CLIMATE EXTREMES IN CALIFORNIA AGRICULTURE

A Paper From:
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DISCLAIMER

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Preface

The California Energy Commission's Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program conducts public interest research, development, and demonstration (RD&D) projects to benefit California's electricity and natural gas ratepayers. The PIER Program strives to conduct the most promising public interest energy research by partnering with RD&D entities, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts focus on the following RD&D program areas:

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- Energy-Related Environmental Research
- Energy Systems Integration
- Environmentally Preferred Advanced Generation
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy Technologies
- Transportation

In 2003, the California Energy Commission's PIER Program established the **California Climate Change Center** to document climate change research relevant to the states. This center is a virtual organization with core research activities at Scripps Institution of Oceanography and the University of California, Berkeley, complemented by efforts at other research institutions. Priority research areas defined in PIER's five-year Climate Change Research Plan are: monitoring, analysis, and modeling of climate; analysis of options to reduce greenhouse gas emissions; assessment of physical impacts and of adaptation strategies; and analysis of the economic consequences of both climate change impacts and the efforts designed to reduce emissions.

The California Climate Change Center Report Series details ongoing center-sponsored research. As interim project results, the information contained in these reports may change; authors should be contacted for the most recent project results. By providing ready access to this timely research, the center seeks to inform the public and expand dissemination of climate change information, thereby leveraging collaborative efforts and increasing the benefits of this research to California's citizens, environment, and economy.

For more information on the PIER Program, please visit the Energy Commission's website www.energy.ca.gov/pier/ or contract the Energy Commission at (916) 654-5164.

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Abstract

Changes in extreme events may represent an important component of climate change impacts on agricultural systems in California. This study considered the relative historical importance of extreme events, as measured by insurance and disaster payments. The causes for each main event for 1993–2007 were classified into general categories to compare the importance of dry vs. wet and hot vs. cold events. The study found that the most common cause of both insurance indemnity and disaster payments is excess moisture, followed by cold spells and heat waves. Climate change is likely to have different effects on the occurrence of each of these, for instance with frosts becoming less common but heat waves increasing in frequency and duration. The specific nature of these changes and the overall net effect of changes in climate extremes remain a topic for future investigation.

Keywords: Frosts, floods, heat waves, crop insurance, disaster payments

1.0 Introduction

California is home to a vast array of crops, all of which vary in production from year to year. These variations are driven in part by changes in average climatic conditions, such as average temperature or total rainfall in a particular month or season. However, some of the most substantial changes can be traced to singular weather events, such as freezes, floods, or hail storms. These extreme events have long been acknowledged as a potentially important aspect of climate change, given that some extremes are likely to increase in frequency in the future.

Quantitative estimates of the impacts of extreme events on agriculture, however, have proven more difficult to develop than estimates of the effects of shifting average conditions. By definition, extreme events are rare, and therefore few exist with which to calibrate and test numerical models. Some rare examples do exist in which models are modified to include effects of extremes (Rosenzweig et al. 2002), but generally our understanding of how crops respond to extremes is limited. An alternative in this circumstance is to examine specific events that have affected agriculture and estimate the likelihood of these specific events into the future. In essence, this is equivalent to an extremely simple model that has a specified loss when a specified threshold is exceeded, and zero loss otherwise. While simplistic, these can provide a first-order estimate of the direction and magnitude of change in extreme event agricultural impacts.

Here we embark on this approach for California agriculture by reviewing the extreme events that have been important over the past 15 years. Individual events are identified through insurance and disaster records, and then classified according to the type of weather event that caused crop losses. This analysis, when combined with expectations of how each type of weather event will change in the future, allows a qualitative picture of how changes in extremes may impact California agriculture. In the future (Tebaldi 2006), more quantitative estimates of changes in specific events that have been important to agriculture will be investigated.

2.0 Methods

To measure the impact of extreme events on agriculture, we relied on data pertaining to the two primary sources of federal aid to farmers: federal crop insurance and emergency payments, programs, and loans. A private crop insurance market has not developed in the United States because of the high risks associated with farming, such as variable weather and unpredictable price markets. The federal crop insurance system is a branch of the U.S. Department of Agriculture, administered by the Risk Management Agency (RMA). The RMA manages and oversees the Federal Crop Insurance Corporation (FCIC), 16 private firms that sell and service policies. Basic crop insurance coverage is known as Catastrophic Risk Protection, which pays farmers affected by natural disasters 50% of expected yield at 60% market price. Catastrophic level premiums are 100% subsidized. Farmers have the option of buying additional coverage for up to 75% of their crop values. To encourage participation in the program, premiums on these policies are highly subsidized by the federal government. According to a USDA spokesperson, roughly 80% of U.S. farmers are enrolled in the program, and participation in California is currently around 60%. The crop insurance system is supplemented by additional disaster payments and programs and emergency loans.

Crop insurance indemnity records were obtained from the website of USDA's Risk Management Agency—originally sorted by year, state, county, and cause of loss.[1] The RMA provides data for individual counties and attributes losses to specific causes. The indemnity data were first summed by year over counties. Next, causes were binned into the larger categories of Heat, Cold, Fire, Excess Moisture, Wind, Failed Irrigation Supply, and Other from smaller causes of loss.

Several sources provide estimates of disaster payments. The Environmental Working Group, a nonprofit organization that monitors and analyzes government policies related to conservation, compiles disaster payment data from USDA records. However, their figures for disaster payments include all federal payments allocated in response to natural disasters not associated with the federal crop insurance program. The USDA's Economic Research Service also provides disaster payment data, but not disaggregated by specific cause or before 1996.

We therefore relied on a third source, the Storm Event database compiled by National Oceanic and Atmospheric Administration (NOAA).[2] When storms occur, forecasters enter data about the weather event into the database, including an estimate of crop damage. While the numbers of crop damage are only a best guess made by a NOAA employee, based on a variety of sources such as the media and other government agencies, they represent a reasonable measure of damages caused by specific events. However, it is important to note that these estimates are not of actual payments, but only of total damages to agriculture. Moreover, the errors of these estimates are not well known and may vary for different types of events. For example, damages from frost events may be estimated soon after the event, whereas the true magnitude of damage may not be apparent until harvest. In the database, data were originally sorted into individual events. For this project, data was summed by year and binned into broader categories: Heat, Cold, Fire, Excess Moisture, Wind, and Other.

3.0 Results

The indemnity and disaster data show similar patterns over the 1993–2007 period in terms of the average relative importance of different types of events (Figure 1). In both datasets, excess moisture related to heavy rainfall events has been the most costly type of extreme event over this period, followed by cold events and then heat events. Damages from wind, fire, and other events account for a substantially smaller amount of damages.

A breakdown of damages by year indicates that indemnity payments are much less variable than estimated disaster losses, with the former ranging from roughly $20–$130 million per year and the latter ranging from near zero to over $1 billion, in the case of 1998 (Figure 2). Since the disaster dataset assigns the cost to the date of the event, while the indemnity data record the date of payment, there is some mismatch between the years in which particular events show up. For example, the extreme freeze of late December 1998 shows up mainly in 1999 under the indemnity data, but mainly in 1998 in the disaster loss estimates. Nonetheless, the relative importance of different events tends to coincide between the two datasets.

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[1] www.rma.usda.gov/FTP/Miscellaneous_Files/cause_of_loss/

[2] www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~storms

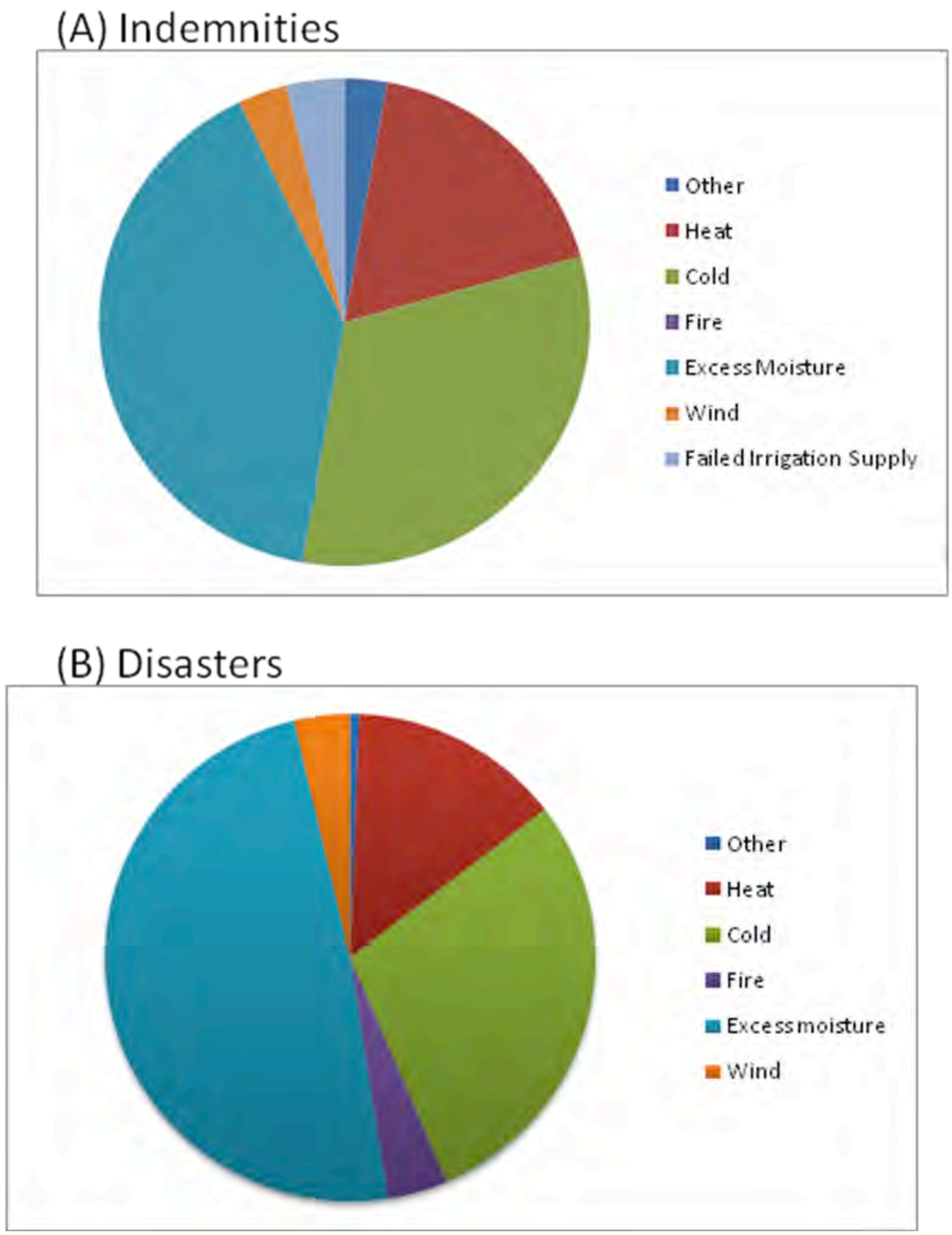

Figure 1. Relative amount of (a) indemnity payments and (b) estimated total losses from disasters attributable to different types of extreme events

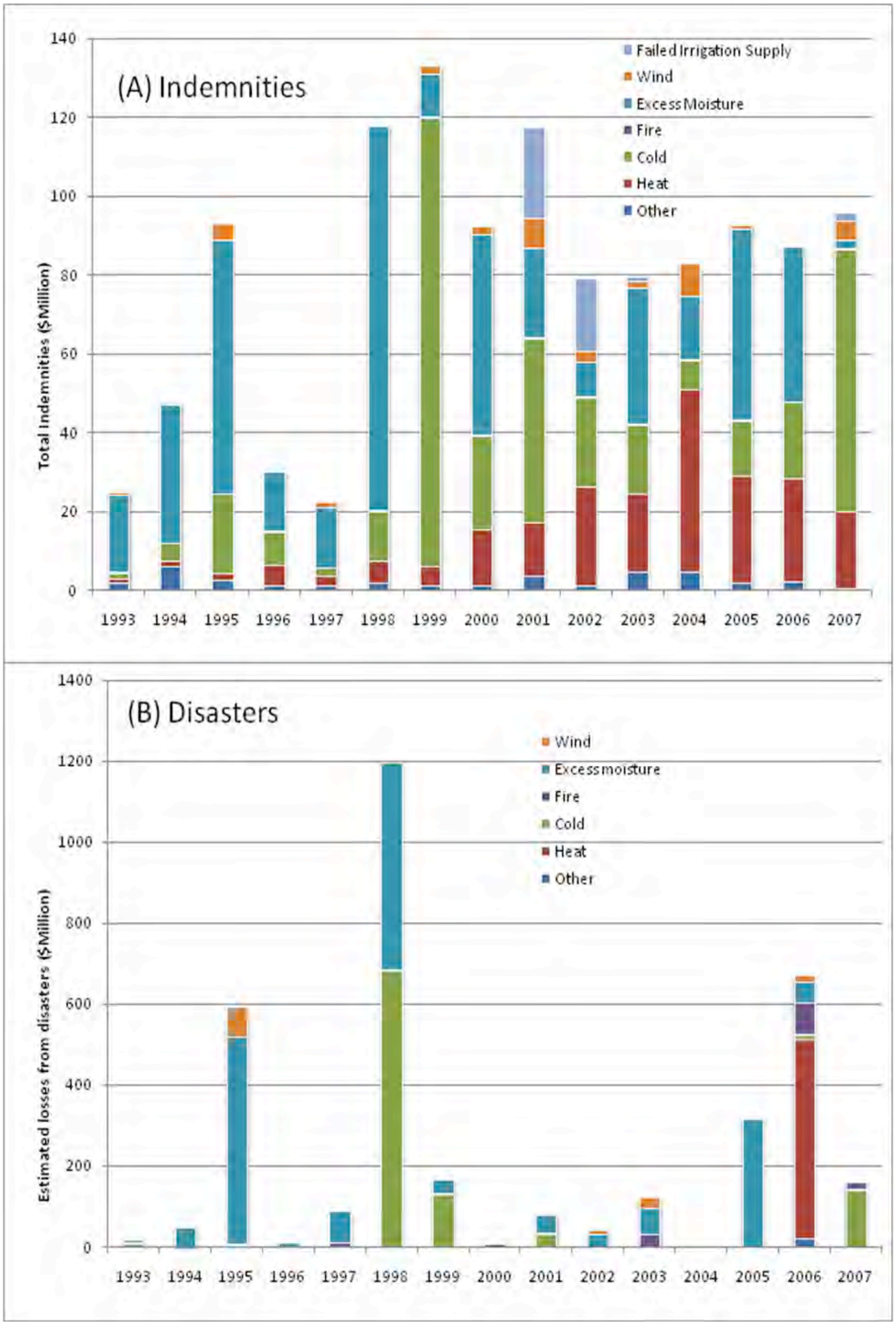

Figure 2 Total amount of (a) indemnity payments and (b) estimated total losses from disasters for each year, by type of extreme event

A list of the top 10 events from 1993–2007, according to the NOAA dataset, indicates that the single most costly event to agriculture in California was the freeze in December 1998, which led to major losses in various crops including oranges, lemons, olives, and cotton (Table 1). The second most important event was a heat wave in July 2006, which was especially damaging to the livestock industry. Heavy rainfall in the spring and winter months was responsible for the next three most damaging episodes in the past 15 years.

4.0 Summary and Future Plans

Data sets on crop damages from extreme events indicate that a wide variety of extremes have affected agriculture in California. Each of those events are likely to exhibit different changes in a warming climate. Cold extremes have already become less frequent throughout most of the world, and this trend will almost certainly continue into the future (Alexander et al. 2006; Tebaldi et al. 2006). Heat waves, in contrast, are very likely to become more frequent in the future (Tebaldi et al. 2006). Future changes in heavy rainfall and flooding events, which have been the most costly extreme events overall in California agriculture, are less clear. On a global basis, precipitation extreme metrics such as the number of days with more than 10 millimeters (mm) rainfall or the maximum amount of rainfall in a five-day period are both expected to increase, but the trends for California are ambiguous, with different climate models projecting different directions of change (Tebaldi et al. 2006).

Given that some extreme events will likely become more common while others become less so, the net change in crop losses related to extreme events remains unclear. In the future, we plan to quantify the potential changes in the types of events listed in Table 1, using multiple climate models to gauge uncertainty, in order to estimate net impacts.

Another important need is to evaluate the accuracy of the damage estimates used here by comparing them to more comprehensive studies of particular events. For example, the official numbers reported in the NOAA database appears to occasionally disagree with values given in the description corresponding to the event. Damage from the 2007 frost, for instance, is listed as $142 million, but the description within the NOAA database states that "Crop damage was estimated at almost $1.3 billion of California's annual $32 billion agricultural production with nearly $709 million in the Interior Central California ag area." More work is required to document the frequency and magnitude of these inconsistencies for different types of events.

Table 1. The top ten extreme events in California agriculture since 1993, based on the NOAA Storm Event database

Rank	Estimated Crop Losses ($M)	Start Date	End Date	Location	Event	Description
1	682	12/19/1998	12/29/1998	Sacramento Valley, San Joaquin Valley, Los Angeles, Santa Barbara, San Luis Obispo, Ventura	Extreme cold	When an arctic airmass began moving over California, the resulting cold air pool from advection and radiational cooling in the lowest levels of the atmosphere led to a devastating freeze to crops, especially citrus, and central and southern California experienced a week-long period of sub-freezing temperatures. The largest percentage of area crop losses were to lemons and oranges but several other unharvested fruit and vegetable crops were damaged, including avocados and broccoli.
2	492	07/16/2006	07/27/2006	Statewide	Excessive heat	New statewide heat records were set as temperatures soared above 100°F, and peak energy use in the state reached an all time high, causing power outages. With accompanying high humidities, consistent light or calm winds, and long durations of high temperatures, the heat negatively impacted agriculture, especially the dairy and cattle industry, although yield in produce from field crops and orchards also diminished to a slight extent.
3	342	03/10/1995	03/10/1995	Monterey, San Luis Obispo, San Benito, Napa	Flood	When the Salinas, Napa, and Pajaro Rivers overflowed due to heavy spring rains, agricultural land and crops experienced widespread flooding. Crops impacted included lettuce, broccoli, cauliflower, almonds, and strawberries.
4	310	05/01/1998	05/15/1998	Tulare, Kern, Madera, Fresno, Merced, Kings, Visalia	Heavy rain	New rainfall records were set as central California experienced heavy early spring rains and below normal temperatures. The wet, cold conditions damaged crops.
5	192	01/07/2005	01/11/2005	San Bernardino, Ventura	Heavy rain	A storm lasting 5 days dropped heavy rain across all of southern California, and flash flooding and mudslides caused millions of dollars of damage to farms, homes, businesses, vehicles, parks, roads, and bridges. Orchards were uprooted, and crops were damaged.

Table 1. (continued)

Rank	Estimated Crop Losses ($M)	Start Date	End Date	Location	Event	Description
6	142	01/06/2007	01/24/2007	Statewide	Freeze	Many records were broken as temperatures dipped into the 20s and 30s along the coast and the teens in the valleys. The freeze lasted for up to a week or longer, and local farmers were hit hard by the freeze. Affected counties were declared disasters areas and made eligible to receive federal aid.
7	131	04/10/1999	04/10/1999	Central and Southern San Joaquin Valley	Extreme cold	Unseasonably cool air led to minor frost episodes, which followed the disastrous freeze of December 1998. The combined effects of the two freezes caused substantial losses to agriculture, especially because during spring, deciduous trees, vineyards, and vegetable crops are vulnerable to temperatures less than 30 degrees.
8	113	03/01/1995	03/05/1995	Kern, Kings, Merced, Tulare, Riverside	Flood/rain/winds	Heavy rains caused extensive damage to agricultural crops due to flooding, and most field work stopped as growers waited for the soil to dry.
9	100	06/01/1998	06/30/1998	Southern San Joaquin Valley	Flood	Higher than normal water runoff from snowpack in the Southern Sierra Nevada filled reservoirs, and over 32000 acres of bottom land used for farming primarily south of Corcoran were inundated.
10	80	12/29/2005	01/03/2006	Mendocino, Sonoma, Napa, Kings	Flood	A series of strong Pacific storm systems began on December 18 and continued through the end of the month. Widespread low-land flooding occurred across Sonoma County with mainstem river gages along the Russian River remaining above flood stage for several days. An average of 4 to 6 inches of rain fell over a 24 hour period, 2 days after 1 to 3 inches drenched the same area. Severe flooding occurred as the Napa River exceeded flood stage at St. Helena.

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