# Addressing Pesticide Use in California Through Implementation of Healthcare Interventions and Development of Novel Technologies

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**Executive Summary:** Pesticide use in California supports the state's vast agricultural yields. However, the overuse of these pesticides may lead to adverse health and environmental effects, including harmful chemical runoff in aquatic ecosystems and longer term health effects such as increasing risk of cancer, disrupting the endocrine system, or causing respiratory damage. In order to continue rectifying this issue in California, public health interventions and the use of novel technology may be implemented. We propose here three policy recommendations centered around public health interventions, precision spraying, and alternative pesticide development.

**I. Introduction: California's ongoing pesticide use**

California has both the largest population and largest agricultural productivity of any US state (California Department of Food and Agriculture 2024). The state grows more than 400 commodity crops and generates over 11 percent of US agricultural value (USDA 2024). Over a third of the country's vegetables and over three-quarters of the country's fruits and nuts are grown in California (California Department of Food and Agriculture 2024).

California heavily uses agricultural pesticides to minimize losses and improve food yield and quality (Tudi et al. 2021). Reported pesticide use in California in 2022 totaled 181 million pounds of applied active ingredients and 92 million cumulative acres treated (CDPR 2022). This extensive use of pesticides affects the health of both California residents and local ecosystems. According to Californians for Pesticide Reform, "a significant fraction of pesticides used in California are "Bad Actor" pesticides capable of causing acute poisoning, cancer, birth defects, sterility, neurotoxicity, damage to the developing child and/or contamination of California groundwater" (Californians for Pesticide Reform 2003). A study by the California Department of Pesticide Regulation found that 80% of air samples collected in four of the most agriculture-intensive communities had detectable levels of pesticides (Formuzis 2024). Workers and people living near fields in one of these communities (Ventura County) suffered rashes, headaches, blurred vision, difficulty breathing, nausea, and hair loss (Carlson, Wilson, & Salgado 2022). Pesticide exposure may also contribute to longer-term health effects such as those observed in the Eastern Coachella Valley (ECV), where there is a disproportionate prevalence of respiratory illness. Approximately 20–22.4% of children living in the ECV along the Salton Sea meet the diagnostic criteria for asthma or other respiratory illness compared to

10% for children in California and 11.3% in the US as a whole (Cheney et al. 2022).

Adverse health outcomes can increase individual health care costs and strain existing health systems (Portela De-Assis et al. 2021). For example, the use of organophosphates, one of the major categories of pesticides used in agriculture, has been estimated to lead to health costs of up to $44.7 billion per year in the United States (Portela de-Assis 2021). A 2024 study predicted that exposure to methomyl, a carbamate insecticide, may increase Parkinson's disease cases by 12% in Central California and lead to $72.0 million in additional healthcare costs over 20 years (Li et al. 2024).

In addition, pesticide runoff may impact aquatic ecosystems, with major pesticide types being found in wastewater that is discharged into water bodies throughout California (Brady et al. 2006). Components from pesticides and other agricultural chemicals have been found in drinking water used by rural California communities, sometimes far from the original contamination sites (Norman 2024). Drinking water with pesticide contamination may lead to cancer, reproductive issues, Parkinson's disease, and acute issues such as asthma and bronchitis (Syafrudin 2021). Additionally, pesticides found in waterways can cause severe biochemical and neurological dysfunction, such as changes in neurotransmitter activity, in freshwater organisms (Saha & Dutta 2024, Renick et al. 2016). Reducing pesticide usage by improving application efficiency would improve health outcomes and ecosystem health.

## II. Current response in California

*i. Public health and environmental exposures*

Agricultural farmworkers and residents living near agricultural sites are particularly vulnerable to acute and chronic health issues from toxic pesticide exposures (De-Assis et al.2020). A soil fumigant popularly used in California's Central Valley, 1,3-dichloropropene (1,3-D), can cause respiratory irritation if inhaled and is classified by the EPA as group B2, a probable human carcinogen (EPA 2000). Environmental health scientists have long linked acute pesticide poisoning with neurotoxic effects, but the effects of lower-dosage, chronic exposures, like the farmworkers' occupational exposures, are still not fully understood (Kamel and Hoppin 2006). Characterizing the frequency and volume of these chronic pesticide exposures remains a significant challenge in developing relevant regulation and interventions (Farcas 2013). A 2025 independent scientific study published by the California Department of Pesticide Regulation (CDPR) also emphasized this crucial need to expand epidemiological research on the chronic, low-level exposures affecting farmworker communities, especially for vulnerable community members such as children, the elderly, and pregnant women (CCST, 2025). The success of long-term initiatives like University of California, Berkeley's Center for the Health Assessment of Mothers And Children Of Salinas (CHAMACOS) project in monitoring the health impacts of chronic pesticide exposures on women and children has not only advanced scientific understanding of chronic effects of environmental exposures but also simultaneously empowered youth in farmworker communities through community-engaged initiatives (Madrigal et al. 2016; Stein et al. 2016). Across its 20 years of comprehensive research, CHAMACOS has partnered with the California Department of Migrant Education office to lead training on pesticide safety to minimize exposures. Given the barriers faced by farmworking community members, such as limited access to comprehensive health services and fears of retaliation related to immigration status, it is crucial to adopt a more localized and community-engaged approach to empower communities to better report incidents and document exposures.

Community stakeholders and state legislators have been proactively seeking to strengthen existing monitoring, regulation, and reporting systems to protect California's agricultural communities. Pesticide exposure monitoring has been conducted by the California Department of Pesticide Regulation (CDPR) starting in 2011 to track air pollution generated by volatilized chemicals in Oxnard, Santa Maria, Shafter, and Watsonville counties. This air monitoring program collects a 24-hour sample once a week from three regional monitoring locations and provides generalized insight into pesticide exposures from 40 pesticides. In a 2023 monitoring

study, 1,3-dicholoropropene was detected in quantifiable and trace amounts in all four counties with the pesticide found present in 28% of all Watsonville collected samples testing for that pesticide (Delgado, 2025). As of March 2025, the CDPR "Spray Days" Notification Program has been implemented to alert enrolled community members 48 hours before the application of a soil fumigant. However, significant knowledge gaps remain to further understand the volatilization, transport, and health effects of these carcinogenic compounds to better quantify human risk and exposure (CCST 2025). Conducting comprehensive studies to analyze pesticide health impacts, transport characteristics, and exposure pathways may be critical to the development of effective protections and interventions for vulnerable populations.

*ii. Precision spraying*

Farmers and agricultural scientists have sought to improve pesticide application efficiency for decades. Improvements in application efficiency can produce significant financial savings for farmers and reduce the environmental consequences of pesticide use. For example, different spray angles and nozzle types are selected to minimize the volume of pesticide needed to treat specific pests, reducing the cost to treat a field (Ozkan 2020). In more complex sprayers, pulse-width modulation (PWM) control systems are used to dynamically adjust pesticide application. PWM systems adjust the flow rate of pesticide through individual nozzles mounted on the boom arms, which can modulate the application of pesticides when the tractor turns or changes speed. These past efforts have led to a steady increase in application efficiency, but recent developments in agricultural computer vision have produced dramatic efficiency improvements.

Academic research of precision spraying technology has yielded promising results for rapid reduction in pesticide usage by incorporating computer vision and artificial intelligence (AI). In this context, "computer vision" refers to algorithms used to rapidly extract useful information from images or depth sensors that can be used to make decisions, an approach which often also uses pretrained AI models. For example, the University of Oregon achieved up to a 70% reduction in pesticide applied to grapevines using their "Intelligent Sprayer," which simply used a high-resolution depth sensor to target spray at the canopy (Warneke 2020). Precision spray systems also result in up to an 87% reduction in spray drift, a major threat to the communities and ecosystems near agricultural fields (Chen 2013). Studies have found that new precision spraying systems are just as effective in pest management as traditional sprayers (Warneke 2020).

Precision spraying systems are a new technology, and commercial options are still not widely adopted. John Deere's See & Spray™ series uses boom-mounted cameras to identify locations of crops and weeds, applying pesticides to specific regions using existing PWM sprayer control systems (John Deere 2024). These systems use pretrained AI vision models and live camera data to differentiate between crops and weeds to apply treatment accordingly. Other companies are currently prototyping similar methods for pesticide-free weeding robots through the use of lasers and mechanical removal of weeds, but these have not yet reached large-scale distribution. The high up-front cost of around $25,000 to upgrade an existing system is a major barrier for farmers, especially for those who own small farms (Lovett 2025). A further challenge is the difficulty of incorporating a novel technology into existing farming systems; workers need to be trained to use new systems and equipment downtime is extremely costly for farmers.

*iii. Alternative pest control*

Existing chemical pesticides include organophosphate and organosulfur chemicals and neonicotinoids, which are harmful to both human health and beneficial pollinators, like bumblebees (Aktar et al. 2009). Despite progress to curb pesticide use in California, these chemicals continue to pervade California agriculture, with 181 million pounds of pesticides being administered in 2022 (CDPR 2022). A roadmap for sustainable pest management, published in 2023, has been developed by CDPR with a focus on urban and rural sustainable pest management planning (CDPR 2023). In 2024, CDPR also emphasized its commitment to providing grants, funding, and other opportunities towards decreasing the use of higher-risk pesticides and expanding access to pesticide alternatives (Jimenez

2024).

Many research groups are investigating the potential of biopesticides as chemical pesticide alternatives in an integrated pest management (IPM) system. Biopesticides, defined as "a mass-produced agent manufactured from a living micro-organism or a natural product and sold for the control of plant pests" (Mnif & Ghribi 2015), do not persist in the environment and can be targeted to specific pests. CDPR describes biopesticides as including "microorganisms and naturally occurring compounds, or compounds similar to those found in nature that are not toxic to the target pest (such as pheromones)" (CDPR 2021). A range of biopesticides have been developed for different plant systems and pests (Dunn-Silver 2024). Accordingly, biopesticide use has increased in California over the past 10 years, by up to 56% in 2022 (CDPR 2022). In comparison, the usage of traditional chemical pesticides such as cholinesterase inhibitors and fumigants were decreased 45% and 17%, respectively, by 2022 (CDPR 2022). However, further expansion of biopesticide use to augment chemical pesticides is dependent on the development of additional options targeting new pests (Brodeur 2012). Furthermore, off-target effects of biopesticides may exist, such as the potential proliferation of microorganisms used in microbial biopesticides and production of harmful toxic metabolites (Wend et al. 2024). Therefore, further development and improved testing may be a necessary step in decreasing pesticide use, as emphasized in a new CDPR-commissioned report released by the California Council on Science and Technology (CCST 2025).

While the strategies mentioned here may reduce off-target effects of pesticide administration, alternatives to pesticide use can also be developed alongside them. Integrated pest management strategies, such as the application of natural predators to control pests, are also promising components of improved pest control in the future (Zhou et al. 2024).

## III. Policy recommendations

The three overarching policy recommendations outlined here focus on the utilization of AI and engineering, as well as novel public health and chemical design interventions. Different technologies are being developed that enable more efficient and precise application of pesticides, the development of novel, safer pesticides, and better health practices for affected communities. These recommendations are directed towards three agencies in the California state government (CDPR, CDFA, and California Air Resources Board) and both re-emphasize successful past policies and propose future directions involving improved technology and health mitigation.

### *i. Expand funding to characterize pesticide transport and environmental exposure routes*

While existing routine monitoring programs, like those organized by CDPR, provide an existing framework for pesticide monitoring, they do not account for specific routes of exposure (time, location, situation) which could better inform public health interventions.

Several California universities, including the University of California, Riverside and University of California, Davis, have found success in utilizing a more granular, individualized network of monitoring projects, collecting and analyzing the direct pesticide exposures through personal monitors for farmworker volunteers (Bennett 2024). These results provide a deeper understanding of individual pesticide exposures across smaller spatial and temporal scales. Supported through initiatives led by the California Air Resources Board, these air quality research programs are funded for communities and university partners through the California Community Air Protection Program's grant program. Expanding state and private funding resources for this field of research should additionally include inclusion and project co-development by marginalized populations, such as farmworkers. Building respectful, equitable partnerships helps ensure that the research addresses the community's needs and that community members are empowered to take action (Eskenazi 2011). Some ways that this equitable partnership could be realized through co-development of project objectives or integrating cultural awareness into health interventions. Incorporating established community-based

organizations (CBO) and respected industry partners in the development of pesticide testing and educational programs for farmworkers has proven successful in guiding appropriate research efforts and supporting the adoption of interventions (Hamilton 2011). **We recommend expanding funding for California Community Air Protection Program grants, with emphasis on projects that investigate pesticide pollution pathways and exposure risks for vulnerable populations.**

*Advantages*

With enhanced monitoring and data, public health officials can design educational programs and targeted interventions for pesticide transport and exposure. Involving community organizations in these monitoring efforts promotes community empowerment through active participation in addressing environmental health concerns.

*Disadvantages*

Investing in a more robust state-wide pesticide exposure monitoring program will require an associated increase in capital and operational costs. Additionally, this expansion would provide insights into exposure metrics, but would not necessarily guarantee fully capturing representative exposures across an entire population, especially as the chemicals can be volatilized and spread far from their original application site. Collaboration across multiple community and institutional stakeholders may add more complexity to developing these research projects. Additionally, if grants do not prioritize or clearly outline requirements for community engagement, there is a risk that these resulting interventions may fail to effectively address the concerns of the impacted communities.

*ii. Allocate state government funding to encourage the application of precision technology enabled by large vision models*

Providing subsidies which reduce the cost of sustainable farming equipment is a well-established method used to encourage adoption of new technology. In 2024, the California Department of Food and Agriculture (CDFA) offered grants to support the adoption of sustainable manure management and water efficiency practices to reduce greenhouse gas emissions and water usage respectively. We propose the establishment of a similar state grant program to help fund farmers' adoption of precision spraying technology and aid their transition to more efficient pesticide application.

**We recommend increased funding placed into the CDFA's Conservation Agriculture Planning Grants program to encourage a full transition to precision sprayers.** Precision sprayers use video data collected by a set of cameras to spray individual crops instead of an entire region. This can result in a 70% reduction in pesticide usage and 87% reduction in spray drift to nearby communities and ecosystems (Chen 2013; Warneke 2020). Precision sprayers have a significant up-front cost to purchase and implement, but they reduce farmers' operating costs over the long term. Strategic and creative funding programs could help amortize the acute costs that are currently a barrier to adoption. For example, providing dedicated CDFA grants to subsidize adoption of precision spraying systems would allow farmers to mitigate the environmental impact of their pest management, while also increasing long-term profit. In addition to assisting with the costs of the sprayers, these grants should include funding to train workers to use new systems, as this is another obstacle slowing adoption of precision sprayers. To ensure that these grants do not exclusively benefit larger farms, we propose providing additional targeted funding for farmers who make up to $400,000 in annual gross sales. This threshold is already used in the California Underserved and Small Producer (CUSP) program, which provides relief and assistance to small farms.

*Advantages*

Precision spraying systems can reduce pesticide usage by nearly 70%, depending on crop type (Chen 2013). Increasing wide-spread adoption of these systems could result in a massive decrease in the unnecessary release of extra pesticide into nearby communities and water sources. In addition to the environmental benefits, these systems significantly reduce yearly expenses for farmers, and state-provided financial incentives for adoption of these systems would help ease the initial cost.

*Disadvantages*

Despite the reduction to upfront costs, financial incentives do not address the difficulty of incorporating these systems into existing workflows and training employees to use them. We propose inclusion of funds for workforce development, but the time required to train employees and implement new systems is unavoidable. Additionally, precision spraying systems are still new to the market and their long-term durability and reliability have not yet been established, preventing a complete cost-benefit analysis. Furthermore, although the resultant model may be efficient to run on farm equipment, the training of large and robust AI vision models is energy intensive. This could result in a tradeoff between efficient pesticide application in the field and the water and energy consumed near computing centers to produce new models.

*iii. Invest further into the development of pesticides for both easier application and less off-target effects through CDPR Pest Management Research Grants*

The above recommendations may improve public health outcomes. However, further research into alternative pesticide types will be necessary to ensure long-term efficacy and less off-target effects of pesticide use (CCST 2025). We recommend further investment into novel pesticide formulations which may replace or supplement CDPR's existing "Priority Pesticides". In support of this goal, one of the major priorities stated in the 2023 CDPR "Accelerating Sustainable Pest Management" policy memo is to support "the fast-tracking of alternative projects" to high-risk pesticides (CDPR 2023). Recent legislation in California (AB 363 2023) has also been passed to limit the use of traditional neonicotinoid pesticides in non-commercial settings (Assembly Bill No. 363 2023).

At the same time, the amount of biopesticides used in California has increased by 2,826,391 pounds (56%) from 2013 to 2022 (CDPR 2022). Further development of other promising biopesticides is needed in order to bring them to market (CCST, 2025).

While funding has been previously provided to generally "advance integrated pest management (IPM) knowledge, tools and practices in agricultural, urban and wildland settings," we recommend that further focus be placed specifically on the development of biopesticides and phytopesticides, which are molecules of plant origin, and their potential extension to practical use (CDPR 2023).

CDPR pest management grants totalled $3,150,000 in 2023, with emphasis on improving IPM in urban areas and underserved communities, as well as decreasing the use of high-risk pesticides (CDPR 2023). However, only one project in 2023 was funded for biopesticide development. Further biopesticide projects may focus on integrating biopesticide use into IPM practices, introducing novel compounds, or developing improving testing to mitigate potential off-target effects of biopesticides (Wend et al. 2024). **We recommend that in future years, specific allocations are made for biopesticide-related projects (California Grants Portal 2023). Additionally, we suggest the continued support of projects focused on the production of plant and algal produced pesticides.**

*Advantages*

Increased focus on biopesticide development will provide novel alternatives in the market that can be further developed through extension to field utilization. These biopesticides, such as bacterial products and plant-derived antimicrobial peptides, have viability in field applications (Huang et al., 2021). Furthermore, while mostly used against various orders of insect pests in agriculture, bacterial biopesticides can also curb the growth of plant-harming bacteria and fungi (Mawcha et al., 2025). The development of additional biopesticides may also stimulate the creation of new business and startups in California. An example of such a business is Marrone Bio Innovations, a biopesticide company founded in 2006 that is continuing to grow today. Further development of biopesticides in California may allow the state to become an exporter of these compounds to other areas of the country (Verified Market Research 2024).

*Disadvantages*

Disadvantages include the difficulty in ensuring farmer utilization of these pesticides, especially as their efficacy remains to be determined. Utilization

of these pesticides may need to be accomplished along with conventional pesticides (CCST 2025). Furthermore, financial incentives may be effective for short-term recruitment but may not translate into long-term retention (Winkler-Schor & Brauer 2024). Thus, outreach initiatives and extension of pilot projects must also be a focus of CDPR in encouraging the adoption of these technologies. Additionally, some biopesticides may be only specific for one pest, leading to rapid pesticide resistance (Kumar et al. 2021). This may necessitate the rotation, or ongoing production of, additional biopesticides to supplement those currently in use (Ayilara et al. 2023).

**IV. Costs of inaction**

A pressing issue in California agriculture is the development of pesticide resistance, which would create pests insensitive to current chemical treatments (Roche 2022). In the near future, it is possible that most major pests will be resistant to the predominant chemical pesticides used in the field (EPA 2018). While resistance is also a concern with biopesticides, the wholesale application of a limited number of chemical pesticides accelerates the development of resistant pests.

Furthermore, the broad use of pesticides may continue to cause health problems across the state, from which follows increased health care costs and loss of productivity This may particularly affect agricultural areas such as the Salinas Valley and the San Joaquin Valley, where residents were found to breathe in detectable levels of pesticides (KALW 2020; Bennett et al. 2025). Wholesale pesticide applications may also be more costly and have increased impacts on the surrounding environment (Zanin et al. 2022). Biological alternatives, public health interventions, and precision spraying may mitigate both environmental and public health effects.

**V. Summary of recommendations**

We recommend a focus on all three of the above policy recommendations. A plausible implementation strategy may be enacted in three major steps, such that each recommendation is enacted at a different time scale. Recommendation I may be implemented first to characterize health exposures and empower communities with exposure information on a more granular scale. The results of these studies may provide more immediate information about pesticide health risks, especially in vulnerable communities, motivating research in the fields mentioned in recommendations II and III. Recommendation II may subsequently be implemented, such that existing precision spraying technology is used to reduce the harm of commonly used pesticides. The large vision models used by existing commercial sprayers are already highly effective, and are becoming increasingly robust with recent strides in general model development. The use of this technology may in turn slow the development of pesticide resistance and the drift of chemical residues into agricultural communities.

Finally, further research into biopesticides, as mentioned in Recommendation III, may be supported in the form of longer term projects. One such project may develop a set of biopesticides that can be rotated to slow the development of pesticide resistance. These biopesticides projects will allow researchers to expand the options available for future growers to use in controlling pests.

Taken together, these recommendations may be enacted in series to better understand the health effects of pesticide use and exposure, improve pesticide application, and diversify the molecules available for pest management.

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