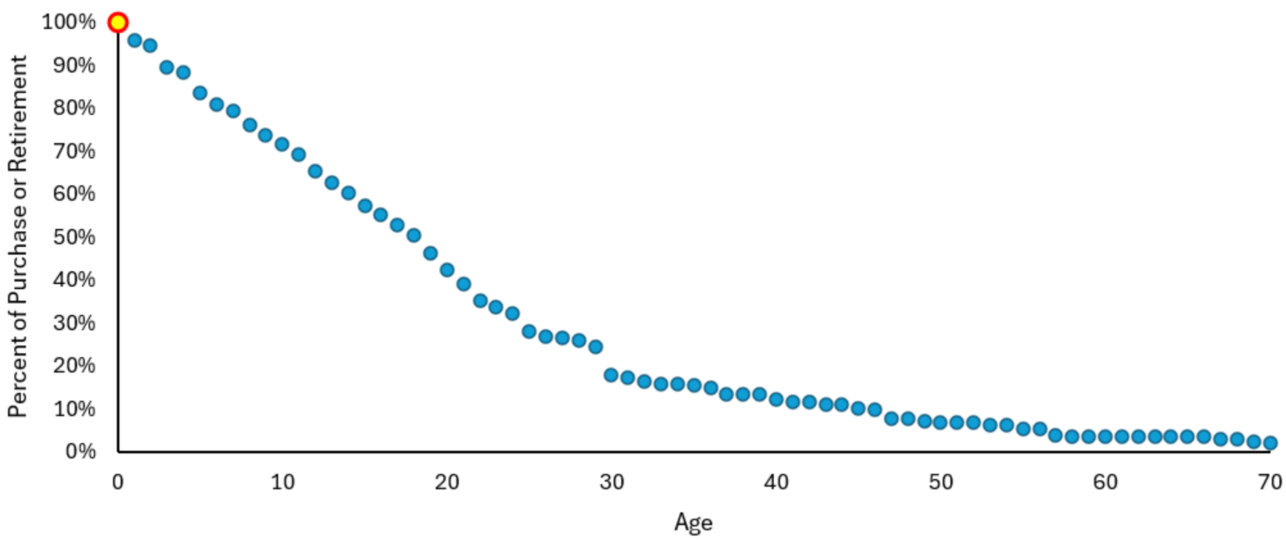
To forecast equipment in future years, the inventory predicts average, or business as usual, purchasing and retiring equipment practices in the absence of any additional emission reduction programs, such as air quality incentives. Purchase and retirement behavior are modeled using the same base year 2024 profile bins as described in Table 5. Also, this assumes the survey data is a reasonable depiction of the average California equipment population in most years, and that it is representative enough of the average year to derive purchasing and retirement practices.

A retirement curve signifies the percentage of equipment remaining in service by equipment age. Future age distributions are projected by allowing equipment to retire following the retirement curve pattern and are replaced with equipment purchases.

According to the equipment characteristics of Bin 1, Figure 11 presents the purchase and retirement pattern developed from the survey data that was used to project the age characteristics described in the previous section. In this bin, all equipment is modeled as new purchases, indicated by the yellow circle outlined in red. This is based on the survey data's age distribution which did not indicate used purchases ever exceed retirement trends in this bin. This does not mean producers never purchase used equipment, only that equipment populations consistently drop as ages increase, i.e. the number of retired equipment outweighs any used purchases.

However, other bins show significant used equipment purchases, where population of new equipment might be significantly below equipment populations in the 20 to 30 age ranges. In Figure 11, there is a gradual retirement of 50% of new equipment by age 18, and about 75% by age 28. Between age 60 and 70, nearly all remaining equipment in this bin is forecasted to be retired. This same process was applied to all profile bins. Each profile bin has individualized purchase and retirement distributions, based on the characteristics of the equipment in those bins.

Figure 11 Bin 1 - Purchase and Retirement Curve



4.3 Statewide Scaling

The 2024 statewide survey provides the raw data necessary for scaling to statewide agricultural equipment and operations in California. The survey data is scaled up based on the number of statewide acres reported in the survey compared to the statewide acres recorded in the 2022 USDA Agricultural Census. This same scaling methodology was used in previous inventories.

The following example walks through the scaling process steps and simplified calculations.

4.3.1 Simplified Population Scaling Example

As an example, consider a survey response with the following characteristics: one 200-acre nut farm with two 80-horsepower tractors. Two tractors are sorted into the 100-horsepower bin. The farm is categorized as a nut farm and sorted into the 250-acre farm size bin. This data simplifies to an average of one tractor in the 100-horsepower bin per 100-acre nut farm (1 tractor / 100 acres).

Now, assume statewide, nut farms total 45,000 acres on farms between 100 to 250 acres. These fall in the 250-acre farm size bin. This means there are 450 tractors in the 100-horsepower bin operating on nut farms in the 250-acre bin. Here is the sample inventory calculation:

$$\frac{1\ tractor}{100\ acres} \times 45{,}000\ acres = 450\ tractors$$

As covered previously, the 2024 survey had significantly fewer responses than previous surveys. The response rate was sufficiently low that if the 2024 survey were used to update the ratio of equipment per acre, it would have created anomalies when scaling up equipment population. Comparisons with the previous survey showed that the lower response rates, unadjusted, would result in cutting farm tractors down to about 40,000, a drop of about 65% in total population. This drop does not correspond to the shift in acreage or farm sizes, or any recorded shift in farming practices. To address this, the base year 2024 population was adjusted to ensure the equipment population per acre ratio matched the 2021 emissions inventory due to that survey's higher response rate.

4.4 Statewide Fuel

Fuel use is a product of an equipment's brake-specific fuel consumption, load factor, horsepower, population, and activity. As any of these variables change, total fuel use changes, which is why scaling up population and activity creates uncertainty in overall fuel use. To illustrate, if several very high-use, or very low-use, tractors scaled up (see Section 4.3.1) to a large quantity of tractors statewide, it can skew the results. Thus, the inventory adjusts total activity to meet the best available data on statewide fuel use. For instance, if the inventory's total fuel use is 5% too high, all activity is lowered by 5% so that total fuel consumed matches the projected fuel used on farms, statewide.

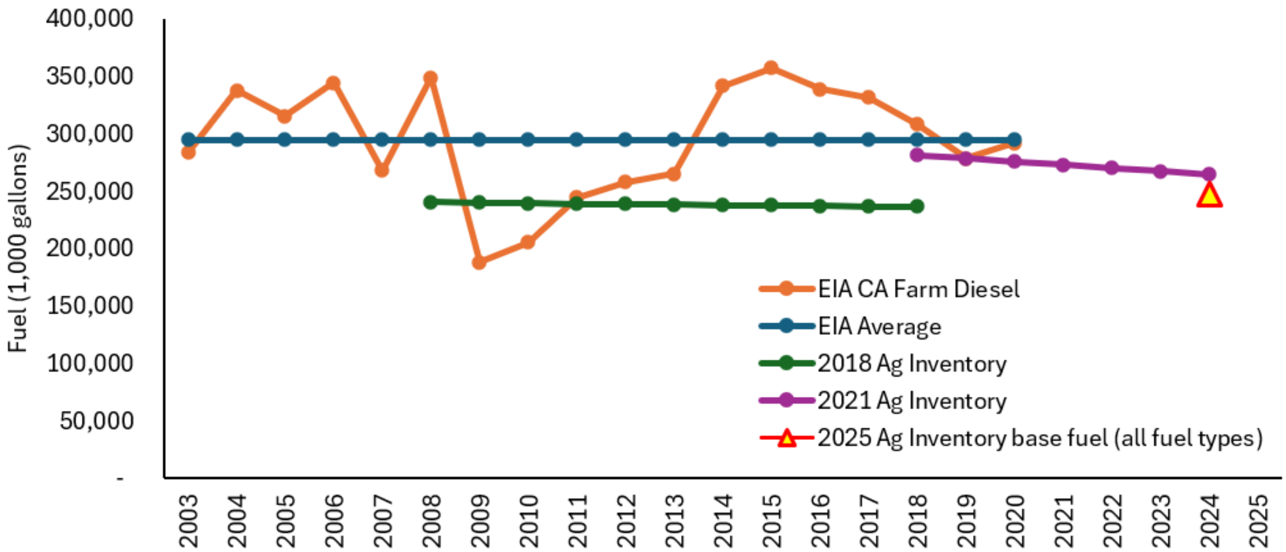
This inventory projects statewide fuel use based on CARB's previous 2021 inventory because that is the most recent and complete data available on farm diesel fuel use. EIA[15] (Energy Information Administration), the only reputable source for fuel consumption in California, provided historical fuel data in previous inventories. Unfortunately, EIA is no longer reporting diesel consumption by end use, including farms (California No. 2 Diesel Sales to Farm Consumers).

Figure 12 displays EIA's historical farm diesel fuel for each year starting in 2003 through 2020 (orange line) with an average of 296 million gallons per year for that period (blue line). The 2018 agricultural inventory's diesel fuel began at 240 million gallons and declined over time. Note that the 2018 inventory was developed in 2011, and the dip in fuel in the graph

[15] https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=K2DVFMSCA1&f=A

around 2008 to 2011 corresponds to an average of 240 million gallons. The 2021 agricultural emissions inventory (purple line) began at 281 million gallons, and in 2024, was an estimated 269 million gallons. The 2024 base year for the new 2025 inventory, combined for all fuel types, begins 20 million gallons of diesel fuel less, with an overall 248 million gallons of fuel. Because the total number of farms and equipment population are already lower than the previous inventory, the 2025 inventory assumes less fuel is consumed.

Figure 12 Historical Fuel Comparisons



4.5 Growth Rates

Data from the 2022 USDA Agricultural Census, 2022 County Agricultural Commissioners' Report, and SGMA assumptions were combined to create new growth rates reflecting trends by both commodity and farm size. Based on the trends in farm size and total acres by commodity over the last 10 years, CARB created the growth rates in Table 6. This is the first time CARB's agricultural inventory implements growth rates according to both commodity type and farm size bin. Including farm size bins better reflects changes in farms, as small farm acreage continues to decline. Additionally, the growth rates reflect a loss of 750,000 harvested acres by 2035 due to SGMA water constraints (see Section 3.3). After 2035, there is no growth reflected and both equipment population and activity are held constant (also described in Section 3.3). Note that farms in the smallest acreage bin consistently have a negative growth rate (less than 1.0). The largest farms either have a positive growth rate (greater than 1.0) or a less aggressive decline. This is true for Citrus, Grapes, Hay/Forage/Pasture/Grains, Nut Crops, Tree Fruit, and Vegetable commodity groups.

Note that, as described further in Section 5.1, fuel use grows after 2035. This is because larger equipment, operated by the largest farms, becomes more prominent, and larger equipment operation requires more fuel even if total statewide activity is constant.

Table 6 Commodity Growth Rates

Commodity Type	Farm Size Bin	Growth Rate
Citrus	50	0.954
Citrus	250	1.001
Citrus	250+	0.971
Grapes	50	0.960
Grapes	250	0.958
Grapes	250+	0.982
Hay, Forage, Pasture, Grains	50	0.991
Hay, Forage, Pasture, Grains	250	0.966
Hay, Forage, Pasture, Grains	250+	1.001
Nut Crops	50	0.934
Nut Crops	250	0.956
Nut Crops	250+	1.001
Row Crops	50	1.001
Row Crops	250	1.001
Row Crops	250+	1.001
Tree Fruit	50	0.936
Tree Fruit	250	0.925
Tree Fruit	250+	1.001
Vegetables, handpicked	50	0.935
Vegetables, handpicked	250	0.925
Vegetables, handpicked	250+	1.001
Vegetables, machine picked	50	0.990
Vegetables, machine picked	250	0.925
Vegetables, machine picked	250+	1.001
Beef Cows	6	0.986
Milk Cows	7	0.981
Nursery, Greenhouse, Floriculture	9	0.931

4.6 Load Factors

This inventory uses the agricultural-specific load factors in Table 7, with an in-depth discussion in CARB's 2025 emission factor technical report[16].

[16] CARB's 2025 Off-road Diesel Emission Factors. *https://ww2.arb.ca.gov/sites/default/files/2025-09/Tech%20Doc%20-%202025%20Emission%20Factors%20for%20Offroad%20-%202025%20ADA%20FINAL.pdf*

Table 7 Agricultural Equipment Load Factors

Horsepower	Load Factor
Less than 175	0.29
175 and greater	0.26

4.7 Emission Rates, Renewable Diesel, and More

This inventory utilizes CARB's 2025 Off-road Diesel Emission Factors[16], developed for off-road diesel equipment, and used in inventories such as construction equipment and forestry, and soon to be implemented in other off-road diesel sectors. CARB's emission factors documentation is summarized in this report.

4.7.1 Load-dependent NOx Emissions

The new load-dependent NOx emissions factors recognize that different amounts of time are spent working at different load bins. About two-thirds of the time is spent at idle or lower loads. Off-road diesel engines emit significantly higher NOx at lower loads than at higher loads, per unit work. This methodology applies to Tier 2 and newer diesel off-road engines. Please see the technical report for an in-depth explanation[16].

4.7.2 All Other Pollutants

The 2025 off-road diesel emission factor update also includes updates for PM, Hydrocarbons (HC), and Carbon Monoxide (CO) for all engine tiers. The updates are based on the average of new engine certification results, described in the technical writeup[16]. These pollutants use the standard off-road diesel emission factor equation that reflects emissions from an engine that is new, known as its zero-hour emission factor, added to the product of the engine's deterioration rate over time and its accumulated lifetime hours. Equation 1 shows the emission factor equation.

Equation 1: Emission Factor

$$EF\left(\frac{grams}{hp-hr}\right) = EF_0 + (EF_{DR} \times Accumulated\ Hours)$$

where EF = Emission Factor $(\frac{grams}{hp-hr})$

EF_0 = Zero-hour Emission Factor $(\frac{grams}{hp-hr})$

EF_{DR} = Deterioration Rate $(\frac{grams}{hp-hr^2})$

Equation 2 represents a simplified emission calculation for one piece of equipment for a specific pollutant and is based on the equipment population, horsepower, activity, age, engine deterioration due to age, load factor, and in some cases the sulfur content of fuel.

When this equation is summed for all pieces of equipment in a sector, it creates a statewide emissions total for that pollutant.

Equation 2: Emission Equation

$$Emission\ (\frac{grams}{year}) = Hp \times Activity \times LF \times EF \times FCF$$

where Hp = Horsepower of the engine (hp)

Activity = usage of engine ($\frac{hours}{yr}$)

LF = Load Factor of the engine (unitless)

EF = Emission Factor ($\frac{grams}{hp-hr}$)

FCF = Fuel Correction Factor (unitless)

The fuel correction factor (FCF) is unitless and accounts for adjustments in the sulfur content of diesel fuel. Diesel's sulfur content had dramatic reductions in 2007 and was further reduced through 2015, with the national average sulfur content of diesel fuel being 11 parts per million. Alterations to the sulfur content significantly impact sulfur oxides (SOx) and PM emissions.

4.7.3 Renewable Diesel

Beginning in 2013, NOx, PM, HC, CO, and CO_2 emissions from non-Tier 4 Final engines have benefited from an emission reduction factor associated with renewable diesel[17]. Table 8 provides the fraction of a pollutant remaining from renewable diesel usage in this inventory. For example, if the remaining value in the table is 0.9, that reflects a reduction of 0.1, or 10%, for that pollutant. After 2023, the remaining percentage is the same as listed for Inventory Year 2023.

Table 8 Renewable Diesel Factors

Inventory Year	NOx RD Blend Remaining	PM RD Blend Remaining	HC RD Blend Remaining	CO RD Blend Remaining	CO_2 RD Blend Remaining
2013	1	0.99	0.99	0.99	1
2014	1	0.99	0.99	0.99	1
2015	1	0.99	0.98	0.99	1
2016	1	0.98	0.97	0.99	1
2017	1	0.97	0.96	0.98	1
2018	0.99	0.97	0.96	0.98	1

[17] *https://ww2.arb.ca.gov/sites/default/files/2023-04/2022InUseDieselInventory.pdf*

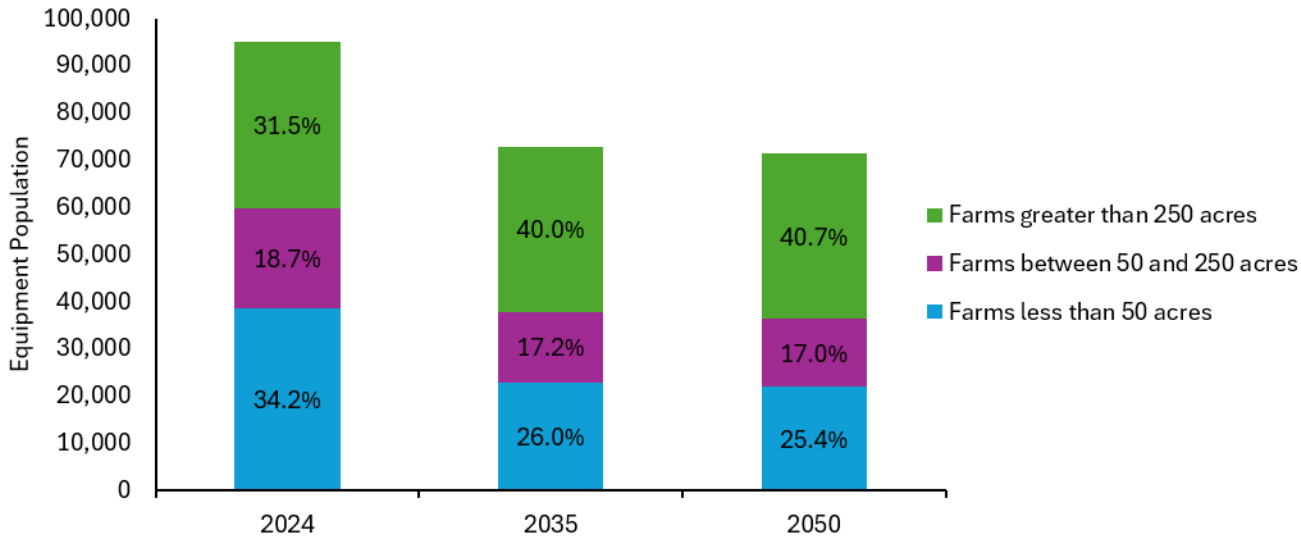
2019	0.99	0.94	0.93	0.97	0.99
2020	0.99	0.94	0.93	0.97	0.99
2021	0.99	0.91	0.89	0.95	0.99
2022	0.98	0.87	0.84	0.93	0.98
2023	0.97	0.81	0.77	0.9	0.97

5 Emissions Inventory Results

The 2025 Agricultural Equipment Emissions Inventory accounts for all equipment horsepower and fuel types related to mobile agricultural production in California. Emissions results reflect equipment age and activity as they work on California's farms to grow and harvest crops, categorized into commodity and farm acre groupings. Equipment is grouped into horsepower bins and categorized into equipment groupings. All emissions projections are based on the above-described equipment profile bins, age distributions, and purchasing and retirement curves, which inform that equipment activity declines with age. This 2025 inventory does not explicitly account for incentive projects, but some may be captured in the base year 2024 survey data of equipment population and model years. Furthermore, this inventory does not reflect the impact of any future incentive funds in accelerating the turnover of older agricultural equipment.

Emissions results account for the decrease in number of farms due to SGMA. Figure 13 demonstrates the relationship between equipment population and farm size by acres, indicating that total equipment population declines with time while also showing a shift in farm size. This figure does not represent total equipment population as it excludes any equipment relating to beef or milk cows and nursery, greenhouse, or floriculture. Overall, the percentage of equipment on small farms (blue bars), those with less than 50 acres, are declining while the percentage of equipment on large farms (green bars), with 250 acres or more, are increasing in number. In 2024, small farms make up 34% of the distribution and are projected to decrease to 25% by 2050. The large farm distribution increases from 31.5% of the distribution to nearly 41% by 2050.

Figure 13 Projection of Equipment Population by Farm Size



5.1 Statewide Results

According to Figure 14, the statewide equipment population declines by about 2.3% annually through 2035. From 2036 to 2050, equipment population remains constant. However, engine tier distributions continue with turnover to the cleanest Tier 4 Final equipment. Overall equipment population is lower than the previous 2021 inventory, depicted by the purple line.

Figure 14 Statewide Equipment Population

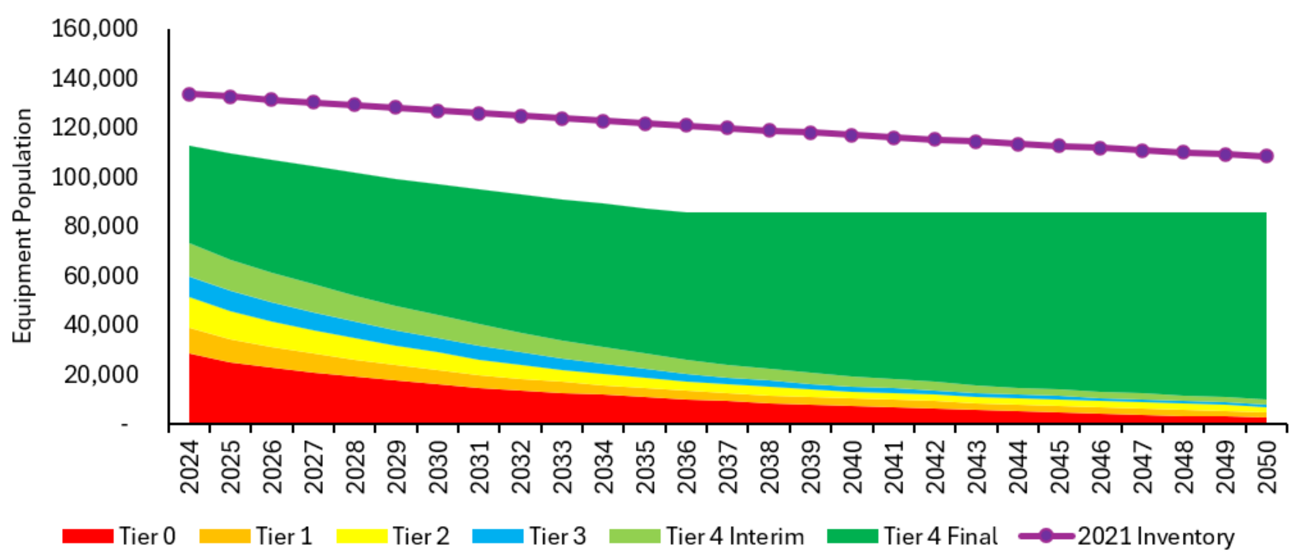


Figure 15 compares the new 2025 inventory fuel projections with the previous 2021 inventory, combined for all fuel types. In 2024, the 2021 inventory (orange line) reported 269 million gallons of fuel use while the new 2025 inventory (blue line) begins with an overall 248 million gallons of fuel. Updated fuel totals are lower than previously projected in the 2021 inventory because the total number of farms and equipment population are already lower than the previous inventory. Thus, the 2025 inventory assumes less fuel is consumed. Fuel consumption totals decline from 2024 to 2035, consistent with the commodity growth rates. In 2036, when both equipment population and activity are held constant, fuel slightly increases. This is due to a shift away from smaller farms to larger farms and the corresponding shift away from smaller horsepower equipment to larger horsepower equipment associated with the larger farms. Larger equipment uses more fuel per hour of use, which explains the increase in fuel consumption after 2035.

Figure 15 Statewide Agricultural Equipment Fuel

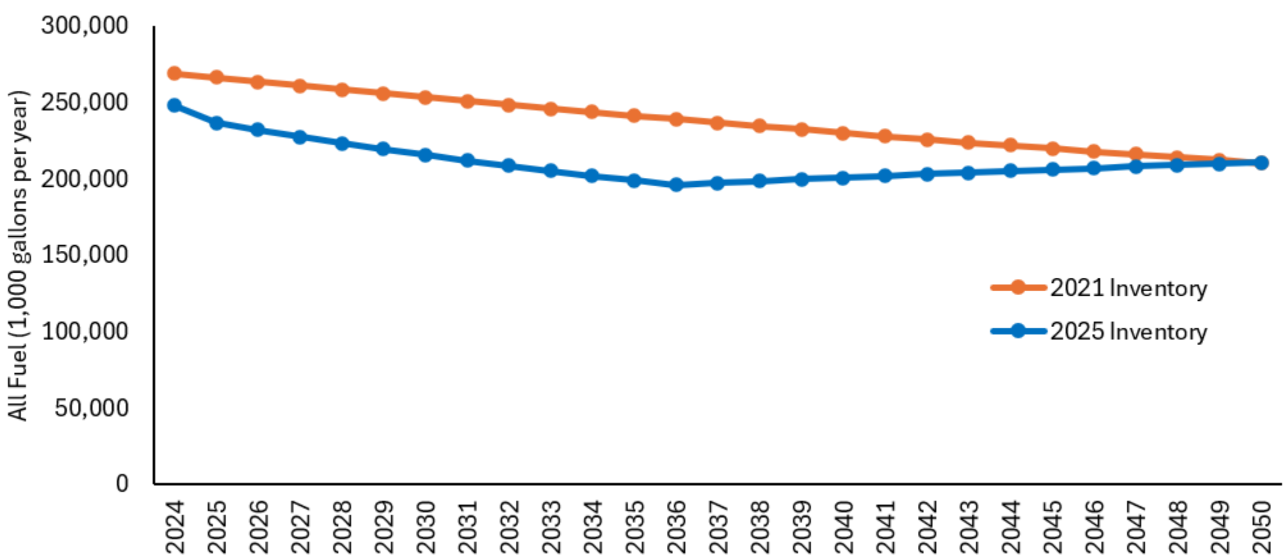


Figure 16 highlights this shift of equipment fuel use by horsepower bin. From 2024 to 2050, the relative distribution of fuel used in the smaller horsepower bins (outlined in red) declines while the relative distribution of the larger horsepower bins (outlined in black) increases. The 50-horsepower bin (green) declines from 7.7% in 2024 to 5% in 2050. The 75-horsepower bin (light blue) decreases from 6.7% down to 4.4% and the 100-horsepower bin (bright pink) drops from 15% to 12.4%. Those smaller bins are estimated to decline by almost 8%. With the larger equipment, the 300-horsepower bin (light purple) increases from almost 19% to over 21% and the 750-horsepower bin (brown) grows from 22% to 28% of the relative distribution from 2024 to 2050.

Figure 16 Statewide Agricultural Equipment Fuel by Horsepower Bin

Figure 17 shows the same information by equipment population. From 2024 to 2035, the relative distribution of equipment in the smaller horsepower bins (outlined in red) declines from about 48% to 44% of the overall population. The relative distribution of the larger horsepower bins (outlined in black) increases from about 16% to 19%.

Figure 17 Statewide Agricultural Equipment Population by Horsepower Bin

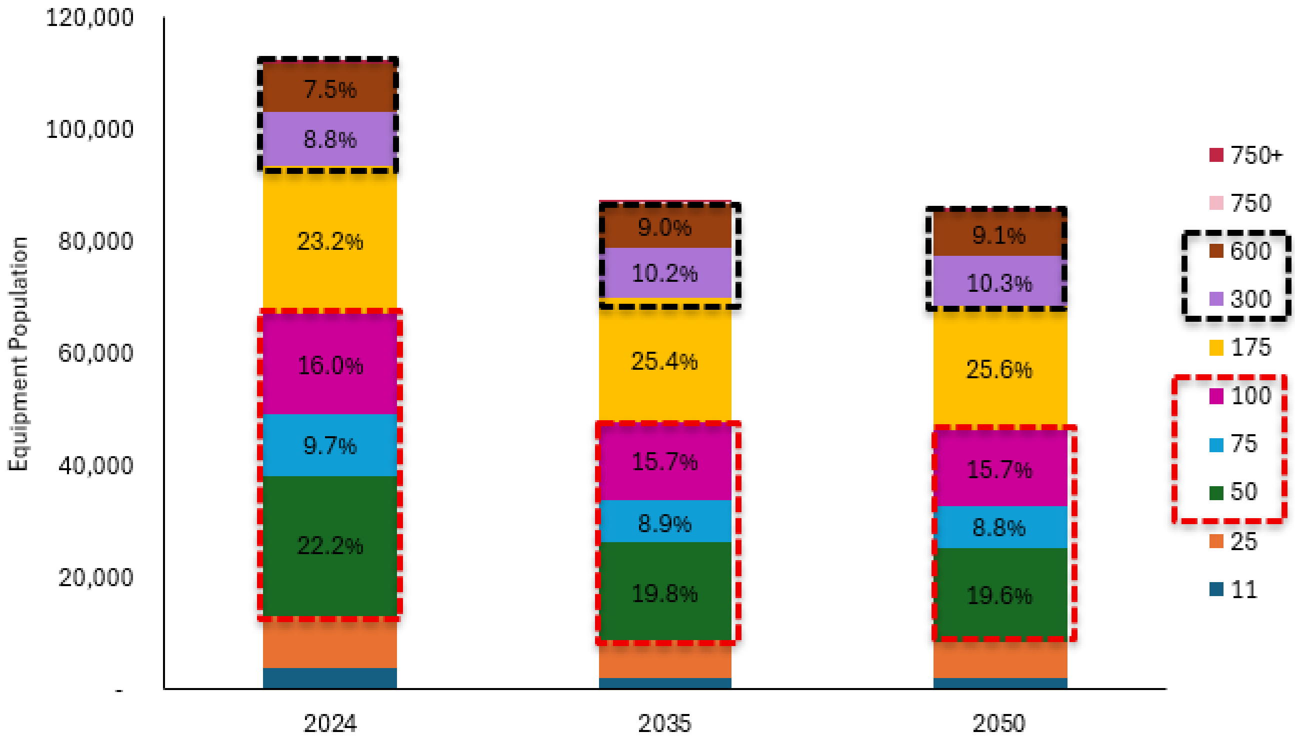
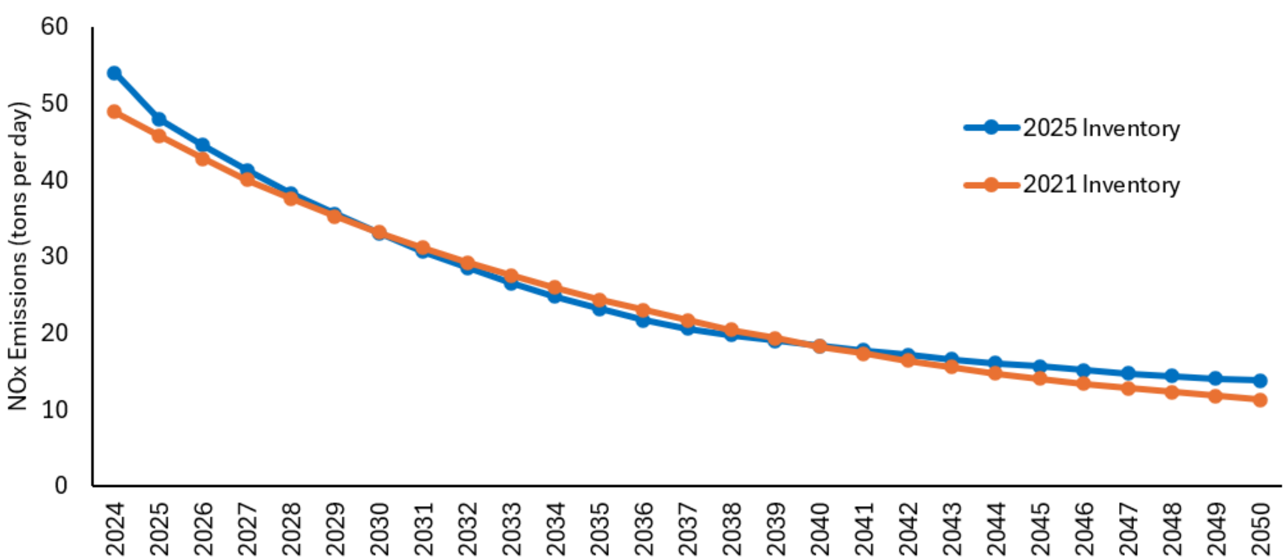


Figure 18 shows that statewide NOx emissions projections in the 2025 inventory are comparable to the previous 2021 inventory. With a shift from smaller horsepower engine equipment to larger horsepower projected to 2050, combined with the load-dependent NOx emission factors, NOx emissions in the 2025 inventory are estimated to be slightly higher in 2050.

Figure 18 Statewide Agricultural Equipment NOx Emissions



5.2 San Joaquin Valley Results

The new 2025 inventory reports that the San Joaquin Valley has 56% of the state's harvested acres, 56% of the state's agricultural equipment, and contributes 57% of the state's agricultural NOx emissions. The new inventory shows no change in relative acres as compared to the previous 2021 inventory for San Joaquin. However, both equipment and NOx emissions have increased as compared to the previous 2021 inventory, at 50% equipment and 53% NOx. This shift is based on the farm size and commodity mixes in San Joaquin compared to the rest of the state.

Figure 19 displays the overall equipment population by engine tier, projected out to 2050. There is an overall decline in population projected to 2035 due to SGMA, and after 2035 the inventory projects population to remain constant. Future incentives are not projected in this inventory but would increase the population of Tier 4 Final equipment.

Figure 19 San Joaquin Valley Equipment Population

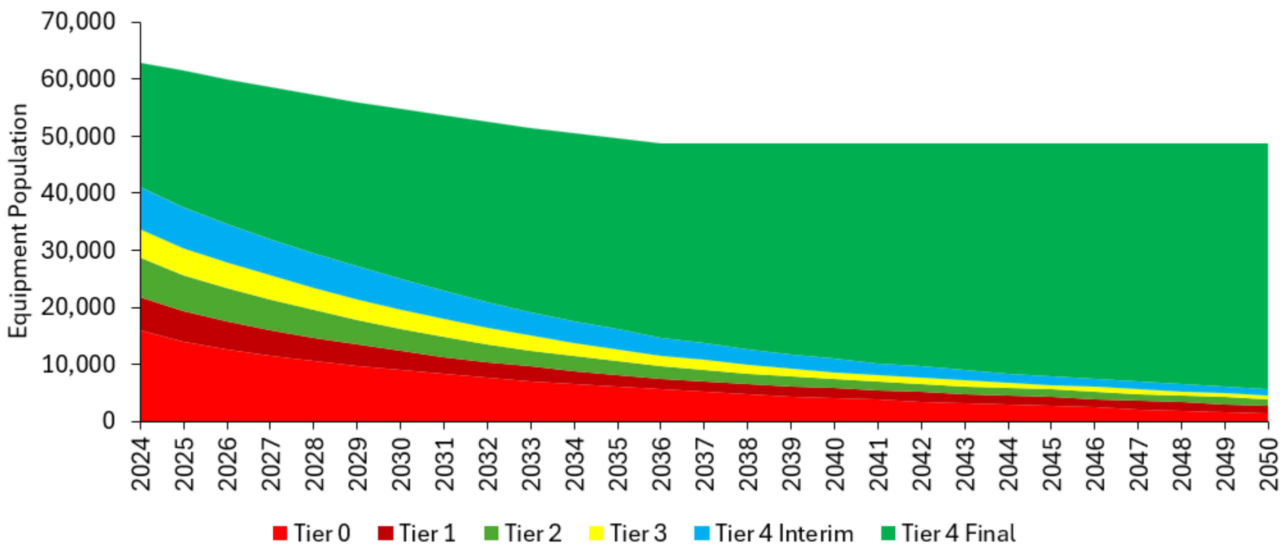


Figure 20 shows an increase in NOx emissions in the San Joaquin Valley, largely driven by the new load-dependent NOx emission factors and the increase of statewide activity in the San Joaquin Valley. In 2024, the new 2025 inventory (blue line) is higher than the previous 2021 inventory (orange line). The 2025 inventory estimates nearly 31 tpd of NOx, with continued reductions over time to almost 8 tpd in 2050.

Figure 20 San Joaquin Valley NOx Emissions

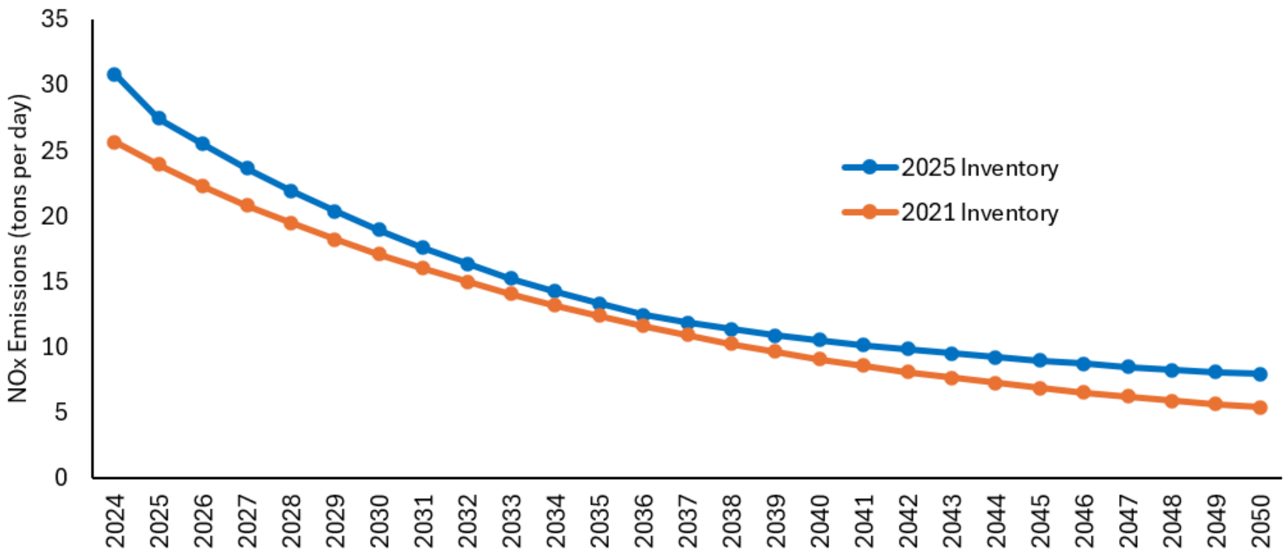
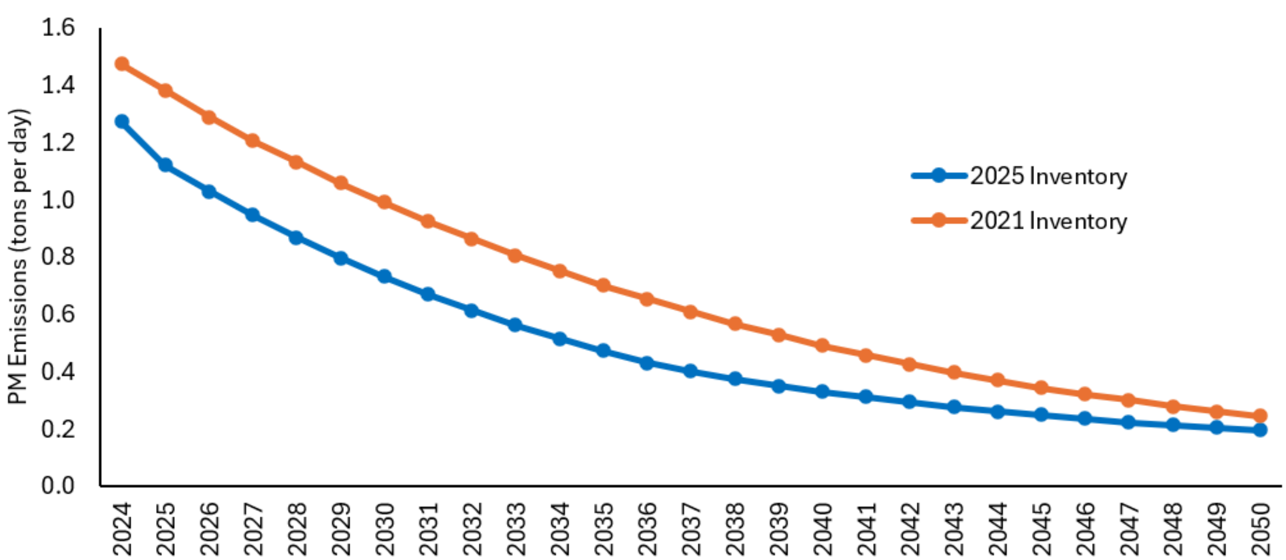


Figure 21 illustrates that PM emissions are lower in the new 2025 inventory (blue line) than the previous 2021 inventory (orange line). This is due to lower acreage and population, and updated PM emission factors.

Figure 21 San Joaquin Valley PM Emissions



5.3 Statewide Allocation

Table 9 reports the relative statewide NOx emissions distribution by air district, comparing results from the previous 2021 inventory to the new 2025 inventory results. The new 2025 inventory shows a slight increase in the San Joaquin Valley's NOx emissions contribution.

Table 9 Base Year 2024 NOx Emissions Distribution by Air District

Air District	2021 inventory	2025 Inventory
San Joaquin Valley Unified APCD	53.00%	57.36%
Imperial County APCD	1.90%	5.07%
Bay Area AQMD	5.10%	4.28%
Monterey Bay Unified APCD	3.10%	3.46%
Yolo/Solano AQMD	2.80%	2.58%
Feather River AQMD	3.10%	2.46%
Butte County AQMD	2.60%	2.19%
Ventura County APCD	2.30%	2.17%
Glenn County APCD	2.30%	2.02%
San Diego County APCD	2.90%	1.83%
San Luis Obispo County APCD	2.10%	1.67%
South Coast AQMD	1.40%	1.64%
Santa Barbara County APCD	1.80%	1.49%
Mojave Desert AQMD	1.70%	1.32%
Colusa County APCD	1.90%	1.25%
Modoc County APCD	0.91%	1.16%
Sacramento Metropolitan AQMD	1.15%	1.12%
Tehama County APCD	1.30%	1.03%
Siskiyou County APCD	0.86%	0.90%
Northern Sonoma County APCD	1.50%	0.85%
Mendocino County AQMD	1.01%	0.67%
Lassen County APCD	0.49%	0.58%
Shasta County AQMD	0.55%	0.40%
Lake County AQMD	0.52%	0.38%
North Coast Unified AQMD	0.92%	0.38%
El Dorado County APCD	0.48%	0.37%
Northern Sierra AQMD	0.34%	0.30%
Placer County APCD	0.74%	0.24%
Great Basin Unified APCD	0.16%	0.19%
Amador County APCD	0.30%	0.19%
Antelope Valley AQMD	0.33%	0.15%
Calaveras County APCD	0.20%	0.13%
Mariposa County APCD	0.12%	0.09%
Tuolumne County APCD	0.14%	0.06%
Eastern Kern APCD	0.01%	0.03%