Chapter 16
The Impact of Climate Change and Extreme Weather Conditions on Agricultural Health and Safety in California

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Introduction

Research indicates that the increasing frequency and severity of extreme weather events, which have been seen across the United States and in other countries, are related to climate change [1, 2]. The impacts of these events on agriculture are particularly important given its central role in food production, nutrition, employment, and the economy. Disruptions to agricultural production, changes in farm management and agricultural processes, uncertainty in agricultural markets, and exposure of workers, crops, and livestock to more extreme weather conditions are among the impacts of climate. Due to their outdoor work in all weather conditions, agricultural employers (i.e., farm owners, farm labor contractors) and farmworkers are exposed to increased occupational hazards in addition to the climate-related health risks faced by the general public. Farmworkers, or those hired to perform agricultural tasks, such as planting, irrigating, weeding, and harvesting, are at particular risk due to their socioeconomic status and vulnerability in the workplace. Unfortunately, there is a gap in existing literature regarding agricultural occupational health and safety and the hazards introduced or exacerbated by climate change and extreme weather.

This chapter describes the impact of extreme weather events on the health and safety of farmworkers with a focus on California. We use three extreme weather

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conditions – drought, heat, and wildfires – to highlight this impact. We also explore the awareness and preparedness of agricultural employers and farmworkers using findings from our qualitative study in California [3]. The chapter then discusses existing policies and practices for protecting farmworkers from the impacts of extreme weather. Finally, recommendations for future research and translation of research findings are explored. Given the size and relevance of California's agricultural sector, its responses to extreme weather-related challenges have effects on consumers worldwide. In addition, thanks to its notable climate change adaptation and mitigation efforts, the state is positioned to develop occupational health and safety policies and practices that serve as examples for other agricultural states and regions.

Climate Change and Occupational Health and Safety

While the impacts of climate change on public health have received considerable academic and policy attention, impacts on occupational health and safety have been relatively overlooked, especially with respect to agricultural workers. Schulte and Chun conducted a systematic review of existing literature to identify the effects of climate change on worker health and safety [4]. They developed a framework with seven areas where an increase in prevalence, distribution, and severity of occupational illnesses and injuries may be observed as a result of climate change. These areas included (1) increased ambient temperature, (2) air pollution, (3) ultraviolet exposure, (4) extreme weather, (5) vector-borne diseases and expanded habitats, (6) industrial transitions and emerging industries, and (7) changes in the built environment [4]. In 2016, the framework was updated with new research findings and three additional considerations: (1) mental health effects of climate-related occupational hazards, (2) economic burden of climate-related occupational safety and health hazards, and (3) geoengineering and the potential for worker hazards [5]. The California Department of Public Health (CDPH) Climate Change and Health Equity Program identified outdoor workers and farmers as among the most vulnerable populations with respect the impacts of climate change. Notably, immigrants were also listed as one of the most vulnerable populations, and farmworkers in California are predominantly immigrants [6]. The effects of climate change on health and safety as described by Schulte and colleagues, and the vulnerable populations identified by the CDPH, highlight the need for a specific focus on the agricultural workforce. Increased ambient temperature, air pollution, extreme weather, vector-borne diseases, and mental health are all particularly relevant in the context of the agricultural industry. In this chapter we present a preliminary framework for climate change and agricultural health and safety (Fig. 16.1).

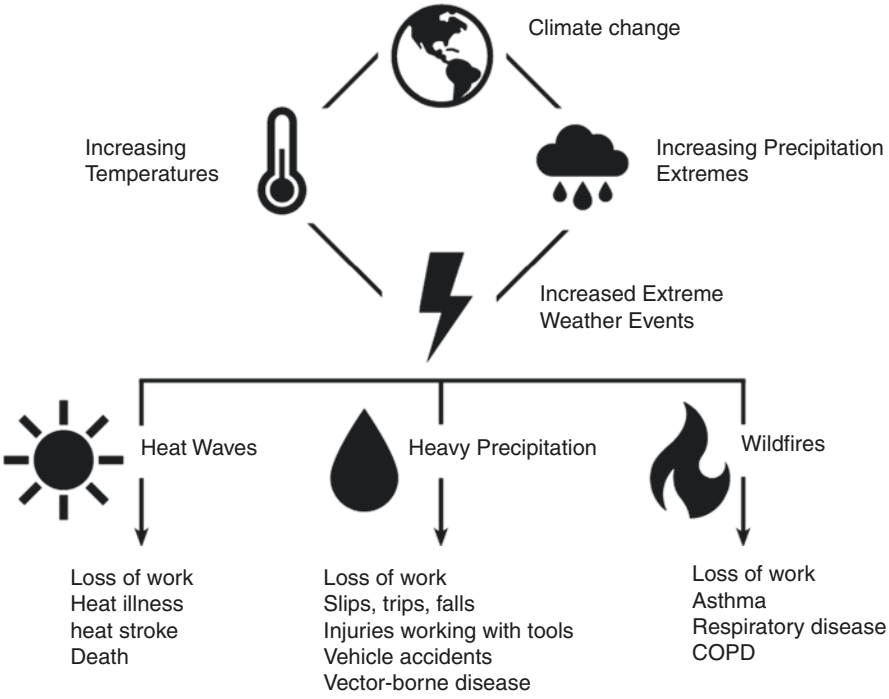

Fig. 16.1 Climate-related occupational hazards to agricultural workers

California Agriculture and Its Workforce

California produces one-third of the nation's vegetables and two-thirds of its fruits and nuts. In 2017, the state had over $20 billion in agricultural exports and registered $50 billion in agricultural cash receipts for over 400 commodities [7]. However, California's large agricultural sector relies on its Mediterranean climate, various micro-climates, and diverse range of marine and terrestrial ecosystems for water and agricultural inputs – all of which are experiencing changes due to climate change. The state has a mix of perennial crops (e.g., almonds, tree fruit, grapes) and annual crops (e.g., salad greens, tomatoes, melons) with varying labor demands with agricultural employment concentrated in the San Joaquin Valley, Central Coast, and Southern Coast, where many of the commodities produced are labor-intensive and hand-harvested. Weather factors into each stage in the growing process, from field preparation and planting to harvesting.

There has been a steady decrease in the size of the agricultural workforce of self-employed farmers, family farmers, and hired farmworkers since 1950. At the same time, the proportion of hired farmworkers in the overall agricultural workforce has increased [8]. California employs an estimated 800,000 farmworkers who work seasonally, rarely hold full-time equivalent jobs for an entire year, and earn an average annual income of less than $18,000 [9, 10]. An estimated 90% of California's farmworkers were born in Mexico, and approximately 60% are unauthorized to work in the United States [11]. In addition to the substantial Spanish-speaking farmworker population, California has a sizable number of workers who speak indigenous languages from Mexico (e.g., Mixteco, Zapotec, Trique), are recent immigrants, and are less likely to speak Spanish. Many farmworkers are paid piece-rate (i.e., by the number of crops picked vs. a set hourly rate), which can result in the pressure to continue working even while enduring physical risk in response to economic hardship [12, 13]. Federally, farmworkers are excluded from some labor law protections in the Fair Labor Standards Act and National Labor Relations Act, including overtime pay and collective bargaining. California has responded with state laws, including Assembly Bill 1066, which provides phased-in overtime pay for farmworkers. California farmworkers have had the right to organize since the mid-1970s, and only a few other states provide this protection.

Farmworker Occupational Hazards and Health Status

Farmers and farmworkers are at higher risk of fatal and non-fatal injuries than workers in most other sectors [14, 15]. In 2016, there were 417 farmer/farmworker deaths from work-related injuries recorded nationally [14]. Common agricultural occupational injuries include strains and sprains, falls, and musculoskeletal trauma. Farmworkers are also at risk of heat illness, hearing loss, pesticide exposure, and stress. The Mexican Immigration to California: Agricultural Safety and Acculturation (MICASA) study, which followed a cohort of immigrant farmworkers in California's Central Valley, found a 1-year cumulative agricultural injury incidence of 4.3%, with impacts from objects, falls, and cutting instruments as the most frequent causes of injuries [16]. While there has been a downward trend in occupational fatalities in California since 1999, agriculture had the highest fatality rate of all industries from 2013 to 2017, at 11 fatalities per 100,000 workers compared to the statewide average of 2.2 per 100,000 for all industries [17].

Farmworkers experience many of the same chronic diseases as the general population but have limited health care access. According to the U.S. Department of Labor's National Agricultural Worker Survey (NAWS), which provides information on the work history and health status of hired crop workers, less than a third of those in California have health insurance [18]. To add to this, few recent studies have

systematically assessed farmworker health status. One such study, the California Agricultural Worker Health Survey (CAWHS), a statewide, cross-sectional survey conducted in 1999, found an obesity prevalence of 29.0% among male farmworkers and 38.0% among their female counterparts [19]. In contrast, obesity prevalence among Californians overall was 19.3% in 2001 and 27.0% in 2014 [20]. CAWHS also documented elevated cholesterol prevalence, as well as many previously undiagnosed health conditions in California farmworkers relative to the general population. Thus, promoting the health and safety of farmworkers in a context of increased hazards brought about by climate change is complicated by their existing higher risk of occupational injury, illness, and chronic disease, and exacerbated by insufficient health insurance coverage and access to health care [21].

Climate Change and Extreme Weather in California

Climate change is at least partially responsible for the increased incidence of extreme weather conditions [22]. Extreme weather refers to unpredictable, unexpected, and unusually severe weather as compared to the range of weather that has occurred in a particular area or region in the past. (Extreme weather is also referred to in the literature as *climate extremes* and *extreme climate events*.) Current predictions suggest the frequency of extreme weather events, including heat waves, cold waves, droughts, and intense precipitation and winds (e.g., thunderstorms, hurricanes, and tornadoes), will continue to increase over time. As the frequency and severity of these extreme events increase, so will wildfires and other downstream impacts of climate change [1].

Like other agricultural regions around the world, research suggests that California has experienced severe weather associated with climate change. Precipitation in California has become more unpredictable over time, with record-setting extremes for both precipitation and drought [23]. In January 2014, the governor of California declared a state of emergency after many consecutive years of drought with record temperature highs. The severe drought led to water shortages, groundwater overdraft, critically low streamflow levels, and increased wildfires. Researchers suggested a greater occurrence of drought years in California over the past two decades versus the past century, and indicated the state's relatively short rainy season, yielding low precipitation in the context of warmer temperatures, is more likely to result in future drought years [24]. Despite this, in late 2016 and early 2017, California experienced a season of extreme precipitation which resulted in severe flooding, overflow, and damage to the Oroville Dam, as well as the resultant evacuation of adjacent communities. While extreme weather events impact all members of society and occupational sectors, farmworkers and the agricultural industry are particularly vulnerable to these events.

Impact of Extreme Weather in Agriculture

Agriculture is directly dependent on climate and affected by the types of changes brought about by extreme weather. Direct impacts of extreme weather, such as flooding, drought, hurricanes, freezes, and extended heat waves, can result in the loss of crops and livestock. US agriculture sustained an estimated $700 billion in losses over the past 30 years (1980–2010), based on 90 extreme weather events [25]. Pathak and colleagues conducted a detailed review of climate change trends in California agriculture and found many negative impacts identifying potentially significant challenges to the industry in the future [26]. California is expected to experience increased variability in precipitation, snowpack, and extreme weather events such as heat waves, drought, and flooding. These changes will impact agricultural growing seasons, water availability, and pest life cycles. Climate impacts on crop yields are dependent on crop type, whether increased temperatures occur in summer vs. winter, and chill hours required for the crop [26]. While the economic impact of extreme weather on agricultural production should not be underestimated, and considerable literature examines short- and long-term impacts, corresponding impacts on the hired agricultural workforce are often overlooked. In addition to economic uncertainty experienced by agricultural employers and farmworkers, new occupational health and safety risks are likely to emerge from agricultural adaptations to climate change, such as the adoption of new crops or farm technology.

Perceptions of Risk: Impact of Extreme Weather on Occupational Health and Safety in California Agriculture

We are currently studying the experienced and anticipated impacts of extreme weather on occupational health and safety in agriculture through interviews and focus groups with agricultural employers and farmworkers, respectively. Our study focuses on extreme weather events, including heat, drought, rain, and wildfires, that are becoming more frequent throughout California. The research was approved by the University of California, Davis Institutional Review Board with interviews and focus groups conducted in 2018. The objective of the study is to identify workplace hazards and develop educational resources or other tools to assist agricultural employers and employees in adapting to an increase in extreme weather events. In the following sections, three impacts of extreme weather are examined: drought, heat, and wildfires. The ways in which these events exacerbate existing occupational health and safety risks of agricultural employers and farmworkers are discussed as reported in the preliminary results of our qualitative research as well as in the existing literature [3].

Case Study: Drought

A drought is defined as a prolonged period of below average precipitation that can be aggravated by hot temperatures. Climate change is likely to contribute to more frequent episodes of drought, which contribute to desertification, dust, air pollution, and airborne pesticide residue. These affect respiratory health among farmworkers and contribute to poor air quality for surrounding communities. Farmworker respiratory health is affected by dust from the soil, which may contain biological (e.g., microorganisms and mycotoxins) and chemical (e.g., gases and pesticides) allergens/immunogens. Farmworkers are exposed to dust while harvesting, pruning, or weeding crops; laying irrigation lines; dealing with livestock; or carrying out other tasks. A systematic review of respiratory health among farming populations found widespread prevalence of lung conditions such as asthma, chronic obstructive pulmonary disease (COPD), and decreased lung function [27]. More frequent droughts and the associated dust may exacerbate these conditions.

Coccidioidomycosis, commonly known as Valley Fever, is a respiratory disease that may be influenced by cycles of extreme precipitation and drought. Valley Fever is caused by a fungus that lives in the soil in dry climates, including portions of the California Central Valley and Central Coast as well as Arizona. While many people exposed to Valley Fever will not exhibit any symptoms, some individuals may experience pneumonia-like effects. In severe cases, Valley Fever may lead to death. Strategies to limit exposure of outdoor laborers (e.g., farmworkers) unable to cease work on windy days include the use of a National Institute of Occupational Safety and Health (NIOSH)-approved respirator and wetting the soil to reduce airborne dust.

During interviews carried out as a part of our research, agricultural employers discussed potential health and safety impacts of drought in the context of extreme heat and heat illness. Specifically related to drought, agricultural employers reported concerns about future access to water, feasibility of growing specific crops, and farming opportunities/capabilities. During focus groups, farmworkers reported an awareness of shorter rainy seasons and longer periods of drought. Most participants agreed that airborne dust was concerning and negatively impacting health, particularly during windy seasons or after drought. Dust was a serious concern for farmworkers because of the exposure to contaminants and pesticides that are mixed into the soil, inhaled, and absorbed through skin and eye contact or dermal-to-oral routes. Many farmworkers described the combination of breathing and working in dusty conditions, where pesticides and chemicals are prevalent, as a major health risk.

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Case Study: Heat

A heat wave is defined as a period of at least five consecutive days in which the maximum daily temperature is more than 5 °C above the average maximum temperature [28]. Heat waves, which have a direct effect on agriculture, are predicted to increase in frequency and severity over the next century as a result of climate change [29]. Because average maximum temperatures are based on historical temperatures, the presence of heat waves contributes to increasing average maximum temperatures over time.

Outdoor workers have been identified as particularly vulnerable due to their increased exposure to heat and their physically demanding work [6, 30, 31]. The Centers for Disease Control and Prevention (CDC) reported that from 1992 to 2006, 423 workers in agricultural and non-agricultural industries died from heat exposure nationally; 16% of these deaths were of those engaged in crop production. The average annual heat-related fatality rate for these workers was 0.39 per 100,000 crop workers, compared to 0.02 per 100,000 for all US civilian workers [32].

Exposure to hot temperatures can lead to dehydration, nausea, exhaustion, stroke, and even death. The signs of these heat illnesses can be confused with other ailments and are not always easy to recognize. Farmworkers are at greater risk for heat illness than other outdoor workers because they wear extra clothing and personal protective equipment that make it difficult to stay cool.

As the climate warms and heat waves become more frequent and severe, the risk of heat exposure will disproportionately increase for outdoor versus indoor workers. Despite this risk, there is currently no federal standard, and only a few state standards (e.g., that in California), to protect farmworkers from heat exposure. The California Division of Occupational Safety and Health Administration (Cal/OSHA) requires all agricultural employers to have a heat illness prevention plan as described in the California Code of Regulations Section (§) 3395, Heat Illness Prevention [33]. The plan must include training on exposure to risk factors for heat illness, the importance of drinking water, and common signs and symptoms of heat illness. Employers must also provide at least one quart of cool fresh water per hour per worker as well as rest and shade whenever temperatures exceed 85 °F. Additional provisions specify guidelines on acclimatization and high-heat procedures.

In their study of heat illness among farmworkers in California, UC Davis researchers found that despite working on farms that were compliant with the Cal/OSHA heat-related illness prevention regulations, nearly 8% of workers were at risk of heat-related illness, nearly 12% were dehydrated at the end of the day, over 12% suffered reversible acute kidney injury over the work day, and 50% said they had at some point experienced a heat illness symptom while working [13, 34]. While the *Water. Rest. Shade.* message of the Cal/OSHA heat standard safety campaign is clear and widely recognized, barriers continue to exist related to adherence and the intended prevention of illness. For example, the piece-rate pay structure was found to significantly increase a workers' risk of heat illness symptoms in the California Heat Illness Prevention Study [12, 13]. Workers being paid a piece-rate are more likely to push themselves physically and not take needed breaks due to the financial incentive to harvest more during a fixed amount of time.

In our study, agricultural employers reported being very familiar with the California heat standard and had policies in place at their worksite to comply. Heat was the most cited challenge for managing employees in the field. Employers reported that heat waves and overall higher temperatures have an impact on both crops and workers – if extreme heat results in crop loss, workers are likely to seek other employment. Agricultural employers tended to place responsibility for self-care on farmworkers and deferred to the workers' choices in workplace clothing, as was found in other heat illness studies [12].

Farmworkers also expressed knowledge of the heat illness prevention standard and identified heat illness as their greatest occupational health hazard. They identified certain groups as being more susceptible to heat illness, including elderly workers or those who had pre-existing health conditions. Farmworkers described symptoms related to heat that they experienced first-hand or witnessed others experiencing while working; these symptoms included dizziness, nausea, vomiting, headaches, and fainting, among others. Most participants agreed that adverse effects from heat would be greatly reduced if employers took additional steps to both provide and promote measures for workers to avoid heat illness. For example, proximity to the bathrooms often played an important role in decisions regarding water consumption during high temperatures, particularly for females. Farmworkers

reported that their ability to take precautions to avoid adverse health effects was highly dependent on supervisors and the work culture they created.

Case Study: Wildfires

Climate change will contribute to the increased frequency and severity of wildfires, which will impact agricultural employers and farmworkers. Exposure to wildfire smoke is strongly associated with mortality and respiratory morbidity including the exacerbation of asthma, COPD, bronchitis, and pneumonia [35–37]. While many negative health effects of acute wildfire smoke exposure in general have been identified, additional research is needed to identify the *long-term impact* of wildfire smoke exposure on human health [37]. Wildfire suppressants generally come in the form of retardants (ammonium phosphates) or foams (detergent-based organic chemicals). The health impacts from pesticide combustion in combination with wildfire suppressant chemicals are unknown [38]. Additionally, wildfire suppressant chemicals may leave residues on crops and in the air that livestock, farmworkers, and neighboring communities breathe.

Photo credit: Pixabay

In 2019, Cal/OSHA passed an emergency regulation to protect outdoor workers from wildfire smoke [39]. The policy stipulates that during wildfire smoke events, when the air quality index (AQI) is 151 or greater, employers are required to provide NIOSH-approved respirators for voluntary use by employees, and supply information on the proper use and limitations of respirators, and the negative health impacts of wildfire smoke exposure, among other topics.

In our study, which collected data prior to the Cal/OSHA wildfire smoke regulation, agricultural employers reported limited knowledge about the health effects of wildfire smoke exposure and how to obtain air quality information [3], unlike with heat illness. Employers had neither safety procedures to withstand wildfire smoke-induced poor air quality, nor discussions on the use of respirators or masks as potential protective equipment. Similarly, farmworkers reported experiencing occupational wildfire smoke exposure and having limited knowledge of appropriate safety precautions. As with heat illness, supervisors were discussed as having the greatest impact on the safety culture of the workplace, and farmworkers reported continuing work despite unsafe conditions due to economic need. We expect the new Cal/OSHA regulation to raise awareness of adverse wildfire smoke-induced health effects and promote strategies to reduce exposures of outdoor workers.

Discussion

Our qualitative study to identify existing and anticipated occupational health and safety hazards in California agriculture discovered varying levels of awareness of extreme weather events and potential strategies to reduce negative health impacts [3]. Additionally, important implications from workplace power dynamics emerged and should be considered during the development of occupational regulations, workplace policies, and climate change adaptation strategies. Specifically, farmworkers' economic dependence on employers and fear, due to a hostile political climate toward immigrants, reduce their ability to advocate for their own safety.

Of the three case studies discussed – drought, heat, and wildfire – agricultural employers and farmworkers are most aware of the negative health impacts of heat and the associated strategies to reduce risk. Despite widespread knowledge of the Cal/OSHA heat standard and health effects of heat stress, workers continue to experience heat illnesses, even on Cal/OSHA compliant farms. *Recommendation*: Research should evaluate the current standard guidelines and determine if modifications would reduce risk. For example, is the acclimatization period long enough? Are the temperature guidelines sufficient? What workplace policies would enable farmworkers to successfully advocate for the water, rest, and shade they need on high heat days. Additional evaluation of the impact of a piece-rate pay structure on adverse health outcomes should be conducted.

The new California state regulation to protect outdoor workers from wildfire smoke should be systematically evaluated from the outset. The regulation creates an opportunity to evaluate a state-wide policy intervention for wildfire smoke exposure. Farmworkers are a vulnerable population working long hours in physically demanding settings. Wildfire smoke compounds their health risks. This regulation is expected to raise awareness of poor air quality during wildfire events and reduce exposure for workers through respirator use, more frequent breaks, and work relocation when possible. *Recommendation*: Research should examine whether respirators provide adequate protection in the real-world agricultural working environment.

Do workers opt to wear respirators? If not, why not? How are employers adopting the new requirements and training their supervisors and workers? State and federal regulations are important components in protecting workers from occupational health and safety risks created and/or exacerbated by extreme weather; ongoing policy evaluations are critical to maintain and improve the intended outcomes.

Education and training are important risk-reducing strategies. All California employers are required to have an injury and illness prevention program (IIPP), which promotes workplace safety and health through the identification of potential workplace hazards and the planning of prevention methods. The California Worker Occupational Safety and Health Training and Education Program (WOSHTEP) provides IIPP training tailored to agricultural employers in English and Spanish [40]. In these trainings, employers gain skills in identifying the Cal/OSHA illness and injury prevention requirements, identify successful elements of an IIPP, and learn to create workplace hazard maps, in a participatory and collaborative setting. *Recommendation:* California employers should be encouraged to use their IIPP as a framework to consider and incorporate extreme weather-induced hazard prevention measures into existing workplace health and safety programs.

Our ongoing work demonstrates the importance of involving agricultural communities, worker advocates, and industry stakeholders in occupational health and safety efforts. *Recommendation:* Workplace safety messages should be tailored for the target audience (i.e., agricultural employers and farmworkers should not be given the same materials). Effective communication to employers should emphasize their obligation and responsibilities as employers with clear, concise, and practical messages. Farmworkers should be informed about their rights as workers and about strategies to take individual safety precautions. Though the majority of farmworkers in California speak Spanish, translation of existing English resources is not sufficient. Safety information should be culturally tailored, with limited text, and a clear message. When possible, agricultural employers and farmworkers benefit from in-person and interactive safety trainings that explain "why" a topic matters and "how" it affects them. As governments devise and implement climate change adaptation strategies relevant to the agricultural industry, they must recognize existing relationships of trust and paths of communication. For example, we find targeting agricultural employers and farmworker gatekeepers to be an effective approach to disseminate health and safety information and resources. Insurance companies, commodity groups, and grower associations are trusted entities by farmers and other agricultural employers, while community organizations, community workers, and *promotores,* or lay health leaders, are well regarded by farmworkers.

Conclusion

Extreme weather events are predictably unpredictable and thus present challenges to governments, communities, employers, and workers to prepare and respond with human health and safety at the forefront. Agriculture is increasingly being viewed

as part of the climate change solution. Farmers are contributing to climate change mitigation and adaptation efforts through the development of climate-resilient farms, the reduction of emissions, and the use of agricultural lands as carbon sinks, among other undertakings. At the state level, policies and programs aim to expand resource conservation districts, and promote water conservation, efficient irrigation and soil health management practices, dairy farm greenhouse gas reduction, farmland conservation, best practice sharing among farms, and climate innovation [41]. While efforts that promote sustainability can be inherently beneficial for health and safety (e.g., reduced pesticide use), all farm management adaptations should be considered through a lens of worker health and safety and assess whether new hazards emerge with practice changes.

In this chapter, we demonstrated the importance of considering the health impacts of climate change on agricultural workers, a particularly vulnerable workforce. Sustaining a healthy and productive agricultural workforce is an important part of climate change adaptation. The concurrence of climate change-fueled events like extreme heat, wildfires, and drought pose a unique risk to outdoor workers in California. It is challenging to separate the effects of individual climate-driven events to best protect workers. For instance, though protecting outdoor workers from wildfire smoke exposure or during a heat wave is a recognized climate-related challenge, currently proposed solutions put workers at risk of losing their employment. Additionally, though many mental health impacts of climate-driven events are known, the combined effects of stress and anxiety related to job security, immigration concerns, and occupational hazards has not been studied. Similarly, the frequent occurrence of extreme weather events may result in yet unstudied chronic health impacts for agricultural workers. A multipronged approach is needed to adequately protect agricultural workers amidst a changing climate. This approach should include farmworkers, agricultural employers, community organizations, and government, and be supported by state and federal regulations, educational opporstunities, technological innovations, and creative solutions.

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