

Drought and Health: Focus on Heat

Jesse E. Bell, PhD

Claire M. Hubbard Professor of Water, Climate and Health

Director of Water, Climate and Health Program at UNMC

Director of Water, Climate and Health at Daugherty Water for Food Global Institute

Department of Environmental, Agricultural, and Occupational Health

College of Public Health

University of Nebraska Medical Center

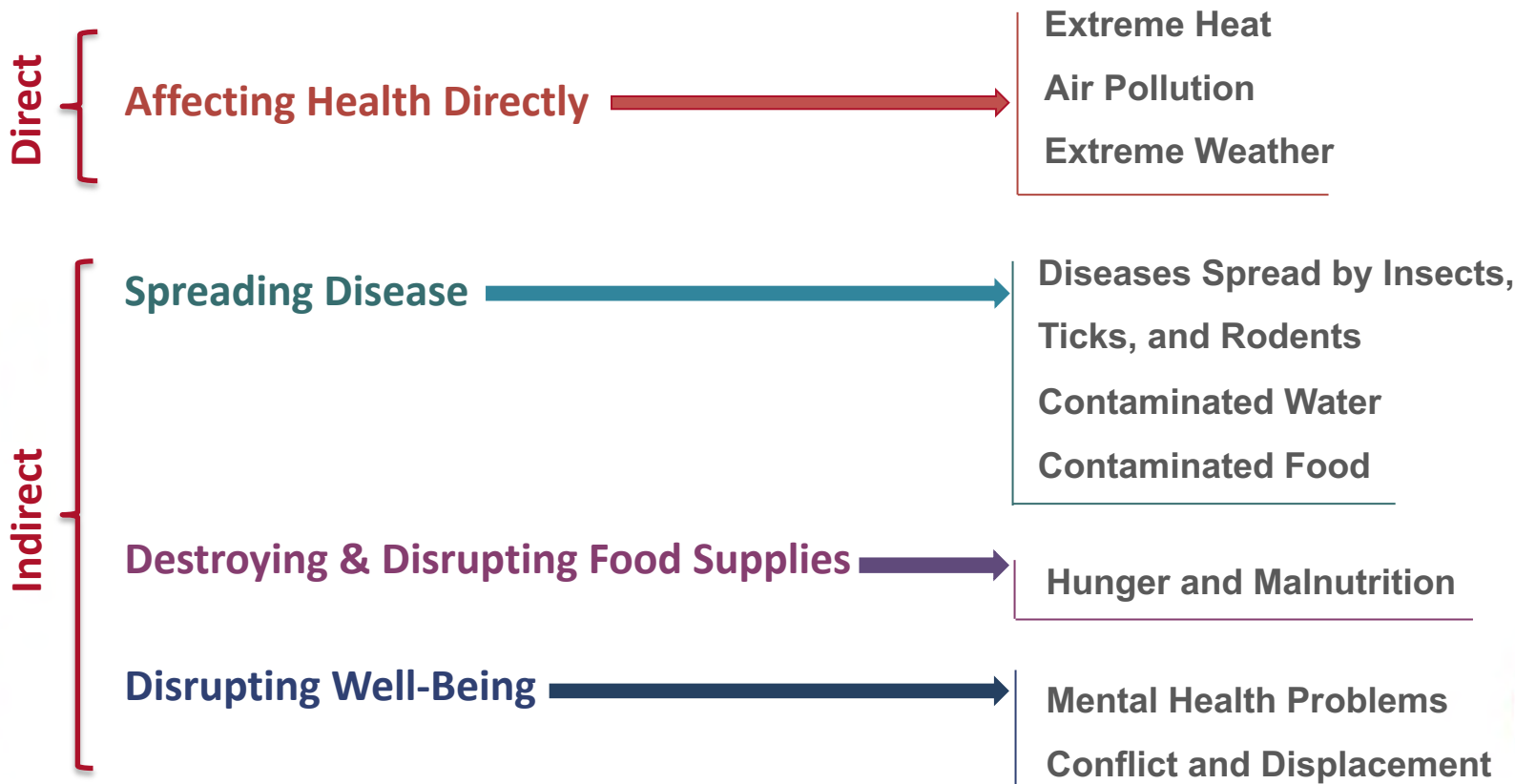
Adjunct Faculty at Gangarosa Department of Environmental Health, Emory University



Relationship of Climate to Health



Climate is Affecting Your Health





Drought has shaped society



An aerial photograph of ancient Mayan ruins, featuring several large stone pyramids and rectangular buildings. The ruins are surrounded by dense tropical vegetation and trees. The sky is filled with white clouds. A quote is overlaid in the center of the image.

“Floods kill people, but droughts destroy civilizations.”

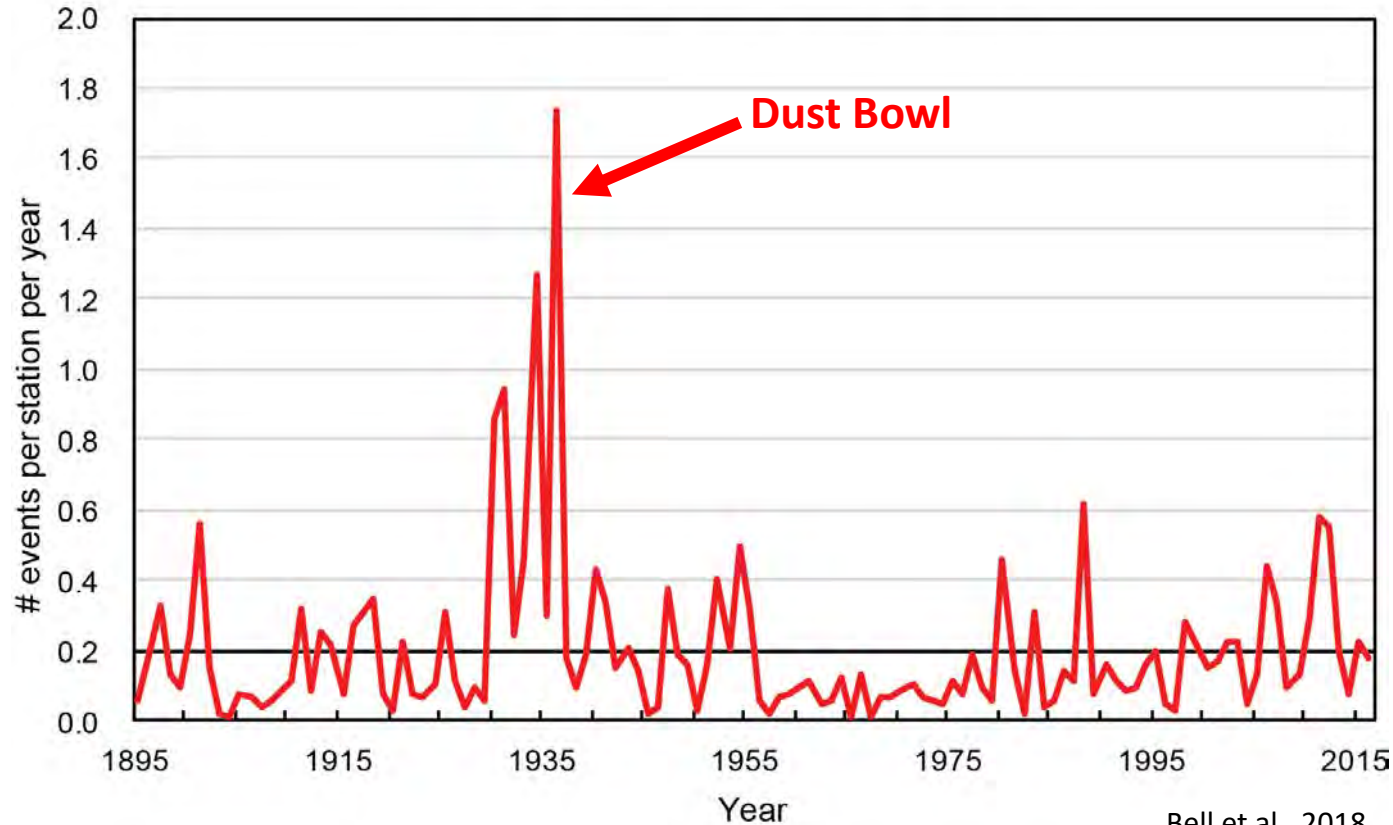
~U.S. Government Official at a Drought Meeting

Dust Bowl of the 1930s



Extreme Heat and Drought

Heat Wave Index: 4-day, 1-in-5yr



Bell et al., 2018

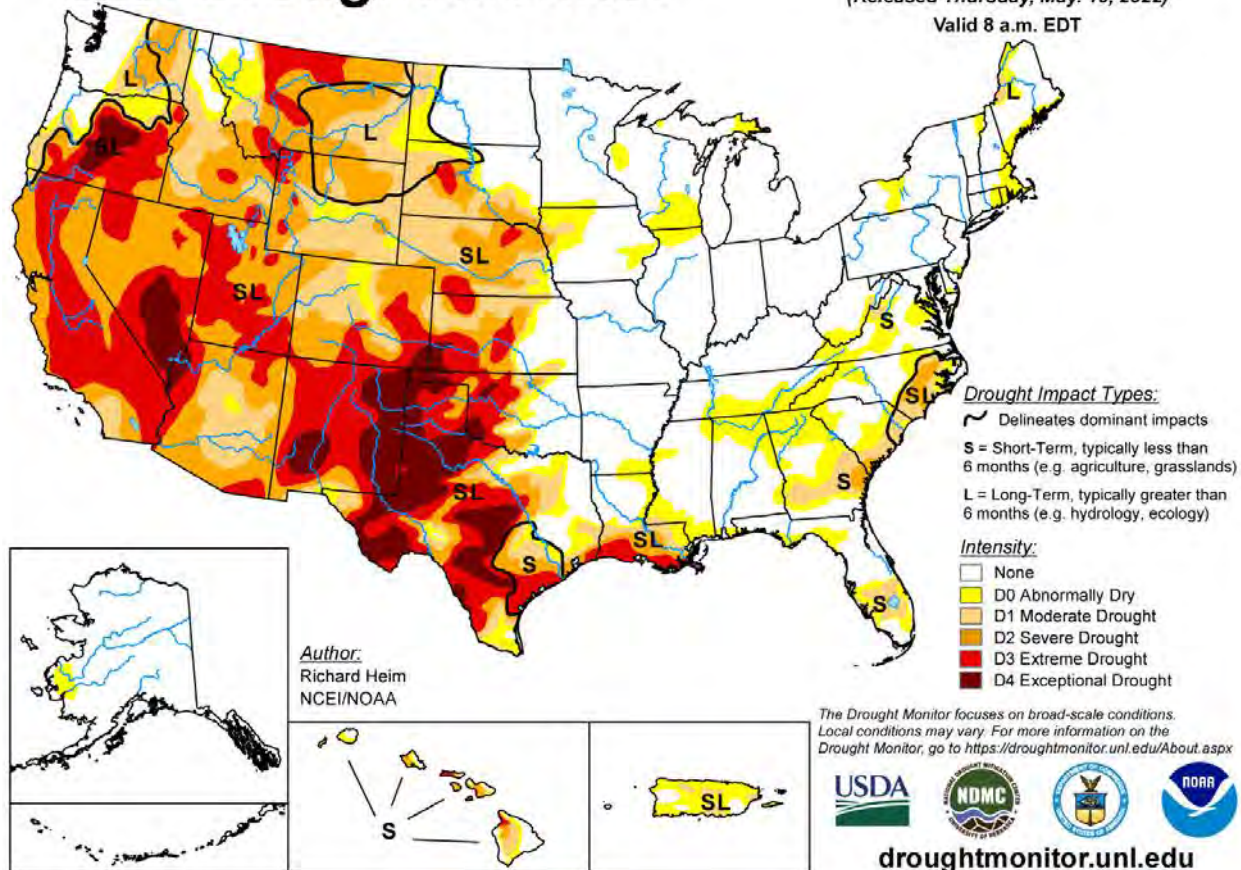


U.S. Drought Monitor

May 17, 2022

(Released Thursday, May. 19, 2022)

Valid 8 a.m. EDT



Connecting Drought to Health



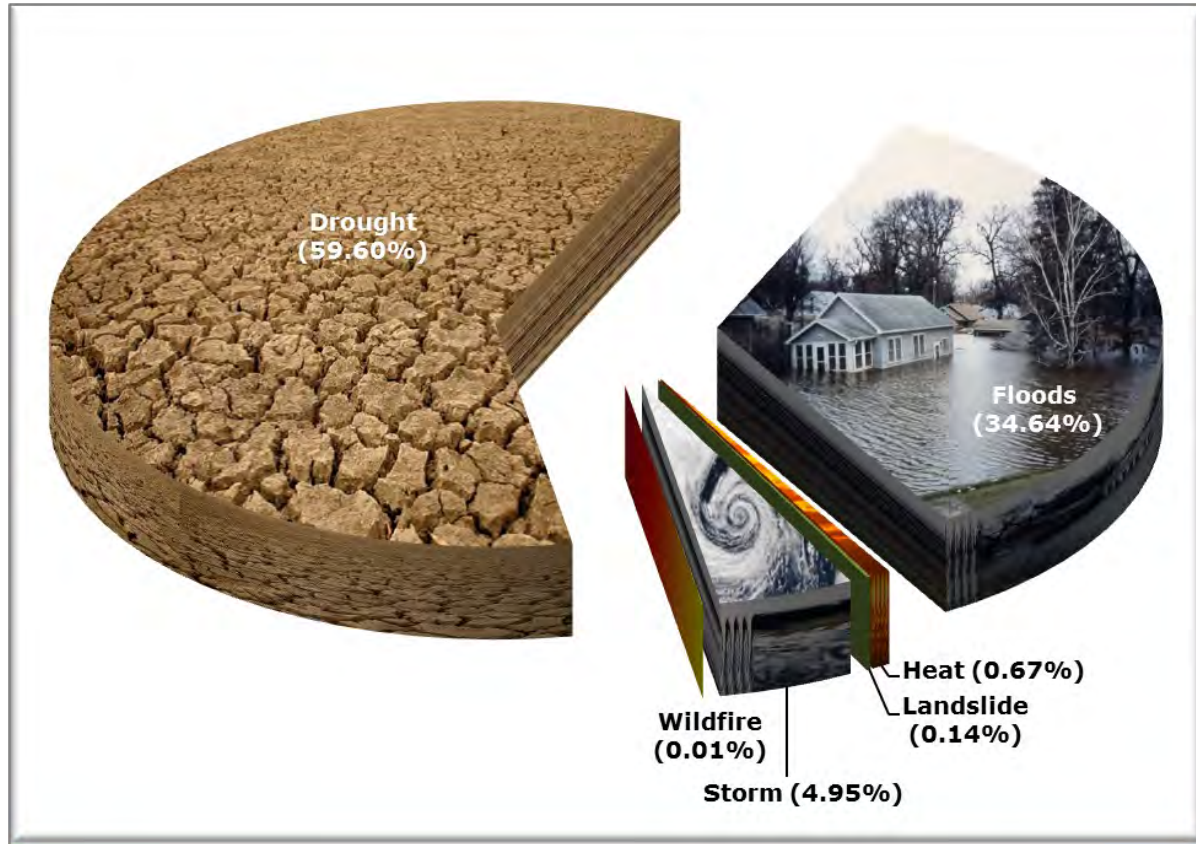
The difference between the fields on either side of dairy farmer Tom Barcellos is water. (Tomas Ovalle / For The Times)



© John Fedele/Blend Images/Corbis



Percentage of disaster-deaths worldwide according to each category of climate-related hazard, (1900-2013)

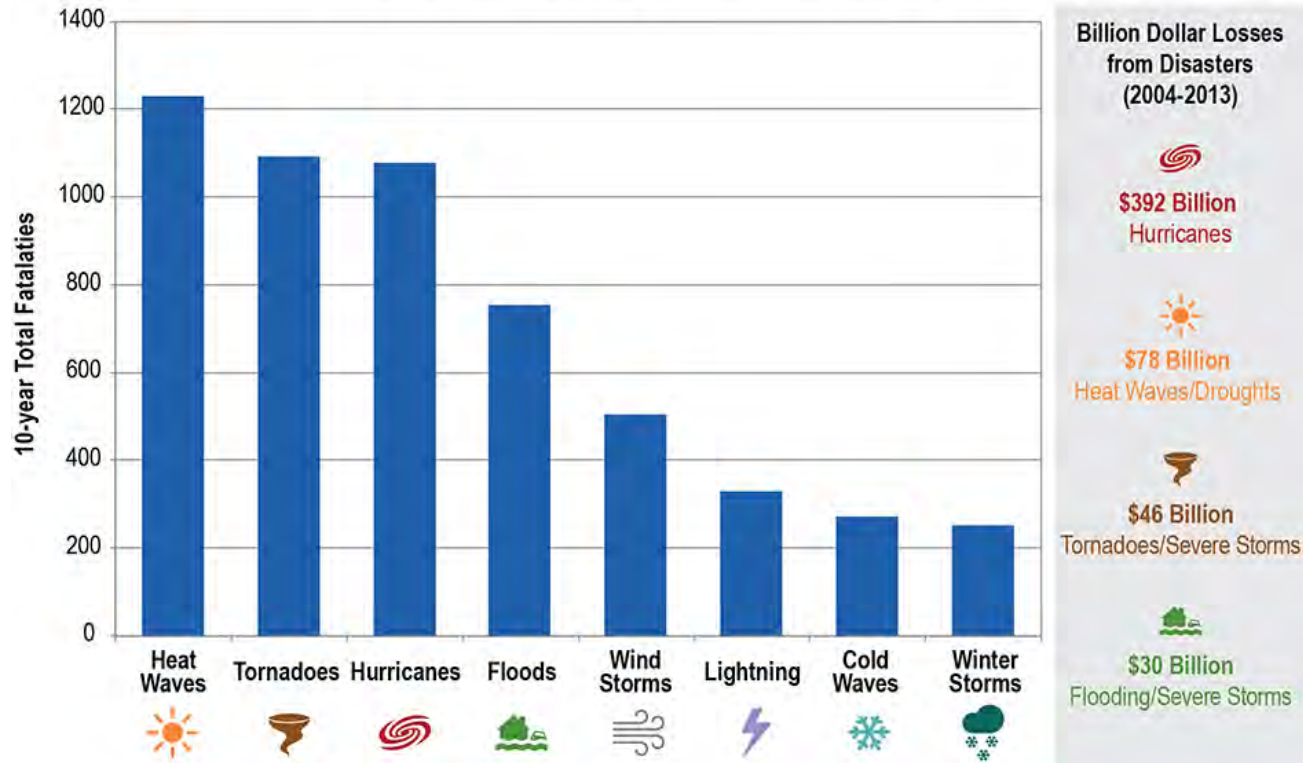


Source: Adapted from EM-DAT: The OFDA/CRED International Database, Belgium 2012
Keim, ME Extreme Weather Events: the role of public health



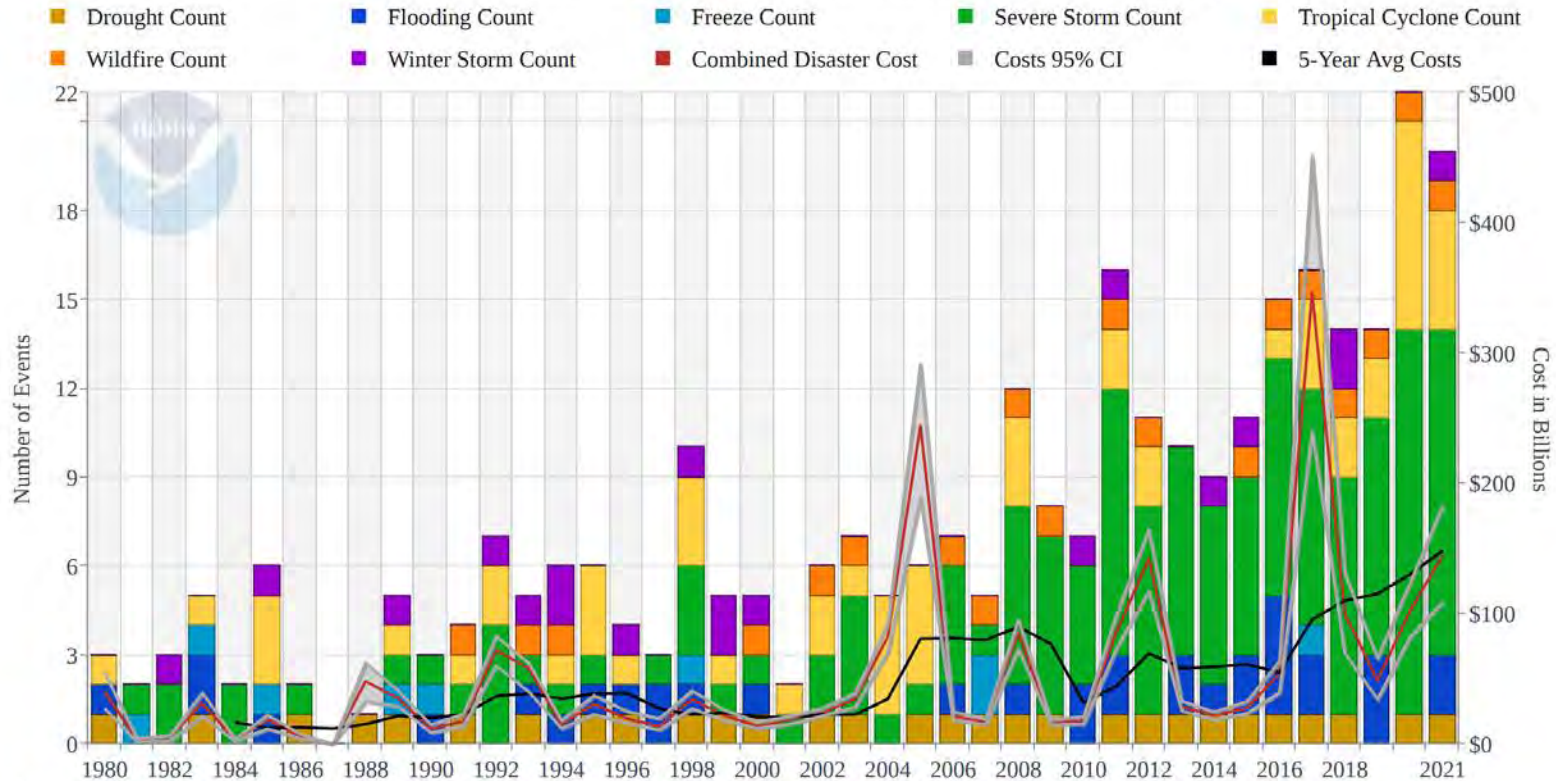
Drought Impacts

Estimated Deaths and Billion Dollar Losses
from Extreme Events in the U.S., 2004–2013



Billion-Dollar Disasters are Increasing

United States Billion-Dollar Disaster Events 1980-2021 (CPI-Adjusted)



















Updated: January 10, 2022



Summary Statistics

Billion-dollar events to affect the United States from 1980 to 2021 (CPI-Adjusted)

| Disaster Type | Events | Events/Year | Percent Frequency | Total Costs | Percent of Total Costs | Cost/Event | Cost/Year | Deaths | Deaths/Year |
|--|------------|-------------|-------------------|---|------------------------|---------------|----------------|--------------------|-----------------|
|  Drought | 29 | 0.7 | 9.4% | \$285.4B  | 13.2% | \$9.8B | \$6.8B | 4,139 [†] | 99 [†] |
|  Flooding | 35 | 0.8 | 11.3% | \$164.2B  | 7.6% | \$4.7B | \$3.9B | 624 | 15 |
|  Freeze | 9 | 0.2 | 2.9% | \$32.8B  | 1.5% | \$3.6B | \$0.8B | 162 | 4 |
|  Severe Storm | 143 | 3.4 | 46.1% | \$330.7B  | 15.3% | \$2.3B | \$7.9B | 1,880 | 45 |
|  Tropical Cyclone | 56 | 1.3 | 18.1% | \$1,148.0B  | 53.2% | \$20.5B | \$27.3B | 6,697 | 159 |
|  Wildfire | 19 | 0.5 | 6.1% | \$120.2B  | 5.6% | \$6.3B | \$2.9B | 401 | 10 |
|  Winter Storm | 19 | 0.5 | 6.1% | \$78.6B  | 3.6% | \$4.1B | \$1.9B | 1,277 | 30 |
|  All Disasters | 310 | 7.4 | 100.0% | \$2,159.9B  | 100.0% | \$7.0B | \$51.4B | 15,180 | 361 |

[†]Deaths associated with drought are the result of heat waves. (Not all droughts are accompanied by extreme heat waves.)

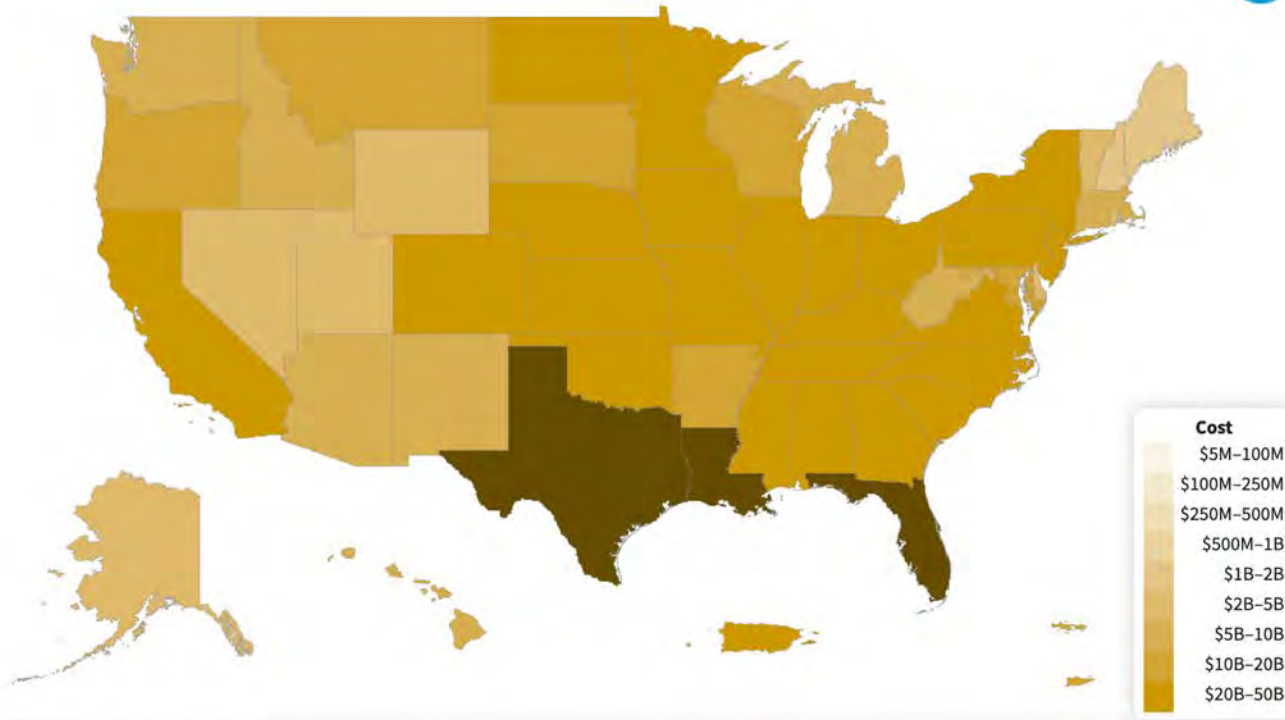
Flooding events (river basin or urban flooding from excessive rainfall) are separate from inland flood damage caused by tropical cyclone events.

The confidence interval (CI) probabilities (75%, 90% and 95%) represent the uncertainty associated with the disaster cost estimates. Monte Carlo simulations were used to produce upper and lower bounds at these confidence levels ([Smith and Matthews, 2015](#)).



1980-2021* NOAA Billion-Dollar Drought Disasters (CPI-Adjusted)

1980-2021 Billion-Dollar Drought Disaster Cost (CPI-Adjusted)



29 Events

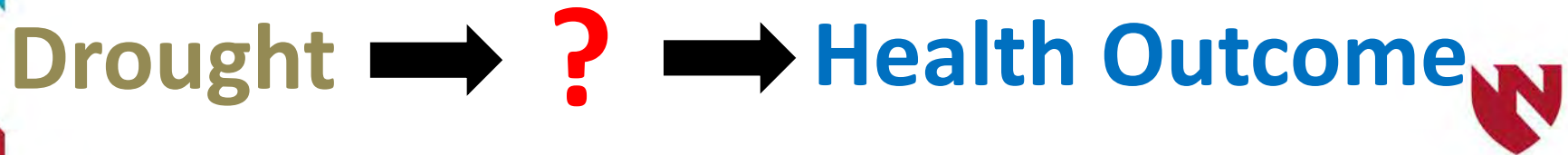
\$285 Billion Lost

4,139 Deaths

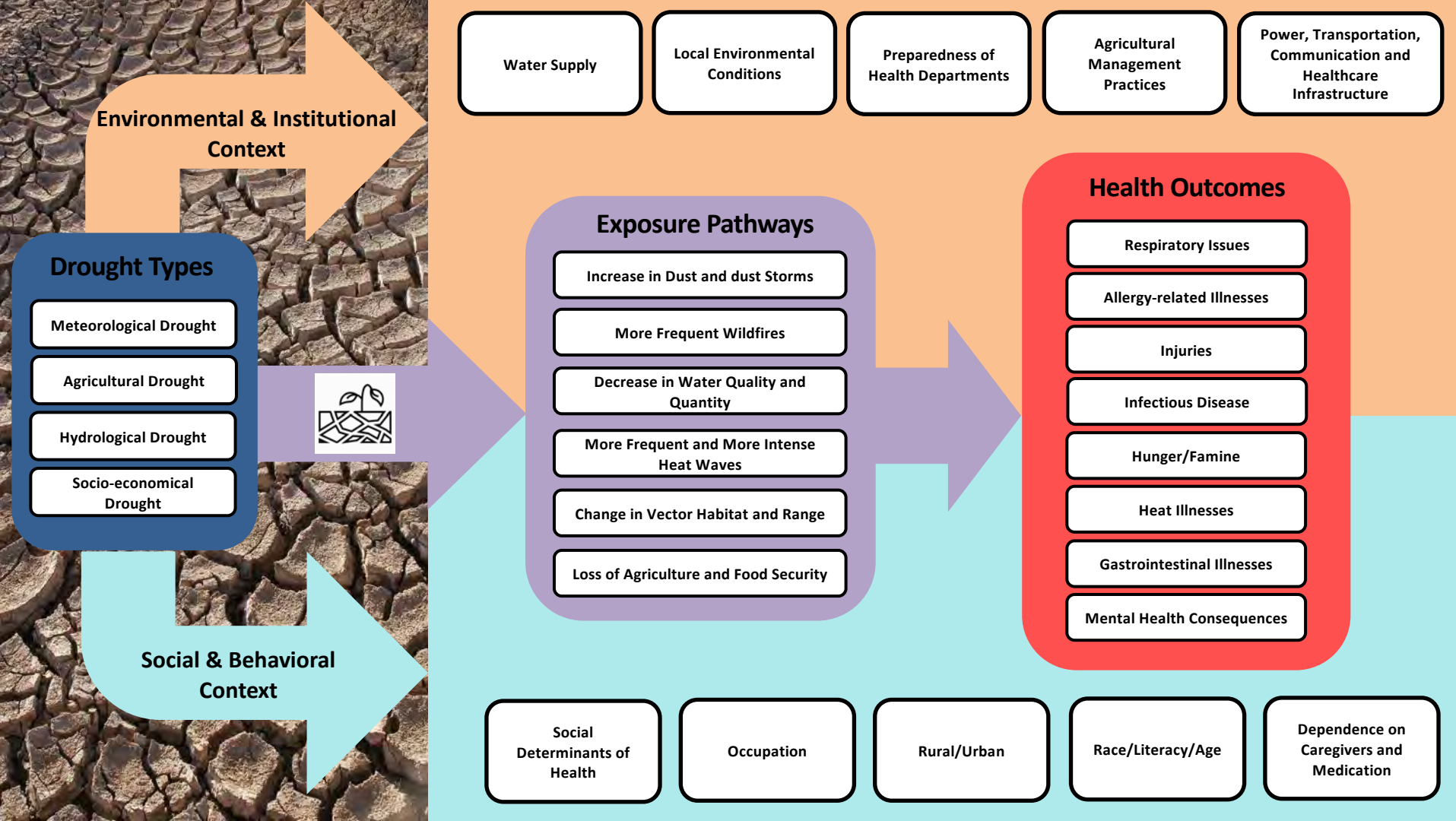


Health Surveillance Data

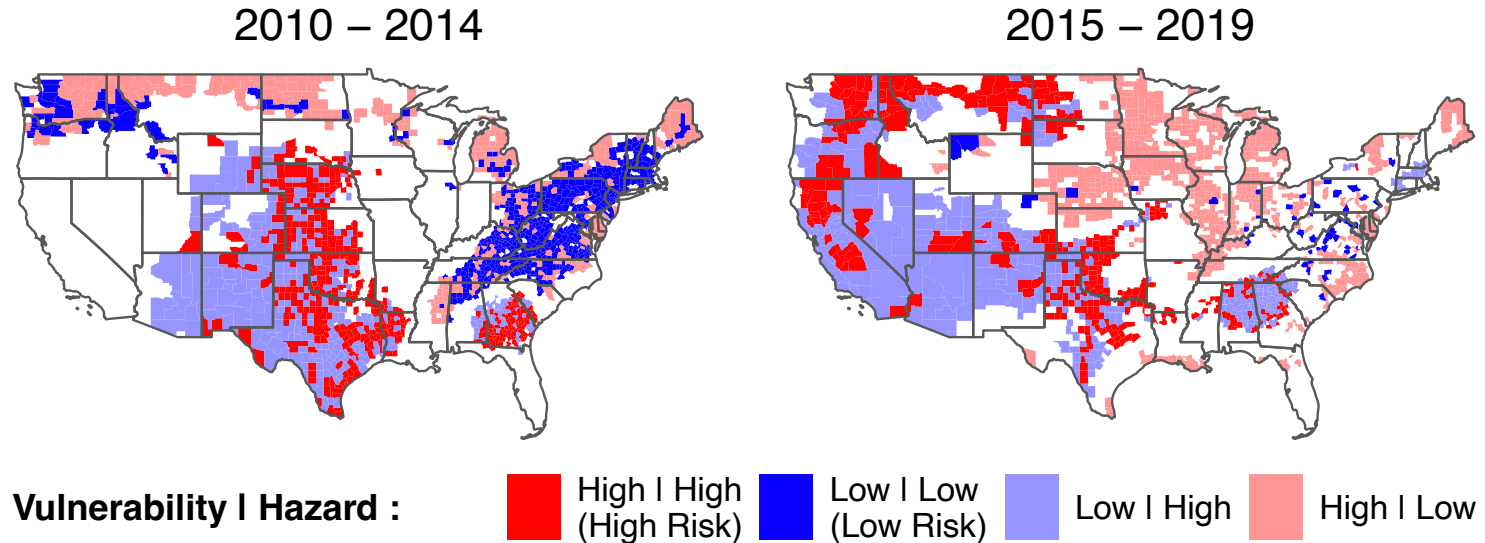
- ✓ Drought can be a slow evolving
- ✓ The impacts are not immediate
- ✓ Can require multiple steps for health outcomes
- ✓ Surveillance is not designed to connect drought and health







Health Risks from Drought Change



Threat Multiplier



Increase in Mortality with Drought

Articles

Drought and the risk of hospital admissions and mortality in older adults in western USA from 2000 to 2013: a retrospective study

Josée D. Berrueta, Felix A. Soto, Roger D. Peng, Francisco Domínguez, Michelle L. Bell

Summary

Background: Occurrence, severity, and geographic extent of droughts are anticipated to increase under climate change, but the health consequences of drought conditions are unknown. We estimate risks of cardiovascular-related and respiratory-related hospital admission and mortality associated with drought conditions for the elderly population in western USA.

Methods: For this retrospective study, we analysed the 2000 to 2013 data from the US Drought Monitor for 418 counties in the western USA to identify full drought periods, non-drought periods, and worsening drought periods stratified by low severity and high severity. We used Medicare claims made between Jan 1, 2000, and Dec 31, 2013, to calculate daily rates of cardiovascular admissions, respiratory admissions, and deaths among adults aged 65 years or older. Using a two-stage hierarchical model, we estimated the percentage change in health risks when comparing drought with non-drought period days, controlling for daily weather and seasonal trends.

Findings: On average, 2.1 million days were classified as non-drought periods and 0.6 million days were classified as drought periods. Compared with non-drought periods, respiratory admissions significantly decreased by -1.99% (95% posterior interval -3.56 to -0.38) during the full drought period, but not during worsening drought conditions. Mortality risk significantly increased by 1.55% (0.17 to 2.95) during the high-severity worsening drought period, but not the full drought or low-severity worsening drought periods. Cardiovascular admissions did not differ significantly during either full drought or worsening drought periods. In counties where droughts occurred less frequently, we found risks for cardiovascular disease and mortality to increase during worsening drought conditions.

Interpretation: Drought conditions increased risk of mortality during high-severity worsening drought, but decreased the risk of respiratory admissions during full drought periods among adults aged 65 years and older. Counties that previously had few or drought events show larger risk for mortality and cardiovascular disease. This research describes an understudied environmental association with global health significance.

Funding: The Yale Institute of Biophoretic Studies, the National Institute of Environmental Health Sciences, the US Environmental Protection Agency.

Copyright: © The Author(s). Published by Elsevier Ltd. This is an Open Access article under the CC BY-NC-ND license.

Introduction

The UN refers to drought as "the most far reaching of all natural disasters".¹ In 2011-12, a pan-continental drought spanned 62% of the contiguous USA land area, exceeding the historical 99th percentile for drought area and affecting nearly 150 million people.² California is seeing an extreme drought that has been ongoing since 2013.³ However, although health effects of some natural disasters (eg, tsunamis and floods) are well studied,^{4,5} little is known about drought, despite its global impact. More drought and health research focuses on developing nations and infectious diseases, such as vector-borne diseases and malnutrition,⁶ but an almost total absence of direct health effects research exists worldwide. So far, the study of drought and health has been hampered by the unique characteristics of drought, including gradual onset, persistence, large geographical extent, and difficulty assessing when one begins or ends.^{7,8} Additionally, drought can be categorised as four distinct types:

meteorological, agricultural, hydrological, and socio-economic.⁹ The distinct drought types can cause challenges in the estimation of human exposures and health effects because each type can potentially affect disease outcomes in a different way.

The biological mechanisms through which drought affects health are unknown. Several pathways are hypothesised. Drought might act on disease through secondary exposures, increasing airborne dust or wildfire smoke and modifying the maintenance and dispersal of allergenic pollen and fungal spores.¹⁰ Long-term drought has the potential to degrade the environment and affect community-level economic wellbeing, inducing psychological stress.^{11,12} Climate stress will likewise influence and physiological responses, including haemodynamic, endocrine, and immunological dysfunction that increase risk of cardiovascular and upper respiratory diseases.^{13,14} In extreme cases, this dysfunction can increase mortality. Community studies from Australia found associations



Lancet Public Health 2017; 2:e105

See Commentaries page 102

School of Forestry and Environmental Studies, Yale University, New Haven, CT, USA (J D Berrueta)

US EPA, Office of Environmental Health/Hazard Assessment, California Environmental Protection Agency, Oakland, CA, USA (F A Soto)

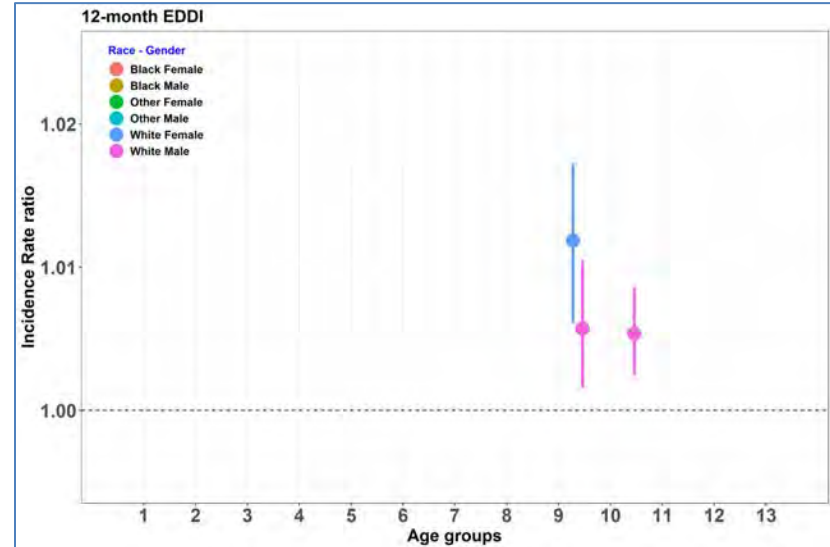
Department of Biostatistics, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD, USA (R D Peng)

Department of Biostatistics, Harvard T.H. Chan School of Public Health, Boston, MA, USA (F Domínguez)

Department of Biostatistics, Harvard T.H. Chan School of Public Health, Boston, MA, USA (M L Bell)

Correspondence to: Dr Josée D Berrueta, Yale School of Forestry and Environmental Studies, New Haven, CT 06511, USA (josée.berrueta@yale.edu)

Drought Mortality in Nebraska



- white females aged 45-54
- white males aged 45-64

Courtesy of Dr. Azar Abadi



Compromised Quantity and Quality of Water

Surface Water



Courtesy of USGS

Groundwater



Courtesy of USDA



Drought May Lead to Elevated Levels of Naturally Occurring Arsenic in Private Domestic Wells

Release Date: MARCH 18, 2021

An estimated 4.1 million people in the lower 48 states are potentially exposed to arsenic levels that exceed EPA's drinking water standards

A new [U.S. Geological Survey study](#) highlights the importance of homeowners testing their well water to ensure it is safe for consumption, particularly in drought-prone areas. The first-of-its-kind national-scale study of private well water, conducted in collaboration with the Centers for Disease Control and Prevention, showed that drought may lead to elevated levels of naturally occurring arsenic and that the longer a drought lasts, the higher the probability of arsenic concentrations exceeding U.S. Environmental Protection Agency's standard for drinking water.

Researchers estimate that during drought conditions, 4.1 million people in the lower 48 states who use private domestic wells are potentially exposed to unsafe levels of arsenic. This is an increase of 54% from the estimated 2.7 million people exposed to unhealthy arsenic levels in private wells during normal, non-drought conditions.

Arsenic is a metal that can occur naturally in bedrock and sediments around the world and is commonly reported in drinking-water supply wells. However, chronic exposure to arsenic from drinking water is associated with an increased risk of several types of cancers, including [bladder](#), [lung](#), [prostate](#) and [skin cancers](#). [Other adverse effects](#) include developmental impairments, cardiovascular disease, adverse birth outcomes and impacts on the immune and endocrine systems.

The study's findings can help public health officials and emergency managers notify well owners in areas potentially affected and further refine their strategies for addressing the issue. The EPA regulates public water supplies, but maintenance, testing and treatment of private water supplies are the



Jacks Pond in Hancock, New Hampshire. Groundwater from this area supplies nearby private wells. (Credit: Melissa Lombard, USGS.)

Contacts

Department of the Interior,
U.S. Geological Survey

Office of Communications and Publishing
12201 Sunrise Valley Drive
Reston, VA 20192
United States
Phone: 703-648-4460

Jason Burton

Public Affairs Specialist
Eastern States Office of Communications
Email: jburt@usgs.gov
Phone: 678-924-6692

Melissa A Lombard

Hydrologist
New England Water Science Center
Email: mlombard@usgs.gov
Phone: 603-226-7816



Secondary/Related Events

- Extreme heat
- Wildfires
- Dust storms/haboobs
- Rain/storm effects



Courtesy of USGS



Courtesy of FCC

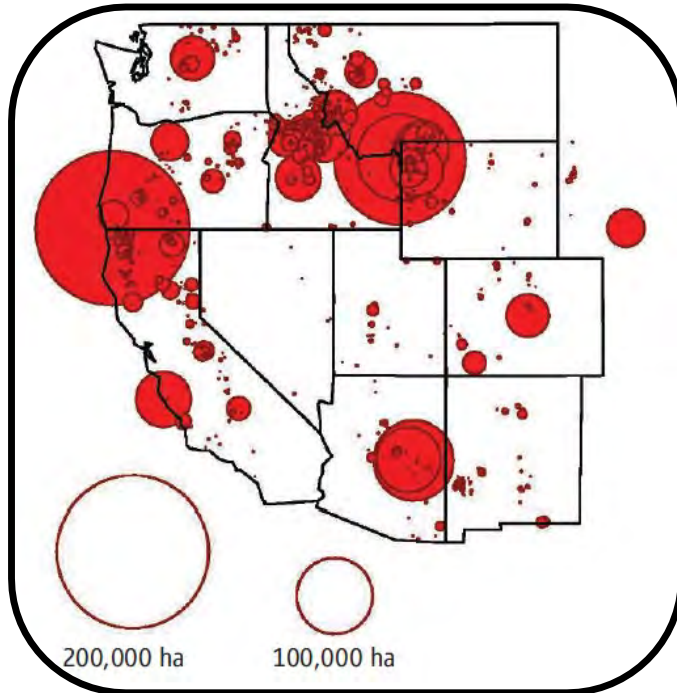


Courtesy of NOAA



Climate Change Impacts Air Quality: Wildfire Smoke

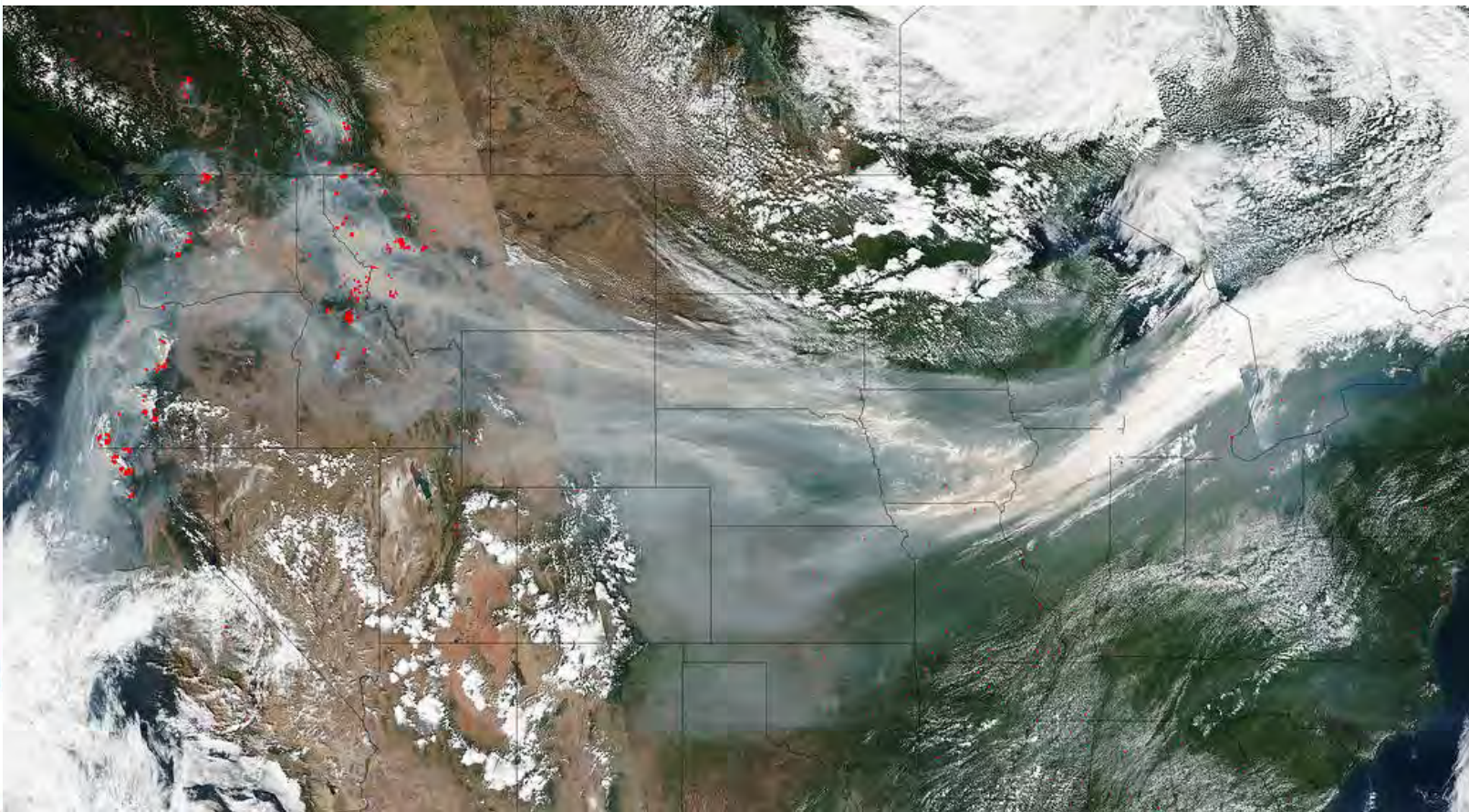
Wildfire Activity Since 1970



■ Since 1970

- Western US wildfire season increased by 78 days
- Average duration of fires increased five fold





NASA image courtesy Jeff Schmaltz LANCE/EOSDIS MODIS Rapid Response Team, GSFC



Increased Disease Incidence

- Infectious disease
- Chronic disease
- Vectorborne and zoonotic disease



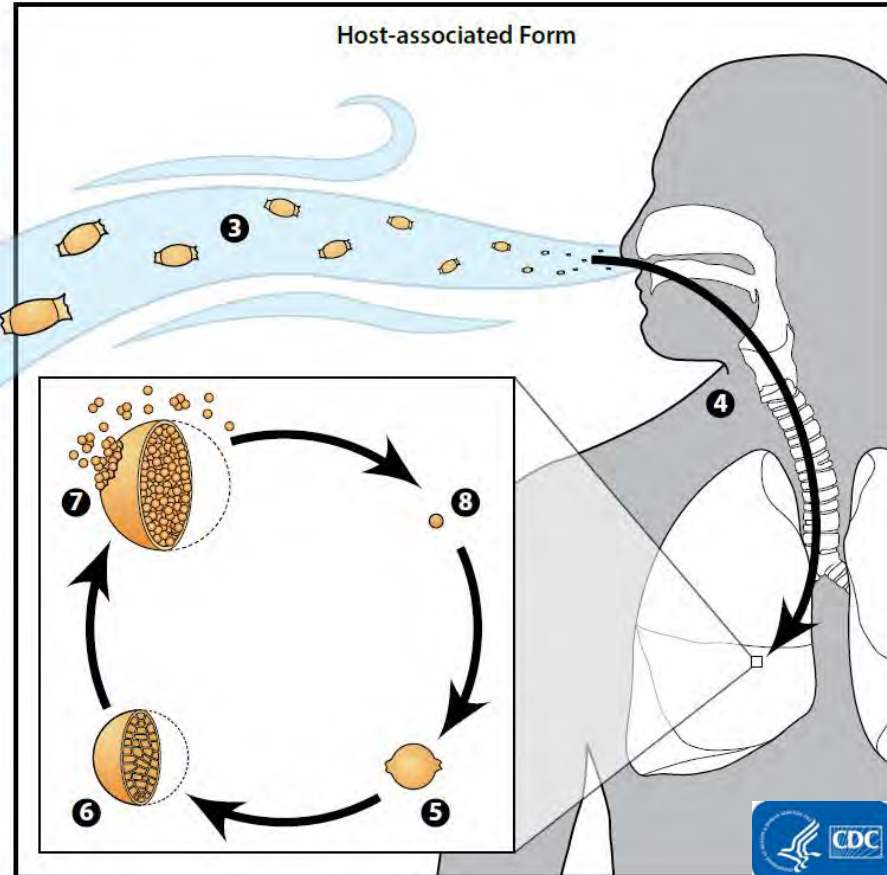
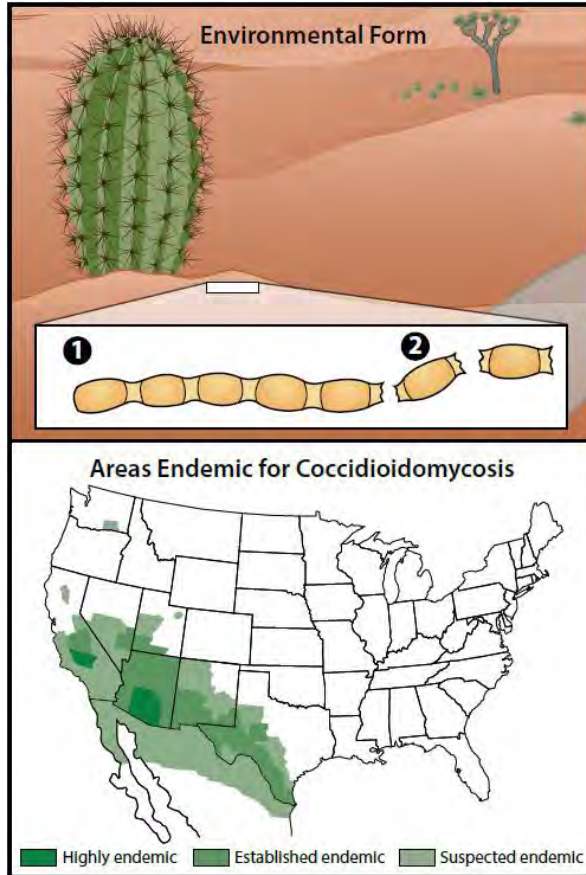
Courtesy of USGS



Courtesy of NSF



Life Cycle of Coccidioidomycosis



Additional Health Risks

- Sanitation and hygiene
- Recreational risks
- Mental and behavioral health



Courtesy of CDC



Courtesy of USACE



Courtesy of House Committee on Agriculture



Complex Pathways: Mental Health



Local

Kansas farmer on alarming suicide rate: 'Nothing gets farmers more down than a drought'

By: Emily Younger

Posted: May 21, 2018 09:34 PM CDT

Updated: May 21, 2018 11:34 PM CDT



WHY BRADY / WHY NOW

EVERY 15 MINUTES
someone is killed by gun violence in the United States

Help us turn back the clock

GIVE TODAY

National | World | Lifestyle | Travel | Entertainment | Technology | Finance | Sport

nsw act

Farmer's recovery from depression which led to two suicide attempts shows cost of drought at family level

STEVE Germon left a suicide note on the porch and set about putting down calves he couldn't feed before turning the gun on himself. Then a ute screamed towards him, his 17-year-old daughter at the wheel.

JACK MORPHET

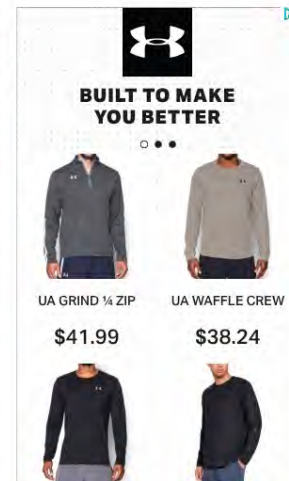
The Sunday Telegraph JULY 1, 2018 1:00AM



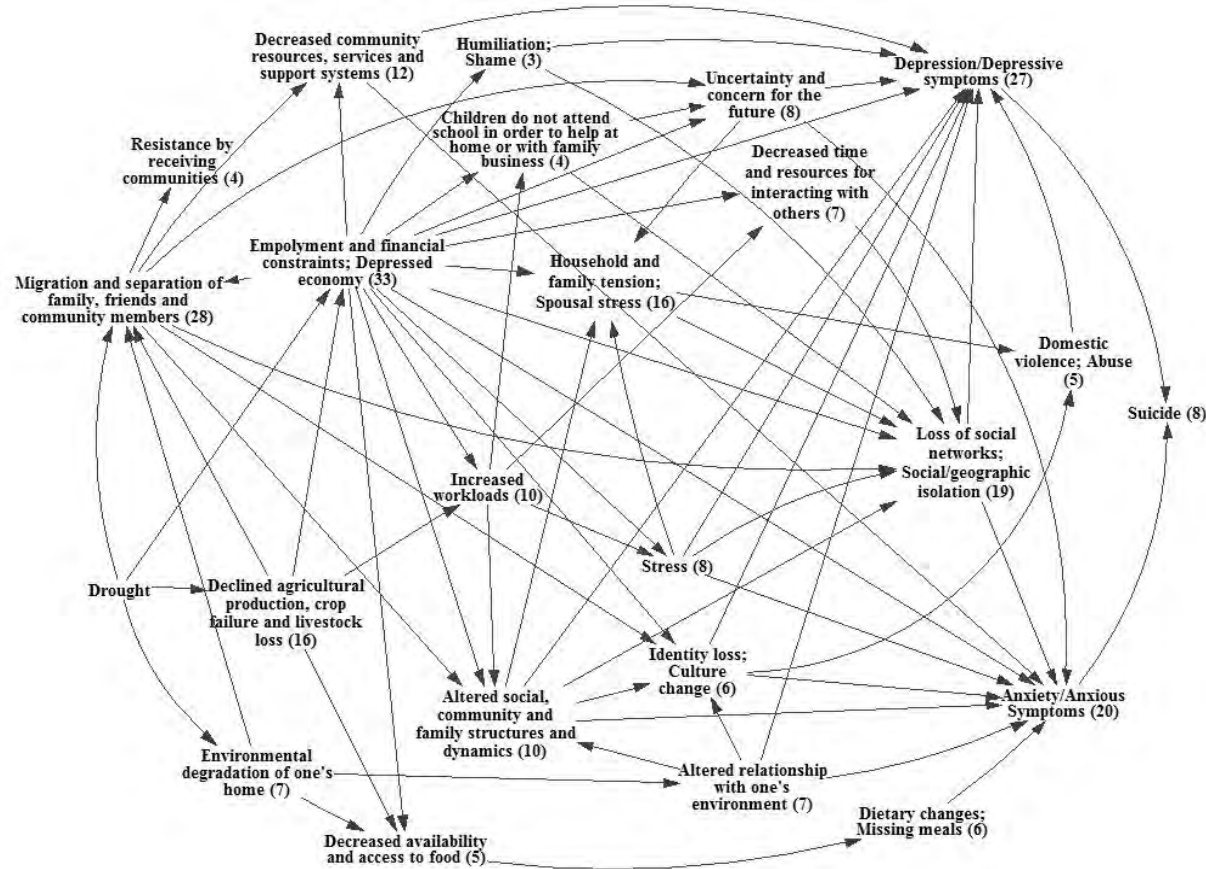
NSW stricken by severe drought.

DAIRY farmer Steve Germon knows what it's like to be on the brink of suicide. He has been there twice in the past three years.

It saved him in 2015, but those lonely moments last year



Causal Process Diagram





The association between drought conditions and increased occupational psychosocial stress among U.S. farmers: An occupational cohort study

Jesse D. Berman^{a,*}, Marizen R. Ramirez^a, Jesse E. Bell^b, Rocky Bilotta^c, Fredric Gerr^d, Nathan B. Fethke^d

^a Division of Environmental Health Sciences, University of Minnesota School of Public Health, 420 Delaware Street SE, Minneapolis, MN 55455, USA

^b Environmental, Agricultural, and Occupational Health, College of Public Health at the University of Nebraska Medical Center, 98438 Nebraska Medical Center, Omaha, NE 68198, USA

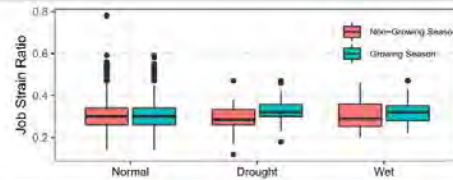
^c Science, LLC, and the National Environmental Health Administration, 131 Fulton Avenue, Asheville, NC 28801, USA

^d Department of Occupational and Environmental Health, University of Iowa College of Public Health, 185 W River Road Drisc, Iowa City, IA 52242, USA

HIGHLIGHTS

- Drought risk for farmer occupational psychosocial stress is unknown.
- Farmers are a vulnerable population to extreme weather events.
- A linear mixed effects longitudinal model evaluated farmer job strain.
- Growing season drought increased farmers occupational psychosocial stress.
- Drought planning should consider occupational psychosocial stress effects.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:

Received 13 April 2021

Received in revised form 5 July 2021

Accepted 20 July 2021

Available online 24 July 2021

Editor: SCOTT SHEDDEN

Keywords:

Drought

Occupational psychosocial stress

Farmers

Occupational health

Climate

ABSTRACT

Background: Drought represents a globally relevant natural disaster linked to adverse health. Evidence has shown agricultural communities to be particularly susceptible to drought, but there is a limited understanding of how drought may impact occupational stress in farmers.

Methods: We used repeated measures data collected in the *Musculoskeletal Symptoms among Agricultural Workers Cohort* study, including 498 Midwestern U.S. farmers surveyed with a Job Content Questionnaire (JCQ) at six-month intervals in 312 counties from 2012 through 2015. A longitudinal linear mixed effects model was used to estimate the change in job strain ratio, a continuous marker of occupational psychosocial stress, during drought conditions measured with a 12-month standardized precipitation index. We further evaluated associations between drought and psychological job demand and job decision latitude, the job strain components, and applied a stratified analysis to evaluate differences by participant sex, age, and geography.

Results: During the growing season, the job strain ratio increased by 0.031 (95% CI: 0.012, 0.05) during drought conditions, an amount equivalent to a one-half standard deviation change (Cohen's D = 0.5), compared to non-drought conditions. The association between drought and the job strain ratio was driven mostly by increases in the psychological job demand (2.08; 95% CI: 0.54, 3.24). No risk differences were observed by sex, age group, or geographic region.

Conclusions: Our results suggest a previously unidentified association between drought and increased occupational psychosocial stress among farmers. With North American climate anticipated to become hotter and drier, these findings could provide important health effects data for federal drought early warning systems and mitigation plans.

© 2021 Published by Elsevier B.V.

* Corresponding author at: Division of Environmental Health Sciences, University of Minnesota School of Public Health, 420 Delaware Street SE, Minneapolis, MN 55455, USA.
E-mail address: jesse@hsph.umn.edu (J.D. Berman).

Drought Causes Stress in Farmers

The effect estimate for drought was 4x greater magnitude than people reporting pain in multiple body parts.



Engagement





Centers for Disease Control and Prevention
CDC 24/7: Saving Lives, Protecting People™



CDC A-Z INDEX ▾

CDC Features

CDC Features

Data & Statistics

Diseases & Conditions

Emergency Preparedness
Response

Environmental Health

Drought and Your Health

Healthy Living

Injury, Violence & Safety

Life Stages & Populations

Travelers' Health

Workplace Safety & Health

Features Media

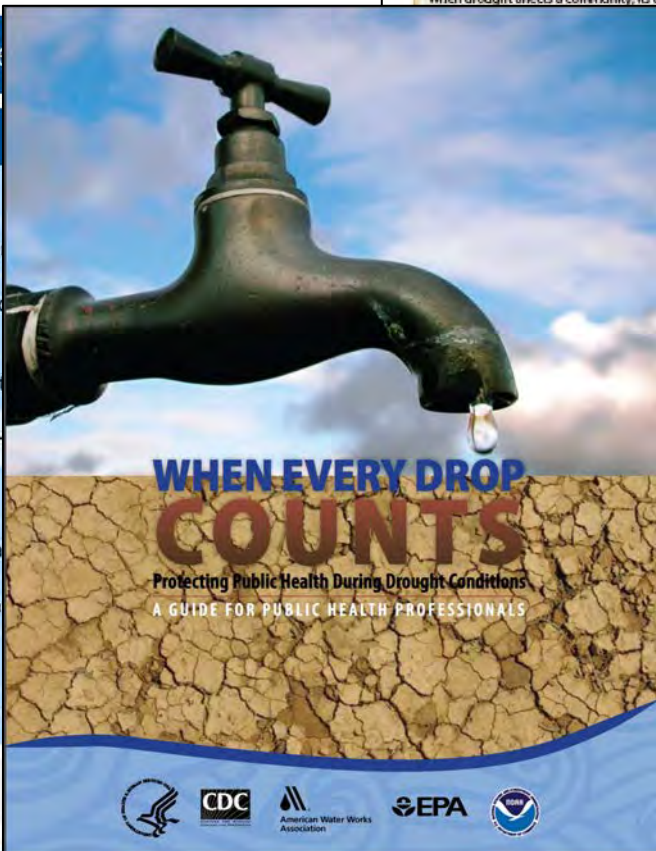


Sign up for Features

DROUGHT AND PUBLIC HEALTH IN THE U.S.

Why drought matters

When drought affects a community, its devastating consequences can include decreased quality and quantity, and increased risk to life, property, and the environment. Drought is complex, and costly.



PREPARING FOR THE HEALTH EFFECTS OF DROUGHT

A RESOURCE GUIDE
FOR PUBLIC HEALTH PROFESSIONALS



- the at-risk populations living within the affected area, and

NATIONAL DROUGHT & PUBLIC HEALTH SUMMIT

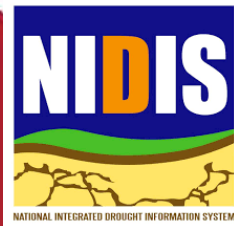
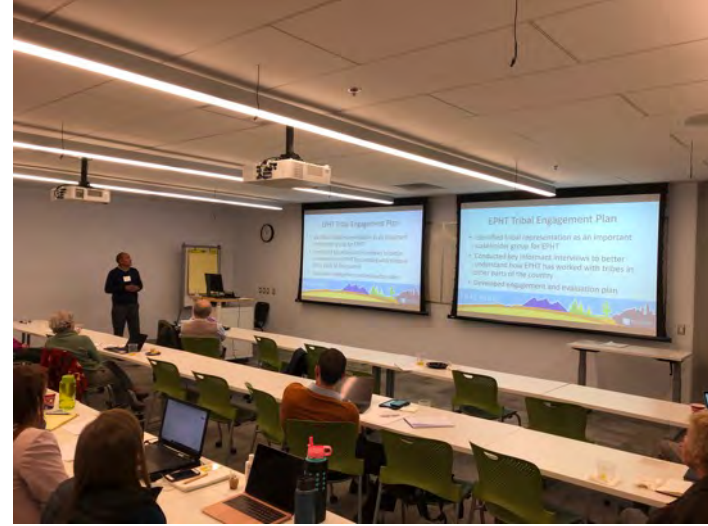
June 17-19, 2019 | Atlanta, GA

Thank you to our Summit Planning Partners:

Centers for Disease Control and Prevention (CDC)
National Integrated Heat Health Information System (NIHHIS)
Environmental Protection Agency (EPA)
Natural Resources Defense Council (NRDC)
UNL National Drought Mitigation Center (NDMC)



COLLEGE
OF PUBLIC HEALTH



Future Needs:



- Still much to be learned about drought and public health
 - What do public health departments need?
- Research is needed in many different areas:
 - Analysis of surveillance data
 - Improved environmental monitoring
 - Role of public health departments
 - Economic impact of drought on public health
 - Lessons learned and best practices



Acknowledgements

UNMC Center for Preparedness Education

- Rachel Lookadoo, JD
- Keith Hansen, MBA

CDC Climate and Health

- Shubhayu Saha, PhD
- Paul Schramm, MS MPH

NIDIS

- Amanda Sheffield, PhD
- Veva Deheza
- Rocky Bilotta
- Molly Woloszyn
- Britt Parker

My Team

- Azar Abadi, PhD
- Yeongjin Gwon, PhD
- Jagadeesh Puvvula

Mike Hobbins

All of the state and local partners

All of the federal and academic partners



Water for Food
DAUGHERTY GLOBAL INSTITUTE
at the University of Nebraska



UNMC

COLLEGE
OF PUBLIC HEALTH





BREAKTHROUGHS FOR LIFE.®

Twitter: @JesseEugeneBell