Impacts of Pesticide Regulation on the California Strawberry Industry

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Environmental regulation of agriculture is becoming increasingly important, and growers are concerned about the effects of these regulations on farm profitability. Regulations governing the use of a pesticide affect its economic viability. Furthermore, growers often face a choice among pesticide alternatives, each with its own set of regulatory restrictions. In this environment, the introduction of a new regulation can have complex effects on growers' profit-maximizing pesticide choices. Buffer zones and regional pesticide usage caps mean that pesticide choices often have important spatial components. Our paper presents an optimization model of pesticide use under regulation that incorporates spatial considerations at the field and regional level.

We apply our model to a specific pesticide choice: fumigant choice by California strawberry growers. The industry is facing an impending ban on the use of methyl bromide (MBr), which in conjunction with chloropicrin has been the standard fumigant for over forty years. This new use restrictions that apply to strawberry growers provides us with an interesting environment for modeling the effects of pesticide regulations. There are currently two legally available fumigants that may substitute for MBr in strawberries: 1,3-dichloropropene (1,3-D) and chloropicrin. 1, 3-D is subject to township caps and buffer zones. Township caps limit total application in a thirty-six square mile area. Buffer zones prohibit applications within a specified number of feet of certain adjacent land uses. We evaluate the effects of these regulations on field-level decisions and overall industry costs and returns. The California Department of Pesticide Regulation is currently undertaking air monitoring and other activities to determine whether or not additional use restrictions should be applied to chloropicrin.

We examine the role of pesticide use regulations in determining growers' profit-maximizing pesticide choices at the field level by combining three datasets with a field-level spatial model of the profit-maximizing fumigation decision. The first dataset includes detailed field-level information regarding the costs and yields associated with alternative fumigants obtained from a multi-disciplinary research project. The second includes chemical-specific California use regulations regarding treatment rates, buffer zones, and other factors. The third includes information on the shapes and sizes of strawberry fields in California. Using these data, the optimization model computes the profit-maximizing treatment for each field. Field-level results are aggregated to evaluate the impact of regional pesticide regulations, and then to estimate the industry-level effects of current and proposed pesticide use regulations.

Existing restrictions on fumigant use are integrated into a field-level programming model of a grower's fumigant decision choice. The program calculates the optimal fumigation plan for a field, given the field's size and shape, and use regulations, and per-acre costs and returns associated with each fumigant. The resulting field-level choices are aggregated in order to check for compliance with township caps. If caps are exceeded, the model is rerun. All choices for all fields are aggregated in order to obtain industry-level results. We perform this procedure for several possible fumigant application scenarios under the current set of restrictions, assessing the profitability of each alternative scenario. We then remove the existing township caps on 1,3-D and calculate the change in results. We evaluate whether growers' fumigant choices are sensitive to the size of the 1,3-D buffer zone.

Previous literature

Carter, Chalfant, and Goodhue (2002) examined the effect of MBr buffer zone requirements on fumigated acreage and returns for the California strawberry industry. In this paper we build on that work and examine multiple regulatory scenarios, explicitly incorporating the costs and returns associated with alternative treatments, and we account for regional use restrictions.

After MBr is banned, the demand for 1,3-D for strawberry fumigation will rise. Carpenter, Lynch and Trout (2001) estimated this potential change in demand for 1,3-D , and the quantity of 1,3-D that could be actually applied given California's township caps. They found that growers would be unable to use as much 1,3-D as they would like in 47 townships Given their limiting data set, Carpenter, Lynch and Trout were unable to include the effect of buffer-zone regulations. They simply assumed that 1,3-D would be the most profitable alternative to MBr. Lynch and Carpenter (2002) evaluated the incidence of different rules for allocating 1,3-D quota when the township quota is binding. They found that demand will exceed the quota in 55 townships, and that acreage to which growers would prefer to apply 1,3-D will exceed acreage allowed under the quota by a third. This previous research did not consider the effect of the quota banking system introduced by DPR, which allows quota that was unused in previous years to be added to current year quota, up to twice the current quota limit. However, the banking system by definition is not a long-term option, because a limited amount of unused quota exists.

Analytical Approach

Field-Level Optimal Fumigation Programming Model

We developed a computer program that determines the fumigation plan that maximizes acres fumigated, given the regulatory constraints. The nature of the fumigation problem does not lend itself to standard optimization. Instead, the code calculates the number of days required to fumigate the entire field according to the following procedure: it begins fumigating the maximum distance away from any mandatory in-field inner buffers, referred to as 'binding' sides. If only one side is binding, then the program does fumigation strips back and forth, beginning on the other side of the field. If two adjacent sides are binding, it does L-shaped strips beginning along the other two sides of the field. If two opposite sides are binding, it does fumigation strips beginning from the center. With three binding sides, it begins in the center with an initial rectangle, then does U-shaped applications that move toward the three binding sides. If all four sides are binding, it completes rectangles, starting from the center of the field. If no sides are binding, it also completes rectangles, starting from the center of the field.

The fumigation optimization program cannot address all possible field shapes in its current form. It can analyze rectangles, right-angle triangles, and quadrilaterals with two right angles (as illustrated in Figure 1). It can also evaluate these shapes when a side is missing acreage on its interior, provided the missing acreage does not intersect one of the field's primary diagonals. However, it cannot evaluate one of these shapes when a corner of the field is missing (a "Utah"-shaped field). The other limitations of the program are that it considers a buffer to be binding for the entire length of a side, considers only one binding buffer width, regardless of the number of buffered sides, and considers only one application bloc per day, regardless of field size. Conceptually, it is possible to relax all of these restrictions; however, it is computationally expensive. Relaxing these restrictions would require extensive programming efforts. The appendix reports the percentage of permit fields and acres analyzed by county.

Field Size and Shape Data

California pesticide use regulations are enforced through a permit system. In order to apply a restricted-use pesticide, a grower must obtain a permit from the county agricultural commissioner. The California Department of Pesticide Regulations (DPR) issues “suggested permit conditions” that are its best scientific estimate of the minimum requirements for protecting human health and the environment. Each county agricultural commissioner may adjust these suggested conditions to reflect local conditions.

Our data are based on a specific permit requirement. In 2001, DPR enacted a new set of use regulations for MBr. Enforcement of these regulations required growers to submit a worksite plan that eventually became part of the fumigation permit. The worksite plan included a map of the field and neighboring properties. We collected copies of all completed 2001 fumigation permits and MBr worksite plans for strawberry fields in the five largest strawberry-producing counties measured by product value: Monterey, Orange, Santa Barbara, Santa Cruz, and Ventura. As a group, these five counties account for 92 percent of the value of strawberries produced in California in 2000 (CDFA Resource Directory, 2001). In total we collected roughly 200 worksite plans and permits.

For each field, we tabulated permit and field numbers, and field acreage. Each field was categorized by shape. Field dimension information was included for fields that could be analyzed using the optimal fumigation program. Table 1 summarizes the collected permit information by county. The appendix documents our data collection procedures and compares our permit dataset to other available information on strawberry acreage and MBr application on strawberries.

The California Department of Pesticide Regulation compiles a comprehensive dataset on annual pesticide applications in California, the Pesticide Use Reports (PUR) database. In Appendix 1, we compare its data on actual MBr use in strawberries to our permit data. The PUR database cannot be used for buffer zone analysis because it reports only field acreage, and not field dimensions or shape.

Cost of Production Data

We obtained data on per-acre production costs and yields from a study of MBr alternatives conducted at two locations in California in 2003: Oxnard (Ventura County) and Watsonville (Monterey County) (Ajwa et al.; Goodhue, Fennimore, and Ajwa). We selected the most profitable Inline treatment and the most profitable chloropicrin treatment under standard plastic for each location. For Oxnard, application rates of 300 pounds per acre were the most profitable for 1,3-D and chloropicrin. For Watsonville, application rates of 400 pounds per acre were the most profitable for 1,3-D and chloropicrin. 1,3-D had a lower cost and resulted in a higher strawberry yield than chloropicrin at both sites.

For Orange County, we applied the production cost and yield information from Oxnard. For Santa Cruz County, we applied the production cost and yield information from Watsonville. Santa Barbara County was more problematic. We applied the production cost information from Oxnard, and adjusted the experimental yields to reflect the percentage difference in 2003 average regional yields.

In addition to these data, we use fresh strawberry demand elasticities reported in Carter et al. to evaluate the effect of production changes on industry revenues (Table 2). Consistent with Han's analysis, we assume that the demand for processed strawberries is perfectly elastic, due to the large number of available substitutes.

Pesticide Use Restrictions Scenarios

In an effort to protect public health, the California Department of Pesticide Regulation (DPR) has implemented pesticide use regulations to minimize long-term inhalation exposure to 1,3-D. DPR has established permit conditions, which include buffer zones, restricted application methods, and maximum application rates. We focus on the economic effects of the buffer zone regulation. DPR requires all buffered fields to have a minimum 100 feet buffer measured from the perimeter of the application block to any occupied residences, occupied onsite employee housing, schools, convalescent homes, hospitals, or other similar sites identified by the county agricultural commissioner. If the 100 foot permit condition buffer zone has been used for one year, a 300 foot buffer zone must be utilized for the next three years. At this point in time, there are no buffer zone requirements for chloropicrin.

Results

Acreage Analysis

We simulated 1,3-D buffer zone permit requirements for fields in Monterey, Orange, Santa Barbara, Santa Cruz, and Ventura counties. For each field, a buffer of 100 and 300 were analyzed. The buffer was only binding for those fields which include a buffered side. Tables 3 and 4 summarize the results of the 100 and 300 foot buffer zone simulations. Our results suggest that Santa Barbara County is most affected by the 1,3-D use regulations. When a grower is required to switch to the 300 foot buffer, the regulation becomes more binding, increasing the share of the field that can no longer be fumigated.

Optimal Fumigant Analysis

We analyze growers' optimal fumigation choices under four fumigation scenarios. In two scenarios, 1,3-D is subject to a 100 foot buffer from sensitive sites. In one of these scenarios growers apply chloropicrin in the buffer zone. In the second they do not fumigate the buffer zone, although they do grow strawberries in that part of the field. In the other two scenarios, 1,3-D is subject to a 300 foot buffer from sensitive sites. Again, in one case chloropicrin is used in the buffer zone while in the other no fumigant is used. Tables 5 to 8 report acreage decisions and production for the four scenarios. Tables 5 and 6 report acreage decisions when growers are assumed to fumigate 1,3-D buffer zones with chloropicrin, and Tables 7 and 8 report acreage decisions when growers are assumed to not fumigate 1,3-D buffer zones.

The first table reports acreage allocation decisions when the 1,3-D buffer zone is 100 feet, and the buffer zone is treated with chloropicrin. Only Santa Barbara and Ventura counties apply chloropicrin to a significant share of total acreage. In all five counties, the only acreage fumigated with chloropicrin is the buffer zone acreage, or entire fields that cannot be fumigated due to the buffer zone requirement. Due to the lower per-acre costs and higher per-acre yields associated with 1,3-D in the field trial results, given a 100 foot buffer, all growers prefer to apply 1,3-D. Results are similar for the case where the 1,3-D buffer zone is 300 feet. Although acreage treated with chloropicrin increases relative to the first scenario, the larger buffer zone does not change the profit-maximizing fumigant for individual fields that were still able to apply 1,3-D to some acreage. These simulations ignore any transactions costs associated with using two different fumigation regimes, so they may overstate the relative profitability of fumigating part of a field with 1,3-D and the rest with chloropicrin. However, in practice some growers already use 1,3-D as a drip product, and fumigate the buffer zones with chloropicrin.

Tables 7 and 8 report acreage allocations for the two buffer widths when the buffer zone is not fumigated, but is used for strawberry production. Compare Table 5 to Table 7. Because returns are lower for untreated acreage than for chloropicrin-treated acreage, growers compare the reduction in returns by moving from 1,3-D to chloropicrin, and the increase in returns from moving from no fumigation to chloropicrin, when deciding what fumigant to use on a given field. In virtually all cases, growers choose to apply chloropicrin rather than accept reduced returns on 1,3-D buffer acreage. The same pattern holds when comparing Table 6 to Table 8. When the 1,3-D buffer is 300 feet, growers apply chloropicrin to all buffered fields in the sample.

Overall, our results suggest that the cost of buffer zone requirements for a given pesticide depends on the alternatives available for use in the buffer zone. Because chloropicrin is a reasonably good alternative to 1,3-D, when it is used in the buffer zone growers' returns are relatively unaffected. If there are no good alternatives available, for technical or regulatory reasons, then buffer zone requirements for a pesticide are more likely to reduce growers' returns, and to influence their pesticide choices.

Township Cap Analysis

In addition to the buffer zone requirements, the use of 1,3-D is subject to a township cap, which can constrain growers' fumigation decisions. We evaluate the effect of the current 1,3-D township cap on growers' independent optimal fumigation choices. In order to do so, we aggregate the results from our field-level analyses to reflect industry acreage. We calculate the percentage of our individual fields using each treatment, and multiply it by the 2004 planted acreage (Table 9) to obtain industry-level acreage numbers.

We calculate a measure of the spatial distribution of 1,3-D use that allows us to estimate the minimum effect of the current 1,3-D township cap on growers' independent optimal fumigation choices. For each county, we obtain the number of townships which reported applications of MBr, 1,3-D, and/or chloropicrin on strawberries in 2001, aggregate by production region, and then scale by the ratio of 2004 to 2001 production. This estimate is a lower bound for three reasons: it maximizes the dispersion of strawberry production in 2001, maximizes the change in dispersion due to the increase in acreage between 2001 and 2004, and ignores the possibility that other crops may utilize part of the 1,3-D cap in a given township. We then divide 1,3-D acreage evenly across townships and calculate total 1,3-D use.

We subtract the cap from the desired 1,3-D use per township to obtain the pounds of 1,3-D exceeding quota when growers make their optimal field-level fumigation decisions. Dividing this number by the regional application rate provides the number of acres per township that cannot apply 1,3-D even though it would be optimal to do so. We assume that this acreage is fumigated with chloropicrin instead. For the scenarios where no fumigant is applied in the 1,3-D buffer zone, we specify that the first fields to transition to chloropicrin instead of 1,3-D are those for which the 1,3-D buffers are binding.

Results of our aggregated analysis are reported in Tables 10 through 13. The first table compares acreage allocation decisions with and without the township caps when the 1,3-D buffer zone is 100 feet, and the buffer zone is treated with chloropicrin. Except for Orange County (South District), the township cap alters regional acreage allocation decisions. In Watsonville, 1,3-D acreage declines from 96.1% to one-third of total acreage. In Ventura County, 1,3-D acreage falls from 94.7% to 52.5% of total strawberry acreage. While the decline in Santa Barbara is less dramatic, 1,3-D's share of total fumigated strawberry acreage is 5.5% smaller when the township cap is imposed.

Tables 12 and 13 examine the effect of the township caps when no fumigant is used in the buffer zone. Recall from the field-level analysis that fewer growers chose to apply 1,3-D when no fumigant is used in the buffer zone than when chloropicrin is used in the buffer zone. Because of this change in field-level decisions, the effect of the township cap is different for Santa Barbara than it was when chloropicrin was applied in the 100-foot buffer zone. Because of the difference in profitability, more acres in Santa Barbara apply chloropicrin, and the township cap is no longer binding for the 100-foot 1,3-D buffer zone. As was the case when chloropicrin was applied in the buffer zone, a 300-foot buffer induces enough acreage to be fumigated with chloropicrin that the township cap is not binding.

In the two areas where the township cap had a very large effect on acreage allocation, Ventura and Watsonville, the cap remains binding, although the share of acreage allocated to each treatment varies slightly. In Orange County, the township cap continues to be non-binding.

Our results demonstrate that the impact of an aggregate spatial use regulation, such as the 1,3-D township cap, is dependent on the impact of other use regulations, including spatial use regulations such as 1,3-D buffer zones. For the case we analyze, the 300-foot buffer zone scenarios are most relevant, because of the restriction that 100-foot buffers can be used only every third year. In this case, the effect of the buffer zone requirement was to eliminate any effect of the township cap on pesticide use decisions in Orange and Santa Barbara counties.

Our results also demonstrate that the effect of multiple pesticide use regulations will not be simply additive, because they interact with growers' profit-maximizing pesticide use decisions. For example, increasing the buffer zone width had a different effect on pesticide use decisions when township caps were present than when they were not. For Watsonville and Ventura, the caps were sufficiently binding that increasing the buffer zone did not affect acreage allocation.

One factor that our analysis holds constant is the spatial distribution of growers. If the presence of buffer zones around sensitive sites or the use of township caps causes growers to alter their production sites, then the effects of spatial use regulations on grower returns may be reduced. Growers would continue to apply the pesticide; their location simply would have changed. We have chosen to specify a spatial distribution that minimizes the effect of township caps on growers' profit-maximizing decisions; actual production patterns may have a larger effect.

Market-level analysis

One of the notable characteristics of the California fresh strawberry industry is that different production regions produce for the fresh market at different times of the year. We evaluate the consequences of yield differences across alternatives in regions for the price of fresh strawberries. To do so, we employ the stage demand elasticities reported by Carter et al., and compute total volume for each stage by adding the volume delivered from each region. This volume is calculated for each region by multiplying its total production by the share of its fresh production delivered in that time period. Like Carter et al., we assume that the demand for processed strawberries is perfectly elastic, so that there are no price effects on processed berries due to regulations.

Because chloropicrin is a reasonably good substitute for 1,3-D in terms of maintaining yield, the market-level effects on output and prices are small, so revenues remain virtually unchanged. However, chloropicrin is more costly, so that industry costs increase. The increase in cost is less than $300 per acre, however, so the cost effects of the regulations are also relatively small. Under the most realistic scenario, where chloropicrin is applied on 300-foot 1,3-D buffers and township caps are applied, revenues decline by 1.15 percent or less, depending on the stage of the season.

Conclusions

Environmental regulation of agriculture is becoming increasingly important. The impending 2005 methyl bromide ban is a substantial concern for important segments of California agriculture. By explicitly analyzing the effect of regulations affecting methyl bromide alternatives in a model that includes both the spatial dimensions of regulations and the costs and yields associated with each alternative, we obtain a more detailed and accurate assessment of the costs of these regulations than is currently available. Our results provide a greater understanding of the effects of these regulations on industry profitability, and how these regulations interact.

At the industry level, the revenue and cost effects of the regulations will be negligible, relative to the case where growers all apply 1,3-D. Although in all cases the effects are small, they are larger when the township cap is taken into account, and when there is a 300-foot buffer instead of a 100-foot buffer. Because our analysis focused only on chloropicrin and 1,3-D, our results cannot be used to evaluate the effect of the MBr ban on the industry. Instead, we simply compare alternative post-ban scenarios under existing regulations.

Our model could be applied to other cases of pesticide regulations. It has the benefit of incorporating spatial considerations. It is important to aid policymakers in understanding how environmental regulations interact with each other, possibly in unexpected ways.

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Appendix: Data Quality

For this analysis, we collected copies of workplans and, in some cases, permits from five counties: Monterey, Orange, Santa Barbara, Santa Cruz, and Ventura. Samples of each county's workplan and DPR's suggested format are available at http://www.agecon.ucdavis.edu/facultypages/chalfant/papers/CDFAJuly22-appendix.pdf.

Data Collection

Table A1 reports the total strawberry acreage collected using the permits and workplans from the county agricultural commissioner offices. The acreages are compared to district production acres for the 2002 crop year, obtained from the California Strawberry Commission (2004). (Fumigation occurs in the late summer or fall for production the next year.) The low total acreage, relative to total strawberry acreage, suggests that in addition to the use of alternatives, some permits and methyl bromide workplans are not included in our analysis. There are two obvious reasons to expect the acreages to differ. First, some acreage used alternatives to methyl bromide, so no methyl bromide workplan was submitted. Second, we collected permits by county, rather than district, so that acreage in adjoining counties would not be included. The latter factor is likely most important for the Santa Maria production region. A significant share of this region is in San Luis Obispo County, whereas we only evaluate Santa Barbara. It seems unlikely, however, that these factors account for all of the acreage difference. We are uncertain of the reasons underlying remaining acreage differences.

The next table compares the number of distinct entities applying for permits and permit acreage to the number of unique grower identification numbers and methyl bromide fumigation acreage reported in the California Department of Pesticide

Regulation's 2001 Pesticide Use Report database (PUR). These differences are due to at least two factors. First, the permits were collected as copies of permits from the individual County Agricultural Commissioners. There was no guarantee that we obtained one hundred percent of all applications. This difference is reflected most clearly in the number of growers obtaining permits, which is smaller than the number of grower identification numbers associated with methyl bromide use. Use acreage is higher than permit acreage in Monterey, Ventura, and Santa Cruz counties. Second, because the permits are granted prior to the actual application and reflect grower intentions, it is unlikely that there would be an exact correspondence between intended acreage and actual acreage. The noticeably smaller PUR acreage relative to permit acreage in Orange and Santa Barbara counties is consistent with growers simply choosing to fumigate fewer acres with methyl bromide than they had initially projected.

Optimal fumigation data analysis

We entered field dimensions when we could determine measurements with a reasonable degree of confidence. For example, if we had information regarding the length of a rectangular field and its acreage, we could calculate the width. When we could not determine field dimensions, we did not include fields in the analysis. No counties explicitly required information regarding field dimensions in their workplans.

Table A3 summarizes the fields analyzed in the simulation program, and compares them to the total fields collected by collecting workplans and permits from the county agricultural commissioner offices. Monterey County had the lowest percentages.

Table 1. Summary: County Methyl Bromide Fumigation Permit Applications: 2001

	Monterey	**Orange**	**Santa Barbara**	**Santa Cruz**	**Ventura**	**Total**
Number of Entities Applying for Permits	72	22	39	65	42	198
Number of fields	82	41	80	64	99	267
Total Acreage in Permits	5,451	1,484	2,860	1,809	5,599	11,604

Source: compiled from individual permits collected from County Agricultural Commissioners.

Table 2. Demand Elasticities and Stage Definitions for the Fresh Strawberry Market

Stage	Own-Price Elasticity of Demand
Stage I (January to Easter)	-1.4
Stage II (Easter to Mothers' Day)	-1.5
Stage III (Mothers' Day to July Fourth)	-2.7
Stage IV (July Fourth to Labor Day)	-1.3
Stage V (after Labor Day)	-1.3

Source: Carter et al. Table 4.

Table 3: 1,3-D 100 Foot Buffer Zone Acreage

County	*Total Field Acreage*	*Buffer Acreage*	*% of Total Field Acreage in Buffers*	*% of Fields with Buffer Acreage*	*Average % of in Buffers for Fields with Buffers*
Monterey	723	18	2.5	14.3	24.6
Orange	606	13	2.2	19.0	26.5
Santa Barbara	517	81	15.7	66.7	38.5
Santa Cruz	580	33	5.7	38.9	18.2
Ventura	1720	91	5.3	25.7	21.8

Source: Field acreage compiled from individual permits collected from County Agricultural Commissioners. Buffer acreage from analysis.

Table 4: 1,3-D 300 Foot Buffer Zone Acreage

County	*Total Field Acreage*	*Buffer Acreage*	*% of Total Field Acreage in Buffers*	*% of Fields with Buffer Acreage*	*Average % of in Buffers for Fields with Buffers*
Monterey	723	45	6.3	14.3	52.2
Orange	606	34	5.6	19.0	61.6
Santa Barbara	517	184	35.6	66.7	76.1
Santa Cruz	580	85	14.7	38.9	46.3
Ventura	1720	241	14.0	25.7	55.8

Source: Field acreage compiled from individual permits collected from County Agricultural Commissioners. Buffer acreage from analysis.

Table 5. Simulation results: Acres per fumigation treatment. 100 ft. 1,3-D buffer, chloropicrin applied in buffer

	Acres	
County	1,3-D	PIC
Monterey	705	18
Orange	593	13
Santa Barbara	436	81
Santa Cruz	547	33
Ventura	1630	91

Table 6. Acres per fumigation treatment. 300 ft. 1,3-D buffer, chloropicrin applied in buffer

	Acres	
County	1,3-D	PIC
Monterey	677	45
Orange	572	34
Santa Barbara	333	184
Santa Cruz	495	85
Ventura	1,489	241

Table 7. Acres per fumigation treatment. 100 ft. 1,3-D buffer, no fumigation in buffer

	Acres		
County	1,3-D	None	PIC
Monterey	644	3	76
Orange	565	3	38
Santa Barbara	228	0	289
Santa Cruz	489	9	82
Ventura	1,308	4	408

Table 8. Acres per fumigation treatment. 300 ft. 1,3-D buffer, no fumigation in buffer

	Acres		
County	1,3-D	None	PIC
Monterey	610	0	112
Orange	532	0	74
Santa Barbara	228	0	289
Santa Cruz	366	0	214
Ventura	1,229	0	492

Table 9. 2004 Planted Acreage by Region

Region	Acres
South District	2,899
Oxnard	10,349
Santa Maria	5,647
Watsonville (Monterey and Santa Cruz)	12,201
Total	31,095

Source: California Strawberry Commission, 2004.

Table 10. Share Regional Acreage by treatment with and without township caps for 100 ft. 1,3-D buffer with chloropicrin

	Field-level Optimum		Township Cap	
	%		%	
Region	1,3-D	PIC	1,3-D	PIC
Orange	97.8	2.2	97.8	2.2
Santa Barbara	84.3	15.7	78.7	21.3
Ventura	94.7	5.3	52.5	47.5
Watsonville	96.1	3.9	33.2	66.8

Table 11. Share Regional Acreage by treatment with and without township caps for 300 ft. 1,3-D buffer with chloropicrin

	Field-level Optimum %		Township Cap %	
Region	1,3-D	PIC	1,3-D	PIC
Orange	94.4	5.6	94.4	5.6
Santa Barbara	64.4	35.6	64.4	35.6
Ventura	86.0	14.0	52.5	47.5
Watsonville	90.0	10.0	33.2	66.8

Table 12. Share Regional Acreage by treatment with and without township caps for 100 ft. 1,3-D buffer with no buffer fumigation

	Field-level Optimum %			Township Cap %		
Region	1,3-D	None	PIC	1,3-D	None	PIC
Orange	93.3	0.5	6.3	93.3	0.5	6.3
Santa Barbara	44.1	0.0	55.9	44.1	0.0	55.9
Ventura	76.0	0.3	23.7	52.5	0.0	47.5
Watsonville	86.9	1.0	12.1	33.2	0.0	66.8

Table 13. Share Regional Acreage by treatment with and without township caps for 300 ft. 1,3-D buffer with no buffer fumigation

	Field-level Optimum %			Township Cap %		
Region	1,3-D	None	PIC	1,3-D	None	PIC
Orange	87.8	0.0	12.2	87.8	0.0	12.2
Santa Barbara	44.1	0.0	55.9	44.1	0.0	55.9
Ventura	71.4	0.0	28.6	52.5	0.0	47.5
Watsonville	75.0	0.0	25.0	33.2	0.0	66.8

Table A1. Collected Permit Data by County versus 2002 Production Acreage by District

Permits	Acres	Production	Acres
Orange	1,484.3	Orange, San Diego	2,538
Ventura	5,984.0	Oxnard	8,582
Santa Barbara	2,824.8	Santa Maria	4,100
Monterey, Santa Cruz	7,199.9	Watsonville	11,300
Total	17,493.0		22,352.1

Source: Permit acreage compiled from individual permits collected from County Agricultural Commissioners. Production acreage from CSC (2004).

Table A2. Summary: County Methyl Bromide Fumigation Permit Applications Vs. PUR data: 2001

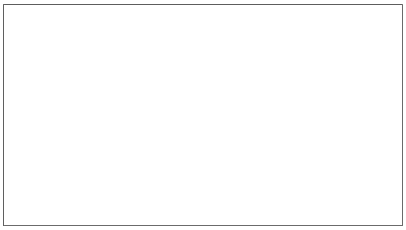
	Monterey	Orange	Santa Barbara	Santa Cruz	Ventura	Total
Number of Entities Applying for Permits	72	22	39	65	42	198
Number of PUR Grower IDs	110	19	35	51	58	
Total Acreage in Permits	5,451	1,484	2,860	1,809	5,599	11,604
Total PUR acreage	7,064	1,051	2,671	2,891	7,799	

Source: compiled from individual permits collected from County Agricultural Commissioners and from DPR Pesticide Use Report Database.

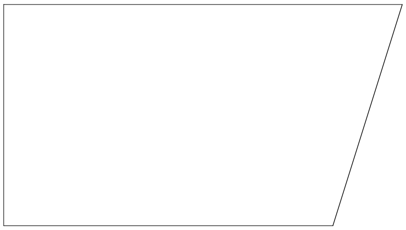
Table A3. Optimal Fumigation Program Coverage Summary

County	Permit Fields	Sim. Fields	% Fields Sim.	Total Permit Acres	Total Sim. Acres	% Acres Sim.	Average Permit Acres	Average Sim. Acres
Monterey	134	25	18.7%	5,401.2	634.5	11.7%	40.6	25.4
Orange	44	22	50.0%	1,484.3	610.8	41.2%	33.7	27.8
Santa Barbara	80	23	28.8%	2,824.8	484.2	17.1%	35.3	21.1
Santa Cruz	59	14	23.7%	1,798.7	432.4	24.0%	28.1	30.9
Ventura	98	28	28.6%	5,984.0	1,371.2	22.9%	61.1	49.0
Total	415	102		17,493.0	3,533.1			

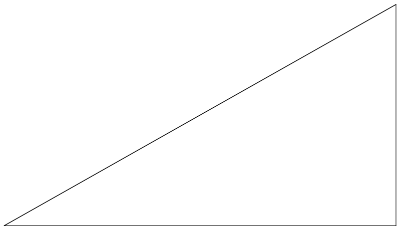
Figure 1. Field Shapes Included in Computation Acreage Loss Analysis



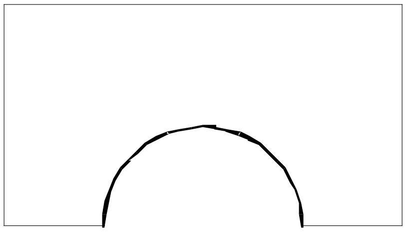
a. rectangle



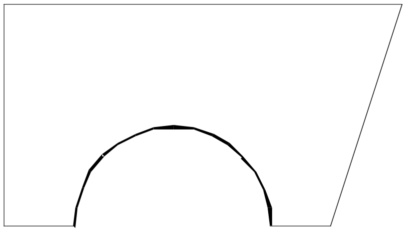
b. quadrilateral with two right angles



c. right angle triangle



d. rectangle with interior acreage missing



e. quadrilateral with interior acreage missing[1]

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[1] Rectangular interior missing acreage modeled as half-circle of the same acreage.