Economic and Pest Management Evaluation of Proposed 1,3-Dichloropropene Regulation

Prepared for the Department of Pesticide Regulation by the California Department of Food and Agriculture's Office of Pesticide Consultation and Analysis, and the University of California, Davis

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Executive Summary

1,3-dichloropropene (1,3-D) is a pre-plant soil fumigant used to control soil-borne pests such as nematodes, insects, and disease organisms in a variety of California crops. Human health risks associated with 1,3-D emissions resulted in restrictions on the use of 1,3-D in California beginning in the mid-1990s. It is a restricted use material that requires a permit from the agricultural commissioner.

The Department of Pesticide Regulation (DPR) has been examining potential strategies to reduce acute and chronic human exposure to 1,3-D emissions from agricultural applications. In October 2019, DPR held a public workshop to gather input on proposed mitigation strategies. In late 2020, DPR began a pilot project to test the effectiveness of these mitigation strategies in twelve townships identified by DPR as having relatively high annual 1,3-D use. The pilot project resulted in five field studies, which provided data to improve and validate DPR's models. With that new information DPR is proposing a set of changes to the rules governing 1,3-D applications.

The currently proposed regulation addresses exposure in two ways. First, acute exposure is being reduced by changing requirements around application methods, setbacks to occupied structures, blocks size, and soil moisture content. The proposed changes add a new application method type, 24-in injection; substantially limit shallow applications (tarped and untarped); and reduce the maximum allowed block size for most untarped application methods. The extent of the reduction depends on the application rate and setback distance. These changes will likely simultaneously address chronic exposure. Second, if chronic exposure continues to be a problem after the acute mitigations, 1,3-D use limits within specific areas – called township caps – will be triggered. The proposed regulation includes an adjustment to the township caps that are currently in place; the new caps will be higher but still protective of chronic exposure when paired with the mitigations for acute exposure.

Previously, December applications were prohibited. DPR is now considering specifying different permitted combinations of application rate, application method, and maximum block size for winter and non-winter months. The authors are preparing an addendum to this report that will address this modification.

This report focuses on the mitigations for acute exposure through application method changes, setbacks to occupied structures, and block size and presents an analysis of potential management options for growers, and economic impacts associated with these proposed changes. DPR's proposed regulation regarding these three factors is reported in tables for each mitigation option showing the maximum allowed daily acres treated (block size), which are based on distance from the field to an occupied structure (100 ft, 200 ft, or 500 ft) and the application rate. In general, the higher the application rate and shorter the distance to an occupied structure the lower the maximum application block size for each application method. The maximum permitted block size can range from 0 acres (application not permitted) to as much as 80 acres for some application methods and rates. But for untarped applications the proposed maximum block size has been reduced to achieve the minimum 100 ft setback from occupied structures even with new application methods. Current restrictions allow a block size of up to 80 acres in an application while maintaining a 100 ft setback from occupied structures.

We examine the cost of complying with the proposed regulation for acute exposure in two ways. First, we evaluate the cost for all 1,3-D applications to comply with the proposed changes by adopting, if needed, a new application method and/or reducing block size to retain a 100 ft setback and current application rate, regardless of whether or not the applications are in fact near an occupied structure. This approach identifies how costly the proposed changes would be if all applications had to comply with the combinations of application rate, application method, and maximum block size permitted under the proposed regulation. This analysis uses data on applications from 2017-2020 (Method 1). Second, for three focal counties in 2017-2018, Fresno, Kern, and Stanislaus, we integrate GIS data with application data and isolate only those applications within certain distances of occupied structures. We then identify how much acreage would have been impacted directly for all crops and the associated mitigation cost (Method 2). However, we cannot know with certainty that all of the applications examined using Method 2 are ones that would have been impacted by the occupied distance restriction because fields, not applications, are mapped. If not all of a field was fumigated with 1,3-D it is conceivable that the proposed setback distance for that application would not be binding.

Table ES-1: Annual Cost of Compliance with Occupied Structure Setback for Statewide 1,3-D Applications Assuming a 100 ft Setback and Current Application Rate

Year	Total Cost
2017	$1,897,283
2018	$1,996,093
2019	$1,278,772
2020	$1,729,988

Annual compliance costs for application method changes and splitting an application into multiple ones for all 1,3-D applications statewide are estimated at $1,278,772 (2019) to $1,996,093 (2018) based on the assumption that a 100 ft setback was necessary for all applications (method 1). This is a conservative estimate because some fields do not have any occupied structures nearby.

While the three focal counties cannot be assumed to be representative for the state as a whole, comparing the cost for the two years in the spatial analysis used in Method 2 to those estimated using Method 1 provides an estimate of the overstatement of costs in the latter for these counties. The overstatement is driven by two considerations. First, not all fields are near an occupied structure. Second, fields that are more than 200 ft but fewer than 500 from an occupied structure can elect to comply with the 200-ft requirements rather than use the 100-ft ones imposed under Method 1. For the three focal counties, the total estimated cost to comply with the proposed regulation from the spatial analysis was 61% and 68% of the total estimated cost for those three counties under the conservative Method 1 approach. Most of the reduction in estimated costs is due to fewer block splits being required with the larger setback distances. Due to heterogeneity across counties, the percentage cost reduction should be interpreted with caution. Other counties could see a much higher or much lower cost reduction than these three San Joaquin Valley counties.

The proposed regulation will lead to additional costs that are not considered in this report. Changes to the township caps are not included in this analysis. Provisions regarding soil moisture are not included either. We do include a discussion of the potential costs of these two aspects. The treatment of winter applications in the proposed regulation, e.g., retaining or modifying the December ban versus separate setback requirements for winter and non-winter months, was not determined at the time of this report. The authors will write an addendum to address this component.

This report is part of the interagency consultation between DPR and the Office of Pesticide Consultation and Analysis (OPCA) in the California Department of Food and Agriculture (CDFA). Accordingly, the analysis is limited to evaluations of the pest management and economic effects on California agriculture of regulations regarding pesticides under consideration by DPR, which is OPCA's mandate as specified in the California Food and Agricultural Code, Section 11454.2. CDFA was presented with the final mitigation options on May 17 and completed this analysis prior to mid-June at the request of DPR.

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Introduction

1,3-dichloropropene (1,3-D) is a pre-plant soil fumigant used to control soil-borne pests such as nematodes, insects, and disease organisms in a variety of California crops. Human health risks associated with 1,3-D emissions resulted in restrictions on the use of 1,3-D in California beginning in the mid-1990s (US EPA 2008; OEHHA 2017). In response to a risk characterization document regarding inhalation exposure (DPR 2015) and recent monitoring of 1,3-D emissions (DPR 2019a, b), the Department of Pesticide Regulation (DPR) initiated the process of mitigating both acute and chronic exposure. Acute exposure post application is related to the method of application. A pilot mitigation project started in the Fall of 2020 (DPR 2020) near the communities of Delhi (Merced and Stanislaus Counties), Parlier (Fresno County) and Shafter (Kern County) to test mitigation options. The pilot project was a refinement of earlier mitigation options presented by DPR in October 2019 (DPR 2019c) and March 2020 (DPR 2020). The pilot project resulted in five field studies, which provided data to improve and validate DPR's models.

With that new information in hand. DPR is proposing a set of changes to the rules governing 1,3-D applications. DPR is addressing this in two ways. First, acute exposure is being reduced by changing requirements around application methods, setbacks, and soil moisture content. This will likely simultaneously address chronic exposure. Second, if chronic exposure continues to be a problem after the acute mitigations, caps to use within specific areas – township caps – will be triggered. The caps will be higher than the township caps that are currently in place. Previously, December applications have been prohibited. DPR is now considering specifying different permitted combinations of application rate, application method and maximum block size for winter and non-winter months. The authors are preparing an addendum to this report that will address this modification.

The proposed regulation will change how growers manage 1,3-D applications as well as the cost of treating a field. The proposed mitigations for acute exposure add a new application method type – 24-in injection, – and substantially reduce the maximum allowed block size for untarped and some tarped applications. Exact setbacks and block size requirements depend on the application rate and method (Table 1, Table 2, Table 3, Table 4, and Table 5). 1,3-D emissions are lower when soil moisture is higher; however, fumigation is not efficacious if the moisture content is too high. DPR's proposed regulation changes set the minimum soil moisture content at 50% to minimize acute exposures post application.

It is thought likely that the mitigation for acute exposure will also mitigate chronic exposure. Consistent with this expectation, DPR is also increasing the 1,3-D township cap, which is currently

136,000 adjusted total pounds (ATP) per township per year (DPR 2017).[1] The new caps will only be triggered if a certain threshold is reached. We do not consider the impact of an increase in the cap in this report because data on ATP are not available at this time. Any impact of the larger township cap would be realized only in townships that are constrained by it currently. A larger township cap would allow more acres to be treated with 1,3-D and/or higher application rates without triggering the cap. Whether either of these would occur would depend on crop choices and the cost impact of the proposed regulations intended to address acute exposure.

Our analysis evaluates the potential economic and pest management impacts of the changes under consideration for acute exposure regarding permitted combinations of application methods, rates, setbacks, and block size using 1,3-D applications from 2017-2020. We examine the cost of complying with the proposed regulation in two ways. First, we evaluate the cost of all 1,3-D applications to comply with new setbacks to occupied structures given permitted application rates, methods, and block sizes, regardless of whether or not the applications are near an occupied structure, using data from 2017-2020. This component assumes that the 100 ft setback applies on all sides. Second, for Fresno, Kern, and Stanislaus counties in 2017-2018, we isolate only those applications within certain distances of occupied structures and identify how much acreage would have been impacted directly for all crops and the associated mitigation cost. The first cost estimate is an upper bound representing the cost if every application has an occupied structure within 100 ft. The second cost estimate utilizes spatial data to limit costs to fields that would be impacted by the proposed restrictions due to nearby occupied structures. It does not provide cost estimates for the revisions to the soil moisture content requirement regarding allowed methods for determining soil moisture because a large majority of applications are already complying with this requirement.

1,3-D use has four distinction use patterns in California for four groups of crops: perennial trees and vines; annuals; berries; and nursery use. Appendix A provides an in-depth discussion of pest management. Perennial crops apply at higher rates, only at planting, and mostly use a broadcast deep (18-inch) shank injection method. On average, almond, walnut, and grape comprised approximately 72.5% of all the perennial tree and vine crop acres treated with 1,3-D annually from 2017-2020. Yield loss data from orchard and vineyard preplant fumigation studies comparing 1,3-D treatments to other fumigants are limited, however, those studies that have been done show significant yield losses in all of these crops for unfumigated controls compared to plots treated with 1,3-D.

Annual crops use lower application rates and apply with each planting. Annual crops that use a significant share of 1,3-D include roots and tubers and berries. We examine three annual crops:

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[1] Adjusted total pounds is the quantity of 1,3-D active ingredient applied during an application adjusted by an application factor relative to the application method and time of year.

carrot, sweet potato, and strawberry. Together, they accounted for 66.3% annually on average of all 1,3-D applications to annual crops from 2017-2020.

Most carrot and sweet potato is treated using a broadcast deep shank injection method, then sealed with tillage equipment, though carrot in Imperial Valley tends to use shallow (12-inch) injection depths. Carrot and sweet potato comprised approximately 33.2% of annual crop acreage treated with 1,3-D annually from 2017-2020. Similar to the perennial crops discussed above, there are limited yield loss data for carrot and sweet potato. Overall, based on the studies available fumigating with 1,3-D provided significant yield increases compared to unfumigated control plots.

Strawberry comprised approximately 33.1% of annual acreage treated with 1,3-D in the 2017-2020 time period. 1,3-D is often applied with chloropicrin, and sometimes followed by metam-sodium or metam-potassium fumigant treatments. The primary application methods are broadcast, shallow or deep shank injection applications prior to bed formation and bed applications via drip tape. Both methods rely on tarps to reduce emissions and increase efficacy.

Outdoor nursery stock production for commercial crops is also treated with 1,3-D, especially where pest-free nursery stock is required for intrastate, interstate, and international commerce. Yield loss data for nursery stock production were not identified in a literature search, though failure to meet certification requirements can result in a 100% economic loss through nonsalable stock.

This report is part of the interagency consultation between DPR and the Office of Pesticide Consultation and Analysis (OPCA) in the California Department of Food and Agriculture (CDFA). Accordingly, the analysis is limited to evaluations of the pest management and economic effects on California agriculture of regulations regarding pesticides under consideration by DPR, which is OPCA's mandate as specified in the California Food and Agricultural Code, Section 11454.2. CDFA was presented with the final mitigation options on May 17 and completed this analysis prior to June 8 at the request of DPR.

Methods and Data

Methods and data are presented separately for Method 1 and Method 2.

Application Changes Method 1: Changes in application methods to retain 100-foot distance to occupied structures

The proposed regulation has new maximum block sizes if occupied structures are near the application site for all non-tarped and some tarped fumigation methods. Using 1,3-D application data from 2017-2020, we calculate the cost of growers coming into compliance with these new block size limits by choosing a different application method while holding their application rate constant and maximizing block size. Data on application methods, block sizes, and 1,3-D use were obtained from DPR. This analysis assumes that all applications would have to choose an application method and/or split applications into multiple blocks in order to comply with the maximum block size specified in the proposed regulation for the observed application rate and a 100-ft setback. The new setbacks and max acres for 12-in, 18-in, 24-in, and TIF tarp application methods proposed by DPR are presented in Table 1, Table 2, Table 3, Table 4 and Table 5, respectively. No changes are proposed for TIF methods using deeper injection (FFMs 1242, 1247, 1249). The tables were provided by DPR in May 2022.

Table 1: Maximum Block Size (Acres) for Application Rate-Occupied Structure Distance Pairs for Untarped Application Methods Using 12-in Injection (FFMs 1201, 1202, 1203, 1204, and 1205)

Application Rate (lbs/acre)	**Maximum Application Block Size (ac) and Occupied Structure Distance**		
	100 ft	200 ft	500 ft
100	4 ac	5 ac	20 ac
110	3 ac	5 ac	20 ac
125	2 ac	5 ac	15 ac
150	1 ac	3 ac	10 ac
200	Not allowed	2 ac	5 ac
250	Not allowed	1 ac	5 ac
300	Not allowed	Not allowed	3 ac
332	Not allowed	Not allowed	3 ac

Table 2: Maximum Block Size (Acres) for Application Rate-Occupied Structure Distance Pairs for Application Methods Using 18-in Injection (FFMs 1206, 1207, 1210, and 1211)

Application Rate	**Maximum Application Block Size (ac) and Occupied Structure Distance**		
	100 ft	200 ft	500 ft
100 lbs/ac	40 ac	55 ac	80 ac
110 lbs/ac	30 ac	45 ac	80 ac
125 lbs/ac	20 ac	35 ac	75 ac
150 lbs/ac	15 ac	25 ac	55 ac
200 lbs/ac	5 ac	10 ac	30 ac
250 lbs/ac	4 ac	5 ac	20 ac
300 lbs/ac	2 ac	5 ac	15 ac
332 lbs/ac	2 ac	4 ac	10 ac

Table 3: Maximum Block Size (Acres) for Application Rate- Occupied Structure Distance Pairs for Untarped Application Methods Using 24-in Injection (FFMs 1224 and 1225)

Application Rate	**Maximum Application Block Size (ac) and Occupied Structure Setback Distance**		
	100 ft	200 ft	500 ft
100 lbs/ac	80 ac	80 ac	80 ac
110 lbs/ac	80 ac	80 ac	80 ac
125 lbs/ac	80 ac	80 ac	80 ac
150 lbs/ac	80 ac	80 ac	80 ac
200 lbs/ac	40 ac	60 ac	80 ac
250 lbs/ac	25 ac	35 ac	75 ac
300 lbs/ac	15 ac	25 ac	55 ac
332 lbs/ac	10 ac	20 ac	45 ac

Table 4: Maximum Block Size (Acres) for Application Rate-Occupied Structure Distance Pairs for TIF Application Methods Using Shallow Injection (FFMs 1243, 1245, and 1259)

Application Rate	**Maximum Application Block Size (ac) and Occupied Structure Distance**		
	100 ft	200 ft	500 ft
100 lbs/ac	80 ac	80 ac	80 ac
110 lbs/ac	80 ac	80 ac	80 ac
125 lbs/ac	80 ac	80 ac	80 ac
150 lbs/ac	80 ac	80 ac	80 ac
200 lbs/ac	55 ac	80 ac	80 ac
250 lbs/ac	30 ac	50 ac	80 ac
300 lbs/ac	20 ac	30 ac	70 ac
332 lbs/ac	15 ac	25 ac	55 ac

Table 5: Maximum Block Size (Acres) for Application Rate-Occupied Structure Distance Pairs for Drip Application (FFM 1209)

Application Rate	**Maximum Application Block Size (ac) and Occupied Structure Distance**		
	100 ft	200 ft	500 ft
100 lbs/ac	10 ac	20 ac	45 ac
110 lbs/ac	5 ac	15 ac	40 ac
125 lbs/ac	5 ac	10 ac	30 ac
150 lbs/ac	4 ac	5 ac	20 ac
200 lbs/ac	2 ac	4 ac	15 ac
250 lbs/ac	1 ac	2 ac	10 ac
300 lbs/ac	Not allowed	2 ac	5 ac
332 lbs/ac	Not allowed	1 ac	5 ac

When choosing an application method, growers balance multiple factors; ideally, they want to minimize setbacks to occupied structures and costs while maximizing block size and maintaining pest control efficacy. Application rate, application method, occupied structure distance, and block size can all be adjusted to get the most cost-effective result. We make a series of assumptions about grower actions to estimate the cost. We assume that:

- Growers will not change application rates; application rates are determined by what is effective for pest control for that crop so applying at a lower rate for any given method is largely not an option. Appendix A presents more detailed information on pest management.
- Growers will not switch to TIF tarp application methods due to cost (except chemigated fields, discussed below). Adding TIF tarp is currently estimated to cost around $1,150 an acre, including tarp removal. Additionally, currently there is not a sufficient supply of TIF tarp to allow all crops to use it. If there were a substantial shift to increased TIF, the price could increase.
- Growers using shallow injection and TIF tarp will switch to deep injection and TIF tarp when shallow injection applications would lead to greater setbacks.
- Growers will not increase the setback to occupied structures because in many cases that would lead to leaving a section of the field untreated. These sections would have to planted to nematode-resistant plants or left fallow. Nematodes are mobile in the soil and can infect a field from one untreated section. For perennial crops like almonds, having an untreated section would risk significant long-term yield loss. For annual crops like sweet potato the margins are too small to absorb a loss of acreage or yield for the year. We look at the potential lost acreage in the Method 2 analysis. Appendix A presents more detailed information on pest management.

- Growers will choose the least costly application method that maximizes block size. Blocks that exceed the maximum size based on application method, application rate, and occupied structure setback are split into smaller blocks that are within the size requirements. In other words, growers will not shift to an alternative application method or rate in order to increase the maximum block size, even if that would be sufficient for an existing application to meet the proposed requirements. Using TIF tarps would allow growers to maintain 80-acre blocks but comes at a cost. In comparison to the $1,150 per acre cost of TIF, the maximum estimated cost to split an 80-acre block (derived below) is $1,480, which amounts to $18.50 per acre on average. There is likely heterogeneity in the cost to split a block across fields and growers.
- Growers using chemigation (FFM 1209) will add TIF tarps at the cost of $1,150/ac and keep using chemigation. This is more expensive than switching to deeper injection. However, if a field is set up to use chemigation, it would likely require significant time and effort to re-do that field to instead use deep injection.

We first identified any application statewide in our study period that would not have been in compliance under the proposed regulation, assuming they had to comply with the combinations of application rate, application method and maximum block size required in order to maintain a 100 ft setback from an occupied structure, regardless of whether or not one is present. Use rates are rounded up to the next level (i.e., an application with a use rate of 101 lbs/ac would be bound by the 110 lbs/ac rules). Given the assumptions above and DPR's updated fumigations tables, applications were separated into three sets: already compliant with the proposed regulation, able to comply by changing application method, and requiring splitting to comply.

We estimate two types of costs: application method costs and costs associated with splitting fields into smaller blocks. Based on stakeholder input, we set the cost of converting from 12-in or 18-in injection to 24-in injection depth at $10 per acre due to increased fuel costs[2]. At the time of this report, adding TIF tarp cost around $1,150 an acre including tarp removal, as noted above. Any costs that could be associated with additional soil preparation operations such as deep tillage, if required under some conditions, are not considered. Given that, and due to the small magnitude of the increase in fuel cost, 24-in injection depth is the lowest-cost application method for untarped and tarped applications if the method must be altered for compliance with the proposed regulations. FFM 1207 was not included in these calculations because the current method is more expensive than the 24-in injection method so there would be no cost increase.

Bringing fields into compliance may also require splitting blocks into two or more smaller ones in order to not exceed the maximum block size for a given rate and the lowest-cost application method. For fields that need to be split into blocks, beyond any change in application costs

[2] These fuel cost estimates were obtained prior to the 2022 increases in the cost of fuel.

growers bear an additional cost in terms of time spent managing the splitting. We estimate that for each time a block is split, the grower will need to spend, on average, four hours dealing with logistics. This could include, but is not limited to, coordinating with the applicator, ensuring proper field conditions, managing multiple plant deliveries from the nursery, moving staff and equipment from other farm operations, and preparing the small blocks separately. We estimate the loaded hourly rate for owner/operators using the US Department of Labor Bureau of Labor Statistics (BLS) data on median hourly wage for NAICS 11-9013 (Farmers, Ranchers, and Other Agricultural Managers) and a BLS estimate of the hourly benefit cost for construction, extraction, farming, fishing, and forestry series workers, as shown in Table 5. Assuming a fully loaded hourly rate of $46.48, the cost to farmers per split is $185.92. In total, the change in cost for a given field will be the change in application methods cost ($10 per acre for 24-in injection) plus the splitting cost ($185.92 per split).

Table 6: Labor Cost (NAICS 11-9013)

Item	**Formula**	**Value**
Median Unloaded Hourly Rate[3] ($/hour)	W	32.73
Benefits Percentage (%)	B=b/W	42.01
Benefits Per Hour[4] ($/hour)	b=W*B	13.75
Loaded Hourly Rate ($/hour)	L=b+W	46.48

In addition, we separated applications by application rate, where application rates below 150 lbs/acre are categorized as low, application rates of 150 through 300 lbs/acre are categorized as medium, and application rates above 300 lbs/acre are categorized as high. The impact of the updated fumigation tables in the proposed regulation depends on the application rate. Looking at the categories separately allows us to highlight more specific areas of importance.

Application Changes Method 2: Spatial analysis of fields impacted by 100 ft, 200 ft, and 500 ft occupied structure distances in three counties

In order to assess how conservative our Method 1 estimate of the cost of the proposed regulation was, we conducted a GIS analysis of fields that applied 1,3-D in 2017 and 2018 in Fresno, Kern,

[3] Median hourly wage for 11-9013 (Farmers, Ranchers, and Other Agricultural Managers) from the May 2020 Occupation Employment and Wages report found at https://www.bls.gov/oes/current/oes119013.htm

[4] Benefit cost in $/hr obtained from the September 2021 Table 2. Employer Costs for Employee Compensation for Civilian Workers by Occupational and Industry Group dataset for the construction, extraction, farming, fishing, and forestry series found at https://www.bls.gov/news.release/ecec.t02.htm

and Stanislaus counties. 1,3-D use data were obtained from DPR. Field-level GIS data were obtained from CalAgPermits and county websites. For each county in each year, use data were matched to GIS data using permit numbers/grower IDs and site IDs, unique identifiers in each data set. Once fields that used 1,3-D were identified, the size of each polygon was calculated and used as the size of the field. This calculation was necessary because of discrepancies in the field sizes given in the CalAgPermits data and the data received from DPR. We then created three buffers around each field—one spanned from the field edge to 100 ft, a second from 100 to 200 ft, and a third from 100 to 500 ft. These buffers enabled us to evaluate the acreage impacted by the larger setbacks. Importantly, rather than requiring all applications to comply with the requirements to retain a 100-ft setback, the GIS data enabled us to specify whichever setback was relevant for the field and occupied structure in question.

These buffers were overlaid on the 2019 ESRI World Imagery satellite image. Identifying occupied structures involved making decisions based on visual inspection of the satellite image. Potentially occupied structures from the field edge to 500 ft were digitized. We then created buffers of 100, 200, and 500 ft around each potentially occupied structure. This is equivalent to having 100 ft, 200 ft, and 500 ft set back from occupied structures. The buffers around occupied structures were intersected with the field shapes and the overlap was designated as the area affected by the setback (Figure 1).

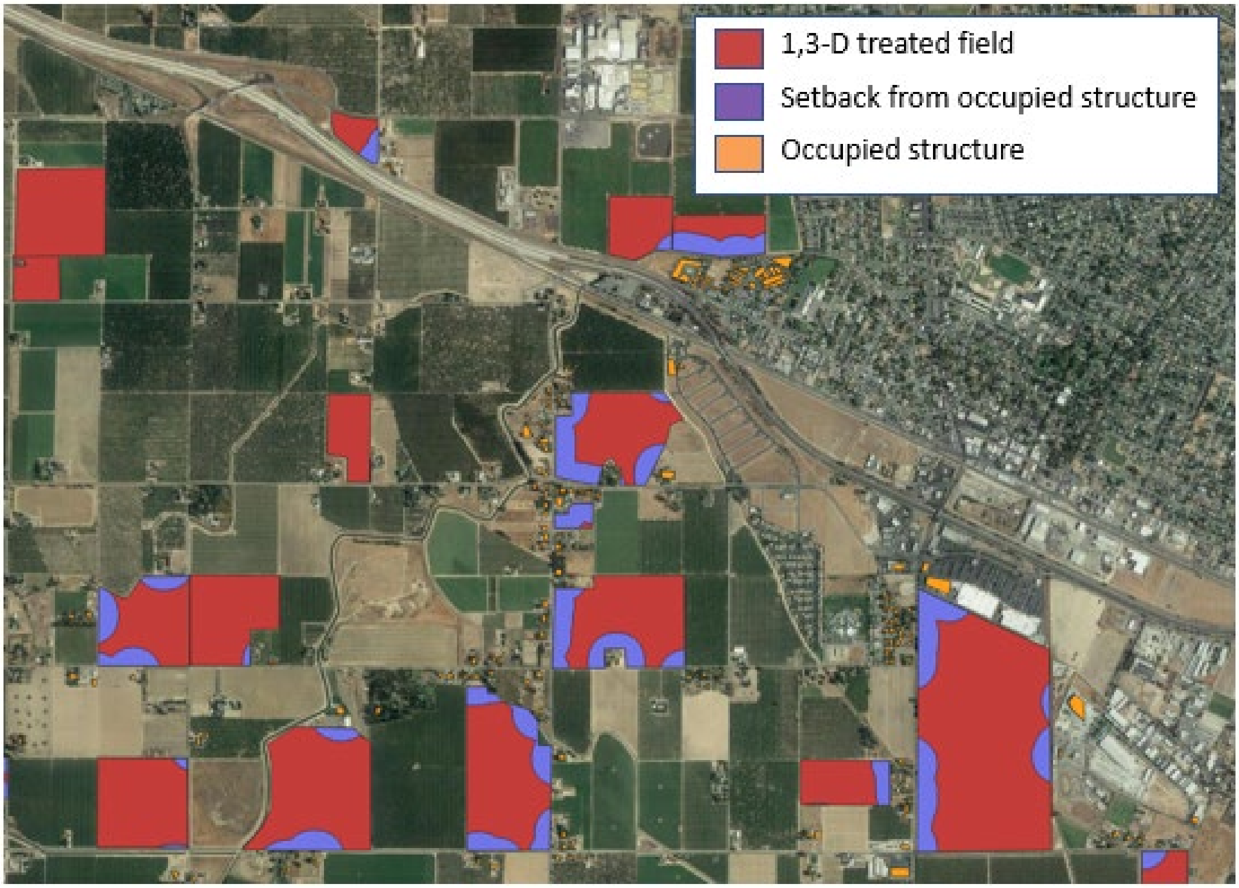
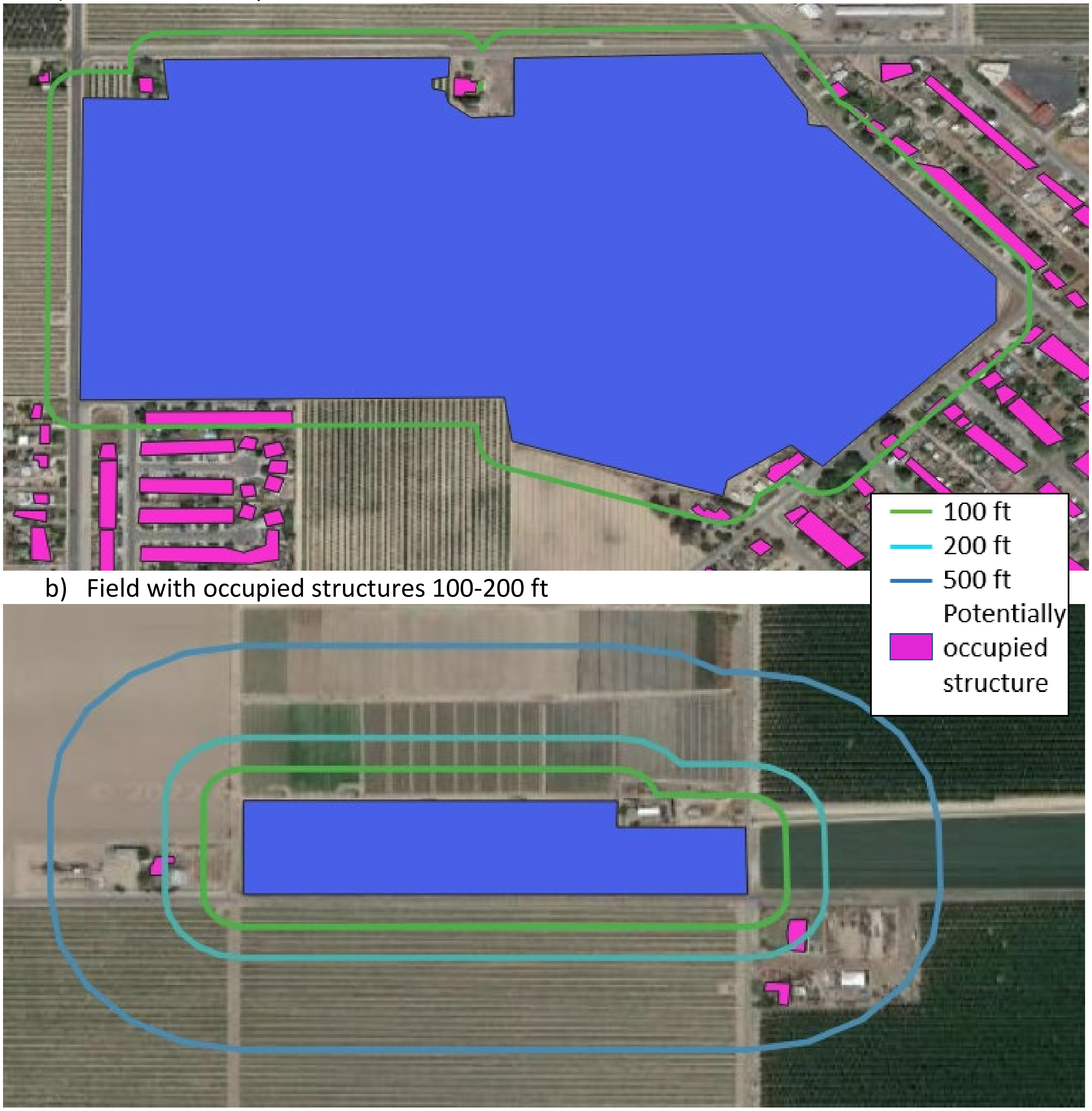


Figure 1: Occupied structure setback overlap with fields treated with 1,3-D

We first identified the minimum-cost application method following the same procedure as in Method 1. We then examined how many fields had structures within 200 ft and assumed that those fields would need to take the actions required to retain the 100 ft setback as they would using Method 1 (Figure *2*). Fields that had no occupied structures within 500 ft could use the 500 ft setback rules (Figure 4, Table 1, Table 2, Table 3, Table 4) because a 500 ft setback would not reach the field. Remaining fields, with occupied structures between 200 ft and 500 ft, could use the 200 ft setback rules (Figure 3, Table 1, Table 2, Table 3, Table 4) because a 200 ft setback from any structure would not reach the field. These estimated costs were then added together and compared to the Method 1 analysis.

a) Field with occupied structures within 100 ft



b) Field with occupied structures 100-200 ft

Figure 2: Fields using the 100 ft setback requirements

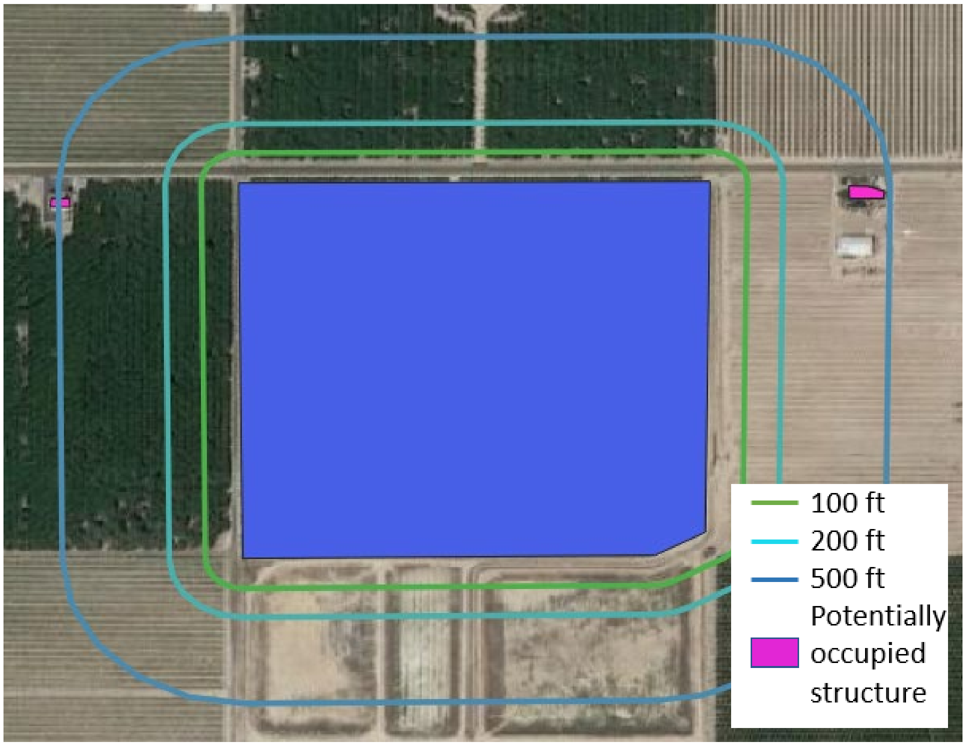


Figure 3: Field using the 200 ft setback requirements

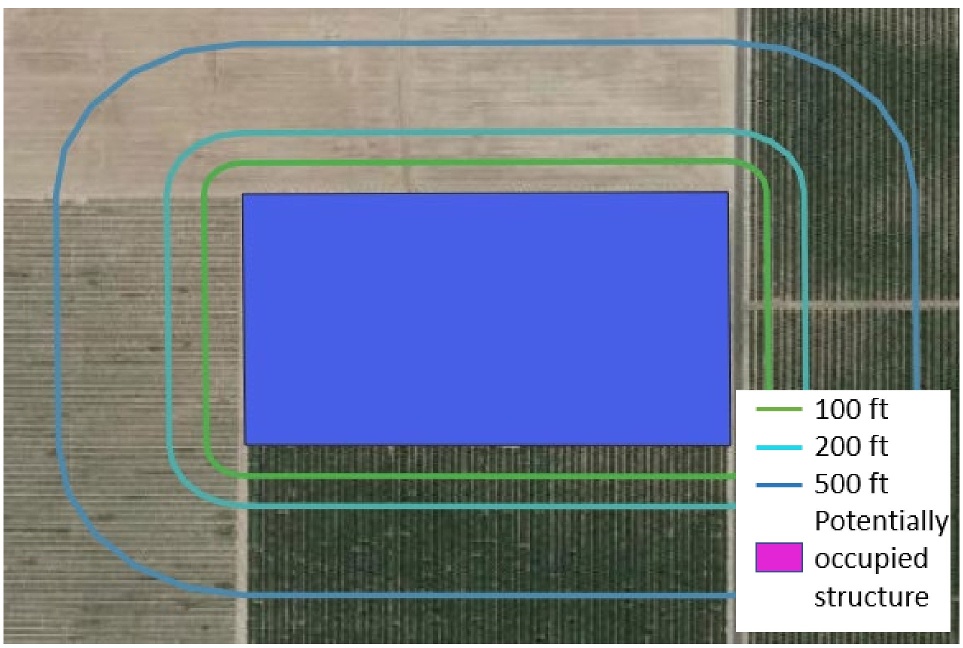


Figure 4: Field using the 500 ft setback requirements

Caveats

There are multiple significant caveats for this analysis, detailed below.

Methodology

There are a number of caveats regarding the estimates in this report. Here we mention the most significant general ones regarding methodology. First, the costs associated with the different application methods do not include additional soil preparation or increases in application fees to growers that may be required. Second, the cost to growers of splitting application blocks may vary significantly from the estimate used here. It is likely heterogeneous; some growers may need more or less time to manage each split. Third, the Method 1 analysis uses data from 2017-2020, and the Method 2 analysis uses data from 2017 and 2018. These periods may not represent production conditions in current and future years. Any such changes could affect the cost of regulation, although the direction of the impact is indeterminate ex ante and may vary by crop and location. Fourth, the focal counties used for Method 2 are all in the San Joaquin Valley and may not be representative of the state as a whole. Finally, this analysis does not consider the possibility that growers may change their acreage allocation across crops in response to changes in market conditions or regulatory changes such as the proposed one examined here.

Additional Provisions of Proposed Regulation

Apart from the methodological caveats, the proposed regulation has expanded to include a number of dimensions not considered in this analysis.

Soil moisture requirement

The proposed regulation to address acute risk would require that all have moisture levels at or above 50% of field capacity. The impacts of this provision are difficult to estimate for several reasons. Fumigation is most effective in moist soil. Applications directions on the product labels state to apply in 'moist' soil. The method for determining acceptably moist from the label[5] is similar to one option provided by DPR to determine 50% field capacity. Based on that, it is likely that most applications are already in compliance with this aspect of the proposed regulation, and we do not include any costs for complying with this additional requirement. This is likely an underestimate as an unknown number of growers and applicators will have to spend more time checking and/or buy new soil moisture probes.

Township caps

The loosening of the township cap in the proposed regulation means that more ATP of 1,3-D can be applied in an individual township each year. The impact of this change cannot be assessed

[5] https://www3.epa.gov/pesticides/chem_search/ppls/062719-00032-20090320.pdf

using the same historical data we use to examine the proposed new restrictions on block size as a function of occupied structure setbacks and application methods and rates. Growers could expand acreage treated with 1,3-D if the cap had been binding historically, or could not change their 1,3-D use at all if the cap had not been binding. Regardless of whether or not the cap was binding, changes in market conditions could expand 1,3-D use or reduce it.

Winter and non-winter regulations

DPR is now considering specifying different permitted combinations of application rate, application method and maximum block size for winter and non-winter months. The authors are preparing an addendum to this report that will address this modification.

Interactions with Chloropicrin Buffer Zone Distances

Around 20% of 1,3-D is applied in products that also include chloropicrin, another soil fumigant. Regulations governing the use of chloropicrin may interact with the proposed regulation for 1,3-D in complex ways at the field and application levels. Importantly, the buffer zone distances mandated for chloropicrin may alter the effects of the occupied structure setback distances proposed for 1,3-D.

Review of Efficacy of 1,3-D Application Methods

In order to reduce the overall impact exposure to 1,3-D, DPR has revised the fumigation application tables that define maximum block size as a function of the application rate and added a new option for 24-in injection (Table 1, Table 2, Table 3, Table 4, Table 5). As is the case under the existing regulations, growers can choose to use TIF tarp on any field. However, that is cost-prohibitive for most crops that are not already using it. The following overview presents information from the literature and discussions with pest management experts regarding efficacy and feasibility issues associated with deeper injection and the use of TIF tarps.

24-inch injection depth

Increasing injection depth increases the amount of time the fumigant is in contact with the soil, thereby reducing emissions as more fumigant breaks down in the soil, based on results from computer simulations and field studies. Using the HYDRUS computer model, Brown and Kandelous (2019) reported a decrease in both cumulative (39% average) and peak emissions (over 50%) for 16 different soil types (varying in soil texture and moisture content) in simulations of 24-in shank injections compared to the standard 18-in shank injections. Emission differences among soil types were largely due to estimated differences in water content directly above the injection point; the greater the soil moisture, the greater the emission reduction.

Empirical emission measurements comparing standard (18 in) to deeper (approx. 24 in) injection depths, though limited, tend to show reduced emissions for deeper injections. In a Central Valley field trial, Gao et al. (2018b) showed significantly lower peak emission rates as well as increased fumigant concentrations for the 24-in compared to the 18-in injection depth. However, emission levels were generally low overall owing to rain events in the days after the fumigant applications. In another study with sandier soil, (Gao et al. 2018a) noted higher fumigant concentrations at 30-45 cm soil depths for the 18-in injection depth and 45-60 cm for the 24-in injection depth; the 24-in injection depth also had higher concentrations at 100 cm. Emission rates were significantly lower for the deeper injection, though rain events again likely impacted overall emission rates. Analyzing both field and modelling data, Yates et al. (2016) demonstrated that deep injection (24 in) can reduce emissions by decreasing near surface concentration gradients and increasing soil residence time in a sandy loam soil, allowing for greater fumigant degradation.

Soil preparation can be especially critical for deeply rooted orchard crops planted in more fine-textured soils (McKenry and Thomason 1974), where fumigant dispersion is often more limited compared to more coarse-textured soils. A limited number of studies using this method of 1,3-D injection have produced variable results concerning emissions. Initial results indicate this method may result in a 50% emission reduction as half of the fumigant is delivered to 24 in or deeper. Emissions were not reduced for the Buessing shank compared to the standard shank in a sandy loam soil (Qin et al. 2009). The authors noted that shank design and/or the relatively low soil moisture at the time of application may have been the cause. Though emission rates weren't measured in a Hanson et al. (2013) field study in sandy loam soil, fumigation distribution in the upper 90 cm was similar between the Buessing and standard shanks.

Overall, the deeper shank injections have shown equal or better nematode efficacy vs. the standard shank injection. In the study mentioned above (Hanson et al., 2013), both types of shanks effectively controlled nematodes at 12, 24, and 36 in depths. Jhala et al. (2011) also noted effective nematode control between the two different shank treatments (18 in vs simultaneous 16 in and 26 in depths) in a sandy loam soil near Delhi where no live nematodes were found in any of the treatments. Nematode efficacy was also found to be similar between the deep and shallow injection depth by Gao et al. (2018b). Between two study sites, better efficacy was obtained at deeper depth (approx. 100-130 cm) at Delhi (application depths 46 and 71 cm) compared to Merced (46 cm only). The coarser soil at Delhi also likely allowed greater fumigant diffusion.

To date, studies have indicated that lower emissions associated with a deeper injection depth seems to provide comparable, if not better, nematode efficacy than standard shank injections. Note that more intensive soil preparation (e.g., deeper ripping, more cultivation passes) and/or use of more powerful tractors may be necessary for deeper injections. If this proves to be the case, costs will be higher for deeper injections than the fuel costs considered here.

TIF tarps

The use of tarps in California agricultural production systems has been a focus of fumigant emission research for the past fifteen years (Gan et al. 1998; Gao and Trout 2006; Gao et al. 2008, 2009, 2016, 2018b; Hanson et al. 2011, 2013; Qian et al. 2011; Fennimore and Ajwa 2012; Jhala et al. 2012; Ajwa et al. 2013). During this time, tarp material has improved in emission reduction efficiency, advancing from materials such as high-density polyethylene (HDPE), to virtually impermeable film (VIF) to totally impermeable film (TIF), the latter being most effective in reducing 1,3-D emissions. The increase in emission reduction tends to correspond with increasing efficacy as the fumigant remains in the soil longer and at higher concentrations. Current TIF use in California is almost exclusively used in high value crops, i.e., berries and nurseries.

The vast majority of fumigated orchard/vineyard acreage in California is treated using a deep shank (18-in injection depth), broadcast method with 1,3-D near the maximum label rate of 332 lb/ac. The soil surface is then "sealed" rather than using a tarp. Sealing involves the use of tillage equipment such as a tandem disk, ring roller and/or cultipacker in order to disrupt or eliminate traces of the chisel or plow used during the fumigant injection. Several studies in California's Central Valley have been conducted with 1,3-D (and other fumigants) and TIF. Overall, TIF-covered plots show greater efficacy against soil pathogens (*Phytophthora* spp., *Verticillium* spp.), nematodes, and weeds (Hanson et al. 2011, 2013; Jhala et al. 2012; Gao et al. 2016) compared soil covered with TIF to soil sealed with tillage equipment. However, based on observed application method decisions, the pest control provided by sealing with tillage equipment has proven sufficient to offset any augmented pest control benefits provided by the more costly TIF tarps.

Results

Discussion of the results is separated by method.

Method 1: Economic analysis of changes in application methods to comply with 100-ft setback distance for all 1,3-D applications

We grouped applications by application rate, where application rates below 150 lbs/ac are categorized as low, application rates of 150 through 300 lbs/ac are categorized as medium, and application rates above 300 lbs/ac are categorized as high. These categories roughly correspond to annual crops such as sweet potato and carrot (low); berries and nursery crops (medium); and tree and vine crops (high). Table 8 summarizes the number of violations when the proposed requirements are applied to historical applications, affected acreage, and the costs of bringing violating blocks into compliance with the maximum block size restriction at their current application rate using the least expensive method while complying with the requirements for a 100 ft setback distance. This cost is comprised of the cost of switching from non-TIF tarp 12-in and 18-in injection applications to 24-in injection applications and the logistical cost to growers associated with splitting blocks that exceed the maximum block size.

The number of acres that would have been affected annually by the regulation ranged from 18,651 to 21,232 for low-rate applications, 2,109 to 3,644 for medium-rate applications, and 21,100 to 24,869 for high-rate applications. A total of 41,436-46,981 acres per year would have been affected. The number of fields out of compliances with the new proposed regulations ranged from 385 to 510 for low-rate applications, 81 to 144 for medium-rate applications, and 966 to 1,110 for high-rate applications. A total of 1,432-1,665 fields per year would have been out of compliance.

Table 7: Incremental Cost Due to 1,3-D Restrictions, 2017-2020

Use Rate Category	Year	# of Violations	Affected Acres	# of Splits	Split Cost ($)	Deep Injection Cost ($)	TIF Cost ($)	Total Cost ($)	Share of cost due to splits (%)	Share of cost due to deep-injection (%)	Share of cost due to TIF 1209 Injection (%)
Low	2017	510	21,232	42	7,809	202,691	1,107,841	1,318,340	1	15	84
Low	2018	430	18,751	30	5,578	178,156	1,075,687	1,259,420	0	14	85
Low	2019	450	18,651	29	5,392	183,145	386,492	575,029	1	32	67
Low	2020	385	17,749	37	6,879	170,448	809,370	986,697	1	17	82
Medium	2017	144	3,644	76	14,130	36,438	0	50,568	28	72	0
Medium	2018	125	2,670	55	10,226	25,777	105,800	141,803	7	18	75
Medium	2019	122	2,615	47	8,738	24,652	171,925	205,315	4	12	84
Medium	2020	81	2,109	57	10,597	19,392	195,776	225,765	5	9	87
High	2017	975	22,105	1,653	307,326	221,049	0	528,375	58	42	0
High	2018	1,110	24,869	1,862	346,183	248,687	0	594,870	58	42	0
High	2019	985	21,100	1,546	287,432	210,996	0	498,428	58	42	0
High	2020	966	21,578	1,623	301,748	215,778	0	517,526	58	42	0
Total	2017	1,629	46,981	1,771	329,265	460,178	1,107,841	1,897,283	17	24	58
Total	2018	1,665	46,290	1,947	361,987	452,620	1,181,487	1,996,093	18	23	59
Total	2019	1,557	42,366	1,622	301,562	418,793	558,417	1,278,772	24	33	44
Total	2020	1,432	41,436	1,717	319,224	405,618	1,005,146	1,729,988	18	23	58

No blocks in the low-rate category exceeded maximum block size restrictions for their use rates, so all costs in this category were due to switching the application method to 24 in-deep injection. In contrast, medium-rate blocks require 47-76 splits and high-rate blocks 1,546 to 1,862 splits annually to bring them into compliance and, thus, the shares of total annual compliance costs attributed to splits were approximately 4 percent and 58 percent, respectively. In total, annual compliance costs ranged from $575,029 to $1,318,340 for low-rate applications, from $50,568 to $225,765 for medium-rate applications, and from $498,428 to $594,870 for high-rate applications. The $50,568 for medium-rate applications was from 2017 and is lower than the other years because no applications had to switch to TIF. For all crops, annual compliance costs are estimated at $1,278,772-1,996,093.

The increased cost for the low-rate category was due mostly to having to switch to 24 in injection. For the medium use rate category, there is a drastic difference between 2017 ($50,568) and the other years ($141,803 to $225,765). This is due to applications using chemigation having to add TIF tarp. In 2017 no fields required TIFs but in 2018-2020 there were many. Adding TIF tarp accounts for 25-86 percent of the cost increase. For the high-rate fields, the vast majority of which are tree and vine crops, around 58% of the estimated change in cost is due to the logistical costs of splitting fields into smaller blocks. These applications could face even higher costs if applicators decide to charge more per acre for the smaller blocks resulting from split fields and/or charge for mileage to and from the field. Additionally, it is possible that some new maximum block sizes are so small that if all applications were divided into such blocks applicators simply wouldn't have the time or resources to treat all of them in time for planting, particularly if the affected fields are geographically dispersed. That scenario could likely be resolved by increased hiring and investment in equipment by applicators but does present a potentially very damaging situation in the short term if growers struggle to meet planting times and must leave fields fallow.

Costs disaggregated by crop and year are available in Appendix B. Estimated Costs by Crop and Year.

Method 2: Spatial analysis of fields impacted by 100 ft, 200 ft, and 500 ft occupied structure setback distances in three counties

There were 1,711 1,3-D applications in the three focal counties in total for the years 2017 and 2018. For these counties in total, the estimated costs obtained using Method 1 were $340,462 in 2017 and $358,029 for 2018. That includes $160,449 from the cost of split blocks and $180,013 from deeper injection in 2017 and $172,534 from split blocks and $185,496 from deeper injection in 2018. Limiting attention to the actual fields and acreage affected by the regulations reduce costs by 72% in 2018 and 68% in 2017. Table 8 compares costs from the first analysis (Method 1) and the spatial analysis (Method 2), disaggregated into costs from splitting blocks, using deeper injection, and using TIF. It also reports the spatial costs as a share of the first analysis by cost component. Notably, across years and counties the cost of 24 in-injection under Method 2 is a significantly higher percentage of its cost under Method 1 than is the case for the cost of block splitting.

Table 8. Comparison across Methods of Estimated Cost of Complying with Proposed Regulations on Occupied Structure Setbacks, Application Methods and Rates, and Maximum Block Size

	Year	**Method 1 Costs ($)**				**Method 2 Costs ($)**				**Method 2 Cost as a Share of Method 1 Cost (%)**			
		Split	**Deep Inj.**	**TIF**	**Total**	**Split**	**Deep Inj.**	**TIF**	**Total**	**Split**	**Deep Inj.**	**TIF**	**Total**
Fresno	2017	69,348	67,279	0	136,627	43,319	57,785	0	101,104	62	86	0	74
Kern	2017	55,590	70,400	202,400	125,990	18,034	61,835	80,500	79,869	32	88	40	63
Stanislaus	2017	35,511	42,333	0	77,844	24,170	41,132	0	65,302	68	97	0	84
Total	2017	**160,449**	**180,013**	**202,400**	**340,462**	**85,523**	**160,752**	**80,500**	**246,275**	**53**	**89**	**40**	**72**
Fresno	2018	62,097	63,703	0	125,801	39,043	55,163	0	94,206	63	87	0	75
Kern	2018	66,002	73,576	0	139,578	18,034	59,926	0	77,960	27	81	0	56
Stanislaus	2018	44,435	48,216	0	92,651	28,260	42,980	0	71,240	64	89	0	77
Total	2018	**172,534**	**185,496**	0	**358,029**	**85,337**	**158,069**	0	**243,406**	**49**	**85**	**0**	**68**

Table 9 shows the number of fields with occupied structures within 100 ft, 200 ft, and 500 ft. There were 268 fields in 2017 and 353 in 2018 with no occupied structures within 500 ft. This is 33% and 39% of fields, respectively.

Table 9: Number of Fields in 2017 and 2018 with Occupied Structures within 100 ft, 200 ft, and 500 ft Setbacks

Year	Setback (ft)	Fields with structures within setback
2017	100	147
	200	223
	500	179
2018	100	155
	200	226
	500	160

Fields with occupied structures within 100 ft would have to use the 100 ft setback rules in Table 3. This was estimated to cost \$140,373 in 2017 and \$138,996 in 2018, which is 43% and 59% of the total cost in each year respectively (Table 10).

Applications that did not comply with the proposed regulations on fields with occupied structures between 200 and 500 ft would need to use deeper injection applications to comply with the proposed regulations but would be able to use the 200 ft setback rules (Table 3). This was estimated to cost \$47,827 in 2017 and \$32,797 in 2018, which is 15% and 14% of the total cost in each year, respectively (Table 10).

Applications that did not comply with the proposed regulations on fields with no occupied structures within 500 ft would switch to deeper injection and would be able to use the 500 ft setback rules in the proposed regulations (Table 3). This was estimated to cost \$50,519 in 2017 and \$57,449 in 2018, which is 42% and 27% of the total cost in each year, respectively (Table 10).

Table 10: Estimated Costs by Year and Occupied Structure Setback Distance in Focal Counties

Year	Setback (ft)	# of Violations	Affected Acres	# of Splits	Split Cost ($)	Deep Injection Cost ($)	TIF 1209	Total Cost ($)	Share of cost due to splits (%)	Share of cost due to deep-injection (%)	Share of cost due to TIF 1209 Injection (%)	% of Total Cost
2017	100	321	7,121	372	69,162	71,211	0	140,373	49	51	0	43
	200	110	3,481	70	13,014	34,813	0	47,827	27	73	0	15
	500	131	5,122	31	5,764	50,519	80,500	136,783	4	37	59	42
	Total	562	15,724	473	87,940	156,543	80,500	324,983	27	48	25	100
2018	100	325	6,853	379	70,464	68,532	0	138,996	51	49	0	59
	200	102	2,331	51	9,482	23,315	0	32,797	29	71	0	14
	500	172	5,750	32	5,949	57,499	0	63,448	9	91	0	27
	Total	599	14,935	462	85,895	149,346	0	235,241	37	63	0	100

The total estimated cost for the three focal counties to comply with the proposed regulation using the spatially explicit approach was 61% (2017) and 68% (2018) of the total estimated cost using the assumption that all fields had a structure within 100 ft. Most of the reduction in estimated costs is due to fewer splits being required with the larger setback distances except in Kern County where the reduction is also due to fewer fields adding TIF. The increase in cost due to splits was $161,564 and $171,976 in 2017 and 2018 using the assumption that all fields had an occupied structure within 100 ft; however, it was only $87,904 and $85,895 in 2017 and 2018 in the spatially explicit analysis. Note that these three counties and two years may or may not be representative for all counties in all years. In particular, none of these are coastal counties where there are more fields using application methods that would require TIF to be added. However, it does indicate that it is appropriate to treat our estimates from the first analysis as an upper bound. For growers with blocks farther than 200 ft from an occupied structure, splitting costs will be lower than what is estimated for all counties on average.

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Appendix A: 1,3-D Use for Pest Management (for major crops)

In the following sections we review the main crop types using 1,3-D, and how fumigation is part of pest management in those crop systems.

Tree and Vine Crops

Nematodes are the primary target of fumigant applications in tree and vine crops. In addition to providing nematode control, 1,3-D has been shown to aid in managing *Prunus* replant disease in almond and stone fruit (Browne et al. 2013), as well as other diseases such as armillaria root rot, bacterial canker, verticillium wilt, and crown gall. Chloropicrin is sometimes added when both nematode and disease control are necessary. Against nematodes, broadcast applications of 1,3-D at maximum label rates can provide up to six years of protection, while strip and spot applications provide up to about six months of control (McKenry et al. 2003). These applications are typically untarped, deep shank injected (18-in) and sealed with tillage equipment. Results of nematode sampling, soil type, and rootstock resistance can determine the application method. Nematode-resistant rootstocks are available; however they are not resistant to all nematode species (Duncan 2017). Post-plant nematicides, another means of managing nematodes, must be applied annually, often with two applications recommended per year and tend to be less efficacious than a one-time, pre-plant application of 1,3-D. Additionally, pre-plant fumigation with 1,3-D can increase yields (Doll 2015). Other options such as cover cropping with a non-host plant, e.g. true sudangrass, and/or fallowing for one to two years can aid in nematode management as well (Browne et al. 2013). Although metam products kill nematodes, they do not penetrate roots as well as 1,3-D and are more difficult to effectively apply, especially in finer textured soils (McKenry 1999; McKenry et al. 2003). In grape, 1,3-D is primarily used for nematode control, in combination with rootstock selection and cultural practices.

Though other orchard crops use 1,3-D as a preplant treatment for control of similar pests, we focus our analysis on the primary 1,3-D crop uses in 2017-2020: almond, walnut, and grape. The majority of the acreage is treated using a broadcast deep shank injection method, then sealed with tillage equipment. Yield loss data for orchard and vineyard preplant fumigation studies are limited. This is likely due to the relatively long delay between treatment and production (Grieneisen 2015). Given these limited data and the wide variety of growing regions, soils, microclimates, rootstocks, pest pressure, application techniques and rates, cultural practices, etc., extrapolation of these data should be viewed with caution.

Almond

Eight counties reported almond acreage treated with 1,3-D in 2017, nine counties in 2018, and ten counties in 2019 and 2020. Statewide, 9,196 acres were treated with 1,3-D in 2017, 11,229 acres in 2018, 8,977 acres in 2019, and 9,471 acres in 2020. CDFA reported 33,124 planted acres in 2017, 32,331 planted acres in 2018, 22,142 planted acres in 2019, and 14,808 planted acres in 2020 (CDFA 2020a). Fresno County had the most acres treated in 2017, 2018, and 2020 with around 3,300 acres in 2017 and 2018 and around 2,700 acres in 2020. Stanislaus County had the most acres treated in 2019 with around 2,800 acres. Fresno, Stanislaus, Kern, Merced and Madera counties make up the top five in 2017, 2018, and 2020. In 2019, San Joaquin County replaces Madera County in the top five. Those five counties accounted for 89% to 94% of all almond acres treated with 1,3-D annually.

In a 2013 study of preplant 1,3-D treatments on almond yield, Browne, et al. (2013) demonstrated that compared to plots fumigated with 1,3-D at the maximum label rate, the unfumigated control plots showed year three yield losses of 42% and 27% at two different sites. They calculated an economic impact of $1,552/ac and $653/ac respectively. In another study on almond preplant treatments, Browne et al. (2018)showed declines in year three kernel yields of approximately 51-95% for plots control plots compared to those pretreated with 1,3-D. At two of those sites, year four yield data were available and showed declines of 23-51%. In field trials at three different sites in California, Doll (2015) reported reductions in almond yield of 50-88% (six years after treatment), 71-87% (six years after treatment) and 22-46% (five years after treatment) in untreated controls compared to fields treated with 1,3-D. The low ends of the ranges above represent spot treatment with 1,3-D, while the upper ends represent broadcast 1,3-D treatments.

Grape (includes wine, table, and raisin)

Twelve counties reported grape acreage treated with 1,3-D in 2017, thirteen counties in 2018, and twelve counties in 2019 and 2020. Statewide 3,753 acres were treated with 1,3-D in 2017, 4,068 acres in 2018, 3,106 acres in 2019, and 4,050 acres in 2020. Of those treated acres, roughly 30% were wine grape in 2017, 45% in 2018, 32% in 2019, and 40% in 2020. The remaining acres were table or raisin grapes. Kern County had the most 1,3-D treated grape acreage in 2017 (1,530 acres), 2018 (1,395), and 2019 (1,525). Kern, Fresno, Madera, Monterey, and Santa Barbara make up the top five counties in 2017. Monterey County is replaced by San Joaquin County in the top five in 2018 and 2019 and by Riverside County in 2020. The top five counties account for between 82% to 91% of total acres treated with 1,3-D each year. As reported by CDFA, 10,673 acres of grape were planted statewide in 2017, 8,289 acres in 2018, and 6,209 acres in 2019 (CDFA 2020b). At the time this report was prepared 2020 acreage was not available.

For grape, Cabrera et al. (2011) reported Merlot yield losses of approximately 24% and 14-31% yield loss for Thompson seedless (four years after treatment) comparing 1,3-D/chloropicrin treated soils to untreated control plots. In another study of 1,3-D fumigated soils versus unfumigated controls, Raski et al. (1976) showed a year three yield loss of 40-79% for Muscat depending on 1,3-D application rates and the previous crop (grape vs barley); an 11-77% loss for

Alicante Bouchet, depending on application rates and the harvest year (years 4-6), and a 60-67% yield loss for Thompson seedless, based on application rates. For Cabernet Sauvignon, Raski and Goheen (1988) reported yield losses of 19% and 21% for years three and four respectively, again comparing 1,3-D fumigated plots with unfumigated controls.

Walnut

Nine counties reported walnut acreage treated with 1,3-D in 2017, fourteen counties in 2018, thirteen counties in 2019, and ten counties in 2020 (CDFA 2020c). Statewide 1,864 acres were treated with 1,3-D in 2017, 2,503 acres in 2018, 1,807 acres in 2019, and 1,561 acres in 2020. Butte County had the most acres treated in both 2017 and 2018 (703 acres in 2017, 677 acres in 2018). Sutter County had the most acres treated in 2019 of 383 and San Joaquin County had the most acres treated in 2020 of 459. Butte, Yuba, Stanislaus, Sutter and San Joaquin make up the top five in 2017. In 2018, Placer County replaced Yuba County. Sutter, Stanislaus, Yuba, Monterey, and Butte make up the top five in 2019. San Joaquin, Monterey, Sutter, Stanislaus, and Butte make up the top five in 2020. The five counties accounted for between 78% to 85% of all walnut acres treated with 1,3-D in each year. CDFA (2020) reported 2,977 acres planted in 2017, 3,094 acres in 2018, and 3,023 acres in 2019 (CDFA 2020c). At the time this report was prepared 2020 acreage was not available.

Beede et al. (2013) compared the effects of different soil fumigants on yield and other parameters for two different walnut rootstocks. Compared to the 1,3-D treated soil, the unfumigated control soil showed an approximately 49% yield reduction in year five (the first production year) and approximately 57% in year six (the second production year). The other rootstock showed yield reductions of approximately 53% and 47% in years five and six respectively. However, given the widespread occurrence of root lesion nematodes in walnut orchards (McKenry 1994) and their detrimental impact on early tree growth , almost complete orchard losses can occur depending on soil type and nematode pressure (Walnut Crop Profile 1998).

Annual Crops: Carrot and Sweet Potato

Together, carrot and sweet potato comprised approximately 33.2annual crop acreage treated with 1,3-D annually from 2017-2020. Similar to the perennial crops discussed above, there are limited yield loss data for carrot and sweet potato. Given the variety of growing regions, soils, microclimates, cultivars, pest pressure, application rates and techniques, cultural practices, etc., extrapolation of these data should be taken with caution.

Carrot

Eleven counties reported carrot acreage treated with 1,3-D in 2017, eight counties in 2018, seven counties in 2019, and ten counties in 2020. Statewide 8,135 acres were treated in 2017, 7,096 acres in 2018, 7,416 acres in 2019, and 7,211 acres in 2020. Imperial County had the most treated acres in all years (4,830 acres in 2017, 4,931 in 2018, 5,139 in 2019, and 4,376 in 2020). Kern, Fresno, Santa Barbara and San Joaquin counties round out the top five in 2017, 2018, and 2020. In 2019, Santa Barbara County is replaced by San Luis Obispo. The top five counties account for between 89% to 97% of total acres treated with 1,3-D each year. According to (USDA 2020a, 2021a) 62,500 acres of carrot were planted statewide in 2017, 62,800 acres in 2018, 62,600 acres in 2019, and 60,400 acres in 2020.

1,3-dichloropropene is used in carrot production primarily to manage nematodes. Root knot nematode, widely distributed throughout California, can cause extensive damage to growing root tips, leading to substantial stand and yield reduction if not controlled (California Fresh Carrot Advisory Board 2005). Other nematode pests include stubby root nematode (statewide) and needle nematode (California Fresh Carrot Advisory Board 2005). Preplant soil testing for nematodes helps determine treatment, which is also based on soil type, soil temperature and cultivar susceptibility (California Fresh Carrot Advisory Board, 2005). Metam-sodium and metam-potassium are also used for nematode control and can provide control on a broader spectrum of weeds, though 1,3-D is generally considered a better material for high nematode populations than the metam products (California Fresh Carrot Advisory Board 2005). Cultural practices such as fallowing, crop rotation, and soil solarization can provide limited nematode management (UC-IPM 2020).

In the Imperial Valley, 1,3-D (at approximately 90-100 lbs/ac) is typically broadcast shank-applied at shallow depths (12 in) then sealed with tillage equipment. In the other growing regions of California, 1,3-D is typically applied at higher rates and deeper depths, at an average of 125 lbs/ac b broadcast shank-applied at 18 in. The soil is then sealed with tillage.

A handful of carrot trials over the past several decades have produced a variety of results regarding the impact of fumigation on carrot yield. Three carrot trials at the South Coast Research and Extension Center in southern California resulted in yield differences between fumigated soil and untreated controls (Westerdahl 2013, 2015; Westerdahl et al. 2014). In terms of marketable yield, those studies showed increases in the 1,3-D fumigated plots of 30% (Westerdahl 2015), 76% (Westerdahl 2013) and 110% (Westerdahl et al. 2014) compared to the untreated control plots. One of those trials also included a metam-sodium treatment, which showed a yield increase of 76%, compared to 110% for 1,3-D in the same trial (Westerdahl et al. 2014). A 1986 carrot trial in Kern County showed increases in marketable yield of 39% for 1,3-D, and a 31-40% increase for metam-sodium relative to the untreated control (Roberts et al. 1988). In this study, the range for metam-sodium was due to two different application rates. Outside of Bakersfield in 1997, Hutchinson et al. (1999) showed an increase in total marketable carrot yield of 15% for 1,3-D and a decrease of 43% for metam-sodium treated plots. The authors attributed the decrease to possible poor soil distribution of the metam-sodium (metam applications rely on moisture to distribute the chemical throughout the soil profile—if not done properly, poor distribution of the AI is possible). Results from two trials in Davis, Calif. from Stapleton et al.

(1987) showed a -20-2% yield difference (kg carrots/row) for 1,3-D and a 10% increase for metam-sodium relative to the untreated control in a sandy loam soil, and a 15-17% increase for 1,3-D and a 20% increase for metam-sodium relative to the untreated control in a heavier silty clay loam soil. The low values for 1,3-D in the first trial were attributed in part to the addition of irrigation water after injection, which could have hydrolyzed the 1,3-D to a less volatile and phytotoxic byproduct.

Sweet potato

Three counties reported sweet potato acreage treated with 1,3-D in 2017 through 2020. Statewide 8,858 acres were treated in 2017, 9,118 acres in 2018, 7,130 acres in 2019, and 7,718 acres in 2020. Merced County had the most treated acres in each year, followed by Stanislaus and Kern counties. From 2017 to 2020 Merced County accounted for an average of 80% of treated 1,3-D acreage annually, Stanislaus accounted for an average of 19% and Kern accounted for an average of 2%. Statewide, 21,000 acres of sweet potato were planted in both 2017 and 2018, 21,500 acres in 2019, and 22,000 acres in 2020 (USDA 2020a, 2021a)

In sweet potato production, 1,3-D is used to manage pests such as wireworms, grubs of beetles and nematodes (UC-IPM 2020). Root knot nematode and stubby root nematode commonly occur in sweet potato fields, with the former more important in terms of economic damage (e.g., yield loss, unmarketable sweet potato) (Stoddard et al. 2013). Preplant soil testing for nematode is an important part of sweet potato IPM. 1,3-D generally provides better nematode control in heavily infested soils compared to metam-sodium and metam-potassium; the latter metam product tends to be more expensive but can provide additional weed suppression and the benefit of adding potassium to the soil (Stoddard et al. 2013). Cultural practices such as fallowing, crop rotations, and use of resistant cultivars are other important IPM strategies (UC-IPM 2020). 1,3-D is typically deep, broadcast shank-applied around 90-120 lb/acre, then sealed with tillage equipment.

Trials comparing the efficacy of fumigants on sweet potato yield have been conducted over the past several decades in Merced County, California. The results discussed here are based on total marketable yield comparing fumigated plots to untreated controls. In 3 trials, Roberts and Scheuerman (1984) showed average yield increases of 91% (1979 trial), 84% (1981 trial), and 36% (1982 trial). A 2003 trial showed yield increases of 12% and 24% in two different trials for plots treated with 1,3-D relative to the unfumigated controls (Stoddard, 2003). In the 2012 trial, the 1,3-D+metam plots showed a 29% increase in yield compared to 1,3-D treated plots (Browne et al. 2013). As mentioned earlier, a number of other factors such as soils, microclimates, cultivars, pest pressure, cultural practices, application rates and application methods can impact yield.

Strawberry

Eleven counties reported strawberry acreage treated with 1,3-D in 2017, eight counties in 2018, ten counties in 2019, and eleven counties in 2020. Strawberry was the leading commodity in terms of acres treated with 1,3-D in 2017 with 17,434 treated acres, 15,763 treated acres in 2018, 14,904 acres in 2019, and 15,639 acres in 2020. Monterey had the most treated acres in every year (7,825 in 2017, 7,447 in 2018, 6,389 in 2019, and 7,459 in 2020). Santa Barbara, San Luis Obispo, Ventura, and Santa Cruz Counties round out the top five in each year. These five counties comprise approximately 99% of the total strawberry acres treated statewide from 2017 to 2020. Statewide, 39,000 acres of strawberries were planted in 2017, 35,300 acres in 2018, 34,500 acres in 2019, and 33,500 acres in 2020 (USDA 2020b, 2021b)

In strawberry production, 1,3-D is typically applied with chloropicrin and sometimes followed with metam-sodium or metam-potassium to manage a variety of pests such as nematodes (e.g., root knot), insects (e.g., root beetles), soil borne pathogens (e.g., fusarium wilt, macrophomina crown rot (charcoal rot), phytophthora crown and root rot, verticillium wilt), and weeds that can greatly impact yield. The primary application methods in strawberry are broadcast shank applications prior to bed formation or bed applications via drip tape. Both methods rely on tarps to reduce emissions and increase efficacy.

Cultural practices such as fallowing, cover crops, crop rotations, and use of resistant cultivars are other important pest management strategies. However, certain soil-borne pathogens such as fusarium wilt, *Macrophomina*, and *Phytophthora* can persist in small survival structures (e.g., propagules, sclerotia) in the absence of the host, impacting the efficacy of cultural controls.

Numerous strawberry yield studies have been conducted in California over the past several decades. A meta-analysis by Shaw and Larson (1999) summarized the effect of different fumigants on strawberry yield over 11 production seasons at three different sites (Watsonville, Oxnard and Irvine). These studies involved various combinations of cultivars, pest pressure, fumigant application rates and methods. In those studies, compared to methyl bromide/chloropicrin fumigation (the grower standard at the time), marketable yields for untreated controls were 94.4% lower (45 studies), chloropicrin-only were 9.6% lower (34 studies), 1,3-D/chloropicrin were 14.4% lower (10 studies) and metam-sodium treated fields had 29.8% lower marketable yields (8 studies). Results of other strawberry yield studies are presented below (Table 7) and show consistently higher (though widely variable) yields for 1,3-D relative to untreated controls.

Nursery Crops

Nursery stock production for commercial crops is subject to the same pest pressures (weeds, pathogens, insects, nematodes, etc.) as their field production counterparts. Pest-free nursery stock is critical to establishing productive orchard, vineyard and other crops, and often required for intrastate, interstate, and international commerce of that stock. Recognizing the importance of such requirements, CDFA has established a Nursery Inspections Procedure Manual (CDFA 2010). A key means of certifying nursery stock is utilizing pre-plant fumigant treatments, 1,3-D in particular, primarily for nematode control. Inspections for the presence of nematodes are also permitted if fumigants are not used, but their presence, and thus failure to meet certification, can result in 100% crop loss through nonsalable stock, emphasizing the importance of 1,3-D in these systems. In addition there are fewer herbicides available for use in commercial production nurseries, and 1,3-D has been shown to provide control of both broadleaf and grass weeds (Shrestha et al. 2008; Fennimore and Ajwa 2012; Hanson et al. 2013).

Three sites codes represent nursery plants in the PUR database, all of which are for outdoor plantings as indoor use of 1,3-D is prohibited. “N-outdoor plant” represents the majority of nursery plantings (primarily orchard, vine, rose and bulb stock). N-outdoor flower represents primarily cut flowers grown in coastal counties led by Santa Barbara, with Ventura, Monterey and San Diego counties rounding out the remainder. N-outdoor transplant primarily represents sweet potato transplants (Merced County) as well as other trees such as Christmas trees.

No yield loss data were identified in a literature search. As mentioned, failure to meet certification requirements can result in 100% economic crop loss through nonsalable stock. In addition to pest control, studies have shown growth benefits resulting from the use of 1,3-D, which effectively functions as an improvement in crop quality when prices are based on plant size (Schneider et al. 2009; Hanson et al. 2013).

Appendix B: Estimated Costs by Crop and Year

Commodity	Year	Fields not in compliance	Acres not in compliance	Splits needed	Split costs	Deeper injection costs	TIF 1209	Total cost
ALMOND	2017	384	9,155	659	122,521	91,552	0	214,073
ALMOND	2018	501	11,198	780	145,018	111,980	0	256,997
ALMOND	2019	407	8,917	616	114,527	89,166	0	203,693
ALMOND	2020	421	9,363	680	126,426	93,628	0	220,053
APPLE	2018	2	19	1	186	190	0	376
APPLE	2019	2	23	1	186	225	0	411
APRICOT	2017	5	64	4	744	639	0	1,383
APRICOT	2018	1	4	0	0	40	0	40
APRICOT	2020	3	65	5	930	650	0	1,580
ASIAN PEAR	2019	1	7	0	0	65	0	65
BEAN DRIED	2017	1	48	0	0	480	0	480
BEET	2017	2	15	0	0	150	0	150
BEET	2019	0	0	0	0	0	0	0
BLACKBERRY	2017	0	0	0	0	0	0	0
BLACKBERRY	2018	0	0	0	0	0	0	0
BLACKBERRY	2019	0	0	0	0	0	0	0
BLACKBERRY	2020	0	0	0	0	0	0	0
BLUEBERRY	2017	2	111	10	1,859	1,107	0	2,966
BLUEBERRY	2018	2	178	16	2,975	1,780	0	4,755
BLUEBERRY	2019	1	40	3	558	400	0	958
BROCCOLI	2017	4	113	0	0	1,130	0	1,130

BROCCOLI	2018	0	0	0	0	0	0	0
BROCCOLI	2019	2	60	0	0	602	0	602
BROCCOLI	2020	1	33	0	0	333	0	333
BRUSSEL SPROUT	2017	90	1,807	5	930	18,071	0	19,000
BRUSSEL SPROUT	2018	65	1,294	4	744	12,941	0	13,684
BRUSSEL SPROUT	2019	82	1,491	3	558	14,909	0	15,467
BRUSSEL SPROUT	2020	35	793	2	372	7,930	0	8,302
BRUSSEL SPROUT SEED	2020	1	17	0	0	170	0	170
CABBAGE	2017	5	56	0	0	557	0	557
CABBAGE	2018	1	10	0	0	95	0	95
CABBAGE	2019	1	11	0	0	110	0	110
CABBAGE	2020	1	14	0	0	140	0	140
CANTALOUPE	2017	3	336	3	558	3,360	0	3,918
CANTALOUPE	2018	4	372	2	372	3,720	0	4,092
CANTALOUPE	2019	7	635	2	372	6,350	0	6,722
CANTALOUPE	2020	5	401	2	372	4,010	0	4,382
CARROT	2017	141	8,020	24	4,462	80,197	0	84,659
CARROT	2018	123	6,945	15	2,789	69,452	0	72,241
CARROT	2019	142	7,393	13	2,417	73,926	0	76,343
CARROT	2020	119	6,973	20	3,718	69,734	0	73,452
CAULIFLOWER	2017	0	0	0	0	0	0	0
CAULIFLOWER	2018	0	0	0	0	0	0	0
CAULIFLOWER	2020	10	152	0	0	1,523	0	1,523
CHERRY	2017	16	341	27	5,020	3,407	0	8,426
CHERRY	2018	16	340	27	5,020	3,402	0	8,421
CHERRY	2019	10	222	16	2,975	2,223	0	5,198
CHERRY	2020	13	183	11	2,045	1,826	0	3,871

CITRUS	2017	0	0	0	0	0	0	0
CORN FOR/FOD	2017	1	27	2	372	270	0	642
EGGPLANT	2017	1	40	0	0	400	0	400
EGGPLANT	2018	0	0	0	0	0	0	0
EGGPLANT	2019	3	85	0	0	849	0	849
EGGPLANT	2020	0	0	0	0	0	0	0
FALLOW OR IDLE LAND	2018	1	37	0	0	370	0	370
GF-GROUND COVER	2019	1	43	4	744	432	0	1,176
GP-VINE	2018	1	78	7	1,301	778	0	2,079
GRAPE	2017	67	2,226	172	31,978	22,259	0	54,237
GRAPE	2018	51	1,858	133	24,727	18,581	0	43,309
GRAPE	2019	47	1,749	118	21,939	17,487	0	39,425
GRAPE	2020	75	1,997	128	23,798	19,966	0	43,764
GRAPE, RAISIN	2017	14	351	24	4,462	3,514	0	7,976
GRAPE, RAISIN	2018	20	343	24	4,462	3,429	0	7,891
GRAPE, RAISIN	2019	17	349	26	4,834	3,486	0	8,320
GRAPE, RAISIN	2020	17	436	35	6,507	4,355	0	10,862
GRAPE, WINE	2017	37	1,127	85	15,803	11,268	0	27,072
GRAPE, WINE	2018	40	1,845	162	30,119	18,453	0	48,572
GRAPE, WINE	2019	35	990	79	14,688	9,897	0	24,585
GRAPE, WINE	2020	31	1,582	128	23,798	15,823	0	39,620
GRAPEFRUIT	2018	1	3	0	0	25	0	25
GRAPEFRUIT	2019	1	14	1	186	135	0	321
HONEYDEW MELON	2017	4	380	3	558	3,800	0	4,358
HONEYDEW MELON	2018	4	345	1	186	3,450	0	3,636
HONEYDEW MELON	2019	5	556	3	558	5,560	0	6,118
HONEYDEW MELON	2020	6	510	2	372	5,100	0	5,472

KIWI	2018	1	12	1	186	118	0	304
KIWI	2020	1	3	0	0	33	0	33
LEMON	2017	2	50	3	558	500	0	1,058
LEMON	2018	11	108	5	930	1,080	0	2,010
LEMON	2019	5	162	13	2,417	1,618	0	4,035
LEMON	2020	2	55	4	744	549	0	1,292
LETTUCE HEAD	2017	1	15	0	0	150	0	150
LETTUCE HEAD	2018	3	193	0	0	1,930	0	1,930
LETTUCE HEAD	2020	2	54	0	0	540	0	540
LETTUCE HEAD SEED	2017	1	55	0	0	550	0	550
LETTUCE LEAF	2017	2	148	0	0	1,481	0	1,481
LETTUCE LEAF	2018	1	150	1	186	1,500	0	1,686
LETTUCE LEAF	2020	1	34	0	0	343	0	343
LETTUCE ROMAINE	2019	2	144	0	0	1,443	0	1,443
MELON	2019	1	76	0	0	760	0	760
N-OUTDOOR FLOWER	2017	1	5	0	0	0	5,463	5,463
N-OUTDOOR FLOWER	2018	0	0	0	0	0	0	0
N-OUTDOOR FLOWER	2019	0	0	0	0	0	0	0
N-OUTDOOR FLOWER	2020	0	0	0	0	0	0	0
N-OUTDOOR PLANT	2018	2	10	0	0	99	0	99
N-OUTDOOR PLANT	2019	1	5	0	0	45	0	45
N-OUTDOOR PLANT	2020	0	0	0	0	0	0	0
N-OUTDOOR TRANSPL	2018	0	0	0	0	0	0	0
N-OUTDOOR TRANSPL	2019	1	2	0	0	21	0	21
NAPA CAB(TGHT HD)	2017	61	604	0	0	6,038	0	6,038
NAPA CAB(TGHT HD)	2018	35	379	0	0	3,790	0	3,790

NAPA CAB(TGHT HD)	2019	47	453	0	0	4,534	0	4,534
NAPA CAB(TGHT HD)	2020	44	538	0	0	5,384	0	5,384
NECTARINE	2017	27	204	6	1,116	2,035	0	3,151
NECTARINE	2018	25	225	9	1,673	2,254	0	3,927
NECTARINE	2019	23	179	6	1,116	1,792	0	2,908
NECTARINE	2020	15	186	11	2,045	1,860	0	3,905
OF-BULB	2017	0	0	0	0	0	0	0
OF-BULB	2019	1	6	0	0	62	0	62
OLIVE	2017	3	92	8	1,487	922	0	2,409
OLIVE	2018	9	272	19	3,532	2,724	0	6,256
OLIVE	2020	1	22	2	372	219	0	591
ONION DRY	2019	1	4	0	0	40	0	40
OP-BULB	2017	14	121	2	372	1,212	0	1,584
OP-FLOWERING PLANT	2017	5	57	1	186	572	0	758
OP-VINE	2017	7	329	12	2,231	3,289	0	5,520
OP-VINE	2018	8	476	13	2,417	4,760	0	7,177
OP-VINE	2019	4	306	14	2,603	3,064	0	5,667
ORANGE	2017	5	87	6	1,116	869	0	1,985
ORANGE	2018	7	200	15	2,789	1,998	0	4,786
ORANGE	2019	2	33	2	372	325	0	697
ORANGE	2020	4	62	4	744	618	0	1,361
ORANGE NAVEL	2019	1	10	0	0	100	0	100
ORANGE NAVEL	2020	3	54	3	558	536	0	1,094
OT-DEC. TREE	2017	1	15	1	186	145	0	331
OT-DEC. TREE	2018	1	9	0	0	88	0	88
OT-DEC. TREE	2019	2	14	0	0	140	0	140
OT-DEC. TREE	2020	1	3	0	0	25	0	25

PARSLEY	2017	0	0	0	0	0	0	0
PEACH	2017	71	743	33	6,135	7,428	0	13,563
PEACH	2018	56	496	21	3,904	4,957	0	8,861
PEACH	2019	45	444	22	4,090	4,438	0	8,528
PEACH	2020	39	432	21	3,904	4,322	0	8,226
PEACH PROCESSING	2017	14	143	5	930	1,427	0	2,357
PEACH PROCESSING	2018	8	92	5	930	921	0	1,851
PEACH PROCESSING	2019	5	35	1	186	353	0	539
PEACH PROCESSING	2020	2	13	0	0	132	0	132
PEAR	2019	1	7	0	0	68	0	68
PEAR, ASIAN	2017	1	13	1	186	127	0	313
PEAS	2019	0	0	0	0	0	0	0
PECAN	2017	0	0	0	0	0	0	0
PEPPER FRUITING	2017	23	745	0	0	3,798	420,440	424,238
PEPPER FRUITING	2018	19	643	0	0	3,832	299,184	303,016
PEPPER FRUITING	2019	30	981	3	558	7,235	295,665	303,458
PEPPER FRUITING	2020	31	717	0	0	1,000	709,320	710,320
PEPPER FRUITING SD	2017	0	0	0	0	0	0	0
PEPPER FRUITING SD	2018	0	0	0	0	0	0	0
Pepper, Bell	2020	6	360	1	186	3,600	0	3,786
PERSIMMON	2018	1	8	0	0	80	0	80
PISTACHIO	2017	1	13	1	186	130	0	316
PISTACHIO	2020	4	69	5	930	691	0	1,620
PLUM	2017	10	74	2	372	743	0	1,115
PLUM	2018	16	100	1	186	1,001	0	1,186
PLUM	2019	15	159	7	1,301	1,589	0	2,890
PLUM	2020	6	35	1	186	354	0	540
POTATO	2017	22	1,049	5	930	10,485	0	11,415

POTATO	2018	24	1,028	5	930	10,276	0	11,206
POTATO	2019	29	1,308	3	558	13,078	0	13,635
POTATO	2020	13	830	2	372	8,299	0	8,670
POTATO SEED	2017	0	0	0	0	0	0	0
POTATO SEED	2018	1	85	1	186	850	0	1,036
PREPLANT/SOIL FUM	2017	267	5,564	376	69,906	55,635	0	125,541
PREPLANT/SOIL FUM	2018	280	4,951	321	59,680	49,507	0	109,187
PREPLANT/SOIL FUM	2019	313	5,720	381	70,836	57,195	0	128,031
PREPLANT/SOIL FUM	2020	281	5,482	368	68,419	54,815	0	123,234
PRUNE	2017	9	363	31	5,764	3,634	0	9,398
PRUNE	2018	14	341	26	4,834	3,413	0	8,247
PRUNE	2019	8	106	6	1,116	1,063	0	2,179
PRUNE	2020	3	133	11	2,045	1,335	0	3,380
RASPBERRY	2017	1	12	0	0	0	13,800	13,800
RASPBERRY	2018	0	0	0	0	0	0	0
RASPBERRY	2019	1	11	0	0	0	13,202	13,202
RASPBERRY	2020	2	25	0	0	0	28,888	28,888
RESEARCH COMMODITY	2017	0	0	0	0	0	0	0
RESEARCH COMMODITY	2019	1	5	0	0	50	0	50
RESEARCH COMMODITY	2020	1	3	0	0	26	0	26
RUTABAGA	2019	0	0	0	0	0	0	0
SOIL FUMI/PREPLANT	2017	6	124	6	1,116	1,239	0	2,355
SOIL FUMI/PREPLANT	2018	3	33	1	186	332	0	518
SOIL FUMI/PREPLANT	2019	4	30	0	0	297	0	297
SOIL FUMI/PREPLANT	2020	6	212	18	3,347	2,124	0	5,471

SQUASH, SUMMER	2018	4	74	0	0	740	0	740
SQUASH, SUMMER	2019	1	18	0	0	180	0	180
SQUASH, WINTER	2019	1	34	0	0	340	0	340
STONE FRUIT	2020	1	7	0	0	70	0	70
STRAWBERRY	2017	31	1,586	0	0	11,636	485,737	497,373
STRAWBERRY	2018	36	1,993	0	0	16,284	419,267	435,551
STRAWBERRY	2019	19	1,462	0	0	12,807	208,150	220,957
STRAWBERRY	2020	17	1,487	1	186	12,915	224,526	237,626
SWEET POTATO	2017	114	5,220	9	1,673	52,198	0	53,871
SWEET POTATO	2018	103	5,009	9	1,673	50,092	0	51,765
SWEET POTATO	2019	92	4,315	10	1,859	43,153	0	45,012
SWEET POTATO	2020	96	4,437	7	1,301	44,369	0	45,671
TANGELO	2017	1	19	1	186	191	0	377
TANGELO	2019	1	25	2	372	246	0	617
TANGERINE	2017	7	133	9	1,673	1,329	0	3,002
TANGERINE	2018	18	200	6	1,116	1,998	0	3,113
TANGERINE	2019	20	341	18	3,347	3,409	0	6,755
TANGERINE	2020	9	196	13	2,417	1,961	0	4,377
TANGERINE, SEEDLESS	2017	7	264	20	3,718	2,643	0	6,361
TANGERINE, SEEDLESS	2018	8	254	21	3,904	2,544	0	6,448
TANGERINE, SEEDLESS	2019	18	654	54	10,040	6,537	0	16,576
TANGERINE, SEEDLESS	2020	9	343	27	5,020	3,431	0	8,451
TOMATO	2017	22	1,781	10	1,859	17,809	0	19,668
TOMATO	2019	5	215	0	0	2,149	0	2,149

TOMATO	2020	3	333	3	558	3,326	0	3,884
TOMATO PROCESSING	2017	2	194	2	372	1,938	0	2,310
TOMATO PROCESSING	2020	3	224	1	186	2,240	0	2,426
UNCULTIVATED AG	2017	40	910	61	11,341	9,097	0	20,438
UNCULTIVATED AG	2018	37	1,096	86	15,989	10,959	0	26,948
UNCULTIVATED AG	2019	34	1,094	91	16,919	10,938	0	27,856
UNCULTIVATED AG	2020	42	1,233	99	18,406	12,326	0	30,732
UNDECLARED COMM	2020	1	56	0	0	564	0	564
WALNUT	2017	66	1,794	141	26,215	17,937	0	44,152
WALNUT	2018	84	2,502	202	37,556	25,023	0	62,579
WALNUT	2019	57	1,386	104	19,336	13,859	0	33,194
WALNUT	2020	43	1,191	97	18,034	11,906	0	29,941
WATERMELON	2017	6	159	0	0	0	182,402	182,402
WATERMELON	2018	14	403	0	0	0	463,036	463,036
WATERMELON	2019	2	41	0	0	47	41,400	41,447
WATERMELON	2020	1	37	0	0	0	42,412	42,412
WHEAT	2017	1	83	1	186	830	0	1,016
WHEAT	2018	3	79	7	1,301	786	0	2,087
WHEAT FOR/FOD	2020	1	52	5	930	520	0	1,450

*generic citrus code that is rarely used