The Lancet Countdown on Health and Climate Change

Policy Brief for the United States of America: Appendix

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LANCET COUNTDOWN: TRACKING PROGRESS ON HEALTH AND CLIMATE CHANGE

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CASE STUDY

Compounding Crises of Our Time During Hurricane Laura

Climate Change, COVID-19, and Environmental Injustice

On August 27, 2020, Hurricane Laura hit the coast of Louisiana, one of the strongest hurricanes to ever affect the state. The storm caused at least 28 deaths in Louisiana[1] and at least $12 billion in economic damage.[2] Climate change is intensifying hurricanes and other extreme weather events (**see Box 1**).[3,4]

BOX 1

Climate change, extreme weather, and health

Human-caused climate change is driving an increase in stronger, more rapidly intensifying, slower moving, and wetter hurricanes. Tropical storms have higher storm surges and more flooding, and the areas vulnerable to these weather events have been shifting.[3–9] Climate change is also increasing the frequency, length, and intensity of extreme heat days, leading to compound hurricane-heat events.[10,11] A research methodology called "detection and attribution" allows researchers to determine how much of an influence climate change had on the severity of an extreme weather event.[12,13] While it is too early to determine to what extent climate change contributed to Hurricane Laura, climate change has been shown to intensify other hurricane events through detection and attribution studies.[14,15] These intense storms and compound weather events impact health in numerous ways, including physical injury and death, loss of essential services such as electricity and shelter, acute and long-term mental health impacts, destruction of social and healthcare services, financial hardship, displacement, exacerbation of chronic diseases, and more.[16,17]

Hurricane Laura deeply affected Black and low-income communities that were already struggling with health and economic devastation resulting from decades of targeted industrial development and from the more recent impacts of the COVID-19 pandemic.[1,18] The hurricane hindered the pandemic response and exacerbated environmental pollution. This event highlights how the crises of climate change, COVID-19, and environmental injustice intersect to disproportionately impact communities of color and low-income communities, compounding health risks and deepening existing health inequities.

A legacy of environmental racism and pollution in Louisiana

Hurricane Laura's impacts were centered in southwest Louisiana, around the City of Lake Charles in Calcasieu Parish, a region affected by high levels of racial residential segregation, poverty, and unemployment (**see Table 1**).[19–21] The region has some of the highest levels of toxic industrial emissions in the country,[22] stemming from the hundreds of oil, gas, and chemical facilities situated along the Louisiana coast, including a dozen new petrochemical facilities approved in the parish in recent years.[23]

Data on racial and economic disparities in exposure to toxic air and water pollution show Lake Charles is among the worst cities in the U.S. for multiple Environmental Justice Index indicators.[24] One result of this environmental racism (**see Box 2**) is the region's disproportionately high rates of cancer, asthma, chronic obstructive lung disease, premature death, low birthweight infants, and depression.[25–27]

TABLE 1.

Selected socio-demographic characteristics of Calcasieu Parish.

Race/Ethnicity	Percent of Parish Population	Percent Living Below Poverty Level	Percent Unemployed
Non-Hispanic White	70.2%	12.1%	4.2%
Black	24.9%	29.2%	9.9%
Hispanic or Latino	3.4%	20.5%	6.9%
Two or more races	2.3%	24%	9%

Source: 2018 American Community Survey 5-year Estimates (Tables S1701, S2301, DP05)

BOX 2

Environmental racism

Environmental racism is racial discrimination in environmental policymaking and the enforcement of regulations and laws that deliberately target communities of color for toxic waste disposal and polluting industries, sanction the life-threatening presence of poisons and pollutants in communities of color, and exclude people of color from mainstream environmental groups, decision-making boards, commissions, and regulatory bodies.

Adapted from Benjamin F. Chavis in the Foreword to "Confronting Environmental Racism, Voices from the Grassroots."

COVID-19 pandemic is deepening health risks and inequities

Mirroring national patterns, COVID-19 is disproportionately impacting Black communities in Calcasieu Parish (**see Table 2**).[28] The legacy of unequal environmental risk exposure may be contributing to this. Early research suggests that chronic exposure to hazardous air pollutants, such as those from the petrochemical industry, may be associated with increased COVID-19 morbidity and mortality rates.[29,30]

TABLE 2.

COVID-19 cases and deaths for Blacks and Whites in the Calcasieu Parish.

Race	Cases per 100,000	Deaths per 100,000
Black	4680	138
White	2670	103

Source: Louisiana Department of Health, 10/14/2020

The economic collapse caused by the pandemic is further exacerbating factors that harm health and create inequity. Louisiana lost over 200,000 jobs — an 11% drop — in the early months of the pandemic, and the unemployment rate rose to 13% — its highest since the mid-1980s.[31] Calcasieu Parish suffered one of the highest levels of COVID-19-related job losses in Louisiana, due in part to its reliance on the gambling and gaming industry, which predominantly employs people of color.[32,33] The parish also has a high level of households at risk of eviction due to severely high rent burden and COVID-related job losses.[32] Food insecurity in the parish is expected to increase to nearly 20% this year as a result of the pandemic (**see the Case Study**).[34]

Hurricane Laura and its immediate aftermath

Heavy winds, storm surge, and inland flooding led to catastrophic impacts, destroying houses and infrastructure, disrupting water systems, necessitating a near total rebuild of the electric grid, and severely damaging nearly all of Calcasieu Parish's school buildings.[35-37] Hundreds of thousands of residents were left without power or access to safe drinking water. Three weeks after the hurricane, mandatory evacuation orders remained in place, half of all residents remained without electricity, and the majority remained under a boil water advisory.[38,39] The lack of electricity was deadly – nine people in Louisiana died from carbon monoxide poisoning associated with generator use.[40] Essential social infrastructure also suffered, as the parish's public schools remained closed for weeks following Laura, senior living centers and low-income housing units were unable to provide adequate services for residents, and many people were threatened with eviction as a result of storm damage to their rental housing.[41]

Healthcare services, already stressed by COVID-19, were heavily impacted. Sixteen hospitals in the state were forced to evacuate, and the largest hospital in Lake Charles severely curtailed services for several weeks because of a lack of electricity and water.[42]

A heatwave immediately followed the hurricane in Louisiana, part of a nationwide heat event, and the heat index rose to 110°F (43°C) in some areas.[43] This heatwave worsened health risks for many, particularly those who lost electricity and outdoor workers removing debris and repairing power lines. At least eight Louisianans died of heat-related illnesses.[40]

A series of cascading failures

The region has faced multiple industrial disasters during prior hurricanes,[44] and Laura was no exception. Many industrial facilities in the state released millions of pounds of toxic emissions during shut-down procedures in the days prior to the storm, with more emissions following as a result of storm damage and power outages.[45] In one notable example, the BioLab chemical plant just outside of Lake Charles caught fire due to hurricane damage, releasing chlorine gas and other hazardous pollutants (**see Figure 1**).[46] Residents were told to shelter-in-place, close their doors and windows, and turn off their air conditioning units to protect themselves from exposure, despite the heatwave.

FIGURE 1.

BioLab chemical plant fire outside of Lake Charles in Louisiana due to damage from Hurricane Laura.

Source: Associated Press, David J. Phillip (rights purchased).

The full extent of hurricane-related toxic pollution is unknown, in part due to inadequate environmental monitoring and reporting standards and infrastructure in Louisiana. Five of the seven regional air monitors were offline following the storm, further limiting the ability to understand air quality impacts. Climate-related industrial disasters are likely to increase over time unless updated construction and emergency planning requirements are put into place to address industrial facilities, the safety of the surrounding "fenceline" communities, and other climate change-related hazards.

Response to Hurricane Laura hampered by COVID-19

The COVID-19 pandemic hindered the hurricane response.[47] Many of the 1.5 million people under evacuation orders were reluctant or unable to evacuate, likely due to a variety of reasons including concerns about increasing their infection risk and existing economic hardships. These concerns were even further compounded because emergency shelter options were already limited due to COVID-19. The pandemic also weakened essential disaster response infrastructure by, for example, interrupting critical supply chains, taxing healthcare workers, and straining healthcare facilities.

At the same time, the hurricane increased the risk of COVID-19 transmission in both evacuation and destination communities as people sheltered in other people's homes or at emergency shelters.[48–50] Laura also interrupted Louisiana's COVID-19 response; all testing facilities were temporarily shut down, and only a small fraction of evacuees in shelters were tested for COVID-19.[51]

What the future holds

The full health damages of Hurricane Laura will not be known for some time. In addition, an understanding of how climate change contributed to the storm will also lag, but it is clear that the intensity of hurricanes is likely to increase as climate change worsens. Hurricane Laura came just hours after evacuation orders for Hurricane Marco were lifted. Hurricanes Sally and Delta followed, prompting new evacuation orders and causing further devastation in regions still early in recovery from Hurricane Laura.

Protecting health and well-being in the face of the multiple interacting challenges of racial, environmental, and health inequities requires a holistic set of solutions. Prioritizing the voices of residents and community advocates in designing solutions is essential to protecting communities made most vulnerable by environmental racism, COVID-19, and climate change. Many local environmental justice organizations are leading such advocacy efforts across Louisiana, and these efforts should receive further investment. At a policy level, it is critical to address systemic racism by strengthening environmental and zoning regulations to protect health, ensuring equitable access to safe and quality housing and healthcare, and building the climate resilience of health and social infrastructure through investments that prioritize equity.

CASE STUDY

The 2019 Floods in the Central U.S.

Lessons for Improving Health, Health Equity, and Resiliency

In spring 2019, the Midwest region endured historic flooding that caused widespread damage to millions of acres of farmland, killing livestock, inundating cities, and destroying infrastructure.[52]

The Missouri River and North Central Flood resulted in over $10.9 billion of economic loss in the region, making it the costliest inland flood event in U.S. history.[52] Yet, this is just the beginning, as climate change continues to accelerate extreme precipitation, increasing the likelihood of severe events previously thought of as "once in 100 year floods."[53,54]

This 2019 disaster exhibited the same health harms and healthcare system disruptions seen in previous flooding events, and vulnerable populations – notably tribal and Indigenous communities – were once again disproportionately impacted. Thus, there is an enormous need for policy interventions to minimize health harms, improve health equity, and ensure community resilience as the frequency of these weather events increases.

FIGURE 2.

Before-and-after images of catastrophic flooding in Nebraska. Left image taken March 20, 2018. Right image taken March 16, 2019.

Source: NASA Goddard Space Flight Center, with permission.

The role of climate change, widespread devastation, and compounding inequities

The Missouri River and North Central Flood were the result of a powerful storm that occurred near the end of the wettest 12-month period on record in the U.S. (May 2018 - May 2019).[55,56] The storm struck numerous states, specifically Nebraska (**see Figure 2**), Iowa, Missouri, South Dakota, North Dakota, Minnesota, Wisconsin, and Michigan. Two additional severe flooding events occurred in 2019 in states further south, involving the Mississippi and Arkansas Rivers.

This flood event exhibits two key phenomena that have been observed over the last 50 years as a result of climate change: annual rainfall rates and extreme precipitation have increased across the country.[57] The greatest increases have been seen in the Midwest and Northeast, and these trends are expected to continue over the next century. Future climate projections also indicate that winter precipitation will increase over this region,[57] further increasing the likelihood of more frequent and more severe floods. For example, by mid-century the intensity of extreme precipitation events could increase by 40% across southern Wisconsin.[58] While it is too early to have detection and attribution studies for these floods, climate change has been linked to previous extreme precipitation and flood events.[59,60]

Hundreds of people were displaced from their homes and millions of acres of agricultural land were inundated with floodwaters, killing thousands of livestock and preventing crop planting.[52,61,62] Federal Emergency Management Agency (FEMA) disaster declarations were made throughout the region, allowing individuals to apply for financial and housing assistance, though remaining at the same housing site continues to place them at risk of future flood events.

In Nebraska alone, 104 cities, 81 counties and 5 tribal nations received state or federal disaster declarations. FEMA approved over 3,000 individual assistance applications in Nebraska, with more than $27 million approved in FEMA Individual and Household Program dollars. In addition to personal property, infrastructure was heavily affected, with multiple bridges, dams, levees, and roads sustaining major damage (**see Figure 3**).[52]

FIGURE 3.

Destruction of Spencer Dam during Missouri River and North Central Floods.[63]

Source: Nebraska Department of Natural Resources, with permission.

[°] Oglala Sioux Tribe, Cheyenne River Sioux Tribe of the Cheyenne River Reservation, Standing Rock Sioux Tribe (North Dakota and South Dakota), Yankton Sioux Tribe of South Dakota, Lower Brule Sioux Tribe of the Lower Brule Reservation, Crow Creek Sioux Tribe of Crow Creek Reservation, Sisseton-Wahpeton Oyate of the Lake Traverse Reservation, Rosebud Sioux Tribe of the Rosebud Sioux Indian Reservation, Santee Sioux Nation, Omaha Tribe of Nebraska, Winnebago Tribe of Nebraska, Ponca Tribe of Nebraska, Sac & Fox Nation of Missouri (Kansas and Nebraska), Iowa Tribe of Kansas and Nebraska, and Sac & Fox Tribe of the Mississippi in Iowa.

As with other climate-related disasters, the 2019 floods had devastating effects on already vulnerable communities as numerous tribes and Indigenous peoples were impacted,[°] adding to centuries of historical trauma.[64,65] Accounts of flooding on the Pine Ridge Reservation in South Dakota demonstrate the challenges that resource-limited communities face in coping with extreme weather events.[64] Delayed response by outside emergency services left tribal volunteers struggling to help residents stranded across large distances without access to supplies, drinking water, or medical care.[66] Lack of equipment and limited transportation hampered evacuations.[67]

Health harms and healthcare disruptions

There were three recorded deaths from drowning, but hidden health impacts were widespread and extended well beyond the immediate risks and injuries from floodwaters. In the aftermath, individuals in flooded areas were exposed to hazards like chemicals, electrical shocks, and debris.[68] Water, an essential foundation for health, was contaminated as towns' wells and other drinking water sources were compromised. This put people, especially children, at increased risk for health harms like gastrointestinal illnesses.[69] Stranded residents relied on shipments of water from emergency services and volunteer organizations and the kindness of strangers (**see Box 3**).

BOX 3

"We just remember the trust and commitment to each other"

Linda Emanuel, a registered nurse and farmer living in the hard-hit rural area of North Bend in Nebraska, helped organize flood recovery efforts. She recalled wondering, "How are we going to handle this? How do we inform the people of all the hazards without scaring them?" In addition to her educational role, she administered a limited supply of tetanus shots, obtained and distributed hard-to-find water testing kits, and coordinated PPE usage. In the first days of the flooding, she hosted some 25 stranded individuals in her home. Reminiscing about how community members came together amidst the devastation, Emanuel remarked, "We just remember the trust and the commitment to each other and to our town. We are definitely a resilient city."[70]

Standing water remained in many small town for months, and a four-year old child at the Yankton Sioux reservation in South Dakota likely contracted Methicillin-resistant Staphylococcus aureus (MRSA) after playing in a pond.[71] The mold and allergens that developed in the aftermath of the floods exacerbated respiratory illness.[72] Flooding also backed up sewer systems into basements; clean up required personal protective equipment (PPE) to prevent the potential spread of infectious diseases. The significant financial burdens, notably the loss of property in the absence of adequate insurance, can contribute to serious mental and emotional distress in flood victims.[73,74]

Infrastructure disruptions, like flooded roads, meant that many individuals in rural areas were unable to access essential services including healthcare. In an interview with the New York Times, Ella Red Cloud-Yellow Horse, 59, from Pine Ridge Indian Reservation, recounts her own struggle to get to the hospital for a chemotherapy appointment.[64] After being stranded by flooding for days, she had contracted pneumonia, but she couldn't be reached by an ambulance or tractor because her driveway was blocked by huge amounts of mud. She was forced to trudge through muddy flood waters for over an hour to get to the highway.

She told the Times, "I couldn't breathe, but I knew I needed to get to the hospital." Her story is an increasingly common occurrence as critical infrastructure is damaged by climate change-intensified extreme events. These infrastructure challenges are also often superimposed on top of the challenges of poverty and disproportionate rates of chronic diseases (**see the Case Study**). Multiple hospitals sustained damage and several long-term care facilities were forced to evacuate, with some closing permanently, as a result of the rising floodwaters,[75] likely exacerbating existing diseases.

A path towards a healthier, equitable, and more resilient future

As human-caused climate change increases the likelihood of precipitation events that can cause severe flooding disasters, public health systems must serve as a first line of defense against the resulting health harms. As such, the broader public health system needs to develop the capacity and capability to understand and address the health hazards associated with climate-related disasters. Often funds and resources for these efforts are focused on coastal communities; however, inland states face many climate-related hazards that are regularly overlooked. Building on or expanding programs similar to CDC's Climate-Ready States and Cities Initiative will help communities in inland states prepare for future climate threats.[76]

Additionally, public health officials, health systems, and climate scientists should collaborate to create robust early warning systems to help individuals and communities prepare for flood events. Education regarding the health impacts of flooding should not be limited to the communities affected, but it should also include policymakers and other stakeholders who can implement systemic changes to decrease and mitigate the effects of floods. Local knowledge offered by community members regarding water systems, weather patterns, and infrastructure will be essential for effective and context-specific adaptation. By implementing these changes and executing more inclusive flood emergency plans, communities will be better situated to face the flood events that are projected to increase in the years to come.

CASE STUDY

Promoting Food Security, Resilience and Equity during Climate-related Disasters

The U.S. is often viewed as a nation of abundance, yet paradoxically, one in ten households were "food insecure" in 2019, meaning that they struggle to get the proper nutrition to keep their family healthy.[77]

These challenges are not borne equally. Rates of food insecurity were nearly three times higher for low-income and single mother-headed households and nearly twice as high for Black and Latino households than for White households.

Early research has found a doubling of the average food insecurity rate across the U.S. linked to the COVID-19 pandemic, with even greater increases among vulnerable populations.[78–81] Disruptive events, whether climate-related disasters or the COVID-19 pandemic, can exacerbate existing barriers to securing healthy food for vulnerable populations and further widen food and health disparities.[82]

Food insecurity has clear health implications. Adults who are food-insecure may be at an increased risk of health problems, including obesity, heart disease, diabetes, depression, and increased susceptibility to COVID-19.[83–85] Food insecurity also puts children at a higher risk of asthma, anemia, and obesity, as well as behavioral, developmental, and emotional problems.[83,86]

Climate-intensified extreme events are compounding existing food insecurity

Climate change is anticipated to worsen existing food insecurity as climate-related disasters, such as drought and flooding, become more frequent and severe and as agricultural pests become more persistent.[72,87] In 2019, there were fourteen climate-related disasters within the U.S. that each caused over a billion dollars in damages.[52]

Historic floods in the Midwest destroyed millions of acres of agriculture and caused widespread infrastructure damage (**see Case Study**). In addition, an above-normal Atlantic hurricane season inundated coastlines with unprecedented rainfall, high winds, and storm surge; and wildfires in California and Alaska caused widespread energy disruptions, compromising the health and well-being of residents.[52]

The mechanisms of food system disruption

Disasters such as these threaten all aspects of food production, distribution, and accessibility, with subsequent impacts for affordability that can further exacerbate food insecurity for vulnerable populations. When food is not consumed where it is produced, it must be processed, stored, transported, and then sold or donated. These processes involve complex interdependent, and at times, international systems. Roads, bridges, warehouses, airports, energy grids, and other transportation or telecommunication infrastructure are at risk of direct damage from climate change, severely disrupting the food system as a whole.[88,89]

For example, following the 2019 floods in the Central states, the flood waters caused more than forty state and federal highways to close, hydroelectric dams to be breached, and threatened nuclear power stations (**see Case Study**).[90,91] These disturbances limited the movement and storage of goods throughout the region and prevented consumers from accessing food sources.[91,92] In the midst of an extreme fire season in California that same year, utility providers turned off power to millions of homes and businesses, plunging low-income households into hunger and financial crisis as their food spoiled.[93]

Recent climate disasters decreased food security

Climate disasters can lead to acute food insecurity in the short-term and exacerbate chronic food insecurity in the long-term (**see Table 3**). Populations already struggling from chronic insecurity, or those who are only marginally food secure, are particularly vulnerable to the socioeconomic impacts of disasters, such as loss of livelihood, rising food prices, forced migration, loss of social support, and health-related impacts. Data from the aftermath of 2019 disasters is still scarce, but the impacts from previous disasters that are similar in nature are well documented.

For example, nearly five years after Hurricane Katrina, many of the households heavily impacted by the hurricane in Louisiana and Mississippi remained food insecure. This was especially true for women, Black households, and those living with chronic illness, mental health issues, or low social support.[94] Similar impacts were demonstrated in New York City following Hurricane Sandy, where one-third of surveyed households in the heavily impacted Rockaway Peninsula reported difficulty obtaining food due to economic hardship, disruption of public transportation, and long-term closure of grocery stores months after the storm.[95]

A path towards equitable food security

Learning from Baltimore

In the era of complex disasters, community-level resilience is essential, as federal relief is often too slow and under-equipped to meet the immediate needs of individuals and households. A growing number of U.S. cities are working to protect and improve food security in the aftermath of climate-related disasters and help build climate-resilient local and regional food systems.

For example, officials from Baltimore, Maryland worked with researchers at the Johns Hopkins University in 2017 to assess the resilience of the city's food supply to climate-related disruptions and to identify ways to support communities at risk of experiencing food insecurity both before and after disasters.[96] This is a wonderful example of the power of academic and public partnerships.

Baltimore also designated a food liaison to sit within the Office of Emergency Management during crises. This city received funding from FEMA to coordinate a collaborative regional food and water resilience plan with surrounding jurisdictions. When COVID-19 spread to Baltimore in early 2020 — closing schools and many businesses — the city quickly put its food resilience planning into action and convened a group of food assistance stakeholders to better coordinate responses supporting food access for residents.

TABLE 3.

Individual, household and community level risk factors to food insecurity following climate-related disasters.

	Risk Factors	Protective Factors
Individual and Household	» Financial instability[95] » Insufficient housing[101] » Limited transportation and/or mobility[95] » Chronic illness[102] » Specialized dietary needs » Single income or female-headed household » Households with children/infants » Pre-existing food insecurity » Loss of livelihood[103] » Residence within a food desert[104] » Minority race[77] » mmigrant status[105] » Minority ethnicity[77] » English as a second language » College students[106]	» Strong community cohesion and social support[107] » Good mental and emotional health[108] » Financial resources[95] » Back-up power at primary residence[93] » Emergency shelter access » Transportation options[93] » Sufficient, stable and safe housing[103] » Access to healthcare » Evacuation options
Community	» Existence of systemic, structural racism and discrimination[100] » Limited disaster resilience planning[109] » Aging, poorly constructed infrastructure[92] » Low social capital[108] » Food waste and lack of food recovery[92] » Lack of local food production[104] » Lack of investment in equitable food distribution mechanisms and local agriculture[110] » Existence of food deserts and lack of public access to food stores or farmers markets[104]	» Equitable and inclusive food and health policymaking[111] » Disaster-resilient infrastructure (e.g., buildings, roads, bridges, energy grids, public transportation)[112] » Resilient and nutritious local and regional food systems[110] » Cross-sectoral food security planning[111] » Pre-existing disaster planning with emphasis on food provision[111] » School food programs[113] » Allowance for SNAP benefits to be used at farmers markets and Community Supported Agriculture (CSA)[113] » Involvement of healthcare sector in healthy food provision and elimination of food waste

Adaptive actions for health and equity

Local and state governments across the country can take similar steps to incorporate food insecurity risk analysis and adaptive planning into emergency management and climate adaptation planning (**see Table 4**). Local governments and community partners can ensure food assistance programs provide well-balanced meals and are targeted to reach vulnerable individuals and communities.

It is critical to support federal and state assistance programs during non-disaster times, such as the Supplemental Nutritional Assistance Program (SNAP), Women, Infants and Children (WIC), and school lunches. As an example, SNAP and WIC services have been pathways to try to meet the rise in food insecurity during the pandemic, and many schools have attempted to continue to provide meals to children most in need.[97,98] Thus, ongoing support can ensure that these programs are even more adaptable, optimally funded, and able to be rapidly mobilized during a disaster of any kind, thus reducing vulnerability and supporting food security in the short- and long-term.

Simultaneously, addressing food insecurity in the wake of disasters goes hand in hand with combating the root causes of food insecurity and health disparities, such as poverty and food deserts.[99] Structural racism is also deeply interconnected through complex pathways, including through the creation of disadvantaged social and economic factors that contribute to food insecurity.[100] Yet, even when these factors are removed, some evidence suggests food insecurity remains for people of color, highlighting the need for further research.[100] Finally, applying a food systems approach to food security after disasters, such as production of and access to healthy foods, and supporting diverse, local, and regional agriculture, is an important long-term strategy with clear benefits for both health and climate change.

TABLE 4.

Suggested adaptive actions for communities and organizations.

ADAPTIVE ACTIONS FOR COMMUNITIES AND ORGANIZATIONS
• Identify and address the impact of systematic racism and discrimination in food insecurity and food distribution systems[100,114] • Assess and consider public access to food for people with limited capacity to travel[94] • Promote policies and practices to enhance access to affordability of nutritious foods, including food diversion programs that reduce food waste[115] • Increase flexibility and access to emergency food for vulnerable populations (D-SNAP, WIC, food banks, and school meals) • Screen for food insecurity in the healthcare setting • Address food sovereignty for tribal and Indigenous people[116] • Identify and address food deserts within communities[99] • Foster partnerships with local food producers through community cooperatives in order to promote food access and local economic resilience • Create community collaborations for resource sharing[117] • Strengthen social support networks among vulnerable populations[117] • Undertake risk assessments to understand climate change threats and the current state of preparedness, specifically with regard to food supply[118] • Undertake food vulnerability mapping to understand risk profiles among neighborhoods[119] • Promote resilient local and regional agricultural practices, including urban agriculture and community gardens[120] • Utilize existing frameworks for addressing food insecurity following disasters: » Urban food chain supply resilience[121] » Local food system resilience and food insecurity[122] » A food systems approach to climate change preparedness[103]

CASE STUDY

Urban Green Space: Health Benefits and Reduction of Inequities

Green space, or "greenness", is an area covered by vegetation like grass and trees that provides a stark contrast to the common man-made surfaces like asphalt found in U.S. cities.

These nature-orientated areas are a key climate change adaptation strategy that can aid in reducing temperatures in "urban heat islands", or parts of the city that get hotter than surrounding areas due to man-made features (i.e. the urban heat island effect). Green space also provides a multitude of other direct and indirect benefits that promote health.[143,144]

These health benefits result from reducing harmful exposures to air pollution, heat, and noise, and by promoting physical activity, mental health and social engagement in both children and adults.[144–146] Epidemiological research also shows exposure to green space can also decrease illness and death.[144,145] Other benefits of adding greenness within a city include managing stormwater run-off, increasing plant and animal life, and storing carbon dioxide — thereby combating climate change.[147–149]

Greenness, however, varies across the United States due to weather patterns, urbanization, type of terrain, and other factors. Overall, cities and urban areas tend to be less green than suburban and rural areas due to the number and density of roads and buildings.

Studies show that access to green space in urban areas is not evenly distributed across different races, ethnicities, levels of income, and other social and economic factors – broadly "socioeconomic status" (SES).[150,151] Often, areas with a population that is predominantly White with a greater proportion of high income individuals and other beneficial SES factors have more greenness compared to areas of lower SES.[150–155] Research has also examined how the varying distribution of greenness along racial, ethnic, and economic lines may contribute to health inequities, thus suggesting that access to greenspace is an environmental justice issue.[150–155]

Given that both health and climate change benefit from the creation of green space, urban planners and policymakers can use these findings to support the equitable greening of cities. Action items that can take place at the community level include: a) planting trees and other vegetation that are native, less susceptible to pests, and do not produce much pollen; b) creating a tree and vegetation planting and maintenance plan for neighborhoods, businesses, or cities; c) leading walks in nature to help encourage neighbors to appreciate urban greenspace; d) creating parks and gardens in areas that are lacking these resources; and e) educating public officials about the multiple benefits of greenspace. Some U.S. communities have already started greening initiatives that focus on affordable housing, youth engagement, job creation, and strategies to prevent gentrification and displacement.[156,157]

Louisville, Kentucky - urban green space access and health inequities

Louisville was found to have one of the most rapidly growing urban heat islands in the U.S. in 2012.[158–160] Furthermore, the extent of the urban heat island varied significantly within Louisville as temperatures differed by up to 10°F across different parts of the city.[159] Concern about urban heat islands, combined with the city's steady decrease in tree canopy,[160] led Louisville to embark on tree planting initiatives like the Green Heart Project.[161] Due to these efforts, the city can serve as a useful case study on how a focus on greenness can impact health and other inequities, and how best to further expand greening endeavors.

Although Louisville, overall, has a relatively high average greenness across the city proper and its surrounding metropolitan area, this resource is not equitably distributed. The potential health impacts of this unequal distribution are significant. **Using epidemiologic exposure-response functions taken from the literature, we estimated that over 400 all-cause deaths in 2015 for those aged 55 and older could have been prevented with just a small increase in greenness. Of those, about 70 deaths (17%) occurred in areas of very low greenness and 45 (11%) occurred in predominantly Black or low-income neighborhoods.** Thus, health can be improved — and lives saved — all while striving to tackle inequities and injustices.

The science: results for the U.S. and Louisville, Kentucky

The 2020 global Lancet Countdown report includes a new indicator measuring access to green space in urban areas.[123] The researchers for the global indicator did additional analyses for Louisville, Kentucky to deepen the discussion and understanding of the relationships between greenspace, race, income, and health.

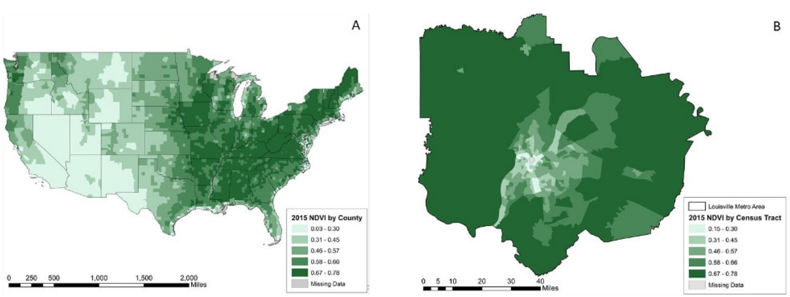
Scientific deep dive: how greenness is measured for U.S. and Louisville, Kentucky

The Normalized Difference Vegetation Index (NDVI) is the most commonly used metric in epidemiologic studies to estimate greenness.[144,145] NDVI is derived from satellite imagery and is calculated as a ratio of near-infrared to visible light. In general, it measures the photosynthetic activity of plants, with values ranging from -1 to +1, with negative values indicating water, values around zero representing bare soil, and values near +1 indicating high amounts of green vegetation.[162] For this case study, NDVI measured by the Landsat satellite program was processed using Google Earth Engine to calculate average greenness per county for the entire U.S. and per census tract for Louisville, Kentucky.[163]

Nationally for the contiguous U.S., the average greenness during the summer months, based on 2015 county-level data, was 0.57 ,with a range between 0.03 and 0.78 (**see Figure 4A**). Louisville, Kentucky (**see Figure 4B**) had an average greenness of 0.54 with a range from 0.00 to 0.75. Figure 5B shows that there tended to be less green around the city center compared to the outskirts, which include more suburban and rural land. Louisville fell only slightly below the national average, by 0.03 units.

FIGURE 4.

Distribution of greenness (NDVI) across A) contiguous U.S. by county and B) Louisville, Kentucky metropolitan statistical area by census tract



Scientific deep dive: how the distribution of greenness varies by race and income in Louisville

Residential segregation, or an index of the concentration of extremes, was used to examine greenness exposure inequities along economic and racial/ethnic disparities. Racial (RRS) and economic (ERS) residential segregation are measures that examine how mixed or isolated two populations are within a geographic area.[164–166] RRS and ERS were calculated at the census tract level and yielded scores that range between -1 and +1. A value close to -1 indicates the population is concentrated in the deprived group (e.g., non-Hispanic Black and lower income), while a value closer to +1 connotes the population is concentrated in the privileged group (e.g., non-Hispanic White and higher income). Scores close to 0 indicate well-mixed communities.[164]

Louisville is an example of an urban area with inequitably distributed greenness. In census tracts that are majority White (> 50%), the average greenness was approximately 0.2 units higher than those that are majority Black: 0.56 compared to 0.38, respectively. Similarly, a difference of 0.2 units in average greenness was observed when looking at majority high income (> $100,000 per year) versus majority low income (< $25,000 per year): 0.59 compared to 0.38, respectively.

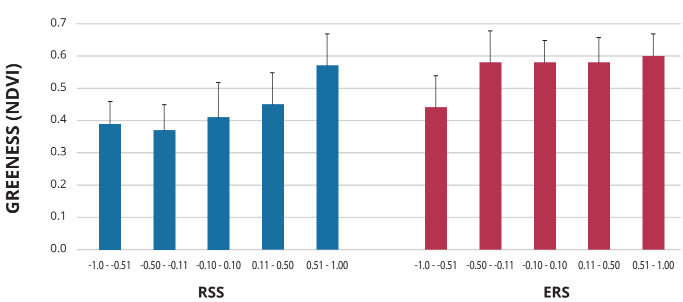
As **Figure 5** depicts, comparing isolated census tracts indicates that more privileged areas (e.g., non-Hispanic White and higher income) have an average greenness 0.2 units higher than the average greenness in less-privileged areas (e.g., non-Hispanic Black and lower income).

Scientific deep dive: potential reduction in mortality and disparities in exposure to greenness in Louisville

To examine the potential mortality disparities in greenness exposure, a health impact assessment was conducted for this case study. This assessment used a greenness and mortality exposure-response function to estimate the potential reduction in deaths for those 55 years of age and older in Louisville if greenness was increased across the entire case-study area by 0.1 NDVI units.[167,168] An estimated overall 413 deaths (95% confidence interval (CI): 309 – 619) could have been prevented in 2015 if the city were able to increase its greenness by 0.1 units, including 71 deaths (95% CI: 54 – 107) in areas with very low greenness (based on distribution in Louisville), and 45 deaths (95% CI: 31 – 68) in predominantly Black or low income neighborhoods.

FIGURE 5.

Greenness by racial and economic residential segregation in Louisville, Kentucky.



Critical Insights

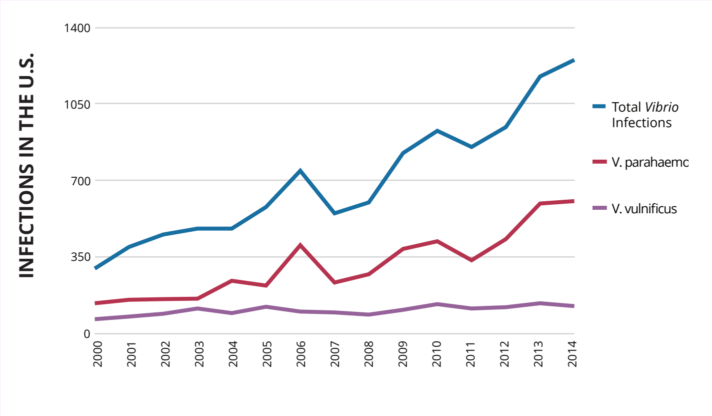
Climate Change and *Vibrio*

Vibrio are a type of bacteria found in coastal waters that can cause water- or food-borne disease. **The suitability of coastal waters for growth of these bacteria has increased. In the Northeast, it has increased by as much as 99%* over the past five years.**[123] Warmer waters with optimum salinity in estuaries, driven by climate change-related warming water temperatures, sea level rise, heavy rainfall, and nutrient changes, are associated with increased concentrations of *Vibrio*.[124–127]

Models of the Chesapeake Bay predict expanded habitats and higher summertime concentrations of *V. vulnificus* and *V. parahaemolyticus*.[125] One simulation suggests that by 2100, waters along U.S. coasts may provide a suitable habitat for V. cholerae, which causes cholera and is currently almost nonexistent domestically.[128] Flooding fueled by climate change is also of concern; along the Gulf Coast, cases of non-cholera *Vibrio* illnesses increased after Hurricane Katrina.[13,129,130]

FIGURE 6.

Total reported infections of non-cholera *Vibrio* species in the U.S., 2000-2014.



* This represents newly published data for the U.S. from Watts et al (2020), and the most recent year of data available is presented. Please see the 2020 global Lancet Countdown report and appendix for further details about this specific indicator.

Implications for health

People can become infected with waterborne *Vibrio* bacteria (*V. vulnificus, V. parahaemolyticus,* and *V. cholerae*) when an open wound is exposed to contaminated saltwater, or by eating contaminated seafood.[131] *Vibrio* can cause severe diarrhea, wound infections, and blood infections that can be life-threatening.[131,132]

Reported *Vibrio* infections in the U.S. are increasing **(see Figure 6)**[131] and expanding to new geographic regions.[133,134] The death rate is 20% for flesh-eating skin infections and exceeds 50% when infection spreads throughout the body; infections are becoming harder to treat given the bacteria's rising resistance to antibiotics.[135,136] Individuals with diabetes, liver disease, and compromised immune systems are at greatest risk for serious complications including limb amputation and organ failure.[131]

A path forward

To address the health harms from *Vibrio*, public health organizations and policymakers should prioritize aggressive climate change mitigation efforts. These efforts can reduce warming of water, sea level rise, and flooding, all of which increase suitability for *Vibrio* bacteria. To reduce the risk of *Vibrio* infections, public health protocols and public education should incorporate seasonality and updated location-specific hazards. The National Shellfish Sanitation Program has risk management plans for shellfish sold to eat,[137] and Maine implemented "time temperature" regulations to reduce the time for bacteria to multiply, thus limiting the potential for infection.[138] In addition, California saved lives by restricting the sale of untreated raw oysters from the Gulf Coast from April to October.[139] Opportunities abound to expand public health messaging in restaurants and healthcare settings to better target high-risk populations.[140–142]

Climate Action in Agriculture can Reduce Air Pollution and Minimize Climate Change

This Critical Insight provides further detail on how climate change action in the agriculture sector can also benefit health through a reduction in air pollution. Agriculture itself is impacted by climate change as, for example, crop yields decrease,[169–171] and agriculture is an important target for climate action.

Agriculture contributes 12.5%* of U.S. greenhouse gas (GHG) emissions with about 50% arising from soil management practices (e.g., application of synthetic nitrogen fertilizers) and 35% from livestock enteric fermentation (e.g., cow belching) and manure management.[172] In addition, three-fourths of human-caused nitrous oxide (NO_x) emissions arise from agricultural soils, and livestock production is the largest source of methane (CH_4) emissions in the U.S. — both potent GHG emissions, as noted in the U.S. Policy Brief.[172]

Overall agricultural GHG emissions increased around 11% between 1990 and 2018, outpacing the overall rise in U.S. GHG emissions of only 3.7%. Nitrous oxide and methane emissions related to manure management increased nearly 60% with the rapid rise in concentrated livestock production.[172] These sources are also intricately connected with the generation of ammonia, which reacts in the atmosphere to form fine particulate matter ($PM_{2.5}$), one of the most harmful forms of air pollution.

Agricultural climate change action can reduce air pollution and benefit health

The agricultural sector has been estimated to be responsible for close to 20% of all human-caused air pollution in the U.S.[173] Over half of the ammonia, the primary source of agricultural air pollution as outlined in the U.S. Policy Brief, comes from livestock and their manure, while nearly a third comes from synthetic nitrogen fertilizer on cropland.[174]

A study found that the Midwest "corn belt" contributed to approximately 4,300 premature deaths annually from the particulate matter air pollution related to corn production, further demonstrating the significant health impacts.[175] The average estimated damages associated with these deaths is $39 billion per year, which often exceeds the market value of the corn. Ammonia emissions from synthetic nitrogen fertilizers and manure drove more than 70% of these deaths. In addition, higher ammonia concentrations in the air are associated with reduced lung function in adults and asthma in children who live near Concentrated Animal Feeding Operations (CAFOs).[176,177] This is yet another avenue of health harms for already vulnerable agricultural workers (**see 2019 Appendix**), who are largely Latino and have higher rates of respiratory symptoms.[178,179]

* This number originates from methods used by the Environmental Defense Fund and includes additional GHG emissions related to agriculture (e.g., agricultural-related fossil fuels, electricity, fertilizer manufacturing and land use change related to agriculture) added to the 9.9% of direct agriculture emissions cited by the EPA.

The health effects of agricultural pollution are not limited to agricultural areas, as pollutants can travel hundreds of miles from their source.[177,180] Moreover, nitrates from agriculture sources have implications for illness beyond just air pollution, such as the health harms (e.g., cancer, thyroid disease, and fetal defects) associated with the ingestion of nitrate contaminated water.[181]

Placing health as a driver for climate change action in agriculture

The complex U.S. agricultural system has a variety of stakeholders, which means there is a wealth of opportunity for action across both consumption and production that will have sweeping benefits for climate change and health. Alterations in consumption include a shift toward plant-based diets, reduced average consumption of meat, and reduced food waste.[182] More generally for production, this should include a shift away from current large-scale industrial agricultural practices to models like regenerative agriculture.[182] Broadly, regenerative agriculture consists of practices that rehabilitate and restore degraded farmland, benefiting the farmer and crops and combating climate change.

More specifically, in addition to working on GHG emission reduction, on-farm interventions can target fertilizer and manure management as a way to reduce ammonia-related air pollution. A crucial intervention is using appropriate fertilizer and manure sources at the right rate, time, and place, and incorporating or injecting manure into cropland soil to avoid ammonia losses to the air.[183,184] Other beneficial practices include low-protein feed additives, use of cover crops, improved manure storage, methane capture, and strategic use of natural infrastructure.

Research shows that improved nutrient management on cropland could reduce nitrous oxide emissions by 33%,[185] and covering manure storage on confined dairy and swine operations could reduce overall manure methane emissions by 50%.[186] Policies and programs that encourage safe nitrogen balances or enable markets for biomethane are a part of this solution.

There are also broader food system reforms at the industrial level that can be implemented to curb rapid expansion of livestock production and the resulting food system emissions, such as those from the production of livestock feed crops. Both the American Public Health Association and the National Association of County and City Health Officials call for a moratorium on all new and expanding Concentrated Animal Feeding Operations until adequate public health protections are in place.[187] Many of these suggested approaches also enhance carbon uptake by soil, make farms more resilient to climate change-related floods and droughts, and benefit human and livestock health.[188,189]

Transitioning to Zero-Carbon Energy Will Improve the Quality of Our Air and Protect Vulnerable Communities

Transitioning to zero-carbon energy in the United States will benefit public health today by improving the quality of our air, leading to longer and healthier lives across the country. It will also protect our health in the long-term by reducing the impacts of climate change. While these benefits will be felt across the country — reducing healthcare spending and sick days — a just and affordable transition to zero-carbon energy can particularly support better health in vulnerable and marginalized communities.[123,190–193]

Climate change and air pollution exacerbate inequalities in the U.S. that stem from systemic racism and other forms of discrimination. The impacts of air pollution in the U.S. are felt across the country, but particularly in Black and Latino communities.[194] For example, rising pollution from the flaring of natural gas has been associated with up to a 50% higher chance of preterm births in mothers – who are largely Latino – living near these flares.[195–197] Furthermore, tribes and Indigenous peoples are also often disproportionately impacted by air pollution and are particularly vulnerable to the impacts of climate change.[198]

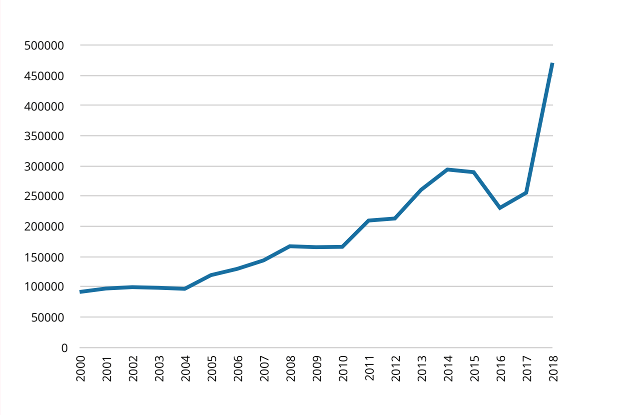
Despite progress over the past few decades, different estimations find that air pollution from the use of fossil fuels still leads to between 50,000-100,000 early deaths each year in the United States.[173] This air pollution comes predominantly from the energy system, including power plants, transportation, and industry. Thus, phasing out the country's remaining coal power plants and transitioning to zero-carbon transportation would save tens of thousands of lives across the U.S. each year.[123] Research has shown that the health benefits of the energy transition can more than offset any costs of policies to reduce GHG emissions.[199] Furthermore, engaging with communities that bear a disproportionate burden of these air pollution and climate change impacts can reduce existing equity gaps.

Natural Gas: Health and Climate Change Harms

While natural gas can lower both GHG emissions and air pollution when it replaces coal power, it is not emissions-free. Natural gas used in power plants still produces around 42% the amount of carbon dioxide (CO2) as coal per unit of electricity that is generated.* Burning natural gas produces air pollution including nitrogen oxide (NO_x), volatile organic compounds (VOCs), and particulate matter (PM), and can lead to ozone formation — all of which contribute to poor health, including respiratory illness.[200–204]

FIGURE 7.

Natural gas vented and flared in the U.S. between 2000-2018 (million cubic feet).



Source: Energy Information Administration. U.S. Natural Gas Vented and Flared (million cubic feet).[210] Additional note: 2017 datapoint is not currently available and so the trend from 2016 to 2018 was determined through linear interpolation.

The use of natural gas in the U.S. rose by 35% over the past decade (**see Figure 7**).[205, 206] In 2019, natural gas produced 35% of the total electricity generated in the U.S. compared to 18% in 2005.[207] Over this same period, GHG emissions from natural gas power plants rose by 81%.[208]

Furthermore, the amount of natural gas that is vented and flared during production (i.e. at the well site) more than quadrupled from 2000-2018 in the U.S.[209, 210] Several studies have found higher risk of asthma attacks and poor birth outcomes among communities living in proximity or downwind of oil and gas activity.[195,196, 211–216]

The main component of natural gas is methane (CH_4). Methane leaks occur throughout the entire natural gas supply chain. While transmission and storage of natural gas contributes to around 19% of this leaked methane (e.g., from leaky pipes), but the majority (67%) of leaks occur during oil and gas production.[217] The sector could cut methane emissions by approximately 70% by using available emission-control technologies and operating practices, including leak detection and repair.[218]

* This value assumes that associated emissions from flaring and leakage – which can significantly increase the carbon footprint of natural gas – can be minimized.[209,210,219]

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THE LANCET COUNTDOWN

The Lancet Countdown: Tracking Progress on Health and Climate Change is an international, multi-disciplinary collaboration that exists to monitor the links between public health and climate change. It brings together 38 academic institutions and UN agencies from every continent, drawing on the expertise of climate scientists, engineers, economists, political scientists, public health professionals, and doctors. Each year, the Lancet Countdown publishes an annual assessment of the state of climate change and human health, seeking to provide decision-makers with access to high-quality evidence-based policy guidance. For the full 2020 assessment, visit **www.lancetcountdown.org/2020-report/**.

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References

1 Morgan S. 28 deaths in Louisiana attributed to Hurricane Laura. KPLCTV. 2020; published online Aug 27. https://www.kplctv.com/2020/08/27/deaths-attributed-hurricane-laura/ (accessed Oct 21, 2020).

2 Chappell B. Hurricane Laura Losses Include 10 Deaths, Up To $12 Billion: Hurricane Laura Live Updates. npr. 2020; published online Aug 28. https://www.npr.org/sections/hurricane-laura-live-updates/2020/08/28/907133279/hurricane-laura-losses-include-10-deaths-up-to-12-billion-it-couldve-been-worse (accessed Oct 21, 2020).

3 Knutson T, Camargo SJ, Chan JCL, *et al.* Tropical Cyclones and Climate Change Assessment: Part I: Detection and Attribution. *Bull Am Meteorol Soc* 2019; **100**: 1987–2007.

4 Kossin JP, Knapp KR, Olander TL, Velden CS. Global increase in major tropical cyclone exceedance probability over the past four decades. *Proc Natl Acad Sci U S A* 2020; **117**: 11975–80.

5 Knutson T, Camargo SJ, Chan JCL, *et al.* Tropical cyclones and climate change assessment part II: Projected response to anthropogenic warming. *Bull Am Meteorol Soc* 2020; **101**: E303–22.

6 Kossin JP. A global slowdown of tropical-cyclone translation speed. *Nature* 2018; **558**: 104–7.

7 Zhang G, Murakami H, Knutson TR, Mizuta R, Yoshida K. Tropical cyclone motion in a changing climate. *Sci Adv* 2020; **6**: 7610–32.

8 Bhatia KT, Vecchi GA, Knutson TR, *et al.* Recent increases in tropical cyclone intensification rates. *Nat Commun* 2019; **10**: 1–9.

9 Ch. 9 Extreme storms. In: Climate Science Special Report: Fourth National Climate Assessment, Volume I. Washington, DC, USA https://science2017.globalchange.gov/downloads/CSSR2017_FullReport.pdf (accessed Oct 21, 2020).

10 Matthews T, Wilby RL, Murphy C. An emerging tropical cyclone–deadly heat compound hazard. Nat. Clim. Chang. 2019; **9**: 602–6.

11 Dahl K, Spanger-Siegfried E, Licker R, *et al.* Killer Heat in the United States | Climate Choices and the Future of Dangerously Hot Days. Union Concerned Sci. 2019; published online July 2. https://www.ucsusa.org/resources/killer-heat-united-states-0 (accessed Oct 21, 2020).

12 Ornes S. How does climate change influence extreme weather? Impact attribution research seeks answers. Proc. Natl. Acad. Sci. U. S. A. 2018; **115**: 8232–5.

13 Ebi KL, Ogden NH, Semenza JC, Woodward A. Detecting and Attributing Health Burdens to Climate Change. *Environ Health Perspect* 2017; **125**: 085004.

14 Van Oldenborgh GJ, Van Der Wiel K, Sebastian A, *et al.* Attribution of extreme rainfall from Hurricane Harvey, August 2017. *Environ Res Lett* 2017; **12**: 124009.

15 Reed KA, Stansfield AM, Wehner MF, Zarzycki CM. Forecasted attribution of the human influence on Hurricane Florence. *Sci Adv* 2020; **6**. DOI:10.1126/sciadv.aaw9253.

16 Shultz JM, Sands DE, Kossin JP, Galea S. Double Environmental Injustice — Climate Change, Hurricane Dorian, and the Bahamas. *N Engl J Med* 2020; **382**: 1–3.

17 Espinel Z, Kossin JP, Galea S, Richardson AS, Shultz JM. Forecast: Increasing Mental Health Consequences From Atlantic Hurricanes Throughout the 21st Century. *Psychiatr Serv* 2019; **70**: 1165–7.

18 Adeola FO. Environmental Injustice in the State of Louisiana?: Hazardous Wastes and Environmental Illness in the Cancer Corridor on JSTOR. *Race, Gend Cl* 1998; **6**: 83–108.

19 Residential Segregation Data for U.S. Metro Areas. Governing. https://www.governing.com/gov-data/education-data/residential-racial-segregation-metro-areas.html (accessed Oct 21, 2020).

20 Residential segregation - Black/White in Louisiana. Cty. Heal. Rank. Roadmaps. 2020. https://www.countyhealthrankings.org/app/louisiana/2020/measure/factors/141/data?sort=desc-2 (accessed Oct 21, 2020).

References

21 2014-2018 ACS 5-year Estimates. United States Census Bur. https://www.census.gov/programs-surveys/acs/news/data-releases/2018/release.html#par_textimage (accessed Oct 28, 2020).

22 Schleifstein M, The Times-Picayune, The Advocate. I've Investigated Industrial Pollution for 35 Years. We're Going Backwards. ProPublica. 2019; published online Oct 30. https://www.propublica.org/article/ive-investigated-industrial-pollution-for-35-years-were-going-backwards (accessed Oct 21, 2020).

23 31 New or Expanded Petrochemical Plants Approved in Hurricane Zone Along TX and LA Gulf Coast Page 15. Environ. Integr. Proj. 2018; published online Sept 26. https://environmentalintegrity.org/news/31-new-or-expanded-petrochemical-plants/15/ (accessed Oct 21, 2020).

24 EJSCREEN EPA's Environmental Justice Screening and Mapping Tool. EPA. 2019. https://ejscreen.epa.gov/mapper/ (accessed Oct 21, 2020).

25 2019 Louisiana Health Report Card. 2020 www.ldh.la.gov/cphi (accessed Oct 21, 2020).

26 Community Health Needs Assessment 2013 Lake Charles Memorial Hospital. 2013 https://www.lcmh.com/documents/Lake-Charles-Memorial-Final-CHNA.PDF (accessed Oct 21, 2020).

27 Uwphi. Louisiana 2020 County Health Rankings Report. 2020 https://www.countyhealthrankings.org/sites/default/files/media/document/CHR2020_LA_v2.pdf (accessed Oct 21, 2020).

28 Louisiana Coronavirus COVID-19 . Louisiana Dep. Heal. 2020. https://ldh.la.gov/coronavirus/ (accessed Oct 21, 2020).

29 Petroni M, Hill D, Younes L, *et al.* Hazardous air pollutant exposure as a contributing factor to COVID-19 mortality in the United States. *Environ Res Lett* 2020; **15**: 0940a9.

30 Pozzer A, Dominici F, Haines A, Witt C, Mü Nzel T, Lelieveld J. Regional and global contributions of air pollution to risk of death from COVID-19. *Cardiovasc Res* 2020. DOI:10.1093/cvr/cvaa288.

31 Wagner GA. Louisiana Economic Activity Forecast 2020:Q3. 2020 https://business.louisiana.edu/sites/business/files/LEAF_Report_2020Q3.pdf (accessed Oct 21, 2020).

32 DiStefano J. Is the U.S. Headed Toward an Eviction Crisis? UrbanFootprint | Mediu. https://medium.com/urbanfootprint/is-the-u-s-headed-toward-an-eviction-crisis-c9f8622ed64 (accessed Oct 21, 2020).

33 2021-2022 Louisiana Economic Outlook Released. LSU E.J. Ourso Coll. Bus. . 2020; published online Sept 15. https://www.lsu.edu/business/newsevents/2020/11-september/2021-2022-louisiana-economic-outlook-released-2020.php (accessed Nov 16, 2020).

34 The Impact of the Coronavirus on Food Insecurity. Feed. Am. Action. 2020; published online June 3. https://www.feedingamericaaction.org/the-impact-of-coronavirus-on-food-insecurity/ (accessed Oct 21, 2020).

35 Fedschun T. Louisiana power grid needs 'complete rebuild' after Hurricane Laura, restoration to take weeks. *FOXBusiness* 2020; published online Sept 3. https://www.foxbusiness.com/energy/louisiana-power-hurricane-laura-lake-charles-restoration-disaster-response-storm-recovery-complete-rebuild (accessed Oct 21, 2020).

36 Deslatte M. Analysis: Laura reminds of Louisiana's fragile water systems. AP News. 2020; published online Sept 13. https://apnews.com/article/technology-storms-hurricane-laura-hurricanes-louisiana-758347b3c08c0fec5cc1de7f13f48453 (accessed Oct 21, 2020).

37 Sentell W. Lake Charles schools suffer $300 million in damages from Hurricane Laura, superintendent says . The Advocate. 2020; published online Sept 16. https://www.theadvocate.com/baton_rouge/news/education/article_0f99e4d4-f75f-11ea-81d2-f78e370b0ec1.html (accessed Oct 28, 2020).

38 Calcasieu Power Outages. PowerOutage.US. https://poweroutage.us/area/county/1643 (accessed Sept 16, 2020).

39 Information for Hurricane Delta. Calcasieu Parish Police. https://www.calcasieuparish.gov/services/emergency-home-page/-backlist-/?fbclid=IwAR3_WX_vF_FqaNz4vR8w_I496U61TWgxnmcNdD7J8KDdINV3qA3VTrVBS0M (accessed Oct 21, 2020).

40 Louisiana Department of Health verifies one additional hurricane-related death, bringing toll to 27 . Louisiana Dep. Heal. 2020; published online Sept 9. https://ldh.la.gov/index.cfm/newsroom/detail/5761 (accessed Oct 21, 2020).

41 Canicosa J. Lake Charles tenants get temporary restraining order blocking their evictions. Louisiana Illum. 2020; published online Sept 15. https://lailluminator.com/2020/09/15/lake-charles-tenants-get-temporary-restraining-order-blocking-their-evictions/ (accessed Oct 21, 2020).

42 KLFY STAFF. Lake Charles Memorial Hospital reopens after Hurricane Laura damages. KLFY.com. 2020; published online Sept 15. https://www.klfy.com/local/lake-charles-memorial-hospital-reopens-after-hurricane-laura-damages/ (accessed Oct 21, 2020).

43 Samenow J, Cusick A. Excessive heat warning in areas ravaged by Hurricane Laura, power outages - The Washington Post. Washington Post. 2020; published online Sept 1. https://www.washingtonpost.com/weather/2020/08/31/hurricane-laura-heat-power-outages/ (accessed Oct 21, 2020).

44 Anenberg SC, Kalman C. Extreme Weather, Chemical Facilities, and Vulnerable Communities in the U.S. Gulf Coast: A Disastrous Combination. *GeoHealth* 2019; **3**: 122–6.

45 Hersher R. Millions of Pounds of Extra Pollution Were Released Before Hurricane Laura Landfall. NPR. 2020; published online Aug 28. https://www.npr.org/sections/health-shots/2020/08/28/906822940/millions-of-pounds-of-extra-pollution-were-released-before-laura-made-landfall (accessed Oct 21, 2020).

46 Mufson S, Fears D. Wind, rain and a chemical fire. Hurricane Laura was gone but the crisis wasn't over. Washington Post. 2020; published online Aug 27. https://www-washingtonpost-com/climate-environment/2020/08/27/hurricane-laura-fire-biolab/te-environment/2020/08/27/hurricane-laura-fire-biolab/ (accessed Oct 21, 2020).

47 Waldrop T. Covid-19 adds extra headache to Hurricane Laura evacuations. CNN. 2020; published online Aug 26. https://www.cnn.com/2020/08/26/us/laura-evacuations-covid-19/index.html (accessed Oct 21, 2020).

48 Shultz JM, Kossin JP, Hertelendy A, *et al.* Mitigating the Twin Threats of Climate-Driven Atlantic Hurricanes and COVID-19 Transmission. *Disaster Med Public Health Prep* 2020; : 1–10.

49 Pei S, Dahl KA, Yamana TK, Licker R, Shaman J. Compound risks of hurricane evacuation amid the COVID-19 pandemic in the United States. *medRxiv* 2020; : 2020.08.07.20170555.

50 Salas RN, Shultz JM, Solomon CG. The Climate Crisis and Covid-19 - A Major Threat to the Pandemic Response. *N Engl J Med* 2020; **383**: e70.

51 Westwood R. Only About 200 Of More Than 11,000 Hurricane Laura Evacuees Have Been Tested For COVID-19 | WWNO. WWNO New Orleans Public Radio. 2020; published online Sept 4. https://www.wwno.org/post/only-about-200-more-11000-hurricane-laura-evacuees-have-been-tested-covid-19 (accessed Oct 21, 2020).

52 Billion-Dollar Weather and Climate Disasters. NOAA Natl. Centers Environ. Inf. DOI:10.25921/stkw-7w73.

53 Knutson TR, Zeng F. Model assessment of observed precipitation trends over land regions: Detectable human influences and possible low bias in model trends. *J Clim* 2018; **31**: 4617–37.

54 [Wuebbles DJ. DWFKAHDJDBCS and TKM (eds.)]. USGCRP. Climate Science Special Report: Fourth National Climate Assessment, Volume I. Washington, DC, 2017 DOI:10.7930/J0J964J6.

55 Rain-soaked U.S. had its 2nd-wettest month on record in May. Natl. Ocean. Atmos. Adm. 2019; published online June 6. https://www.noaa.gov/news/rain-soaked-us-had-its-2nd-wettest-month-on-record-in-may (accessed Oct 30, 2020).

56 Flanagan PX, Mahmood R, Umphlett NA, *et al.* A hydrometeorological assessment of the historic 2019 flood of Nebraska, Iowa, and South Dakota. *Bull Am Meteorol Soc* 2020; **101**: E817–29.

57 Hayhoe K, Wuebbles DJ, Easterling DR, *et al.* Our Changing Climate. In Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II. Washington, DC, USA, 2018 DOI:10.7930/NCA4.2018.CH2.

58 Patz JA, Vavrus SJ, Uejio CK, McLellan SL. Climate Change and Waterborne Disease Risk in the Great Lakes Region of the U.S. Am. J. Prev. Med. 2008; **35**: 451–8.

59 van der Wiel K, Kapnick SB, van Oldenborgh GJ, *et al.* Rapid attribution of the August 2016 flood-inducing extreme precipitation in south Louisiana to climate change. *Hydrol Earth Syst Sci* 2017; **21**: 897–921.

60 Winter JM, Huang H, Osterberg EC, Mankin JS. Anthropogenic impacts on the exceptional precipitation of 2018 in the mid-Atlantic United States. *Bull Am Meteorol Soc* 2020; **101**: S5–9.

61 NOAA National Centers for Environmental Information. State of the Climate: National Climate Report for April 2019 . NOAA Natl. Centers Environ. Inf. 2019. https://www.ncdc.noaa.gov/sotc/national/201904 (accessed Oct 23, 2020).

62 USDA. Crop Production 2019 Summary. 2020.

63 Lieb DA, Casey M. Nebraska dam had history of ice woes before fatal failure . ABC News. 2020; published online April 21. https://abcnews.go.com/US/wireStory/nebraska-dam-history-ice-issues-fatal-failure-70267623 (accessed Oct 30, 2020).

64 Smith M. 'A State of Emergency': Native Americans Stranded for Days by Flooding . New York Times. 2019; published online March 24. https://www.nytimes.com/2019/03/24/us/midwest-flooding-pine-ridge.html (accessed Oct 23, 2020).

65 Frazier I. The Missouri River Flood Hits a Historic Native American Homeland. New Yorker. 2019; published online April 3. https://www.newyorker.com/news/daily-comment/missouri-river-flood-hits-historic-native-american-homeland (accessed Oct 30, 2020).

66 Flooding forces evacuations on South Dakota reservation. KXNet. 2019; published online March 28. https://www.kxnet.com/news/flooding-forces-evacuations-on-south-dakota-reservation/ (accessed Oct 30, 2020).

67 NIGA Urges Assistance to the Great Plains for Disaster Relief. NativeKnot.com. 2019; published online April 2. https://www.nativeknot.com/news/Native-American-News/NIGA-Urges-Assistance-to-the-Great-Plains-for-Disaster-Relief.html (accessed Oct 30, 2020).

68 U.S. EPA. EPA Assists States in Midwest Flood Zone of 2019. U.S. EPA. 2019. https://www.epa.gov/natural-disasters/epa-assists-states-midwest-flood-zone-2019 (accessed Oct 23, 2020).

69 Uejio CK, Yale SH, Malecki K, Borchardt MA, Anderson HA, Patz JA. Drinking water systems, hydrology, and childhood gastrointestinal illness in central and northern wisconsin. *Am J Public Health* 2014; **104**: 639–46.

70 From personal interview with Rachel Lookadoo and Chris Dethlefs. .

71 Keeler J. Tribal Community Faces an Immediate Threat from Climate Change. Lakota Times. 2019; published online Oct 3. https://www.lakotatimes.com/articles/tribal-community-faces-an-immediate-threat-from-climate-change/ (accessed Oct 23, 2020).

72 Crimmins A, Balbus J, Gamble JL, *et al.* USGCRP, 2016: The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment. Washington, D.C., 2016 https://health2016.globalchange.gov/low/ClimateHealth2016_FullReport_small.pdf.

73 Ahern M, Kovats RS, Wilkinson P, Few R, Matthies F. Global health impacts of floods: Epidemiologic evidence. *Epidemiol Rev* 2005; **27**: 36–46.

74 Paterson DL, Wright H, Harris PNA. Health risks of flood disasters. Clin. Infect. Dis. 2018; **67**: 1450–4.

75 Historic flooding in Midwest affects hospitals . AHA News. 2019; published online March 18. https://www.aha.org/news/headline/2019-03-18-historic-flooding-midwest-affects-hospitals (accessed Oct 23, 2020).

76 Marinucci GD, Luber G, Uejio CK, Saha S, Hess JJ. Building resilience against climate effects-a novel framework to facilitate climate readiness in public health agencies. *Int J Environ Res Public Health* 2014; **11**: 6433–58.

References CONTINUED

77 Key Statistics & Graphics. USDA Econ. Res. Serv. . https://www.ers.usda.gov/topics/food-nutrition-assistance/food-security-in-the-us/key-statistics-graphics.aspx (accessed Oct 21, 2020).

78 Schanzenbach D, Pitts A. How Much Has Food Insecurity Risen? Evidence from the Census Household Pulse Survey. APA, 2020 https://www.ipr.northwestern.edu/documents/reports/ipr-rapid-research-reports-pulse-hh-data-10-june-2020.pdf (accessed Oct 21, 2020).

79 Wolfson JA, Leung CW. Food insecurity and COVID-19: Disparities in early effects for us adults. *Nutrients* 2020; **12**: 1648.

80 The Impact of the Coronavirus on Food Insecurity. 2020 https://www.dol.gov/sites/dolgov/files/OPA/newsreleases/ui-claims/20200510.pdf (accessed Oct 21, 2020).

81 Waxman E, Gupta P, Karpman M. More Than One in Six Adults Were Food Insecure Two Months into the COVID-19 Recession. Urban Inst. 2020; published online July 18. https://www.urban.org/research/publication/more-one-six-adults-were-food-insecure-two-months-covid-19-recession (accessed Oct 21, 2020).

82 Bower KM, Thorpe RJ, Rohde C, Gaskin DJ. The intersection of neighborhood racial segregation, poverty, and urbanicity and its impact on food store availability in the United States. *Prev Med (Baltim)* 2014; **58**: 33–9.

83 Brown AGM, Esposito LE, Fisher RA, Nicastro HL, Tabor DC, Walker JR. Food insecurity and obesity: Research gaps, opportunities, and challenges. *Transl Behav Med* 2019; **9**: 980–7.

84 Belanger MJ, Hill MA, Angelidi AM, Dalamaga M, Sowers JR, Mantzoros CS. Covid-19 and Disparities in Nutrition and Obesity. *N Engl J Med* 2020; **383**: e69.

85 Fong AJ, Lafaro K, Ituarte PHG, Fong Y. Association of Living in Urban Food Deserts with Mortality from Breast and Colorectal Cancer. *Ann Surg Oncol* 2020; : 1–9.

86 Gundersen C, Ziliak JP. Childhood Food Insecurity in the U.S.: Trends, Causes, and Policy Options. https://futureofchildren.princeton.edu/sites/futureofchildren/files/media/childhood_food_insecurity_researchreport-fall2014.pdf (accessed Oct 21, 2020).

87 Rippey BR. The U.S. drought of 2012. *Weather Clim Extrem* 2015; **10**: 57–64.

88 Nozhati S, Rosenheim N, Ellingwood BR, Mahmoud H, Perez M. Probabilistic framework for evaluating food security of households in the aftermath of a disaster. *Struct Infrastruct Eng* 2019; **15**: 1060–74.

89 Field CB. VBFSDQDJDKLEMDMK-JMG-KPSKAMT and PMM (Eds. . Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation . 2012 https://www.ipcc.ch/report/managing-the-risks-of-extreme-events-and-disasters-to-advance-climate-change-adaptation/ (accessed Oct 21, 2020).

90 NPPD, OPPD detail response to flooding, severe weather. Am. Public Power Assoc. 2019; published online April 12. https://www.publicpower.org/periodical/article/nppd-oppd-detail-response-flooding-severe-weather (accessed Oct 21, 2020).

91 Bloch S. Historic losses faced by Nebraska farmers "will impact food on your table". Count. 2019; published online March 19. https://thecounter.org/nebraska-south-dakota-wisconsin-flooding-historic-loss-farmers-emergency/ (accessed Oct 21, 2020).

92 Smith M, Healy J, Williams T. 'It's Probably Over for Us': Record Flooding Pummels Midwest When Farmers Can Least Afford It . New York Times. 2019; published online March 18. https://www.nytimes.com/2019/03/18/us/nebraska-floods.html (accessed Oct 21, 2020).

93 Botts J. "We need the food that we lost." Low-income families still reeling from blackouts. CalMatters. 2019; published online Nov 22. https://calmatters.org/projects/california-psps-power-shut-offs-poverty-spoiled-food-hunger/ (accessed Oct 28, 2020).

94 Clay LA, Papas MA, Gill KB, Abramson DM. Factors associated with continued food insecurity among households recovering from hurricane Katrina. *Int J Environ Res Public Health* 2018; **15**. DOI:10.3390/ijerph15081647.

95 Subaiya S, Stillman J, Pumpalova Y. A modified Community Assessment for Public Health Emergency Response (CASPER) four months after Hurricane Sandy. *Disasters* 2019; **43**: 206–17.

96 Roberts E. Community Food Security: The Baltimore City Model . NACCHO. 2014; published online Nov 25. https://www.naccho.org/blog/articles/community-food-security-the-baltimore-city-model (accessed Oct 21, 2020).

97 USDA Extends WIC COVID-19 Flexibilities for Duration of the COVID-19 Public Health Emergency. USDA. 2020; published online Sept 21. https://www.usda.gov/media/press-releases/2020/09/21/usda-extends-wic-covid-19-flexibilities-duration-covid-19-public (accessed Nov 16, 2020).

98 Balch B. 54 million people in America face food insecurity during the pandemic. It could have dire consequences for their health. AAMC. 2020; published online Oct 15. https://www.aamc.org/news-insights/54-million-people-america-face-food-insecurity-during-pandemic-it-could-have-dire-consequences-their (accessed Nov 16, 2020).

99 Block JP, Subramanian S V. Moving Beyond "Food Deserts": Reorienting United States Policies to Reduce Disparities in Diet Quality. *PLoS Med* 2015; **12**: e1001914.

100 Odoms-Young A, Bruce MA. Examining the Impact of Structural Racism on Food Insecurity. *Fam Community Health* 2018; **41**: S3–6.

101 Kirkpatrick SI, Tarasuk V. Housing circumstances are associated with household food access among low-income urban families. *J Urban Heal* 2011; **88**: 284–96.

102 Gregory CA, Coleman-Jensen A. Food Insecurity, Chronic Disease, and Health Among Working-Age Adults. 2017 DOI:10.22004/AG.ECON.261813.

103 Mbow, C, Rosenzweig C, Barioni L, et al. Food security. In: Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security and greenhouse gas fluxes in terrestrial ecosystems. 2019 https://www.ipcc.ch/srccl/ (accessed Oct 21, 2020).

104 Crowe J, Lacy C, Columbus Y. Barriers to Food Security and Community Stress in an Urban Food Desert. *Urban Sci* 2018; **2**: 46.

105 Chilton M, Black MM, Berkowitz C, *et al.* Food insecurity and risk of poor health among US-born children of immigrants. *Am J Public Health* 2009; **99**: 556–62.

106 Majority of College Students Experience Food Insecurity, Housing Insecurity, or Homelessness. Assoc. Am. Coll. Univ. 2019; published online June. https://www.aacu.org/aacu-news/newsletter/majority-college-students-experience-food-insecurity-housing-insecurity-or (accessed Nov 4, 2020).

107 Kaiser M, Barnhart S, Huber-Krum S. Measuring Social Cohesion and Social Capital within the Context of Community Food Security: A Confirmatory Factor Analysis. *J Hunger Environ Nutr* 2020; **15**: 591–612.

108 Maynard M, Andrade L, Packull-McCormick S, Perlman C, Leos-Toro C, Kirkpatrick S. Food Insecurity and Mental Health among Females in High-Income Countries. *Int J Environ Res Public Health* 2018; **15**: 1424.

109 Biehl E, Buzogany S, Baja K, Neff R. Planning for a Resilient Urban Food System: A Case Study from Baltimore City, Maryland. *J Agric Food Syst Community Dev* 2018; **8**: 39–53.

110 Lal R. Home gardening and urban agriculture for advancing food and nutritional security in response to the COVID-19 pandemic. Food Secur. 2020; **12**: 871–6.

111 Dubbeling M, Santini G, Bucatariu C, Vogt C, Eisenbeiß K. City Region Food Systems and Food Waste Management. Bonn and Eschborn, 2016.

112 World Food Programme. Disaster risk reduction. https://www.wfp.org/disaster-risk-reduction (accessed Nov 4, 2020).

113 Carlson S, Keith-Jennings B. SNAP Is Linked with Improved Nutritional Outcomes and Lower Health Care Costs. 2018 DOI:10.1146/annurev-publhealth-031210-101218.

114 Clay LA, Ross AD. Factors associated with food insecurity following hurricane harvey in Texas. *Int J Environ Res Public Health* 2020; **17**. DOI:10.3390/ijerph17030762.

115 Freedman DA, Blake CE, Liese AD. Developing a Multicomponent Model of Nutritious Food Access and Related Implications for Community and Policy Practice. *J Community Pract* 2013; **21**: 379–409.

116 Tribal Food Sovereignty and Climate Change Preparedness of Tribal Agriculture. USDA Clim. Hubs. 2019; published online June 17. https://www.climatehubs.usda.gov/hubs/southwest/news/tribal-food-sovereignty-and-climate-change-preparedness-tribal-agriculture (accessed Nov 16, 2020).

117 Healthy, Resilient, and Sustainable Communities After Disasters. Washington, D.C. : National Academies Press, 2015 DOI:10.17226/18996.

118 Richardson KJ, Lewis KH, Krishnamurthy PK, Kent C, Wiltshire AJ, Hanlon HM. Food security outcomes under a changing climate: impacts of mitigation and adaptation on vulnerability to food insecurity. *Clim Change* 2018; **147**: 327–41.

119 Schmeltz MT, Marcotullio PJ. Examination of human health impacts due to adverse climate events through the use of vulnerability mapping: A scoping review. *Int J Environ Res Public Health* 2019; **16**. DOI:10.3390/ijerph16173091.

120 Smith P, Calvin K, Nkem J, *et al.* Which practices co-deliver food security, climate change mitigation and adaptation, and combat land degradation and desertification? *Glob Chang Biol* 2020; **26**: 1532–75.

121 Hecht AA, Biehl E, Barnett DJ, Neff RA. Urban Food Supply Chain Resilience for Crises Threatening Food Security: A Qualitative Study. *J Acad Nutr Diet* 2019; **119**: 211–24.

122 Béné C. Resilience of local food systems and links to food security – A review of some important concepts in the context of COVID-19 and other shocks. Food Secur. 2020; **12**: 805–22.

123 Watts N, et al. The 2020 report of The Lancet Countdown on health and climate change: responding to converging crises. *Lancet 2020;* https://doi.org/10.1016/S0140-6736(20)32290-X.

124 Deeb R, Tufford D, Scott GI, Moore JG, Dow K. Impact of Climate Change on Vibrio vulnificus Abundance and Exposure Risk. *Estuaries and Coasts* 2018; **41**: 2289–303.

125 Muhling BA, Jacobs J, Stock CA, Gaitan CF, Saba VS. Projections of the future occurrence, distribution, and seasonality of three Vibrio species in the Chesapeake Bay under a high-emission climate change scenario . *GeoHealth* 2017; **1**: 278–96.

126 Hartwick MA, Urquhart EA, Whistler CA, Cooper VS, Naumova EN, Jones SH. Forecasting seasonal vibrio parahaemolyticus concentrations in new England shellfish. *Int J Environ Res Public Health* 2019; **16**: 4341.

127 Baker-Austin C, Trinanes JA, Taylor NGH, Hartnell R, Siitonen A, Martinez-Urtaza J. Emerging Vibrio risk at high latitudes in response to ocean warming. *Nat Clim Chang* 2013; **3**: 73–7.

128 Escobar LE, Ryan SJ, Stewart-Ibarra AM, *et al.* A global map of suitability for coastal Vibrio cholerae under current and future climate conditions. *Acta Trop* 2015; **149**: 202–11.

129 Patricola CM, Wehner MF. Anthropogenic influences on major tropical cyclone events. *Nature* 2018; **563**: 339–46.

130 Vibrio Illnesses After Hurricane Katrina --- Multiple States, August--September 2005. *CDC MMWR* 2005; **54**: 928–31.

131 Vibrio Species Causing Vibriosis. U.S. Centers Dis. Control. https://www.cdc.gov/vibrio/index.html (accessed Oct 21, 2020).

132 Ali M, Nelson AR, Lopez AL, Sack DA. Updated global burden of cholera in endemic countries. *PLoS Negl Trop Dis* 2015; **9**. DOI:10.1371/journal.pntd.0003832.

133 King M, Rose L, Fraimow H, Nagori M, Danish M, Doktor K. Vibrio vulnificus infections from a previously nonendemic area. Ann. Intern. Med. 2019; **171**: 520–1.

134 Vezzulli L, Grande C, Reid PC, *et al.* Climate influence on Vibrio and associated human diseases during the past half-century in the coastal North Atlantic. *Proc Natl Acad Sci U S A* 2016; **113**: E5062–71.

135 Heng SP, Letchumanan V, Deng CY, *et al.* Vibrio vulnificus: An environmental and clinical burden. Front. Microbiol. 2017; **8**: 997.

136 Strom MS, Paranjpye RN. Epidemiology and pathogenesis of Vibrio vulnificus. Microbes Infect. 2000; **2**: 177–88.

137 U.S. FDA. National Shellfish Sanitation Program (NSSP). https://www.fda.gov/food/federalstate-food-programs/national-shellfish-sanitation-program-nssp (accessed Oct 21, 2020).

138 Shellfish Sanitation and Management: Maine DMR Vibrio Education. Maine Dep. Mar. Resour. Bur. Public Heal. https://www.maine.gov/dmr/shellfish-sanitation-management/vibrio.html (accessed Oct 21, 2020).

139 Vugia DJ, Tabnak F, Newton AE, Hernandez M, Griffin PM. Impact of 2003 state regulation on raw oyster-associated vibrio vulnificus illnesses and deaths, California, USA. *Emerg Infect Dis* 2013; **19**: 1276–80.

140 Mouzin E, Mascola L, Tormey MP, et al. Prevention of Vibrio vulnificus Infections: Assessment of Regulatory Educational Strategies. *JAMA* 1997; **278**: 576.

141 Weis KE, Hammond RM, Hutchinson R, Blackmore CGM. Vibrio illness in Florida, 1998-2007. *Epidemiol Infect* 2011; **139**: 591–8.

142 Ndraha N, Wong H, Hsiao H. Managing the risk of Vibrio parahaemolyticus infections associated with oyster consumption: A review. *Compr Rev Food Sci Food Saf* 2020; **19**: 1187–217.

143 Chen A, Yao XA, Sun R, Chen L. Effect of urban green patterns on surface urban cool islands and its seasonal variations. *Urban For Urban Green* 2014; **13**: 646–54.

144 Fong KC, Hart JE, James P. A Review of Epidemiologic Studies on Greenness and Health: Updated Literature Through 2017. *Curr Environ Heal reports* 2018; **5**: 77–87.

145 James P, Banay RF, Hart JE, Laden F. A Review of the Health Benefits of Greenness. *Curr Epidemiol Reports* 2015; **2**: 131–42.

146 Beyer KMM, Kaltenbach A, Szabo A, Bogar S, Javier Nieto F, Malecki KM. Exposure to neighborhood green space and mental health: Evidence from the survey of the health of wisconsin. *Int J Environ Res Public Health* 2014; **11**: 3453–72.

147 Gotsch SG, Draguljić D, Williams CJ. Evaluating the effectiveness of urban trees to mitigate storm water runoff via transpiration and stemflow. *Urban Ecosyst* 2018; **21**: 183–95.

148 Threlfall CG, Mata L, Mackie JA, *et al.* Increasing biodiversity in urban green spaces through simple vegetation interventions. *J Appl Ecol* 2017; **54**: 1874–83.

149 Nowak DJ, Greenfield EJ, Hoehn RE, Lapoint E. Carbon storage and sequestration by trees in urban and community areas of the United States. *Environ Pollut* 2013; **178**: 229–36.

150 Casey JA, James P, Cushing L, Jesdale BM, Morello-Frosch R. Race, ethnicity, income concentration and 10-year change in urban greenness in the United States. *Int J Environ Res Public Health* 2017; **14**. DOI:10.3390/ijerph14121546.

151 Heynen N, Perkins HA, Roy P. The political ecology of uneven urban green space: The impact of political economy on race and ethnicity in producing environmental inequality in Milwaukee. *Urban Aff Rev* 2006; **42**: 3–25.

152 Hoffimann E, Barros H, Ribeiro AI. Socioeconomic inequalities in green space quality and Accessibility—Evidence from a Southern European city. *Int J Environ Res Public Health* 2017; **14**: 0.

153 Dai D. Racial/ethnic and socioeconomic disparities in urban green space accessibility: Where to intervene? *Landsc Urban Plan* 2011; **102**: 234–44.

154 Wolch JR, Byrne J, Newell JP. Urban green space, public health, and environmental justice: The challenge of making cities 'just green enough'. *Landsc Urban Plan* 2014; **125**: 234–44.

155 Cole HVS, Lamarca MG, Connolly JJT, Anguelovski I. Are green cities healthy and equitable? Unpacking the relationship between health, green space and gentrification. *J Epidemiol Community Health* 2017; **71**: 1118–21.

156 Jennings V, Baptiste AK, Osborne Jelks N, Skeete R. Urban green space and the pursuit of health equity in parts of the United States. *Int J Environ Res Public Health* 2017; **14**. DOI:10.3390/ijerph14111432.

157 Rigolon A, Christensen J. Greening Without Gentrification. Park. Recreat. Mag. | NRPA. 2019; published online Nov 26. https://www.nrpa.org/parks-recreation-magazine/2019/december/greening-without-gentrification/ (accessed Nov 16, 2020).

158 Stone B, Lanza K, Mallen E, Vargo J, Russell A. Urban Heat Management in Louisville, Kentucky: A Framework for Climate Adaptation Planning. *J Plan Educ Res* 2019; : 0739456X1987921.

159 The Urban Heat Island Project . Louisv. Metro Open Data. https://data.louisvilleky.gov/story/urban-heat-island-project (accessed Oct 21, 2020).

160 Louisville UTC Fact Sheet. https://louisvilleky.gov/sites/default/files/community_forestry/community_foresty_files/louisvillefactsheet.pdf (accessed Oct 21, 2020).

161 Urban Greening Project . Green Hear. Louisv. https://greenheartlouisville.com/ (accessed Oct 21, 2020).

162 Measuring Vegetation (NDVI & EVI). NASA Earth Obs. . https://earthobservatory.nasa.gov/features/MeasuringVegetation/measuring_vegetation_2.php (accessed Oct 21, 2020).

163 FAQ – Google Earth Engine. Google Earth Engine. https://earthengine.google.com/faq/ (accessed Oct 21, 2020).

164 Krieger N, Waterman PD, Spasojevic J, Li W, Maduro G, Van Wye G. Public health monitoring of privilege and deprivation with the index of concentration at the extremes. *Am J Public Health* 2016; **106**: 256–63.

165 Yitshak-Sade M, Lane KJ, Fabian MP, *et al.* Race or racial segregation? Modification of the PM2.5 and cardiovascular mortality association. *PLoS One* 2020; **15**: e0236479.

166 Fong KC, Lane KJ, Yitshak-Sade M, *et al.* Effect Modification of the PM2.5 Association with Birthweight by Local Residential Racial and Economic Segregation. *ISEE Conf Abstr* 2018; **2018**. DOI:10.1289/isesisee.2018.o01.03.53.

167 Rojas-Rueda D, Nieuwenhuijsen MJ, Gascon M, Perez-Leon D, Mudu P. Green spaces and mortality: a systematic review and meta-analysis of cohort studies. *Lancet Planet Heal* 2019; **3**: e469–77.

168 Underlying Cause of Death 1999-2018. Centers Dis. Control Prev. https://wonder.cdc.gov/wonder/help/ucd.html (accessed Oct 21, 2020).

169 Zhao C, Liu B, Piao S, *et al.* Temperature increase reduces global yields of major crops in four independent estimates. *Proc Natl Acad Sci U S A* 2017; **114**: 9326–31.

170 Agnolucci P, Rapti C, Alexander P, *et al.* Impacts of rising temperatures and farm management practices on global yields of 18 crops. *Nat Food* 2020; **1**: 562–71.

171 Rising J, Devineni N. Crop switching reduces agricultural losses from climate change in the United States by half under RCP 8.5. *Nat Commun* 2020; **11**: 1–7.

172 U.S. EPA. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2018. 2020 https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks (accessed Oct 22, 2020).

173 Thakrar SK, Balasubramanian S, Adams PJ, *et al.* Reducing Mortality from Air Pollution in the United States by Targeting Specific Emission Sources. *Environ Sci Technol Lett* 2020; **7**: 639–45.

174 Xing J, Pleim J, Mathur R, *et al.* Historical gaseous and primary aerosol emissions in the United States from 1990 to 2010. *Atmos Chem Phys* 2013; **13**: 7531–49.

175 Hill J, Goodkind A, Tessum C, *et al.* Air-quality-related health damages of maize. *Nat Sustain* 2019; **2**: 397–403.

176 Casey JA, Kim BF, Larsen J, Price LB, Nachman KE. Industrial Food Animal Production and Community Health. Curr. Environ. Heal. reports. 2015; **2**: 259–71.

177 Smit LAM, Heederik D. Impacts of Intensive Livestock Production on Human Health in Densely Populated Regions. DOI:10.1002/2017GH000103.

178 Hoppin JA, Umbach DM, Long S, *et al.* Respiratory disease in United States farmers. *Occup Environ Med* 2014; **71**: 484–91.

179 USDA Economic Research Service. Farm Labor. Unites States Dep. Agric. Econ. Res. Serv. . https://www.ers.usda.gov/topics/farm-economy/farm-labor/ (accessed Oct 23, 2020).

180 US Environmental Protection Agency. What is Particle Pollution? United States Environ. Prot. Agency. https://www.epa.gov/pmcourse/what-particle-pollution (accessed Oct 23, 2020).

181 Ward MH, Jones RR, Brender JD, *et al.* Drinking water nitrate and human health: An updated review. Int. J. Environ. Res. Public Health. 2018; **15**. DOI:10.3390/ijerph15071557.

182 Willett W, Rockström J, Loken B, *et al.* Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems. Lancet. 2019; **393**: 447–92.

183 Leytem A, Kleinmann P, Dell C, Pote D. Subsurface Injection of Manure to Reduce Ammonia Losses and Odor. https://www.ars.usda.gov/ARSUserFiles/np212/LivestockGRACEnet/ManureInjection.pdf (accessed Oct 23, 2020).

184 Bittman S, Dedina M, Howard C.M., Oenema O, Sutton MA. Options for Ammonia Mitigation Guidance from the UNECE Task Force on Reactive Nitrogen. Edinburgh, UK , 2014 www.clrtap-tfrn.org, (accessed Oct 23, 2020).

185 Fargione JE, Bassett S, Boucher T, *et al.* Natural climate solutions for the United States. *Sci Adv* 2018; **4**: eaat1869.

186 Pape D, Lewandrowski J, Steele R, *et al.* Managing Agricultural Land for Greenhouse Gas Mitigation within the United States. 2016 https://www.usda.gov/sites/default/files/documents/White_Paper_WEB71816.pdf (accessed Oct 23, 2020).

187 NACCHO. Statement of Policy: Concentrated Animal Feeding Operations. Natl. Assoc. Ctry. City Heal. Off. 2018. https://www.naccho.org/uploads/downloadable-resources/18-06-Concentrated-Animal-Feeding-Operations.pdf (accessed Oct 23, 2020).

188 Agus F, Elbehri A, Erb K, *et al.* Framing and Context. In: Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems . Patrick Meyfroidt, 2019.

189 Climate Change and Land: An IPCC Special Report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems. 2020 https://www.ipcc.ch/site/assets/uploads/sites/4/2020/02/SPM_Updated-Jan20.pdf (accessed Oct 23, 2020).

190 2035 The Report. 2020 http://www.2035report.com/wp-content/uploads/2020/06/2035-Report.pdf?hsCtaTracking=8a85e9ea-4ed3-4ec0-b4c6-906934306ddb%7C-c68c2ac2-1db0-4d1c-82a1-65ef4daaf6c1 (accessed Nov 16, 2020).

191 U.S. EPA. Air Quality - Cities and Counties. U.S. EPA. https://www.epa.gov/air-trends/air-quality-cities-and-counties (accessed Nov 16, 2020).

192 Bell ML, Ebisu K. Environmental inequality in exposures to airborne particulate matter components in the United States. *Environ Health Perspect* 2012; **120**: 1699–704.

193 Hajat A, Hsia C, O'Neill MS. Socioeconomic Disparities and Air Pollution Exposure: a Global Review. Curr. Environ. Heal. reports. 2015; **2**: 440–50.

194 Tessum CW, Apte JS, Goodkind AL, *et al.* Inequity in consumption of goods and services adds to racial-ethnic disparities in air pollution exposure. *Proc Natl Acad Sci U S A* 2019; **116**: 6001–6.

195 Cushing LJ, Vavra-Musser K, Chau K, Franklin M, Johnston JE. Flaring from Unconventional Oil and Gas Development and Birth Outcomes in the Eagle Ford Shale in South Texas. *Environ Health Perspect* 2020; **128**: 077003.

196 Casey JA, Savitz DA, Rasmussen SG, *et al.* Unconventional natural gas development and birth outcomes in Pennsylvania, USA. *Epidemiology* 2016; **27**: 163–72.

197 Walker Whitworth K, Kaye Marshall A, Symanski E. Drilling and Production Activity Related to Unconventional Gas Development and Severity of Preterm Birth. *Environ Health Perspect* 2018; **126**: 037006.

198 Tribal Air and Climate Resources. United States Environ. Prot. Agency. https://www.epa.gov/tribal-air (accessed Oct 22, 2020).

199 Thompson TM, Rausch S, Saari RK, Selin NE. A systems approach to evaluating the air quality co-benefits of US carbon policies. *Nat Clim Chang* 2014; **4**: 917–23.

200 U.S. Energy Information Administration (EIA). How much carbon dioxide is produced per kilowatthour of U.S. electricity generation? https://www.eia.gov/tools/faqs/faq.php?id=74&t=11 (accessed Nov 16, 2020).

201 Allen DT. Atmospheric Emissions and Air Quality Impacts from Natural Gas Production and Use. *Annu Rev Chem Biomol Eng* 2014; **5**: 55–75.

202 Helmig D. Air quality impacts from oil and natural gas development in Colorado. *Elementa* 2020; **8**. DOI:10.1525/elementa.398.

203 Gilman JB, Lerner BM, Kuster WC, De Gouw JA. Source signature of volatile organic compounds from oil and natural gas operations in northeastern Colorado. *Environ Sci Technol* 2013; **47**: 1297–305.

204 U.S. EPA. Integrated Science Assessment (ISA) for Particulate Matter (Final Report, Dec 2019). Washington, DC, 2019 https://cfpub.epa.gov/ncea/isa/recordisplay.cfm?deid=347534 (accessed Oct 22, 2020).

205 U.S. EPA. Integrated Science Assessment (ISA) for Ozone and Related Photochemical Oxidants (Final Report, Apr 2020) | ISA: Integrated Science Assessments | Environmental Assessment | US EPA. Washington, DC, 2020 https://cfpub.epa.gov/ncea/isa/recordisplay.cfm?deid=348522 (accessed Oct 22, 2020).

206 U.S. EIA. Natural gas explained - Use of natural gas. U.S. EIA. 2020; published online July 22. https://www.eia.gov/energyexplained/natural-gas/use-of-natural-gas.php (accessed Oct 22, 2020).

207 U.S. EIA. The United States set record for daily natural gas power burn in late July. U.S. EIA. 2020; published online Aug 26. https://www.eia.gov/todayinenergy/detail.php?id=44896 (accessed Oct 22, 2020).

208 U.S. EIA. Monthly Energy Review, Table 7.2a. Electr. Power Mon. 2020; published online Feb. https://www.eia.gov/energyexplained/electricity/electricity-in-the-us.php (accessed Nov 3, 2020).

209 U.S. EPA. Table 3-9 In: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2018. 1990 https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks (accessed Nov 3, 2020).

210 U.S. EPA. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2018. 2020 https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks (accessed Oct 20, 2020).

211 U.S. EIA. U.S. Natural Gas Vented and Flared. U.S. EIA. 2020. https://www.eia.gov/dnav/ng/hist/n9040us2a.htm (accessed Oct 22, 2020).

212 Rasmussen SG, Ogburn EL, McCormack M, *et al.* Association between unconventional natural gas development in the marcellus shale and asthma exacerbations. *JAMA Intern Med* 2016; **176**: 1334–43.

213 Willis MD, Jusko TA, Halterman JS, Hill EL. Unconventional natural gas development and pediatric asthma hospitalizations in Pennsylvania. *Environ Res* 2018; **166**: 402–8.

214 Currie J, Greenstone M, Meckel K. Hydraulic fracturing and infant health: New evidence from Pennsylvania. *Sci Adv* 2017; **3**: e1603021.

215 Tran K V., Casey JA, Cushing LJ, Morello-Frosch R. Residential proximity to oil and gas development and birth outcomes in California: A retrospective cohort study of 2006–2015 births. *Environ Health Perspect* 2020; **128**. DOI:10.1289/EHP5842.

216 Fann N, Baker KR, Chan EAW, *et al.* Assessing Human Health PM2.5 and Ozone Impacts from U.S. Oil and Natural Gas Sector Emissions in 2025. *Environ Sci Technol* 2018; **52**: 8095–103.

217 Holder C, Hader J, Avanasi R, *et al.* Evaluating potential human health risks from modeled inhalation exposures to volatile organic compounds emitted from oil and gas operations. *J Air Waste Manag Assoc* 2019; **69**: 1503–24.

218 U.S. EPA. Estimates of Methane Emissions by Segment in the United States. https://www.epa.gov/natural-gas-star-program/estimates-methane-emissions-segment-united-states (accessed Oct 22, 2020).

219 U.S. IEA. Methane Tracker 2020. U.S. IEA. 2020; published online March. https://www.iea.org/reports/methane-tracker-2020/interactive-country-and-regional-estimates (accessed Oct 22, 2020).