Appendix G
San Joaquin Valley Agricultural Equipment Incentive Measure
CARB 2011 Emissions Inventory for Agricultural Diesel Vehicles

Emissions Inventory for Agricultural Diesel Vehicles December 2018

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 $40 billion in annual sales and over 400,000 jobs statewide. Off-road diesel vehicles and machines are the primary engines used in agricultural goods production and supply, and a large contributor to California's air quality issues. One region in particular, the San Joaquin Valley (SJV), contains over 50% of the state's agricultural equipment and faces significant challenges in meeting air quality standards. A better understanding of the type, number, and characteristics of farm equipment operating in California is critical to developing the most cost effective strategies for reducing their emissions.

This report details development of the California Air Resources Board's (CARB) 2011 agricultural emissions inventory, based on a 2008 survey of agricultural producers, custom operators, and first processors for self-propelled diesel agricultural equipment over 25 horsepower in size. This inventory replaces CARB's OFFROAD2007 agricultural inventory and is the product of a close collaboration between CARB, the San Joaquin Valley Air Pollution Control District (SJVAPCD), and the agricultural community, who conducted a large-scale outreach operation in an effort to collect and process agricultural equipment data for the entire state of California. This multi-year effort involved numerous agricultural stakeholders, farmers, producers, and equipment operators, among others, throughout the state.

The goal of the survey was to collect California-specific data on equipment use per acre of crop for a sample of representative growers across the state. Using regional weighting factors, the survey successfully gathered information from almost 1,800 respondents and over 10,000 pieces of equipment in different agricultural regions of California. Survey responses addressed such questions as equipment population, activity data, retirement and purchasing rates, load factor, and more. To develop a comprehensive statewide inventory, the survey responses were scaled up using acreage data from the County Ag Commissioners and the USDA 2007 Census of Agriculture reports.

The final inventory estimates that in 2008, there were approximately 158,000 diesel agricultural vehicles greater than 25 horsepower in size operating in California, of which 80,000 of these vehicles operate within the SJV. Agricultural equipment, as compared to other off-road vehicles, have an extended life, particularly on small farms. Thus, it is common to find vehicles of 50 and 60 years of age on these smaller operations. Equipment longevity leads to over 50,000 of the approximately 60,000 tractors operating in the SJV with Tier 0 or Tier 1 engines, at the time of the survey. Tier 0 and Tier 1 engines are older, dirtier engines with little or no emissions control.

Natural attrition, along with hundreds of millions of dollars in incentive funding, have significantly reduced harmful emissions from agricultural off-road diesel equipment by replacing older equipment with newer, cleaner engines. By 2017, over 5,700 pieces of equipment in the SJV, the majority of which were tractors, were replaced with the assistance of incentives. CARB estimates that in 2017, incentive replacement, along with natural equipment turnover, leaves approximately 55% of agricultural equipment in California with Tier 0 and Tier 1 engines. Although this equipment turnover has reduced emissions since the survey was conducted in 2008, there is a need for continued incentive funding to address emissions from the oldest and dirtiest equipment. Without further incentives, more than 25,000 Tier 0 and Tier 1 tractors will continue operating in the SJV in 2024.

This inventory has significantly improved our understanding of California's agricultural equipment usage, emissions associated with them, and the importance of incentives. Further work is needed to understand other factors impacting air quality including: updated agricultural practices, shifts of farming from small to larger farms, and the significant drought which occurred in 2010 to 2013 that impacted many areas of California.

CARB staff is in the process of initiating a new survey of agricultural equipment that will be used to update the inventory described here. This new inventory, when completed in 2020, will allow a better assessment of ongoing turnover of California's agricultural industry to cleaner equipment in different regions and for different types and sizes of operations. Periodic inventory updates are critical for ensuring emissions benefits are properly attributed to incentive programs as well as other measures for encouraging the lowest possible emissions from California agriculture.

2. Diesel Agricultural Emissions Inventory Development

An emissions inventory is an account of all equipment, engines, activity, and pollutants from a particular sector, such as agriculture. This emissions inventory focuses on pollutants created by self-propelled diesel equipment used in agricultural operations in California. The majority of the equipment in this inventory is a form of farm tractor, with the rest being a mix of harvesters, combines, agricultural forklifts, or similar equipment. This report will cover the inputs and methodology of the inventory, with the calculation of pollutants from these engines discussed in detail in Section 5.3.

In 2011, the California Air Resources Board (CARB) developed the diesel agricultural mobile sources emissions inventory to replace and improve CARB's prior inventory, the OFFROAD2007 Model. Updating the inventory focused on working with farmers and others within the agricultural sector while using substantive, specific information on California commodities, equipment, and farming practices. The collected data were used to build a new agricultural inventory based directly on reports from farms and first processors, and not on surrogate data or data aggregated from other states. Incorporating California specific data on both farm size and commodities grown provides the updated inventory with an increased level of detail and specificity, which is needed to understand where emissions from the agricultural sector occur, thereby informing potential approaches to reduce emissions.

The inventory also reflects increased turnover due to incentive projects administered by the San Joaquin Valley Air Pollution Control District (SJVAPCD or SJV District) and the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) through May 2017. These incentive programs have been focused in the San Joaquin Valley region and have significantly accelerated the turnover of agricultural equipment in that region.

2.1 Previous Agricultural Inventory in OFFROAD2007

The 2011 diesel agricultural emissions inventory replaces the agricultural inventory in the OFFROAD2007 model. Developed by CARB in 2007, OFFROAD2007 was an emissions estimation tool for the entire off-road sector, including diesel agricultural equipment. It was based on the best information available at the time, which were national averages for diesel equipment. Power Systems Research (PSR) supplied data including equipment population, survival rates, activity usage, and load data from 1991 to 1997. Equipment population and survival rates were based on manufacturer surveys and data, not in-use data, and represented nationwide averages. Due to PSR's equipment generalities, engine load was based on generic diesel engines; therefore, load was not specific to agricultural equipment. At the time, this was the best data available, even though it was lacking specificity for the agricultural sector.

Compared to the previous 2007 inventory, the updated 2011 agricultural diesel inventory described in this report:

- updates the input data vintage by approximately 15 years (Refer to Section 3)
- is based on data from California farms and farming practices instead of nationwide data (Refer to Section 3)
- improves specificity to include commodities grown and farm size, as well as many equipment types previously not included in the inventory (Refer to Section 4)

- reflects the decline in activity as equipment ages rather than having one average activity regardless of equipment age (Refer to Section 4.4)
- updates load factors to reflect agricultural practices and not general diesel engine operations (Refer to Section 4.6)
- updates fuel use (Refer to Section 4.7)
- reflects USDA and County Ag Commissioner's data on California acreage for allocation across the state (Section 4.10)
- includes updated emission factors and fuel correction factors (Refer to Section 5.3), and
- reflects the large number of agricultural equipment incentive projects accomplished with the assistance of SJVAPCD funds, NRCS funds, and Moyer funding sources from 2009 to 2017.

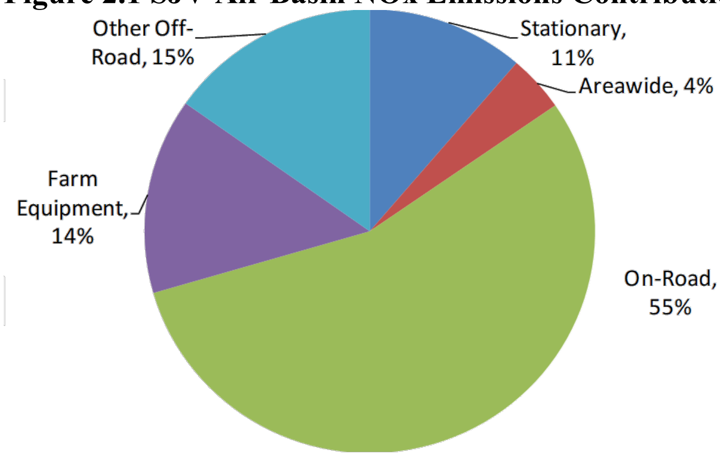
2.2 Nonattainment Status

The updated 2011 diesel agricultural emissions inventory creates a detailed, California-specific picture of agricultural equipment. The need for refining the prior inventory is most prominent in two specific areas of the state: the San Joaquin Valley (SJV) and the South Coast Air Basin. The San Joaquin Valley[1] and the South Coast Air Basin[2] are the two only areas in the country classified as extreme ozone nonattainment areas. Specifically, the SJV has the most burdensome PM2.5 challenge in the country. It is in nonattainment for the 24-hour PM2.5 standards, measured at 65 and 35 micrograms per cubic meter ($\mu g/m^3$), with attainment dates of 2020 and 2024, respectively; also, the SJV is in nonattainment for the annual PM2.5 standards of 15 and 12 $\mu g/m^3$, with attainment dates of 2020 and 2025, respectively.

Since agriculture is a significant emissions source within the SJV, understanding and addressing emissions from all significant sources within the valley is necessary to meet these attainment goals. Figure 2.1 depicts 2012 agricultural emissions contributions, with farm equipment in purple. Approximately 14% of basin wide nitrogen oxide (NOx) emissions, an important precursor to ozone and PM2.5, originate from farm equipment.

[1] San Joaquin Valley Attainment Status. http://www.valleyair.org/aqinfo/attainment.htm
[2] Attainment Status for South Coast Air Basin. http://www.aqmd.gov/docs/default-source/clean-air-plans/air-quality-management-plans/naaqs-caaqs-feb2016.pdf

Figure 2.1 SJV Air Basin NOx Emissions Contributions



In addition to the SJV, agricultural emissions play an important role in the Sacramento Valley, comprising about 10% of NOx emissions in 2012. Although Sacramento Valley may face challenges reaching its air quality attainment goals, statewide and local programs already in place may be sufficient to bring the area into attainment. The same attainment goals within the SJV will be more challenging and require new strategies to address a broad range of emissions sources. Other areas of the state use diesel agricultural equipment, but they comprise a much smaller percentage of emissions. For example, in South Coast, farm equipment contributed 0.3% to annual NOx emissions in 2012.

As for the other emissions sources shown in Figure 2.1, there have been a number of strategies (e.g., incentive programs, accelerated fleet turnover through in-use diesel regulations and off-road diesel construction equipment) adopted and implemented with the goal of reducing criteria emissions from these sources. Therefore, assessing remaining sources of emissions, such as agricultural equipment, becomes increasingly important to meet future air quality goals.

2.3 Need for Inventory Updates and Incentives Monitoring

Although the emissions inventory described in this document is a significant improvement over the previous information used by CARB, the agricultural sector will require additional inventory updates to capture changes in farming practices, land use, and technology. Also, continued monitoring of incentive programs that accelerate equipment turnover will ensure emissions from the agricultural sector will continue to decrease despite the economic growth.

The inventory updates will be accomplished through additional work with the agricultural industry, to include a new survey and new data from USDA and the County Ag Commissioners. This data will allow CARB to incorporate inventory data that shows changes due to the historic drought in 2011 to 2014, changes and consolidation in farms, updated farming practices and technologies, and land use changes. The inventory will also update the statewide allocation of agricultural equipment, based on the 2017 USDA Census of Agriculture and the 2017 and 2018 data from county agricultural commissioners.

The continued work to monitor and reflect the impact of incentives in the inventory are vital to ensuring that state and regional air quality goals are met, particularly in the SJV, as noted previously. CARB has been continuously collaborating with both the SJVAPCD and NRCS in the past to reflect the incentive programs and ensure that the agricultural sector is meeting needed emissions reductions, and will continue to do so as current and future incentive programs are implemented. Additionally, CARB will work with the Air Quality Management Districts and Air Pollution Control Districts that are participating in incentive programs for agricultural equipment to gather relevant data to ensure the emissions benefits of those programs are reflected in the emissions inventory.

2.4 Overview of Incentive Programs

Since 2009, over $400 million dollars in private and public funding has been invested in the San Joaquin Valley to replace older agricultural tractors with newer, cleaner models. Through 2016, the NRCS Environmental Quality Incentive Program[3] (EQIP), in combination with the SJV District's program, has provided approximately $130 million that helped replace over 5,000 Tier 0 and Tier 1 tractors, plus other agricultural equipment. The incentives targeted replacement of the largest and most used tractors, in addition to other types of farm equipment. Significant continued investments are on-going.

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 addresses the air quality concerns from agricultural operations and meets Federal, State, and local regulatory requirements. From 2009-2018, NRCS obligated $188 million for the turnover of in-use off-road farm equipment operating within nonattainment counties of California, of which $148 million funded San Joaquin Valley projects. Reauthorized in the 2018 Farm Bill, EQIP funding to address California's air quality concerns will continue through 2023.

CARB recently developed the Funding Agricultural Replacement Measures for Emission Reductions (FARMER) Program[4], which facilitates distribution of state funds allocated by the California Legislature to incentivize turnover of agricultural equipment. The FARMER program guidelines, adopted in March 2018, 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. In fiscal year 2017-18, the FARMER program received a $135 million allocation, of which $108 million of those funds were directed to the San Joaquin Valley. The 2018-19 fiscal year included $132 million statewide for the FARMER program, a portion of which will also be allocated to the San Joaquin Valley. Further, the SJVAPCD receives local funds to improve air quality from sources that can also be used to incentivize the accelerated turnover of agricultural equipment.

Due to the success of these incentive programs, the agriculture industry continues to advocate for additional funding to incentivize the replacement of farm equipment. Since 2016, NRCS and the SJV District have funded an additional 1,000 projects. Overall, the incentive projects have targeted the larger horsepower farm equipment. In addition, California's FARMER program will contribute significant funding to replace agricultural equipment.

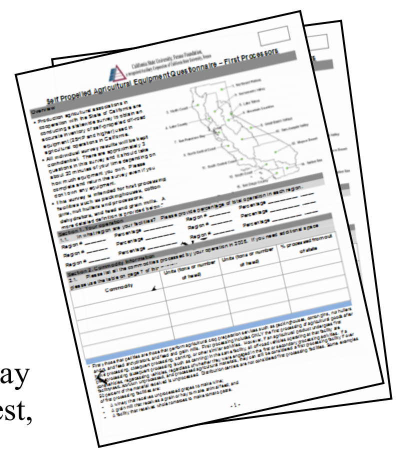
[3] USDA NRCS EQIP, https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/eqip/
[4] CARB FARMER Program, https://ww2.arb.ca.gov/our-work/programs/farmer-program

To provide cleaner tractors to small farms, CARB staff, the SJV District, and the agricultural industry are working to implement a new tractor trade-up program with funding provided by two previous CARB Air Quality Improvement Program[5] (AQIP) grants and the FARMER Program. The tractor trade-up program will assist small farmers in overcoming potential financial barriers in procuring cleaner mobile agricultural technologies, and will accelerate emissions reductions by replacing the oldest tractors with cleaner used models. Maximizing reductions, in light of these economic considerations, will require careful design of the program and the optimum use of incentives.

3. Farm Equipment Survey

The primary data used to update the agricultural inventory was a 2008 survey of California farms, custom operators, first processors, and equipment rental facilities developed and administered by CARB staff, with the assistance of SJVAPCD staff and agricultural stakeholders. The survey gathered a representative sample and used acreage data provided by the USDA 2007 Census of Agriculture[6], to scale up the survey responses to represent statewide farms. Given the great diversity of farms, both by region, crops, and size (and beyond that even basic farming practices), the survey required significant participation from the agricultural industries in California. Overall, the survey was a success with over 1,700 participants, largely due to the efforts of agricultural stakeholders distributing and reaching the agricultural industries, and the participation of so many individual farmers and members of the agricultural industry. The level of detail requested by the survey results provided a strong basis for the new 2011 inventory, both in level of detail and the sheer number of farms represented.

CARB staff, SJV District staff, and agricultural stakeholders and representatives collaboratively developed the survey[7] to collect data from producers, custom operators, and first processors. CARB and the SJV District staff detailed requirements for a complete emissions inventory, specifically information on agricultural vehicles usage, horsepower size, number of operational hours and fuel consumption. Agricultural stakeholders and representatives provided expertise on categorizing and understanding the agricultural industry, where similarities in farm sizes and crops grown could be used to identify groups of growers, and noting differences in seemingly similar farms. For example, citrus and nut farming are both generally orchards and may have similar tree spacing, but use vastly differently equipment to harvest, maintain, and plant crops. Table 3.1 outlines the type of information requested in the survey.



[5] CARB AQIP, https://www.arb.ca.gov/msprog/aqip/aqip.htm
[6] USDA 2007 Census, https://www.agcensus.usda.gov/Publications/2007/
[7] In-Use Mobile Agricultural Equipment Regulation Survey, https://www.arb.ca.gov/ag/agtractor/agsurvey.htm

Table 3.1 Type of Requested Information

Farm	Equipment
Commodities Grown or Harvested	Vehicle Type
Acres (per commodity)	Model Year
Double Cropping Practices[8]	Horsepower
Custom Operator Activity on Farm	Fuel Type and Annual Consumption
Region of the State	Annual Use in Hours
	Manufacturer and Make

For most respondents, there were multiple commodities grown and multiple pieces of equipment reported. Similar data were requested from custom operators and first processors, focusing on the type and amount of custom work performed or the amount of goods processed, respectively. Survey responses were scaled up to represent a statewide inventory based on the USDA 2007 Census of Agriculture[9] according to crop types in each county and the agricultural stakeholders selected crop groupings.

3.1 Outreach and Participation

Industry representatives conducted the primary outreach to agricultural producers at numerous county and district meetings, through industry mailing lists, and personal contacts. A contract with California State University (CSU), Fresno assisted in gathering and analyzing the survey data and providing the survey by request, although industry representatives participating with CARB and the SJVAPCD gathered the majority of the data.

Table 3.2 shows a partial list of the groups participating in the outreach efforts, as well as the collection of surveys from producers, custom operators, and first processors. This is not a comprehensive list since many other agricultural groups collected and funneled survey responses to CARB and CSU Fresno, as well.

[8] Double cropping means growing multiple crop cycles per annum, such as growing two separate crops on the same land. One example would be growing and harvesting grain crops on 15 acres of land in spring and summer, followed by silage corn on the same land and harvesting in autumn. USDA acreage reports count that as two separate 15-acre farms. When scaling up to USDA California totals, it is important to represent double cropping accurately.
[9] USDA 2007 Census, https://www.agcensus.usda.gov/Publications/2007/

Table 3.2 Partial List of Outreach Participants in the 2008 Agricultural Survey

Participating Groups
Almond Board of California
Avocado Commission
California Association of Winegrape Growers
California Cattlemen's Association
California Citrus Mutual
California Cotton Ginners and Growers Association
California Farm Bureau Federation
California Grain and Feed Association
California Grape and Tree Fruit Association
California Poultry Federation
California Rice Commission
California Seed Association
California Warehouse Association
Far West Equipment Dealers Association
Nisei Farmers League
Pacific Egg and Poultry Association
Raisin Bargaining Association
Sun Maid Growers
The California Association of Wheat Growers
The California Bean Shipper Association
The Pacific Coast Renderers Association
Western Agricultural Processors Association
Western Growers
Western United Dairymen

3.2 Collection and Results

To encourage participation and ensure anonymity of the survey data collected, CSU Fresno processed the surveys and kept the results anonymous by assigning each survey a numerical identifier. CSU Fresno and industry representatives stored individual survey information, which was not shared with CARB or the SJVAPCD. Because some large farms would be identifiable by region and size (e.g. the largest farms in certain areas), all raw data were stored with CSU Fresno and later with the California Farm Bureau Federation. These data were not shared with CARB or the SJVAPCD.

Table 3.3 details the number of survey responses by industry sector. The typical participant was a farmer with three or fewer commodities, who completed most of the farm work with their own equipment, but also paid for some custom work such as pruning or harvesting.

Table 3.3 2008 Agricultural Survey Responses

Agriculture Sector	Number of Responses
Producer	1,552
Custom Operator	151
First Processor	52
Equipment Rental Facilities	11
Total	**1,766**

Over 10,000 applicable pieces of equipment were reported, the majority being tractors of various sizes. Approximately 1,000 reported pieces of equipment were excluded from the survey since they were either not self-propelled, the engine did not run on diesel fuel, or the engine was not over 25 horsepower. This survey only included self-propelled diesel engines over 25 horsepower.

The stakeholders identified equipment type choices, which was included in the survey. In most cases, the respondents included one of the 15 equipment types shown in Table 3.4. If the equipment type varied, then the written entry was matched to one shown in Table 3.4.

Table 3.4 Number of Self-Propelled Diesel Vehicles Reported in Survey

Equipment Type	Number in Survey
Agricultural Tractors	7,022
Crawler/Backhoe/Loader/Dozer/Grader	699
Other	627
Nut Harvester	556
Forklifts	271
Other Harvesters	258
Combine Harvesters	233
Swathers/Windrowers/Hay Conditioners	135
Sprayers/Spray rigs	117
Cotton Pickers	112
ATVs	55
Balers (Self-Propelled)	47
Bale Wagons (Self-Propelled)	45
Hay Squeeze/Stack retriever	38
Forage & Silage Harvesters	16
Total	**10,231**

Of the information reported, almost all respondents reported the equipment type, vehicle horsepower, and annual activity in hours. Of these responses, 2,583 reported annual fuel consumption in pounds or gallons of diesel fuel, which was significantly important in determining load and estimating statewide fuel use from the agriculture sector.

4. Emissions Inventory Development

A series of steps were used to process the survey's raw data, which included grouping similar farms and equipment, and profiling the age and activity data of the equipment reported. These steps were necessary to fill in survey gaps and transform the rough data into a model that represented statewide agriculture.

For example, only three pluot producers responded to the survey. Therefore, scaling three responses up to a statewide level could easily create extreme and unreliable results if the farms happened to be examples of particularly high, or low, activity without knowing if the responses are truly representative of the average farm. However, the 288 responses received from tree fruit producers provided greater statistical certainty that the scaled-up inventory is representative of an average farming operation. For this reason, pluots were grouped with tree fruits.

Similarly, looking at specific tractor horsepower bins show only one response was received for the bin representing 1950 model year tractors between 75 and 100 horsepower. This specific tractor's annual use was reported to be 1,000 hours. If scaled up to statewide levels, this would create a few dozen extremely old tractors running at 1,000 hours annually, which is unlikely. Grouping together tractors and creating a profile of activity and age shows that, although such tractors exist, they are the exception and most tractors that are 50, 60 and even 72 years old are used 25 to 100 hours per year. These high activity reports were not discarded, but averaged with reports from similar equipment groups. The grouping of like tractors on similar farms creates a more representative inventory of the average agricultural equipment used in farming operations than directly scaling up the results likely would.

4.1 Farm and Equipment Bins

4.1.1 Commodity

Of the hundreds of commodities grown in California, the USDA identified 55 common groups. With the expertise of stakeholders who represent much of California's agriculture community, these 55 commodities were further assembled into 12 general groups. For example, the commodity 'Romaine' was grouped with 'Lettuce,' which was then grouped into 'Hand-picked Vegetables'.

The purpose of grouping data was to create statistically robust data sets that represent an average farm instead of small data sets that may not represent average operations. Table 4.1 itemizes commodities and larger commodity groups refined with stakeholders and was used to categorize agricultural production for the purposes of the emissions inventory.

Table 4.1 Commodity Groups

Commodity Group	Commodity
Beef Cows*[10]	
Milk Cows*	
Poultry*	
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
	Others (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

10 For these commodities, the individual commodity is the same as the commodity group.

Commodity Group	Commodity
	Orchards, Tree Fruit, Stone Fruit
	Peaches
	Pears
	Persimmons
	Plums
	Pluots
	Pomegranates
	Prunes
Vegetables, hand-picked	Broccoli
	Cabbage
	Lettuce, All
	Melons, All
	Peppers
	Tomatoes (fresh)
	Vegetables
Vegetables, machine-picked	Carrots
	Onions
	Potatoes, Sweet Potatoes
	Tomatoes (processing)

4.1.2 Farm Size

The USDA Census of Agriculture uses a variety of farm size characteristics, which vary between descriptions of farm size by acres, farm employment, and farm income. To scale the survey results up using the USDA data, the inventory used the same farm size characteristics as the most specific USDA data released, which is the county specific listing of acres of production by farm size by county. Table 4.2 lists farm size groupings by acreage. USDA reports will show different farm size categories for different types of data.

Table 4.2 USDA Farm Size Grouping

Farm Size Groups
0 to 15 Acres
15 to 50 Acres
50 to 100 Acres
100 to 250 Acres
250 to 500 Acres
500 to 1,000 Acres
Over 1,000 Acres

For livestock categories, USDA typically groups farms by head. The survey results did receive a sufficient number of responses to create separate bins for livestock, so the USDA livestock groupings by farm size were not necessary.

4.1.3 Equipment Horsepower

Table 4.3 lists the horsepower bins used to group equipment, which are the same horsepower bins used by the U.S. EPA for diesel mobile equipment. Equipment under 25 horsepower in size were excluded from the survey and the resulting inventory.

Table 4.3 U.S. EPA and Inventory Horsepower (HP) Groups

Horsepower Group
25 to 50 HP
50 to 75 HP
75 to 100 HP
100 to 175 HP
175 to 300 HP
300 to 600 HP
600 to 750 HP
Over 750 HP

4.2 Survey Representation

Table 4.4 organizes survey response rates by farm size. Larger farms had greater representation, percentage wise, although they had a similar number of survey responses. Small farms had as many respondents as larger farms, but due to the many thousands of small farms in the state, the percent response rate for small farm acers was low. While representation of the smaller farms is a small percent, the survey still provided data on hundreds of these smaller farms, with thousands of pieces of equipment used on them.

Table 4.4 Survey Representation by Farm Size

Farm Size (Acres)	Number of Surveys	Percent of Statewide Acres in Survey
0-15	233	1%
16-50	493	3%
51-100	323	4%
101-250	398	4%
251-500	243	4%
501-1000	223	7%
Over 1000	291	32%

Table 4.5 arranges the same data by commodity groups.

Table 4.5 Survey Representation by Commodity Group

Commodity	Number of Surveys	Percent of Statewide Acres in Survey
Nut Crops	506	13%
Hay, Forage, Pasture, Grains	474	15%
Grapes	413	9%
Tree Fruit	226	6%
Citrus	166	23%
Row Crops	136	16%
Vegetables, hand-picked	87	15%
Vegetables, machine-picked	29	8%
Beef Cows[11]	71	N/A*
Nursery, Greenhouse, Floriculture	37	N/A*
Milk Cows	12	N/A*

4.3 Profiling Equipment Age and Use

4.3.1 Equipment Bin Size and Selection

As previously described, equipment was combined into similar groups and assigned a profile to calculate average population by age and average use. Ideally, each type and size of farm would have a unique profile for both age and activity for all different types and sizes of equipment. Specifically, each commodity group in Table 4.1 was split by farm sizes in Table 4.2. Then, equipment was organized by type and horsepower. Operator types in Table 3.3 was another division.

This resulted in 15,120 different groupings of equipment, thereby exceeding the number of pieces of equipment in the survey:

> (2 Main Operator Types) * (12 Commodity Types) * (6 Farm Sizes) * (15 Equipment Types) * (7 Horsepower Bins) = 15,120

Hence, combining some farm and equipment types were necessary to develop profiles. Two main questions in analyzing the data pertained to grouping the equipment and the number of equipment pieces in each group.

4.3.2 Group Size Selection

CARB staff analyzed the data to determine the number of equipment in each grouping, based on various factors. The groupings had to be large enough to provide some certainty that they were reasonably representative of an average farm. In addition, the groupings had to provide data on vehicles from a wide age range. The large age range was necessary to develop profiles for activity and population by age. For example, a small data set would likely have a high standard deviation for vehicle activity within a certain age grouping, providing little confidence the data

[11] Percent of statewide data shown is percent of head of beef cows or milk cows.
* Acreage data does not apply to these commodities.

are representative. However, smaller data sets could provide significant findings on young and old vehicles, while missing information on those vehicles in the middle.

To determine the best number of equipment pieces per group, CARB staff grouped equipment in different sized intervals, from 25 to 200, in steps of 25. The results were analyzed for two factors. First, what percentage of groups had equipment data within each 10-year period (e.g. they had some data on equipment aged 0 to 10 years, some for 10 to 20 years, etc.) without gaps. Second, the percent of profiles that had a 95% or higher degree of confidence that the resulting profile was statistically relevant to the data set (i.e. when the data are plotted, it creates an actual profile and not scattered data points).

Table 4.6 lists the analysis results. The statistical relevance (correlation coefficient) of the profiles increase significantly as group size approaches 100 pieces. However, making larger sets produces diminishing returns for group sizes over 100.

Table 4.6 Group Size Analysis

Number of Equipment Pieces per Group	Percent of Groups Without Significant Data Gaps	Average Correlation Coefficient
25	34%	0.39
50	61%	0.54
75	79%	0.72
100	93%	0.83
125	94%	0.86
150	96%	0.85

Therefore, it was determined that data sets of 100 provided enough information to create profiles that were reliable. Groups below 100 had data gaps, and were therefore considered less reliable. Groups above 100 provided slightly more certainty, but began to lose specificity.

4.3.3 Method of Grouping Equipment

Based on the 100-piece grouping, the surveyed equipment had to be combined in a way that sacrificed some of the inventory's specificity. For example, the data could be grouped by farm size (i.e. combining data from farms of all sizes and averaging it, thus losing specificity by farm size). Farm size could be maintained separately, grouping equipment by horsepower (totaling all horsepower and averaging the results).

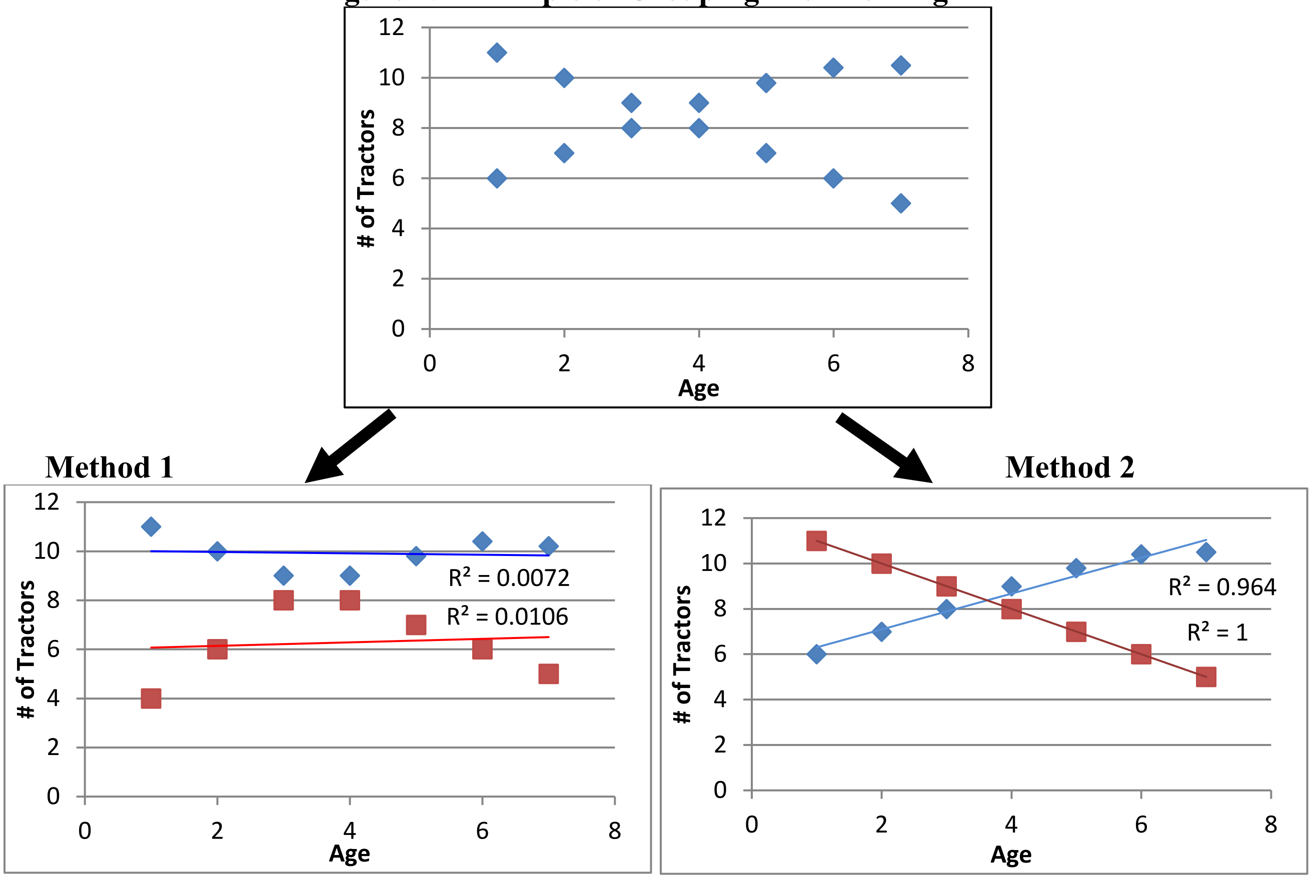
When grouping equipment, the questions to be addressed are:

- What are the important indicators that control how equipment is used?
- Is it the commodity grown, the type of equipment, or the horsepower of the equipment?
- Identifying the most and least important factors were necessary to create the most meaningful bins of 100 pieces of equipment.

To determine the most important factors in determining population by age and activity, CARB staff combined data in multiple ways, developed profiles, and analyzed which method best fit the data by comparing the average correlation coefficient for each profile.

For example, the raw, ungrouped, data shown in Figure 4.1 were grouped using two different methods. “Method 1,” on the bottom left, separated data into high and low values. The profiles created for this grouping had correlation coefficient values near zero, indicating they were poor representations of the data. On the bottom right, “Method 2” grouped data into categories that, when profiled, much more accurately describe (or predict) the behavior of the data. This was reflected in the high correlation coefficient (where one is a perfect representation of the data).

Figure 4.1 Example of Grouping and Profiling Data



CARB performed the same analysis on approximately 400 different groupings to determine which method best describes the data. For small data sets, this method may yield inaccurate results since correlations can be incorrect or appear at random. For over 10,000 data points (pieces of equipment reported in the survey), finding a strong correlation corresponding to a control factor (such as farm size, commodity, or engine horsepower) demonstrates an extremely strong causal relationship.

Table 4.7 shows the average correlation coefficients for profiles created by grouping equipment various ways.

Table 4.7 Equipment Grouping and Profile Analysis Results

Equipment Groupings	Factors Ignored in Grouping	Average Correlation Coefficient
Horsepower Bin Equipment Type Farm Size Commodity Group	Operator Type	0.53
Operator Type Farm Size Commodity Group Horsepower Bin	Equipment Type	0.59
Equipment Type Operator Type Farm Size Commodity Group	Horsepower Bin	0.70
Operator Type Equipment Type Horsepower Bin Commodity Group	Farm Size	0.79
Operator Type Equipment Type Horsepower Bin Farm Size	Commodity Group	0.83

This analysis determined that operator type, equipment type, farm size, and horsepower bin were the strongest factors influencing age and activity of equipment. While commodity played a role, it was not as influential as other factors. According to the survey results, a 50-horsepower tractor on a 200-acre tree fruit farm is more likely to operate similarly to a 50-horsepower tractor on a citrus farm than either a 300-horsepower tractor on the same tree fruit farm or a 50-horsepower tractor on a much smaller 5-acre tree fruit farm. Analysis of this survey data suggested equipment horsepower and farm size have greater influence on equipment behavior than does the commodity grown.

Because of this analysis, surveys were grouped into the 80 bins outlined in Table 4.8 for profiling age and activity (note that population was not combined using these bins, only data on ages and activity).

Table 4.8 Equipment Bins for Profiling Age and Activity

Diesel Tractors							
	Farm Size (acres)	Engine Horsepower Bin					
		25-50	50-75	75-100	100-175	175-300	300-600
Producers	0-15	1	8	15	22	28	32
	15-50	2	9	16			
	50-100	3	10	17	23		
	100-250	4	11	18	24		
	250-500	5	12	19	25	29	
	500-1000	6	13	20	26	30	33
	1000+	7	14	21	27	31	
Custom Operators	0-15	34	35	37	N/A		
	15-50				39	41	42
	50-100						
	100-250						
	250-500			38			
	500-1000		36		40		
	1000+						
Equipment Rental		43		44	45		
First Processors		46				-	-

All Equipment		
Beef, Milk Cows & Poultry	All Sizes	47
Nurseries	All Sizes	48

NonTractors[12]		
	Producer	Custom Op
Combine Harvesters	49	50
Forage & Silage Harvesters		
Cotton Pickers	51	
Nut Harvester	52,53,54	56
Other Harvesters	57,58	50
Balers (Self Propelled)	60	
Bale Wagons (Self Propelled)	61	
Swathers/Windrowers/Hay Conditioners	62	63
Hay Squeeze/Stack retriever	64	
Sprayers/Spray rigs	65	
Crawler/Backhoe/Loader/Dozer /Grader	66, 67, 68, 69, 70	71
Forklifts	72	
ATVs	74	
Others	75,76,77,78,79	80

4.4 Profiling the Equipment Groups

Using the 80 equipment groupings described in the previous section, equipment was analyzed for trends in age and activity. These trends were used in place of the raw data because, as previously described, scaling up the raw data directly with no changes lead to unreliable or unrepresentative results, with extreme cases in the farm survey being exaggerated. Profiling the data trends provided smoother results and a more accurate inventory.

Following are some examples of how the data were visualized to determine trends for different equipment, horsepower, and farm size bins. Figure 4.2 shows the population distribution by age for tractors of 70 to 100 horsepower, on farms of 250 to 500 acres. Figure 4.3 shows the activity

[12] For non-tractor equipment, where multiple bins are listed for an equipment type, they represent splits by horsepower. For example, nut harvesters used by producers were split into three horsepower groups.

distribution by age for tractors in the same horsepower and farm size bins. In both graphs, the overall trend is a moderate reduction in population and activity as age increases. While vehicles over 50 years old remain in the inventory, they are less common than newer vehicles, and have lower activity.

Figure 4.2 Population Distribution, by Age - Tractors (75-100 hp, 250-500 acres)

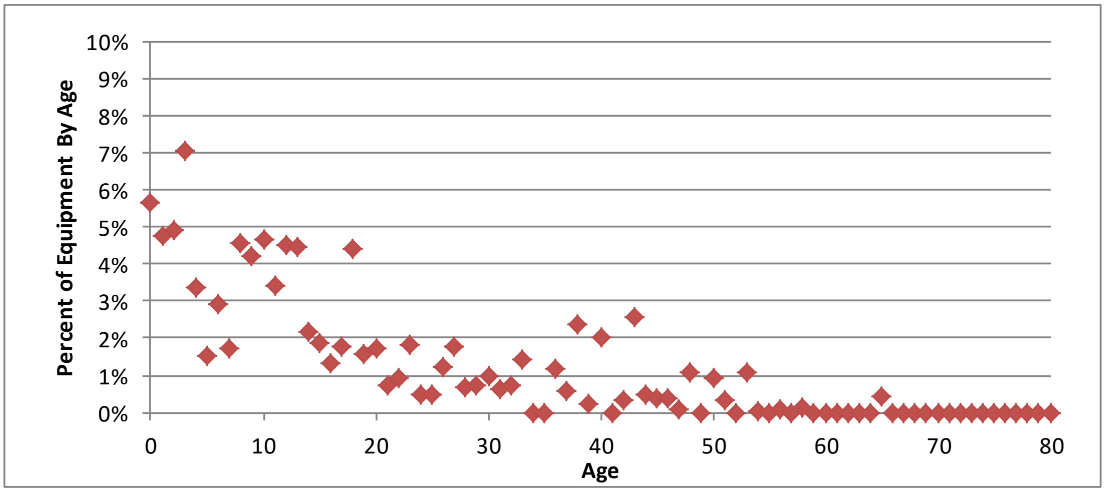
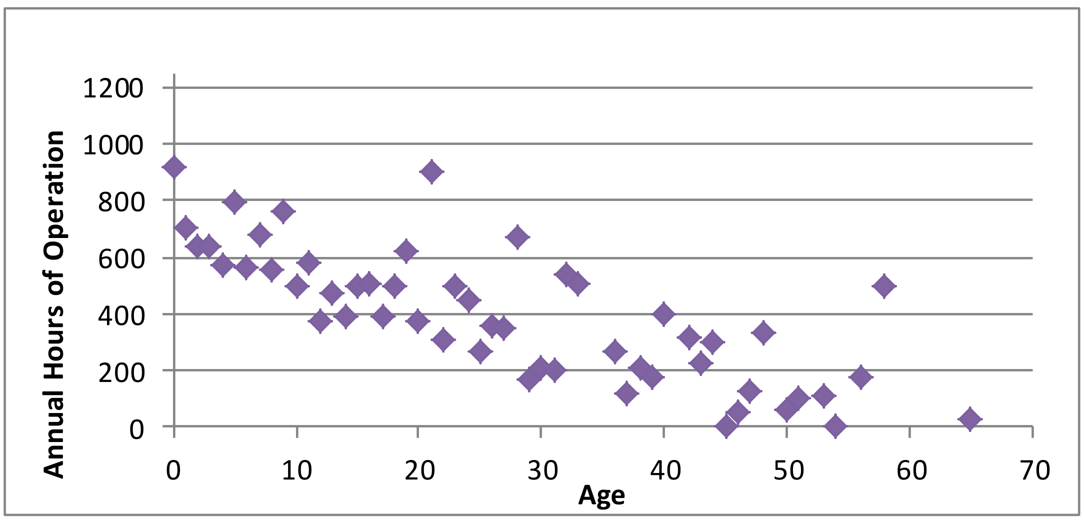
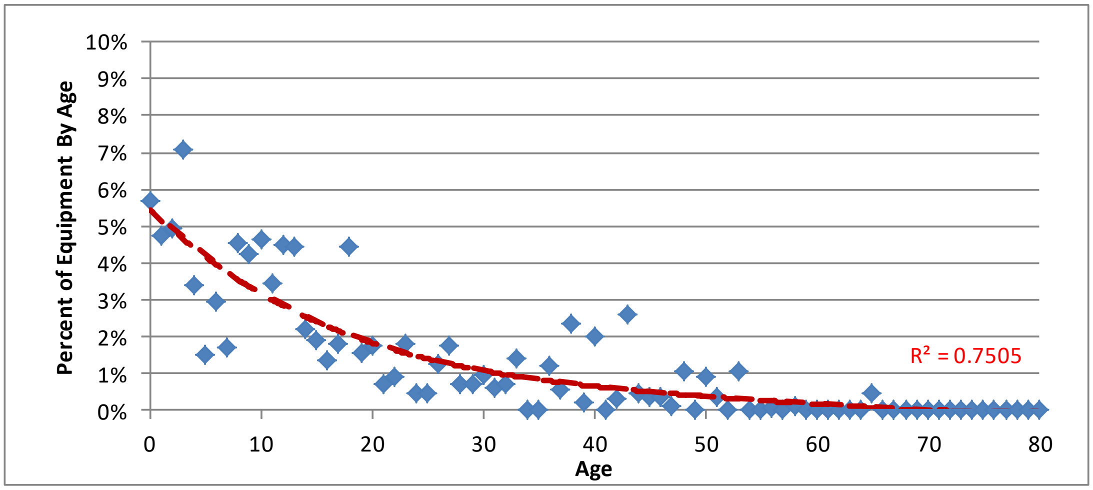


Figure 4.3 Activity Distribution, by Age - Tractors (75-100 hp, 250-500 acres)



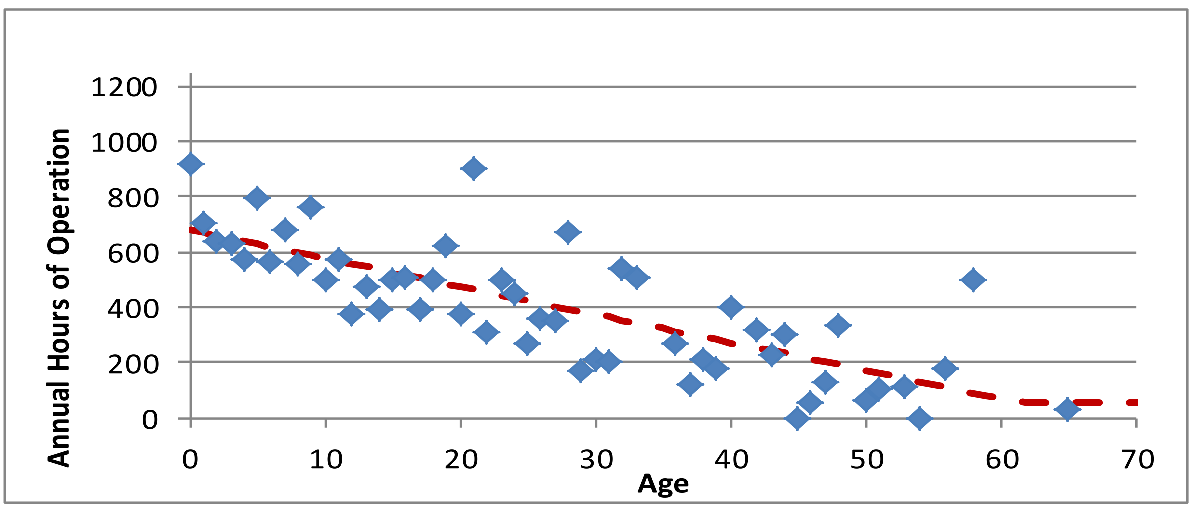
To model population, CARB reviewed a number of methods, including moving averages, polynomial best-fit lines, and logarithmic scales. Farm equipment purchases do not follow any one equation or trend since it is specific to an individual farm's economics and preference. Figure 4.4 reveals the best-fit polynomial for this tractor horsepower and farm size bin with the highest correlation coefficient and best describing the population data.

Figure 4.4 Population Data Best-Fit Polynomial



Varieties of trends were tested on the activity data. For the majority of bins, a best-fit line most closely represented the data. Upon data review and discussions with farmers in the field, there was an adjustment made to the activity profile at the end of the vehicle's life. Tractors and other equipment retained for 50 or more years often become backup vehicles, used only a few dozen hours per year, on average. Based on this information, tractors at the end of their life were modeled using the lowest average use for tractors over 50 years old within a horsepower bin grouping, which was 54 hours per year. Figure 4.5 shows the best-fit line for activity, approaching the end-of-life estimated usage of 54 hours per year.

Figure 4.5 Activity Modeling



4.5 Statewide Population Scaling

The survey provided a sufficiently large number of responses considered to be representative of the majority of agricultural operations. However, these results needed adjustments in order to represent all agricultural equipment within California. As such, scaling factors, or multipliers, were applied so the data could reflect a statewide inventory. Each commodity and farm size required two main pieces of information to calculate multipliers necessary for scaling up the survey results: the number of survey acres reported and the number of acres reported by USDA.

In many cases this was a simple process, but became complex when calculating multipliers for farms that produced multiple commodities and had various equipment spread across their operations. Table 4.9 shows an example of population scaling using the number of farms that produced nut crops between 500 and 1000 acres. The first column records the number of farms and total acres reported. The next column contains the associated number of tractors and harvesters. The third column reports the number of farms and acres in the USDA 2007 Census of Agriculture for nut crop farms of sizes between 500 to 1000 acres. Next, the 7.5 scaling factor is calculated by dividing the 174,408 USDA acres by the 23,361 survey-reported acres. The last column provides the scaled up result when the scaling factor (7.5) is multiplied by the survey-reported tractors in this bin (129). Thus, nut crops on farms of 500 to 1000 acres have an estimated 962 tractors, statewide.

Table 4.9 Statewide Population Scaling Example: Nut Crops, 500 to 1000 Acres

Survey Farms and Acres	Survey Tractors	USDA Acres	Scaling Factor	Statewide Tractors
33 Farms 23,361 Acres	129	263 Farms 174,408 Acres	7.5	962

For beef cows, milks cows, poultry, and floriculture, scaling was performed at the statewide level, as the reports did not have the specificity needed to scale by farm sizes or bins.

An alternative scaling method was considered, which involved scaling by number of farms instead of acres. In most cases, the results were similar. For the example provided above, the scalar would have been 7.9 instead of 7.5. However, the number of tractors per farm had a higher standard deviation than did tractors per acre, thereby suggesting tractors per acre was a more reliable method. A number of farmers also supported using the tractor per acre method. The rationale was that both a 2-acre and a 14-acre farm fall into the same farm size bin. They each count as a single farm, so scaling population by farm counts would be inaccurate.

Table 4.10 outlines the scaling process for custom operators, which is slightly more complicated. USDA data provided statewide acres, but not total acres or portion of the total that employed custom operators. To scale up the custom operator population, the survey reports from producers were used in conjunction with the USDA data. From the survey, producers reported the percent of their land worked by custom operators and the type of work completed. Work type include pruning, harvesting, chemical application, land preparation, and all other work. To determine the portion of acres that had custom work performed, the total acres of custom work among reports (within a certain bin) was summed and compared to the total production acres within that bin. This portion was applied to the USDA data and used to scale the tractors reported by custom operators.

Table 4.10 Custom Operator Scaling Example (within each farm size and commodity bin)

	Task	Data Source	Calculation
Step 1	Find percent of producer acres that employ custom operators	Producer Survey Data	60 acres custom operator / 200 acres reported by producers = **30%** of acres employ custom operators
Step 2	Apply percent to statewide acres	USDA Data	1000 total acres in California for this farm size and commodity 1000 * 30% = **300 acres** assigned custom operations
Step 3	Find scalar for custom operator equipment	Custom Operator Acres Data	50 total acres reported by custom operators 300 custom operator acres estimated statewide / 50 acres reported in survey = scalar of **6.0**
Step 4	Apply scalar to custom operator equipment	Custom Operator Equipment Data	5 tractors reported by custom operators 5 tractors * scalar of 6.0 = **30 custom operator tractors** in the inventory from this farm size and commodity bin

For many larger farms with complex operations, the scaling had to be calculated across different commodities and farm sizes. Consider the farming operations described in Table 4.11. In total, the example farm has 115 acres of production and performs custom operations on an additional 120 acres. Each piece of equipment reported is shared among commodities and activities, based on the number of acres reported. For example, 75 of the 235 acres reported (or 32%) were for corn production, so 32% of each vehicle is allotted to the commodity row crops.

Table 4.11 Equipment Portions for Example Farming Operation

Farm Activity	Bins	Equipment Portion Assigned to Bin
Apples, 20 Acres Plums, 20 Acres	Producer Tree Fruit, 15-50 Acres	40 / 235 Acres = 17%
Corn, 75 Acres	Producer Row Crops, 50-100 Acres	75 / 235 Acres = 32%
Custom operator for 120 acres of corn	Custom Operator Row Crops, 100-250 Acres	120 / 235 Acres = 51%

Although this method does not fully account for differences in production and workload necessary for different commodities, it is a first step toward defining equipment use between commodities and farm sizes based on available information. With additional information from farmers and custom operators defining how the equipment is commonly used, equipment could be more accurately tied to the actual work performed instead of split by acres.

Table 4.12 summarizes the scaling factor for producers by commodity and farm size. In general, the largest farms have the smallest scalars (due to the high levels of representation in the survey), and the smallest farms have the highest scalars.

Table 4.12 Scaling Factors for Producers

Farm Acres	Citrus	Grapes	Hay, Forage, Pasture, Grains	Nut Crops	Row Crops	Tree Fruit	Vegetables, hand-picked	Vegetables, machine-picked
1000+	1.9	6.7	2.8	3.0	2.5	2.4	2.6	2.5
500-1000	2.1	7.8	11.6	7.5	16.0	16.8	26.2	23.0
250-500	23.3	13.8	25.4	13.4	16.6	25.0	40.9	26.0
100-250	9.6	14.6	31.4	13.5	19.3	44.5	108.2	231.2
50-100	16.8	13.0	48.2	20.2	25.5	56.0	49.8	46.9
15-50	27.1	21.7	69.4	26.2	15.5	144.9	63.9	21.2
0-15	119.5	57.8	189.8	65.7	34.0		170.8	36.5

Table 4.13 provides the scaling factors for commodities that could not be split by farm or facility size, and were scaled up based on the total head reported in the survey and the statewide head of livestock reported by USDA.

Table 4.13 Scaling Factors for Livestock and Plant Nurseries

Commodity	Scaling Factor
Poultry	1.2
Nursery, Greenhouse, Floriculture	4.4
Beef Cows	51.1
Milk Cows	401.5

4.5.1 First Processors

In the survey, first processors reported the total quantity of produce that was processed by their facility or plant, in units of pounds, tons, crates, or similar metrics. Scaling up the first processors equipment to a statewide level was done by comparing the total quantity reported in the survey to the total quantity of goods produced in the state, as reported by USDA. For first processors, it was possible to split the facilities by commodities processed, but not by a specific level such as facility size, revenue, or other variables. Table 4.14 describes the quantity of produce reported by facilities in the survey and by the USDA, along with the resulting scaling factor. Not all commodities were reported in the survey, as many do not require intensive first processing.

Table 4.14 First Processor Scaling

Commodity Group	Survey Total (Short Tons)	USDA Production Total for CA (Short Tons)	Scalar
Nut Crops	160,911	1,408,800	8.8
Citrus	291,147	3,061,600	10.5
Tree Fruit	244,704	8,392,200	34.3
Hay, Forage, Pasture, Grains	27,654	1,659,900	60.0
Row Crops	20,346	1,393,000	68.5

4.6 Load Factor

Inventory changes to load factor based on survey data were one of the largest modifications with the most impact, reducing emissions by approximately 30%. A load factor represents the proportion of maximum horsepower an engine produces on average under a particular use. A load factor is unit-less and part of the emissions calculation (Equation 1).

For example, if a 300 horsepower tractor uses 240 horsepower when pulling a plow, it runs at an 80 percent load factor for that use. When pulling a heavy water tank, the same engine might use 150 horsepower, therefore running at 50 percent load. When the tractor is moving across the farm without pulling anything, it may use 60 horsepower, or a 20 percent load.

Equation 4.1 calculates how engine load and activity affect maximum annual fuel usage. For example, a 100 horsepower tractor operating for 100 hours per year at full load (i.e. where the engine is running at maximum horsepower for the entire time that the engine is used, also referred to as 100% load factor). The equation relies on the US EPA[13] constant fuel consumption rate of 0.408 lb. of diesel per horsepower-hour. Thus, the engine has the potential to consume 582 gallons per year.

Equation 4.1 Annual Fuel Usage

$$\text{Max Annual Fuel Usage} = \text{horsepower} * \text{annual activity} * \text{fuel consumption rate} * \text{fuel conversion rate}$$

$$100 \text{ hp} * \frac{100 \text{ hr}}{\text{yr}} * \frac{0.408 \text{ lbs}}{\text{hp-hr}} * \frac{1 \text{ gal}}{7.1 \text{ lbs}} = 582 \frac{gal}{yr}$$

Based on the calculation above, if a tractor's owner reported a tractor used 233 gallons of fuel that year, the average load factor would be 40% using Equation 4.2.

[13] Exhaust Emission Factors for Nonroad Engine Modeling--Compression-Ignition, Report No. NR-009A, February 13, 1998.

Equation 4.2 Load Factor calculation

$$\text{Load Factor} = \frac{\text{Reported Fuel Usage}}{\text{Max Annual Fuel Usage}}$$

$$\text{Load Factor} = \frac{233\ \text{gal/yr}}{582\ \text{gal/yr}} = 40\%$$

4.6.1 Load Factors for All Equipment Types

The following information is necessary for updating load factors and was provided by survey respondents: fuel consumption, annual activity, and horsepower for 1,549 vehicles (70% were tractors). Data on equipment types were combined in the following groups: (1) agricultural tractors, (2) balers and bale wagons, (3) construction, forklifts, ATVs and others, (4) harvesters of all types, (5) hay squeeze, and (6) spray rigs. Since hay squeezes lacked sufficient data, they were combined with tractors, the largest category, and share their load factor. Table 4.15 expresses load factor by equipment type. Based on all the responses, tractors have an average load factor of 0.48, with the other equipment types coming in between 0.4 to 0.5.

Table 4.15 Load Factor by Equipment Type

Equipment Type	Load Factor
Agricultural Tractors	0.48
ATVs	0.40
Bale Wagons (Self-Propelled)	0.50
Balers (Self-Propelled)	0.50
Combine Harvesters	0.44
Cotton Pickers	0.44
Crawler/Backhoe/Loader/Dozer/Grader	0.40
Forage & Silage Harvesters	0.44
Forklifts	0.40
Hay Squeeze/Stack Retriever	0.42
Nut Harvester	0.44
Other Harvesters	0.44
Others	0.40
Sprayers/Spray Rigs	0.42
Swathers/Windrowers/Hay Conditioners	0.48

4.6.2 Load Factor Example: Tractors

Tractors are a large portion of the inventory. Responses provided sufficient data to study load factor by horsepower group, which demonstrates the greatest impact on vehicle activity and age distributions. Table 4.16 lists tractor load factor by horsepower group, the average load factor for all tractors, and the standard deviation of load factor for all tractors.

Table 4.16 Tractor Load Factor by Horsepower Bin

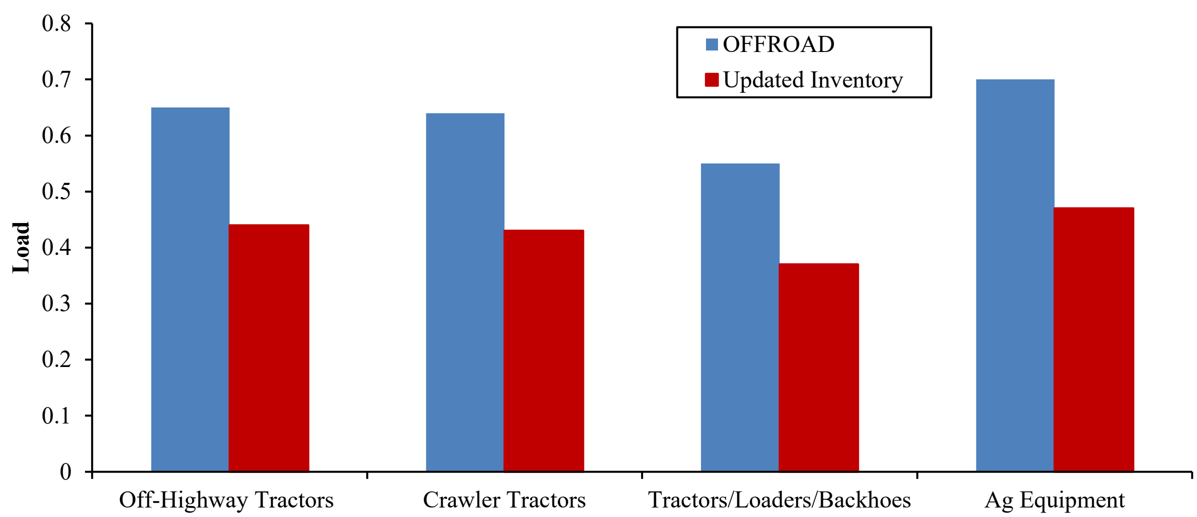
Horsepower Bin	Load Factor
25-50	43.6%
51-75	45.2%
76-100	47.3%
101-175	50.9%
176-300	44.4%
301-600	34.0%
All Bins	**48.2%**
Standard Deviation	**21.8%**

The 21.8% standard deviation signifies that most tractors have a load factor between 30% and 70%. Although this is a wide range, it does not indicate inconsistencies in the data because tractor duties vary. Even though the standard deviation is larger than the difference between any horsepower bin load factor and the average load factor, the relationship between load factors and horsepower bins are not statistically significant. Therefore, the average tractor load factor of 48.2% is used.

4.6.3 Load Factor Comparison

There is little research on agricultural equipment load factors. Notably, when the construction portion of the OFFROAD2007 model was updated, the relatively high load factor of 0.65 for tractor categories was reduced to 0.44. Figure 4.6 compares the old load factors (colored blue) to the updated load factors (colored red). The first three sets of columns compare construction data. The last column displays load factor for agricultural tractors, which shows that load factors for agricultural equipment in the updated 2011 inventory are significantly lower than was assumed in the OFFROAD2007 model.

Figure 4.6 Load Factor Update Comparison with Construction Tractors



4.7 Statewide Fuel and Activity

Fuel use is a product of the fuel consumption rate, load, horsepower, population and activity. The inventory projects statewide fuel use, which was compared against statewide averages from two data sources: the U.S. Energy Information Association (EIA) and USDA fuel costs. EIA reports fuel used within the agricultural sector[14]. EIA's farm fuel use averages 258 million gallons per year over the last 10 years, as shown in Table 4.17. The averaging period was limited to 2001 – 2010 to reflect reasonably current agriculture practices. However, if the average from 1984 to 2011 was used, the result is 260 million gallons per year, a difference of 0.7%. It is important to note that EIA may retroactively adjust their fuel reports, as methodologies are updated and improved.

Table 4.17 EIA Diesel Fuel Used in Agriculture

Year	Diesel Gallons (1000 gals)
2001	262,592
2002	296,703
2003	77,709
2004	309,300
2005	331,896
2006	377,329
2007	261,386
2008	292,083
2009	173,888
2010	193,505
Average	**257,639**

USDA's fuel reporting resource records fuel costs for farmers without specifying diesel versus gasoline, in California. USDA does publish a percentage of fuel costs, by fuel type, by region of the United States, and California is part of the Western Region[15]. California annual diesel use was estimated by dividing the western regional costs by the average fuel cost, and separating the portion of California totals for diesel. Table 4.18 provides the steps and results of this process. USDA's estimate for annual average diesel fuel consumed from 2003 to 2011 was 236 million gallons per year.

[14] California Total Distillate Sales/Deliveries to Farm Consumers, https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=KD0VFMSCA1&f=A (EIA periodically updates methodology, and retroactively alters results.)

[15] Farm Production Expenditures Annual Summary, http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do;jsessionid=F154BA78C7C50C021C8CA924EDB72FD5?documentID=1066 (Example 2006-2007: http://usda.mannlib.cornell.edu/usda/nass/FarmProdEx//2000s/2008/FarmProdEx-08-07-2008.pdf)

Table 4.18 USDA Fuel Costs and Analysis

Year	Dollars Spent on Fuel in California	Average Fuel Price	Total Gallons of All Fuels in CA Ag (1000 gals)	Percent Diesel per USDA	Diesel Gallons (1000 gals)
2003	$ 540,000,000	$ 1.42	379,017	50.07%	189,785
2004	$ 610,000,000	$ 1.81	337,847	58.39%	197,252
2005	$ 910,000,000	$ 2.24	405,794	61.06%	247,778
2006	$ 1,000,000,000	$ 2.51	397,896	61.76%	245,759
2007	$ 1,140,000,000	$ 2.66	428,405	64.49%	276,290
2008	$ 1,300,000,000	$ 3.38	385,141	65.33%	251,594
2009	$ 880,000,000	$ 2.24	392,440	63.98%	251,095
2010	$ 1,030,000,000	$ 2.72	379,320	64.81%	245,829
2011	$ 1,120,000,000	$ 3.51	318,883	67.63%	215,655
				Average	**235,671**

The USDA and EIA averages have a difference of about 22 million gallons of fuel per year, or about 8.5% of the total. EIA collects data from distribution centers within the fuel service industry while USDA data comes from farmer surveys. It is important to note that this total also includes non-mobile (stationary) agricultural fuel use, such as agricultural pumps and wind machines.

CARB's agricultural pump inventory[16] shows average annual fuel use of approximately 12.1 million gallons per year. Wind machines and their fuel usage are not well documented, but a UC Berkeley study[17] estimated half of wind machines were diesel powered (and the other half electric), with an average of 90 horsepower and 120 hours of average annual use. With 12,000 diesel wind machines, this would require about 3 million gallons of gasoline, annually. These two sources account for about 15.3 million gallons of diesel annually. Subtracting this from EIA and USDA average fuel estimates results in an average of approximately 231 million gallons of diesel consumed per year by agricultural equipment covered by this category.

Prior to any fuel adjustments to the survey data, the inventory reports an average of 163 million gallons of fuel used per year by diesel-fueled agricultural equipment, or about 30% below the USDA and EIA averages for fuel in this category. This could be a factor of the survey year being a year with low average fuel use, or even the result of capturing or scaling up farms with lower than average activity.

Adjusting the inventory's fuel use based on EIA and USDA's average fuel use over multiple years aligns the agricultural inventory with an average year in terms of total activity, instead of only one survey year, which could be a potential outlier. A secondary benefit is ensuring the methodology used to scale up both population and activity did not favor either high or low data that would skew the total activity statewide. For example, as data were scaled up based on a ratio

[16] California Air Resources Board CEPAM, Stationary Sources – Ag. Irrigation Engines, http://outapp.arb.ca.gov/cefs/2016ozsip/fcemssumcat_2016o3sip105.php
[17] Cory Parmer, California Air Resources Board, personal communication.

of the farm acres to statewide acres, some received a scaling factor of up 230 while others received a scaling factor of two. This means the activity from some reports, whether high or low, were weighted more heavily than others were. This technique, if applied to a few outliers, could produce statewide activity that is drastically higher or lower than in actuality. Adjusting for average fuel use allows the overall inventory to compensate for this potential shift.

4.8 Turnover and Attrition

To forecast future years, the model must attempt to predict average, or normal, farm practices of retiring and purchasing equipment. Retirement and purchase behavior is modeled across groups of similar farms, not for individual farms. The model's retirement and purchasing behavior is based on a snapshot of farm equipment operated in California in 2008, and assumes data collected in the survey was a reasonable depiction of the average California equipment inventory in most years, and that it was representative enough of the average year to derive purchasing and retirement practices.

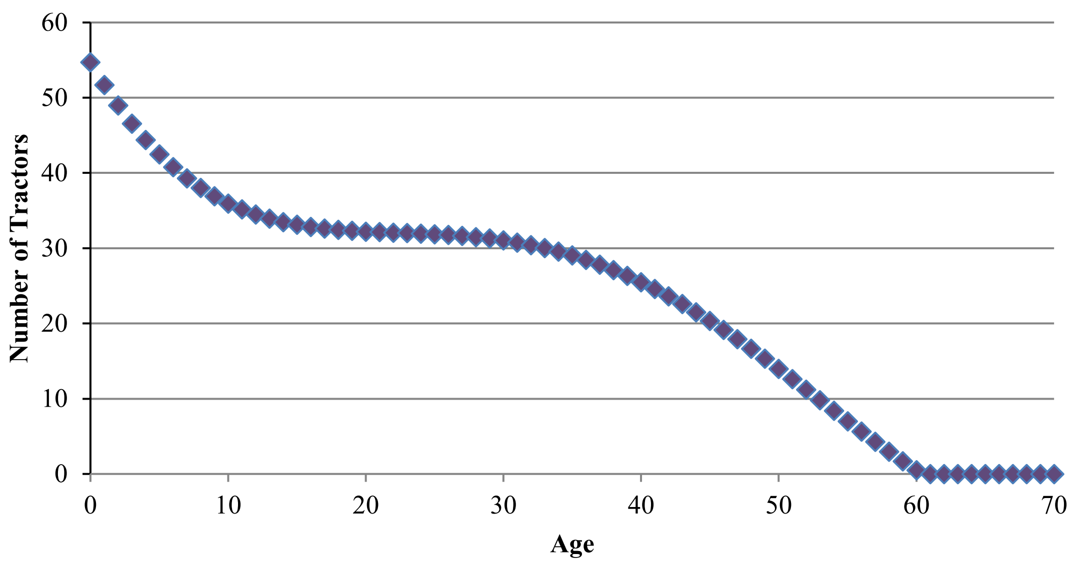
The survey data allowed for a vast improvement in modeling agricultural equipment retention over any previous data sources, but could be further enhanced with multiple years of California farm data, which will occur with future surveys.

4.8.1 Developing Purchase and Retirement Behavior

The model's purchasing and retirement behavior was created to reproduce the survey data. For example, consider tractors between 100 and 175 horsepower on farms of 100 to 250 acres in the production group "Hay, Forage, Pasture, Grains," as shown in Figure 4.7. The minimum behavior necessary to produce this trend would be:

(1) Purchase 55 new tractors, annually.
(2) Gradual retirement of about one third of new tractors by age 12.
(3) Long period where tractors are used from 10 to 35 years of age with few retirements.
(4) Gradual retirement of most or all tractors from age 35 to 60.

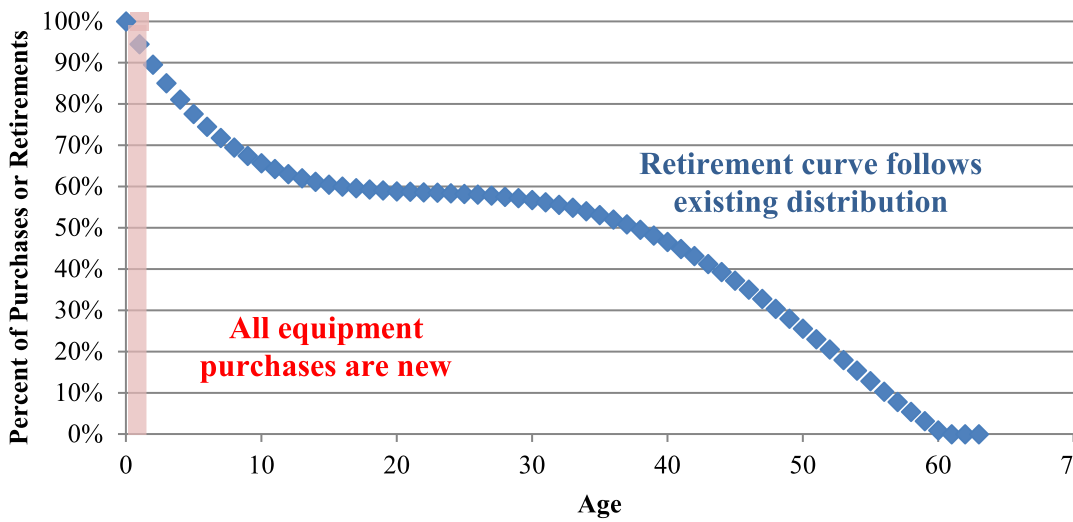
Figure 4.7 Age Distribution – Tractors (100-175 hp, 100-250 acres)



The minimum behavior necessary to produce the trend in Figure 4.8 would be:

(1) Purchasing 55 new tractors annually.
(2) Gradual retirement of about one third of new tractors by age 12.
(3) A period where tractors are used from 10 to 35 years of age, with few retirements.
(4) Gradual retirement of most or all tractors from age 35 to 60[18].

Figure 4.8 Purchasing and Retirement – Tractor (100-175 hp, 100-250 acres)



Not all population distributions are quite as simple as the previous example. In many cases (particularly small farms), much of the purchasing is focused on 10, 20 and even 30 year old tractors, with minimal new purchases.

Next, Figure 4.9 considers the tractor population with 50 to 75 horsepower on grape farms of 25 to 50 acres. It is evident new vehicle purchases must occur, but do not supply the majority of equipment on such farms. For this group, the minimum purchasing and retirement necessary are:

(1) Purchase about seven new vehicles each year.
(2) Purchase one or two used vehicles of age 1 to 25 years old in each year.
(3) Retirement of vehicles 40 to 60 years old.

[18] In reality, there may be significant turnover and replacement that cannot be determined by a single year, and would not reflected in Steps 1 to 4 above. The minimum purchasing and retirement requirements can be determined by a single year.

Figure 4.9 Age Distribution – Tractors (50-75 hp, 25-50 acres)

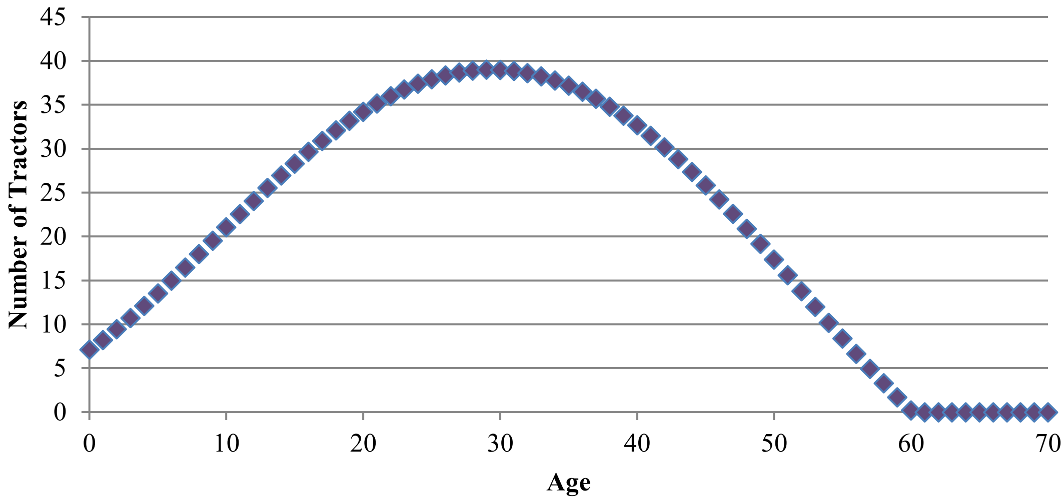
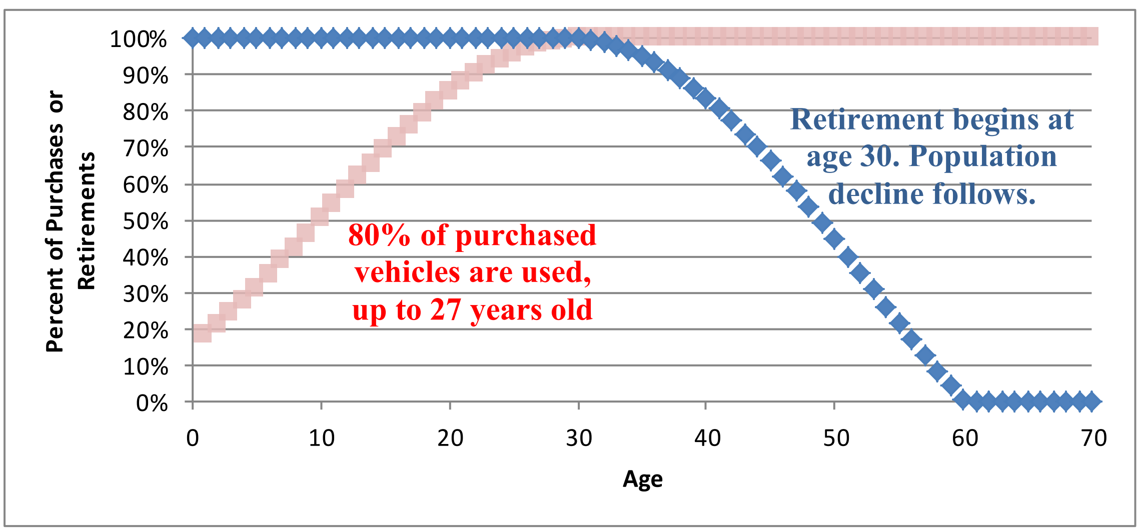


Figure 4.10 displays this behavior in the combined purchasing and attrition curves.

Figure 4.10 Purchasing and Retirement – Tractors (50-75 hp, 25-50 acres)



4.9 Growth

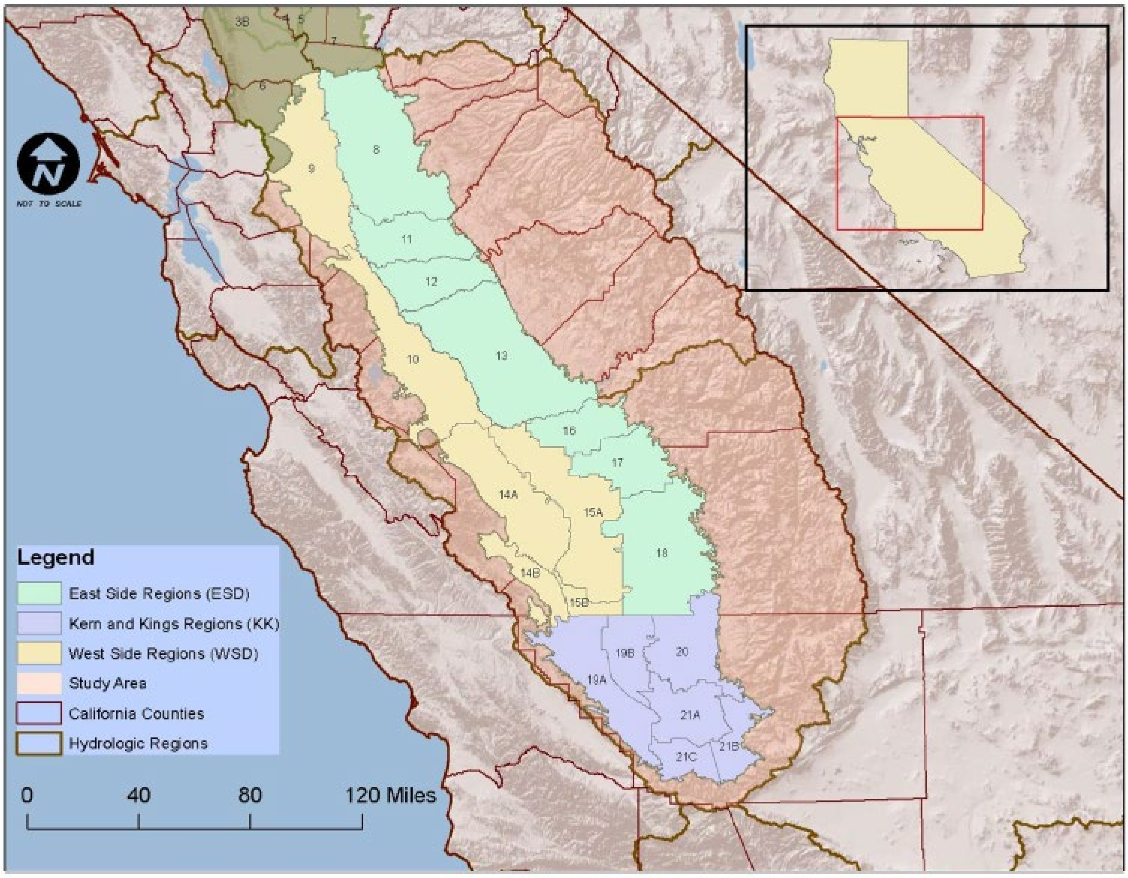
Research teams from URS Corporation and UC Davis, with input and oversight from CARB and a team of agricultural stakeholders, forecasted growth in the agricultural sector. The analysis was dependent on a hydro-economic model called the Statewide Agricultural Production Model, or SWAP[19].

The SWAP model incorporates factors such as water availability and cost, commodity prices and market factors, land use and urbanization, and technology shifts in the agricultural field. In addition to those major factors, additional inputs such as regulatory costs, labor costs, soil salinity, changes in annual yield per acre, and other factors create a growth (or negative growth) scenario that forecasts changes in agricultural acres and total revenue in a future year.

[19]The Statewide Agricultural Production Model, http://swapmodel.com/

The SWAP model divides California into 37 agricultural production regions. The Central Valley comprises 19 of those regions, and are mapped in Figure 4.11. Although some agricultural activity takes place outside of these regions, they comprise approximately 93% of California's active farmland.

Figure 4.11 SWAP Model Regions



Within each region, the SWAP calculates the changes in production acres based on the input variables (commodity prices, water prices, etc.). The growth rate forecasted by the SWAP model is dependent on the scenario inputs (e.g. forecast used for water, markets, etc.). During the forecasting tool development for use in the agricultural inventory, the research team performed a range of scenarios, with both high and low inputs. With the aid of stakeholder groups, a composite scenario with average (or business-as-usual) inputs was compiled. The results of the composite run from the SWAP model became the default growth rate for the agricultural sectors. Further updates to the composite run may be necessary, as technology, water, and demand projections can be measured against reality. Table 4.19 arranges the SWAP model's growth projections by commodity from the composite run.

Table 4.19 SWAP Growth Projection for Composite Scenario

Commodity	2005 Production Acres	2030 Production Acres	Change in Acres (Percent of 2005)
Alfalfa	604,997	600,441	-0.8%
Almonds	659,005	655,808	-0.5%
Artichokes	16,315	17,552	7.6%
Berries	334	368	10.2%
Corn	637,850	597,580	-6.3%
Cotton	660,126	550,303	-16.6%
Cucurbits	61,293	58,934	-3.8%
Dry Bean	34,348	30,389	-11.5%
Field	385,812	350,271	-9.2%
Fresh Tomato	36,563	39,769	8.8%
Grain	270,612	240,282	-11.2%
Onion	43,581	46,000	5.6%
Orchards	367,759	370,745	0.8%
Pasture	212,247	136,388	-35.7%
Potato	25,157	26,419	5.0%
Processed Tomato	226,315	233,990	3.4%
Rice	15,578	15,384	-1.2%
Safflower	30,753	17,259	-43.9%
Subtropical	167,391	164,659	-1.6%
Sugar	20,929	20,440	-2.3%
Vegetables	202,605	216,229	6.7%
Vine	583,902	584,146	0.0%
Statewide Total	**5,263,469**	**4,973,356**	**-5.5%**

Under the composite growth scenario, Table 4.19 summarizes that the SWAP model projected a 5.5% decline in total production acres in the state over a 25-year period. This equates to an annual decline of 0.21% in statewide production acres. Mapping the SWAP commodities to the emissions inventory commodity groups, results in the growth factors shown in Table 4.20.

Table 4.20 Emission Inventory Growth Rates

Commodity Group	25-Year Change in Acres	Annual Change in Acres
Citrus	-2%	-0.07%
Grapes	0%	0.00%
Hay, Forage, Pasture, Grains	-10%	-0.41%
Nut Crops	0%	-0.02%
Row Crops	-12%	-0.52%
Tree Fruit	1%	0.03%
Vegetables, hand-picked	5%	0.19%
Vegetables, machine-picked	3%	0.14%

Based on discussions with farmers and stakeholders on equipment replacement practices, and the general tendency to hold on to equipment through seasons, these growth factors were then applied to the activity of the equipment, and not populations. In general, shareholders indicated that farmers generally keep and maintain equipment as backup, or for use in peak season, wherever possible, and growth rates would be more likely to affect equipment use rather than retirement schedules.

4.10 Spatial Allocation

In some cases, inventory development focuses on statewide populations and emissions, and then allocates the emissions across the state, usually based on surrogate data. For the agricultural inventory, the population was scaled up directly using acreage data from the USDA and California county ag commissioners, who have data on acres by county. Scaling up populations by the acreage in each county results in equipment population and emissions at a county level, and allocating statewide equipment population from the top down is no longer necessary.

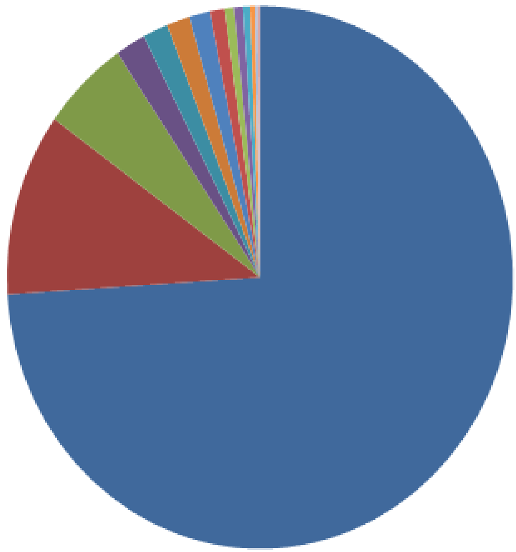
5. Survey Results

A highly detailed county-specific California agricultural equipment inventory was developed by scaling up the survey results, sorting the equipment into bins, and creating profiles for age and activity. This established a baseline inventory, which captures the California agriculture sector in a single year.

5.1 Equipment Population and Farm Size

Stakeholders identified different equipment types to be included in the survey, displayed in Figure 5.1. The results are scaled up according to county, farm size, and crop type from the 2007 USDA Agricultural census to represent equipment in the entire state. Using this scaling approach, it is estimated there are approximately 158,000 agricultural diesel vehicles in California over 25 horsepower in size. Agricultural tractors represent the largest equipment group, at 74% of the inventory's population. Construction equipment follows at 11% of the inventory, with the remaining 15% a combination of the other equipment categories, as shown in Figure 5.1 below.

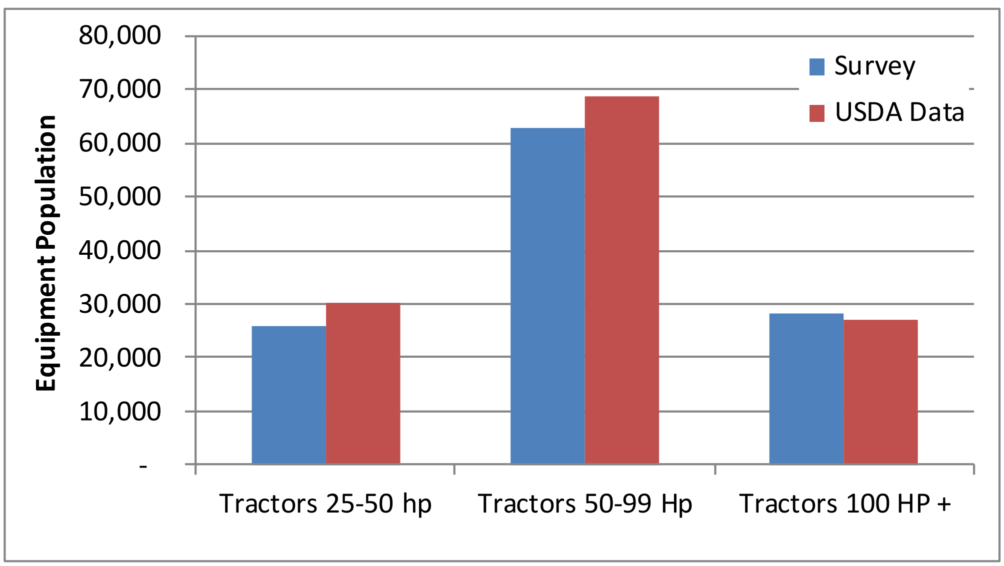
Figure 5.1 Statewide Diesel Agricultural Equipment population, by equipment type



Equipment	Population
Agricultural Tractors	117,139
Construction Equipment	17,253
Nut Harvester	8,845
Combine Harvesters	3,049
Swathers	2,556
Other Harvesters	2,315
Others	2,102
Sprayers/Spray rigs	1,472
Cotton Pickers	948
Balers (Self Propelled)	911
Bale Wagons (Self Propelled)	679
Hay Squeeze/Stack retriever	523
Forage & Silage Harvesters	261
Forklifts	241

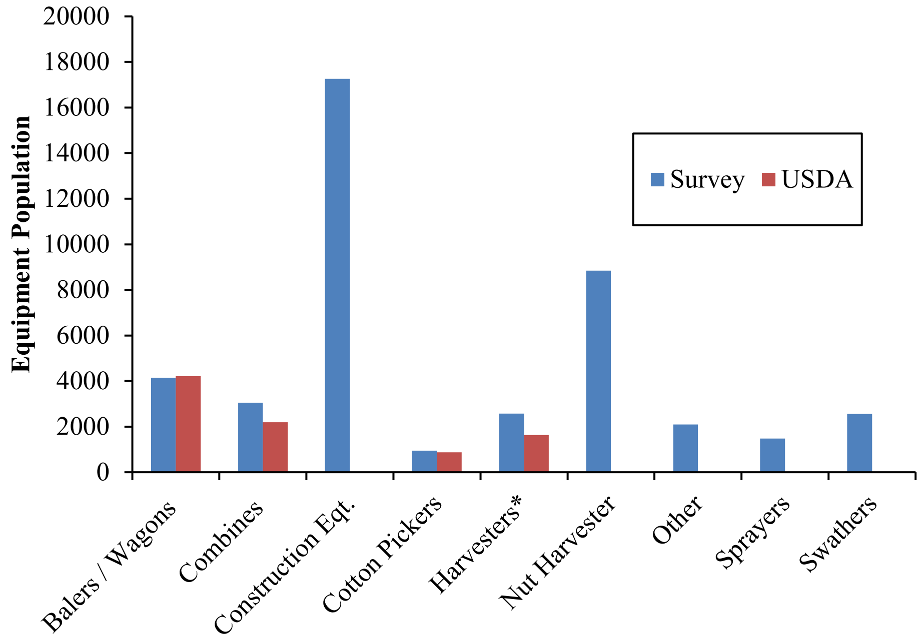
These results were verified against the USDA equipment inventory for tractors and other equipment types reported for California. Figure 5.2 compares diesel tractor data estimated from the most recent CARB survey with USDA estimates, excluding gasoline tractors. If gasoline tractors were included, they would increase the total number of tractors to 126,000, or within 1% of the USDA's 126,100 tractors (which include all both gasoline and diesel tractors).

Figure 5.2 Scaled Survey Results and USDA Data Comparison



There were no USDA data available for construction equipment (loaders and backhoes), nut harvesters, sprayers, and others, so it was not possible to make comparisons for these equipment types. There were no other viable data sources available to compare other survey populations. However, corroboration where possible between the survey estimates and existing USDA categories suggests the survey results and the scaling method are reasonable, and provides a degree of confidence that the method used to find populations is reliable and accurate. Figure 5.3 compares estimated survey and USDA non-tractor equipment numbers for a variety of non-tractor equipment types.

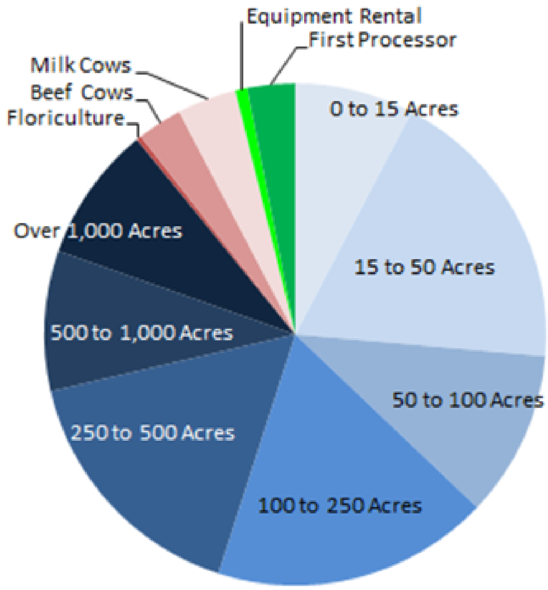
Figure 5.3 Estimated Population of Non-Tractor Agricultural Equipment by Type



Livestock (including beef cows, milk cows, and poultry), floriculture, equipment rental, and first processors were not assigned size categories since there were insufficient responses to divide results by farm size or animal lot. These categories represent 11% of total equipment, with the remaining 89% used by producers or customer operators on cropland.

Figure 5.4 displays the equipment distribution across different farm sizes, which are evenly distributed. Farm sizes of 15 to 500 acres have almost three quarters of all equipment. The remaining farms with 0-15 acres, 500-1000 acres, and 1000+ acres, combine for approximately one quarter of equipment. The equipment used on these farms includes those owned by the farms, as well as custom operator equipment hired by the farm.

Figure 5.4 Population by Farm Size and Type



Farm Size (or Type)	Equipment Count
0 to 15 Acres	12100
15 to 50 Acres	29600
50 to 100 Acres	17000
100 to 250 Acres	28300
250 to 500 Acres	26000
500 to 1,000 Acres	14300
Over 1,000 Acres	13800
Floriculture	500
Beef Cows	4600
Milk Cows	6000
Equipment Rental	1200
First Processor	4900

Table 5.1 shows the breakdown of equipment by commodity. The equipment is heavily concentrated in the top three commodity groups: 'Hay, Forage, Grains, and Pasture', 'Nut Crops', and 'Grapes', which collectively account for 62% of the total equipment population. While certain equipment types are limited to specific commodities (e.g. nut harvesters, cotton harvesters, tomato harvesters), tractors are generally used across commodities.

Table 5.1 Equipment Population by Commodity Group

Commodity Group	Equipment Population
Hay, Forage, Pasture, Grains	38,600
Nut Crops	36,200
Grapes	23,300
Tree Fruit	13,700
Vegetables, hand-picked	12,200
Row Crops	11,400
Citrus	7,900
Milk Cows	6,000
Beef Cows	4,600
Vegetables, machine-picked	2,700
Floriculture	500
Poultry	25

5.2 Age and Activity Profiles

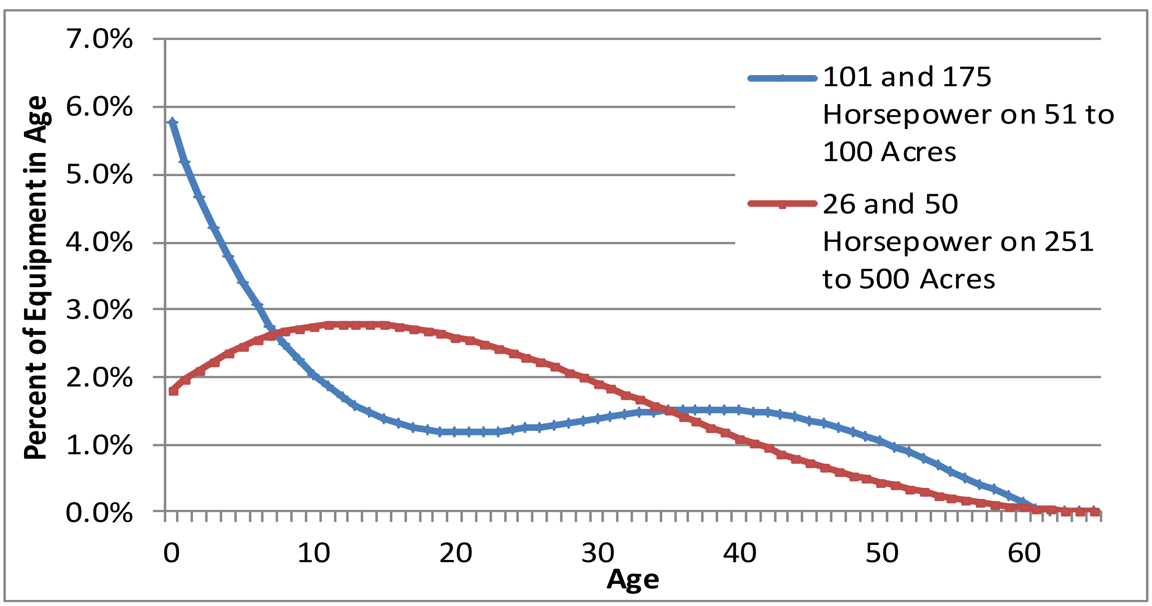
Table 5.2 shows average age (in blue) and activity (in purple) of tractors across different farm size and horsepower bins. The largest farms, those with 1000+ acres, have the newest tractors and the highest activity for almost all horsepower bins. The smallest farms, operating on less than 15 acres, tend to have the oldest tractors. It is also important to notice that tractors with higher rated horsepower tend to be younger and report higher activity, suggesting the newer, larger tractors are generally more utilized (i.e., higher activity). Farms with less than 50 acres have very few large tractors.

Table 5.2 Average Tractor Age and Activity by Farm Size and Horsepower Group

Age and Activity Horsepower	0-15 Acres		16-50 Acres		51-100 Acres		101-250 Acres		251-500 Acres		501-1000 Acres		1000+ Acres	
25-50	24	234	26	273	25	382	24	365	20	545	25	449	17	731
51-75	30	308	26	294	26	437	26	388	24	353	20	482	19	751
76-100	17	435	16	444	15	536	15	591	15	702	14	774	12	974
101-175	19	506	19	500	18	581	21	566	20	639	20	703	16	1009
176-300	24	705	23	716	20	709	19	733	18	740	17	759	14	1226
301-600	-	-	-	-	16	934	16	955	15	941	9	1447	11	1359

An age curve was developed to describe equipment age within each bin of a particular farm size and equipment horsepower bins. Figure 5.5 examines two examples of producer-owned tractors. Tractors between 26 and 50 horsepower on farms of 251 to 500 acres (colored in red), and tractors between 101 and 175 horsepower on farms of 51 to 100 acres (colored in blue) have average ages of approximately 21 years, but their age profiles are significantly different. Even though average ages are the same, different profiles create different purchasing and attrition habits.

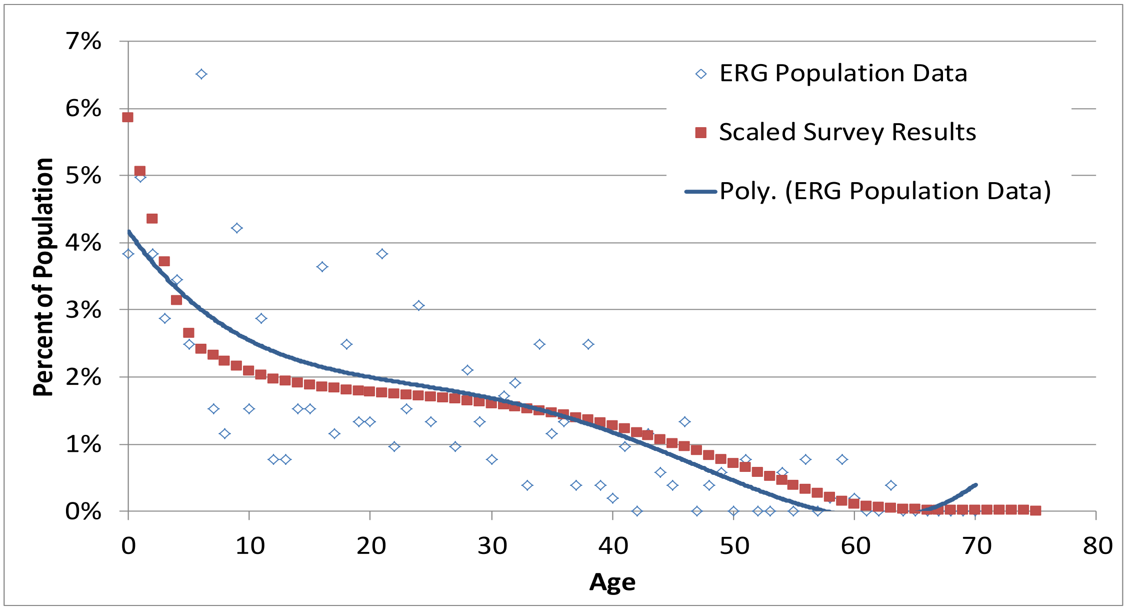
Figure 5.5 Age Profile - Tractors Comparison



As Figure 5.5 demonstrates, the 101 to 175 horsepower tractors have a relatively high new population that is quickly turned over, while a portion of farms in this bin maintain and even purchase older equipment out to 40 to 50 years. Alternatively, tractors with 26 to 50 horsepower are purchased used, up to 20 years of age, and then there is a slow decline out to 60 years of age. These two equipment groups, though they share the same average age, would respond differently to any turnover scenario.

The tractor age distribution was compared to an in-depth tractor study by Eastern Research Group[20]. The tractor age distribution within the inventory (red marks) and ERG's best-fit line (blue line) match closely on Figure 5.6, with one notable difference. The inventory included rental tractors, which increased population in the 0 to 4 age bins, as compared to the ERG data.

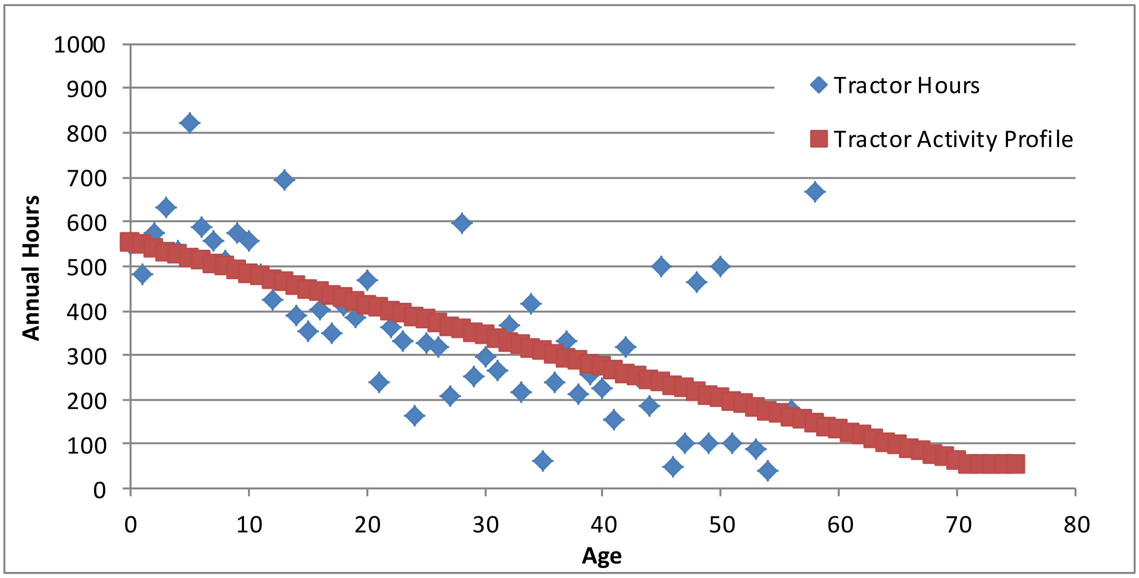
Figure 5.6 ERG and Inventory Tractor Age Comparison



Activity profiles are also unique. For example, Figure 5.7 shows the activity for tractors of 76 to 100 horsepower on farms between 100 and 250 acres. As with all activity profiles, activity of this group declines over time until reaching a steady state. This behavior matches field reports from farmers, where tractors of a certain age are used as backup equipment, and therefore driven only a few dozen hours per year.

[20] Modeling Non-Road Agricultural Tractor Emissions in Central Texas, http://www.capcog.org/documents/airquality/reports/2015/Modeling_Non-Road_Agricultural_Tractor_Emissions_in_Central_Texas_2015-04-12.pdf

Figure 5.7 Example Activity Profile: 76 to 100 Hp Tractors, 100-250 Acre Farms



Averaging all activity profiles across all equipment and horsepower bins (there are 101 unique activity profiles), produces a steady decline in annual equipment usage over time, followed by a period of maintained low use, exhibited in Figure 5.8.

Figure 5.8 Average Activity by Age

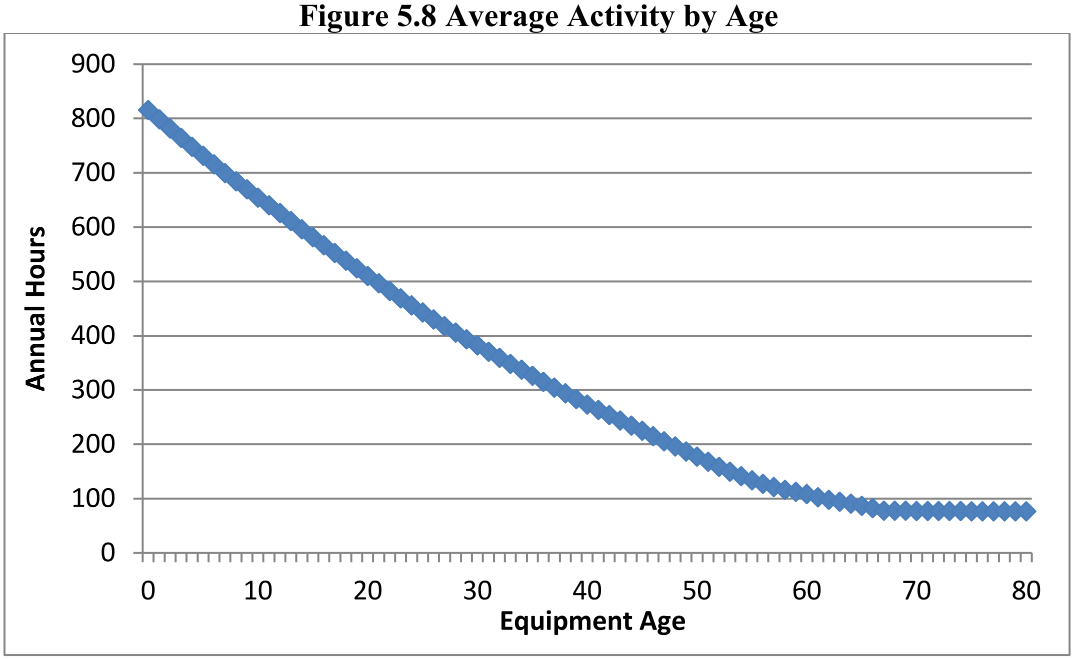
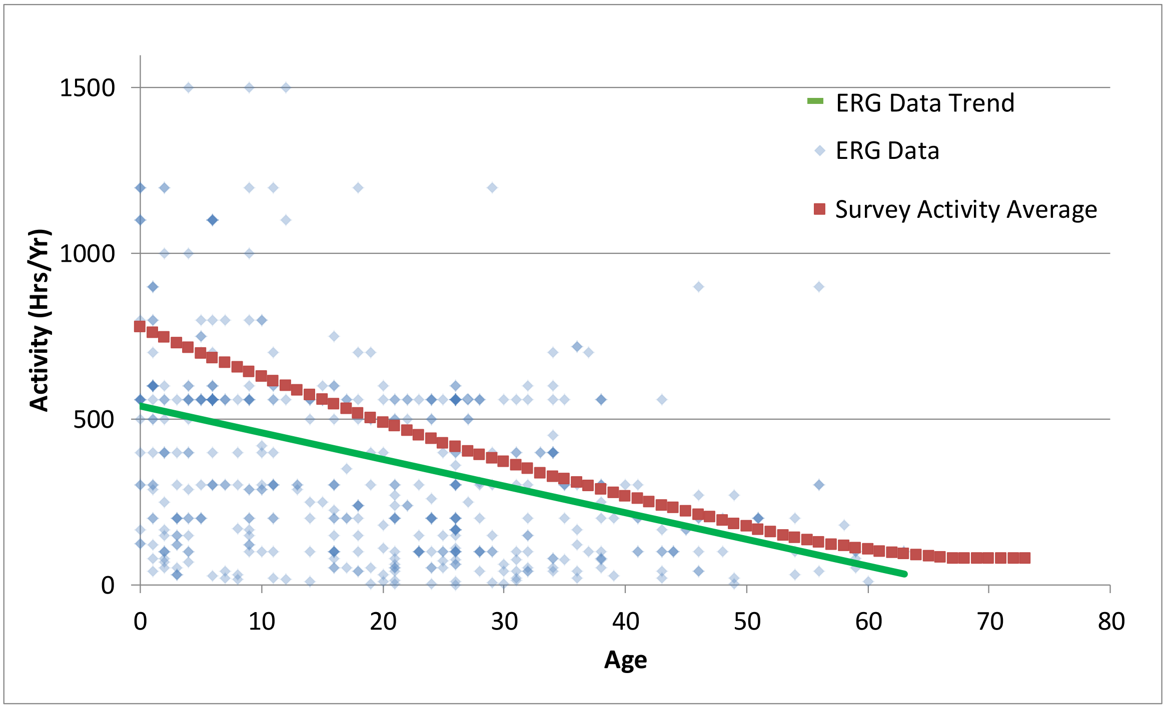


Figure 5.9 compares the activity trend from the survey (red) against the same ERG study (green line) discussed in the age profiles. The same general trend is apparent, as average annual use steadily declines over time. The survey average activity for new tractors is initially higher than the ERG estimates, but declines over the life of the tractor. While the initial difference in activity (about 25%) is significant, estimates of overall activity developed in this latest inventory are

corroborated by the reported average fuel use of the California agricultural equipment, as was described in the inventory development sections of this report.

Figure 5.9 Survey and ERG Activity Profiles



5.3 Emission Rates, Fuel Correction Factors, and Tier Introduction

This inventory utilizes emission factors developed for off-road equipment, which is also used in inventories such as construction equipment, cargo handling equipment, and other off-road diesel sectors. CARB's emission factors documentation[21] is summarized in this report and detailed documentation is available online through the reference link.

An emission factor is a combination of zero-hour emissions (when an engine has a cold start) and the engine's deterioration rate (based on an engine's cumulative lifetime hours).

Equation 5.1 Emission Factor

$$\text{Emission Factor } \left(\frac{\text{grams}}{\text{hp}-\text{hr}}\right) = \text{Zero Hour} + (\text{Deterioration Rate} * \text{Accumulated Hours})$$

Emissions account for the amount equipment is used, the equipment population, sulfur content of fuel, engine deterioration due to age, and engine load. Equation 5.2 represents a simplified emission calculation, which would represent the emissions for one piece of equipment. When this is summed for all pieces of equipment in a sector, it creates a statewide emissions inventory.

[21] Emission Factors for Off-Road Large Compression-Ignited Engines (>25HP), MSC 99-32, https://www.arb.ca.gov/msprog/mailouts/mouts_99.htm

Equation 5.2. Emission Equation

$$\text{Emissions} = \text{Horsepower} * \text{Activity} * \text{Load Factor} * (\text{Emissions Factor}_{\text{Zero Hour}} + \text{Deterioration Rate} * \text{Accumulated Hours}) * \text{Fuel Correction Factor}$$

$$\frac{\text{grams}}{\text{year}} = \text{hp} * \frac{\text{hr}}{\text{year}} * (\text{unitless}) * \left(\frac{\text{grams}}{\text{hp}-\text{hr}} + \frac{\text{grams}}{\text{hp}-\text{hr}^2} * \text{hr}\right) * (\text{unitless})$$

The fuel correction factor is unit-less and accounts for adjustments in the sulfur content of diesel fuel. Information pertaining to adjustments resulting from lower sulfur content in diesel fuel (ultra low sulfur diesel) is available in a U.S. EPA report[22]. Diesel's sulfur content had dramatic reductions in 2007 and further reductions through 2015, when the national average sulfur content in diesel fuel was reduced to 11 parts per million. Alterations to the sulfur content aids in significantly reducing SOx and PM emissions.

For most off-road diesel inventories, modeling the introduction of new engine tiers follows the CARB and U.S. EPA established implementation dates for new engine tiers[23]. However, various agricultural equipment dealers consulted by CARB staff in 2011 estimated that Tier 4 Final engines would not be available in agricultural equipment until the 2020 timeframe due to manufacturers using Average, Banking and Trading or other flexibility provisions in the new engine standard language. Based on these discussions, the current inventory shows Tier 4 Final engines appearing in 2020 and all future years. Based on the latest available data on new agricultural tractors sold, some agricultural Tier 4 Final engines have appeared in the past few years, demonstrating the estimated 2020 introduction overestimated the delay and that the inventory should reflect earlier introduction of these cleaner engines. Future versions of the inventory will more accurately reflect the phase in of Tier 4 Final engines in California agriculture.

6. INCENTIVES REPLACEMENT PROGRAM

An updated 2018 version of the 2011 agricultural diesel equipment inventory reflects replacement projects in the agricultural sector completed by the SJVAPCD and NRCS, published by the SJVAPCD in May 2017[24]. The inventory reported here reflects incentives projects implemented each year, in addition to natural turnover of California agricultural equipment.

The inventory does not calculate per-project emissions reductions. Instead, the projects are part of the baseline emissions inventory. The agricultural equipment inventory quantifies the remaining emissions after the incentives have been completed. For a project's emissions benefits, Moyer-based calculation methods used by the SJVAPCD and NRCS may be consulted.

The per-project data used in the inventory include the horsepower of the vehicle being replaced, its engine tier, and its average annual hours of use. One aspect of the incentives replacement project not yet reflected are the "2 for 1" or "3 for 1" projects, where two or three older tractors are replaced by one newer tractor. This reduces the overall population, although the current

[22] Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling – Compression-Ignition, July 2010, US EPA, EPA-420-R-19-018, https://www.arb.ca.gov/msei/ordiesel/usepa_bsfc.pdf
[23] https://www.arb.ca.gov/msei/ordiesel/ordieselstandards.xls
[24] http://www.valleyair.org/MOP/mop9610_idx.htm

number of projects in this category is minor as compared to the overall incentive program. Currently the inventory reflects each replaced vehicle as a "1 to 1" replacement. This has no impact on emissions since operating hours are unchanged. For example, instead of one new Tier 4 Final engine operating at 2,000 hours, replacing two tractors previously each operating 1,000 hours a year, the inventory reflects two Tier 4 final engines operating at 1,000 hours a year. Thus, the overall emissions are the same, but the total equipment population is reduced. This in an area that will be addressed in future updates to the inventory.

Table 6.1 shows the number of incentive projects and associated agricultural equipment replacement by vehicle type and calendar year, reflected in the inventory.

Table 6.1 Incentive Projects Reflected in Ag Inventory

	2009	2010	2011	2012	2013	2014	2015	2016	2017	TOTAL
ATVs	0	0	0	0	0	0	0	0	0	**0**
Bale Wagons (Self-Propelled)	0	0	0	0	0	2	2	2	0	**6**
Balers (Self-Propelled)	0	0	0	0	0	1	0	0	0	**1**
Combine Harvesters	3	26	6	5	4	0	0	2	1	**47**
Crawler/Backhoe/Loader/Dozer/Grader	7	18	33	56	57	79	74	82	6	**412**
Cotton Pickers	0	0	0	0	1	2	1	4	0	**8**
Forage & Silage Harvesters	0	0	0	0	0	0	0	0	0	**0**
Forklifts	0	0	2	1	1	1	1	4	0	**10**
Hay Squeeze/Stack Retriever	0	0	0	0	1	0	0	0	0	**1**
Nut Harvester	0	0	0	1	0	0	0	0	0	**1**
Other Harvesters	9	1	4	7	13	27	7	13	1	**82**
Other Non-Mobile	0	3	2	11	4	4	1	1	0	**26**
Others	15	21	9	25	14	13	11	4	0	**112**
Sprayers/Spray Rigs	6	4	0	20	1	0	1	0	0	**32**
Swathers/Windrowers/Hay Conditioners	0	2	3	4	8	10	1	6	1	**35**
Tractors	113	514	682	803	723	745	740	609	45	**4974**
TOTAL	**153**	**589**	**741**	**933**	**827**	**884**	**839**	**727**	**54**	**5,747**

In some cases, incentive projects reflected extremely high activity, which equals or exceeds the total horsepower-hours in the inventory for that equipment group. For example, Tier 0 tractors replaced through incentives were reported by the SJVAPCD to fall between 300 and 600 horsepower, on average. In the inventory, the total activity is distributed amongst the projects. When replacing equipment, the remaining emissions become zero to avoid the total remaining emissions becoming negative numbers.

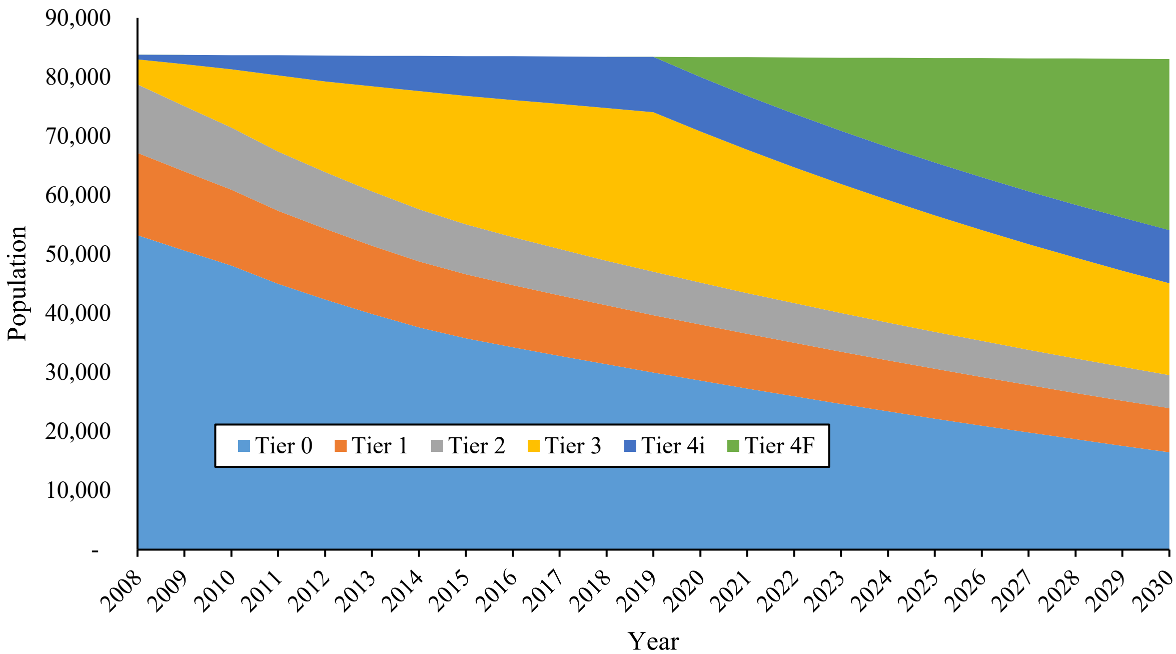
7. Emissions Inventory Summary

The latest emissions inventory splits equipment located within the SJV and outside that region, referred to as "SJV" or "non-SJV" respectively.

7.1 SJV Region

Figure 7.1 illustrates the remaining SJV fleet population projected out to 2030. It accounts for natural turnover as well as incentives reported through May 2017. It is assumed there is going to be a slow introduction of Tier 4i equipment, with Tier 4f joining the fleet in 2020. As the figure shows, the inventory assumes there are still a significant number of Tier 0, Tier 1, and Tier 2 agricultural equipment remaining in use through 2030.

Figure 7.1 SJV Equipment Population by Tier



Based on the remaining populations reflecting incentives reported through May 2017, Figure 7.2 shows NOx emission projections, which continue to decline as the agricultural equipment population evolves from use of older, dirtier tractors to newer, and cleaner engines.

Figure 7.2 SJV NOx emissions by Tier

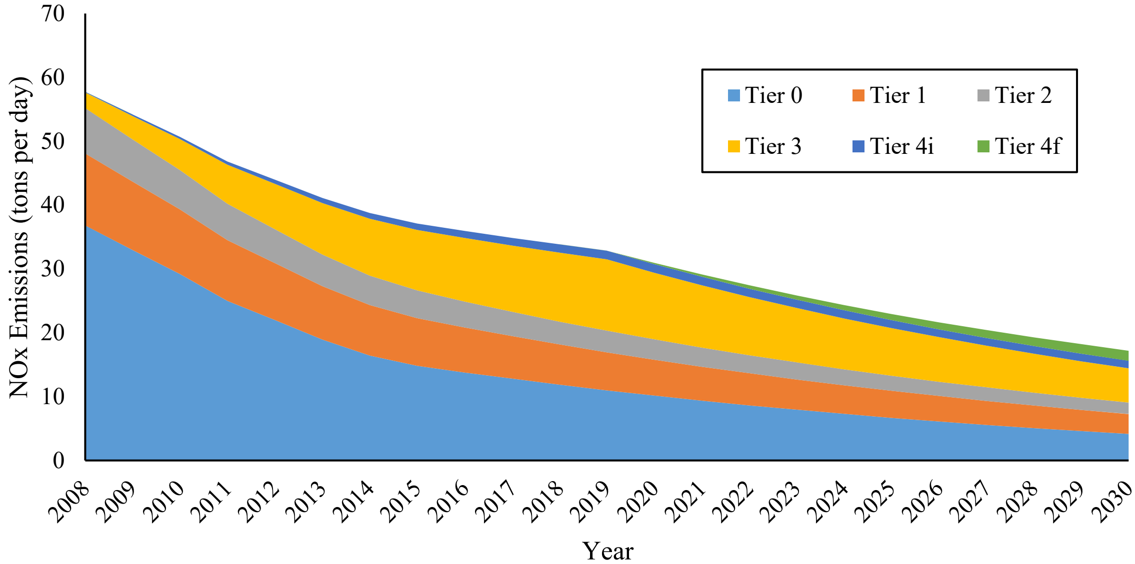
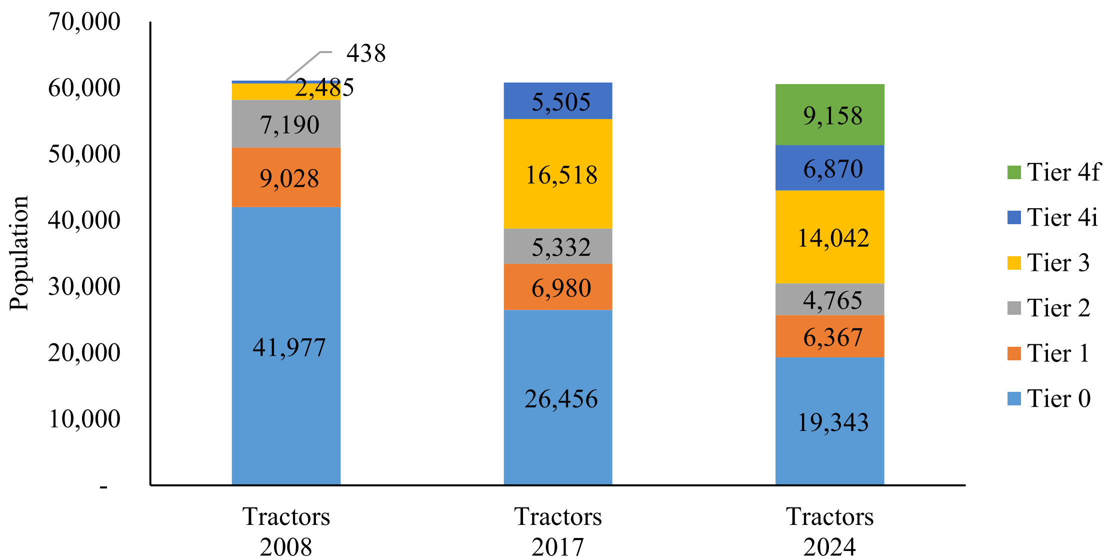


Figure 7.3 provides an overview of the tractor population distribution by technology tier for calendar years 2008, 2017, and 2024, with incentives as reported through May 2017.

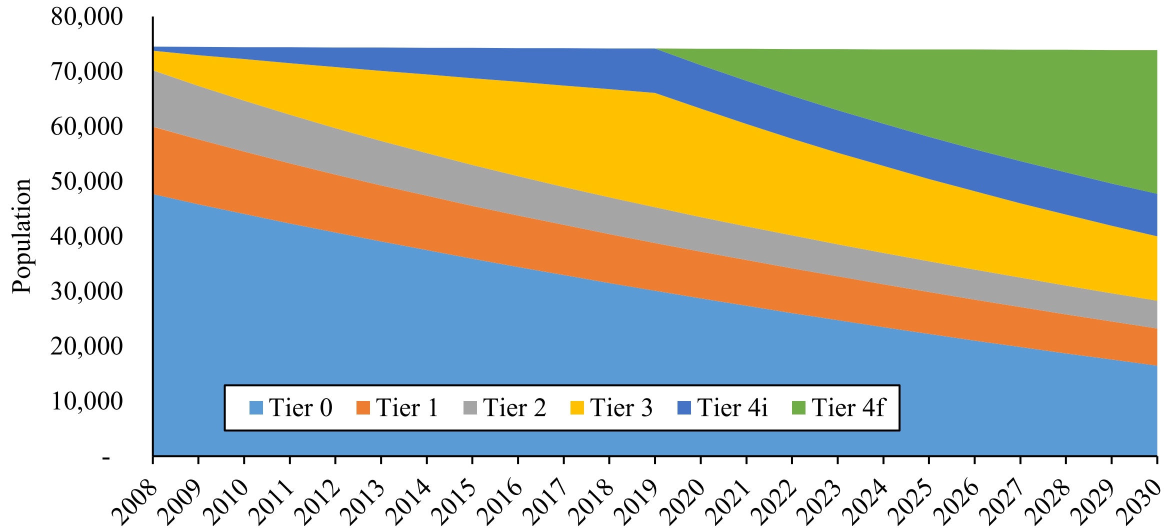
Figure 7.3 SJV Tractor Population by Tier



7.2 Non-San Joaquin Valley Inventory

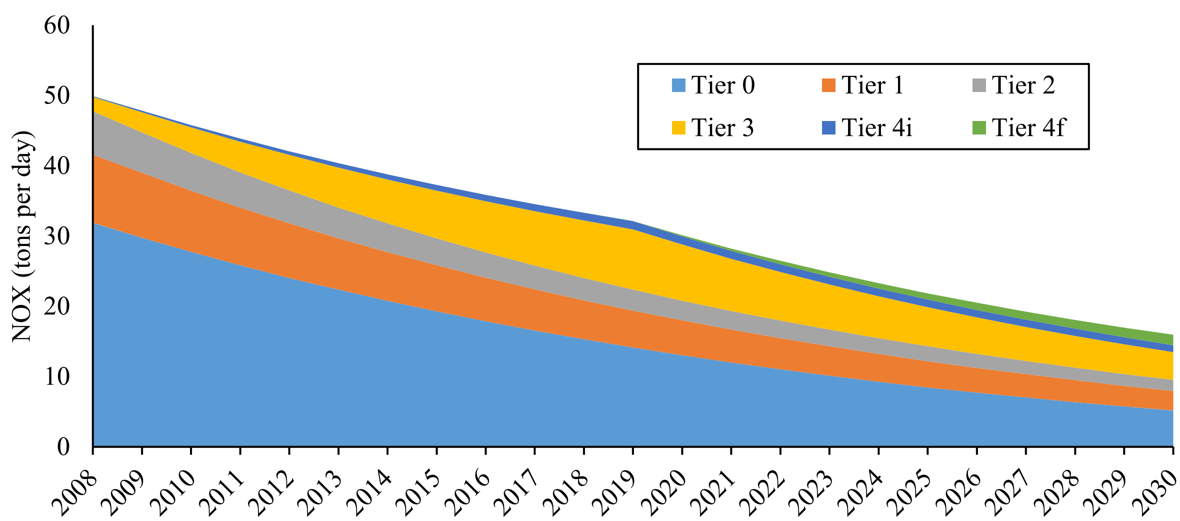
Agricultural equipment located outside the San Joaquin Valley make up 47% of the statewide agricultural equipment population. Figure 7.4 displays the remaining agricultural fleet population outside the San Joaquin Valley, projected out to 2033. At the time of the inventory development, adoption of Tier 4i equipment was assumed to be slow. Tier 4f equipment introduction was not expected until 2020. As the figure shows, there are still a significant number of Tier 0, Tier 1, and Tier 2 agricultural equipment remaining in use outside of the SJV through 2032.

Figure 7.4 Non-SJV Agricultural Equipment Population



The agricultural equipment located outside the San Joaquin Valley make up 46% of the Statewide NOx emissions associated with agricultural equipment, in 2008 prior to the agricultural incentives. The majority of Statewide NOx emissions occur in the San Joaquin Valley due to topography, farming locations, and quantity of equipment. Figure 7.5 displays estimated NOx emission projections, which decline as the agricultural equipment population adopts new, cleaner engines to replace older, dirtier engines.

Figure 7.5 Non-SJV Agricultural Equipment NOx (tpd)



8. Future Inventory Planning

Although this inventory update was a vast improvement over previous emissions inventories for agricultural equipment, there is still significant room for improvements and further detail. CARB, with the guidance and support of the agricultural community and California's air districts, intends to release a new survey in winter 2019 to support an updated emissions inventory. This survey would collect both agricultural equipment and commodity data, similar to the 2008 survey. All data would be anonymized through a third party contractor.

The new emissions inventory would depend on two main data sources: a new survey with additional details and enhancements, and the latest 2017 USDA Census of Agriculture. The main areas for improvement are updated data, inclusion of additional equipment, and appropriate representation of farming practices in the entire state.

Updated data will be useful to:

- Ensure accurate reflection of incentive programs and equipment turnover that have a large impact on the agricultural equipment population;
- Capture the impact of the 2011 to 2014 drought on farms and equipment retirements;
- Reflect the shifting trend in farms from smaller farms to larger, corporate farms, influencing both the types of equipment used and the average age;
- Reflect land use changes and crop choice changes;
- Include updated EIA fuel data and USDA fuel totals;
- Reflect a more accurate introduction of Tier 4f engines; and
- Apply CARB's updated 2017 emission factors for off-road diesel engines[25]

In addition, a new survey will allow the following improvements:

- Include equipment of all horsepower and fuel types, as compared to the 2008 survey that excluded equipment under 25 horsepower;
- Ensure outreach and encourage participation from all areas in the state, aiming for an inventory that reflects different activity and practices at air basin or even county level wherever possible; and
- Provide an electronic survey option for those participants who prefer online entry instead of a paper survey, aiming to increase participation and ease of data entry.

The target completion and release date for the updated inventory is early 2020. This updated inventory will be also included in the FARMER distribution formula.

[25] CARB's Off-road Diesel Engine Emission Factors, https://www.arb.ca.gov/msei/ordiesel.htm