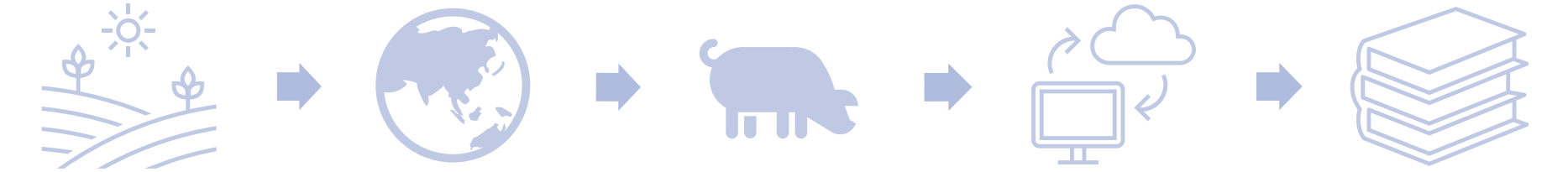
Vulnerabilities to Food Security: Impacts on Military Readiness and National Security

Introduction

This webinar provides a review of the findings of a state-of-the-art report in progress by the Homeland Defense & Security Information Analysis Center (HDIAC), which examines risks that climate change, bioterrorism, and cyberattacks pose on food security. The technologies, techniques, and policies to mitigate those vulnerabilities are also explored.

Agenda



Overview

Impact of Climate Change

Biosecurity and Agroterrorism

Cybervulnerabilities

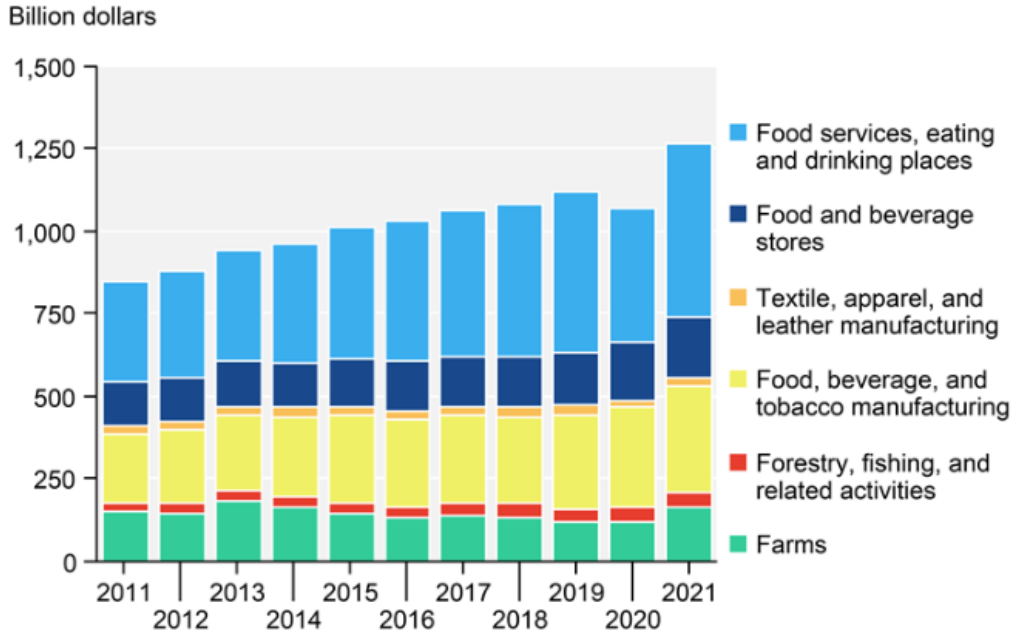
State-of-the-Art Technologies

U.S. Agriculture Overview

Food and Agriculture Sector

- Is 1 of 16 critical infrastructure sectors
- Comprises 6 components
- Is mostly privately owned
- Contributed $1.264 trillion to the gross domestic product (GDP), a 5.4% share, with U.S. farms contributing $164.7 billion of this sum—about 0.7% of U.S. GDP in 2021 [1]

Value added to U.S. GDP by agriculture and related industries, 2011–21



Note: GDP = Gross domestic product.
Source: USDA, Economic Research Service using data from U.S. Department of Commerce, Bureau of Economic Analysis, Value Added by Industry, as of December 22, 2022.

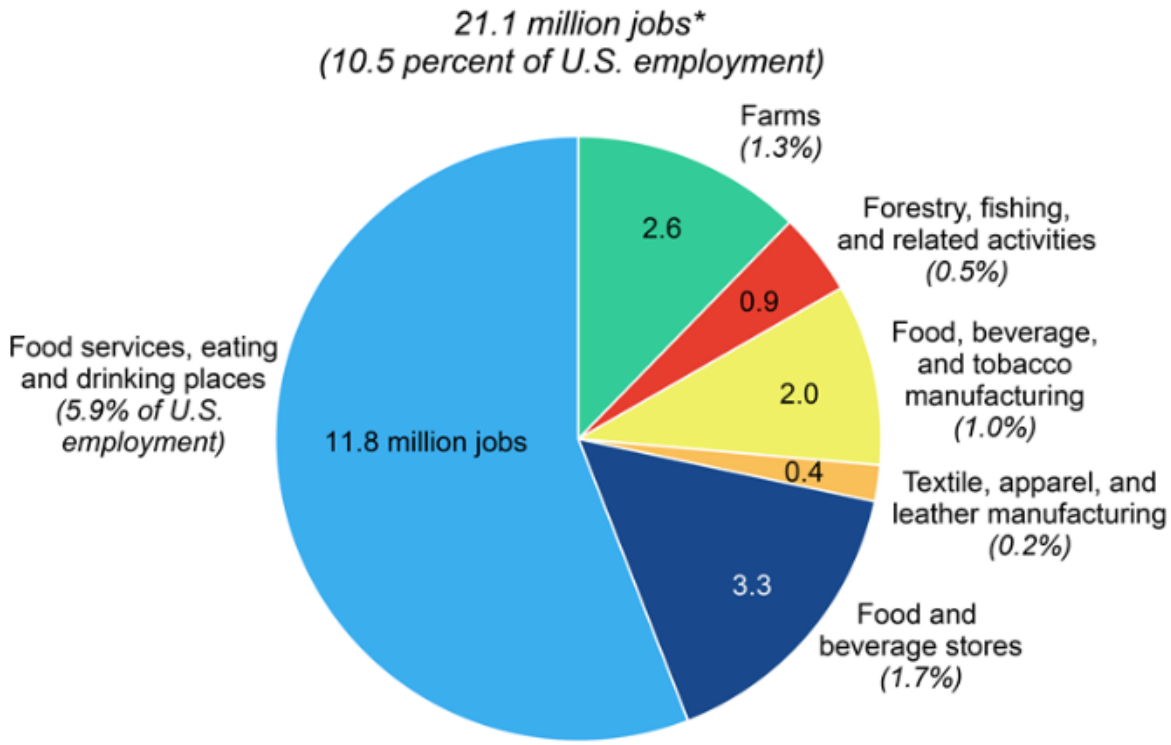
[2]

[1] U.S. Department of Agriculture (USDA), Economic Research Service (ERS), "Ag and Food Sectors and the Economy"
[2] USDA, ERS - Chart Detail

Employment in Agriculture

- **21.1 million** full- and part-time jobs were related to the agricultural and food sectors in the United States, which is **10.5%** of total U.S. employment [1]
- **2.6 million** jobs were direct on-farm employment, which is **1.3%** of total U.S. employment [1]

Employment in agriculture, food, and related industries, 2021



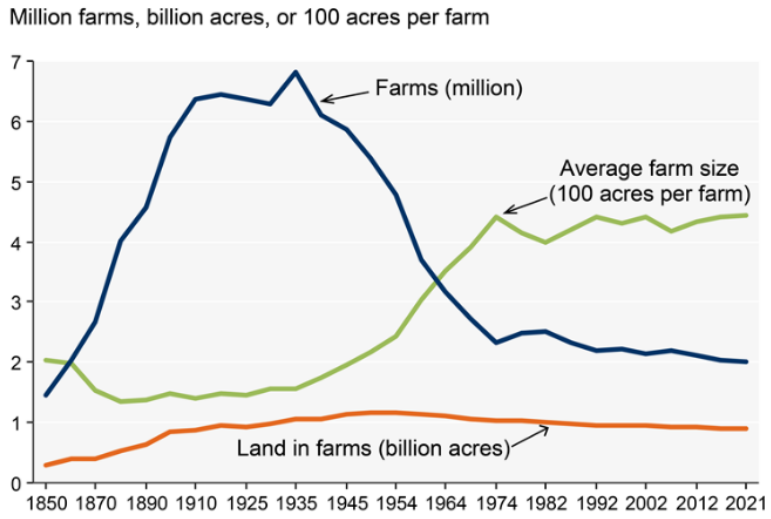
*Full- and part-time jobs. Categories may not sum to total because of rounding.
Source: USDA, Economic Research Service using data from U.S. Department of Commerce, Bureau of Economic Analysis (SAEMP25N), data as of September 30, 2022.

[2]

[1] USDA, ERS, "Ag and Food Sectors and the Economy"
[2] USDA, ERS - Chart Detail

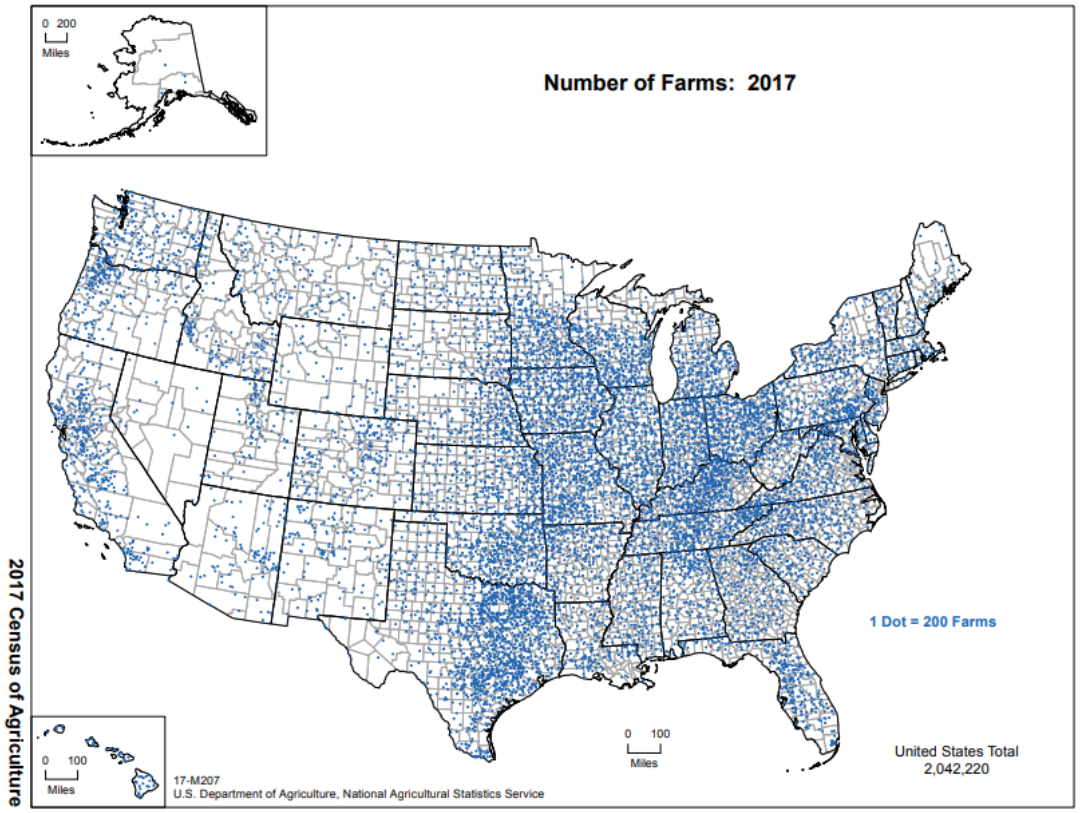
Farms in U.S. Agriculture

- 2.04 million farms [1]
- 900 million acres of land in farms [1]
- 441 acres per farm [1]



Source: USDA, Economic Research Service using data from USDA, National Agricultural Statistics Service, Censuses of Agriculture (through 2017) and *Farms and Land in Farms: 2021 Summary* (February 2022).

[1]

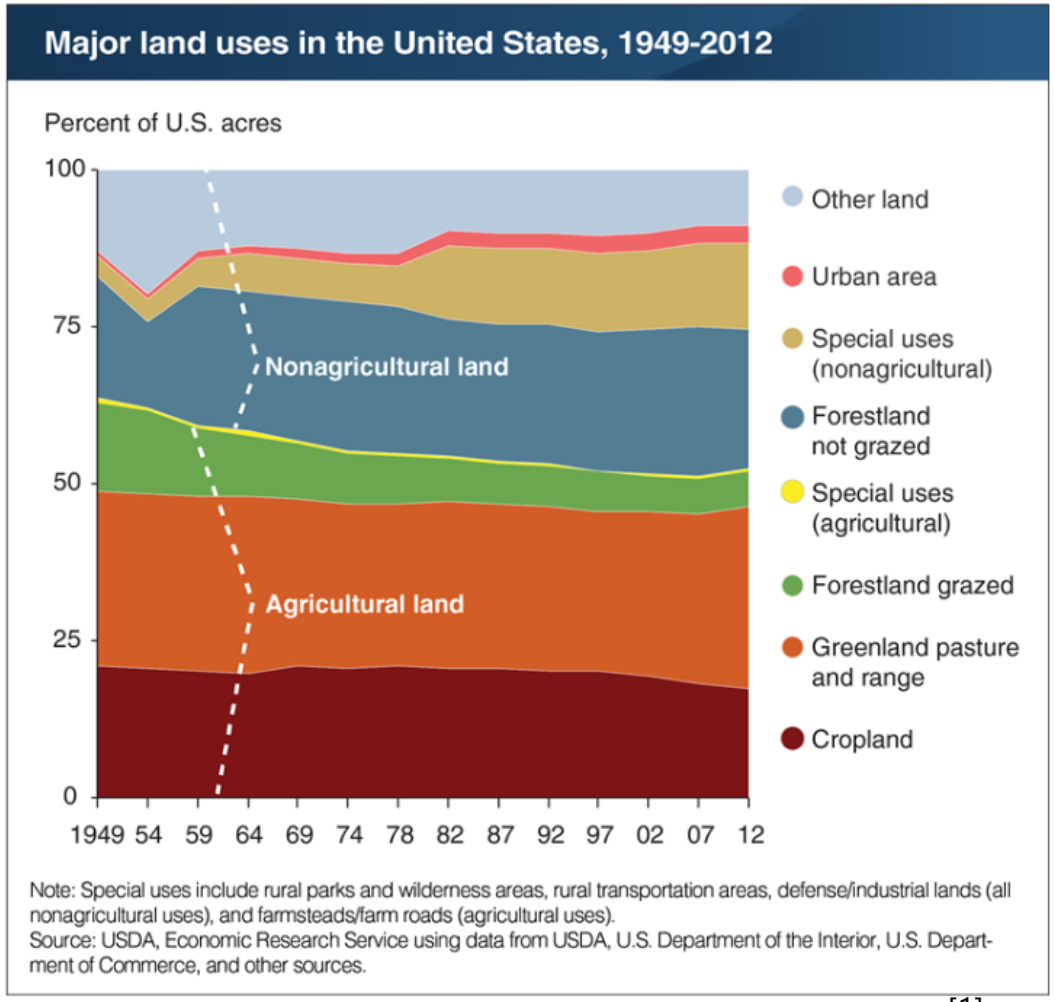


[2]

[1] USDA, ERS, "Farming and Farm Income"
[2] USDA, National Agricultural Statistics Service, "2017 Census Ag Atlas Maps"

Land Uses in the United States

- **Agricultural production** is a major use of land, accounting for over half of the U.S. land base [1]
- **44% of landmass** in the United States is used for crop production, pasture, and range [1]

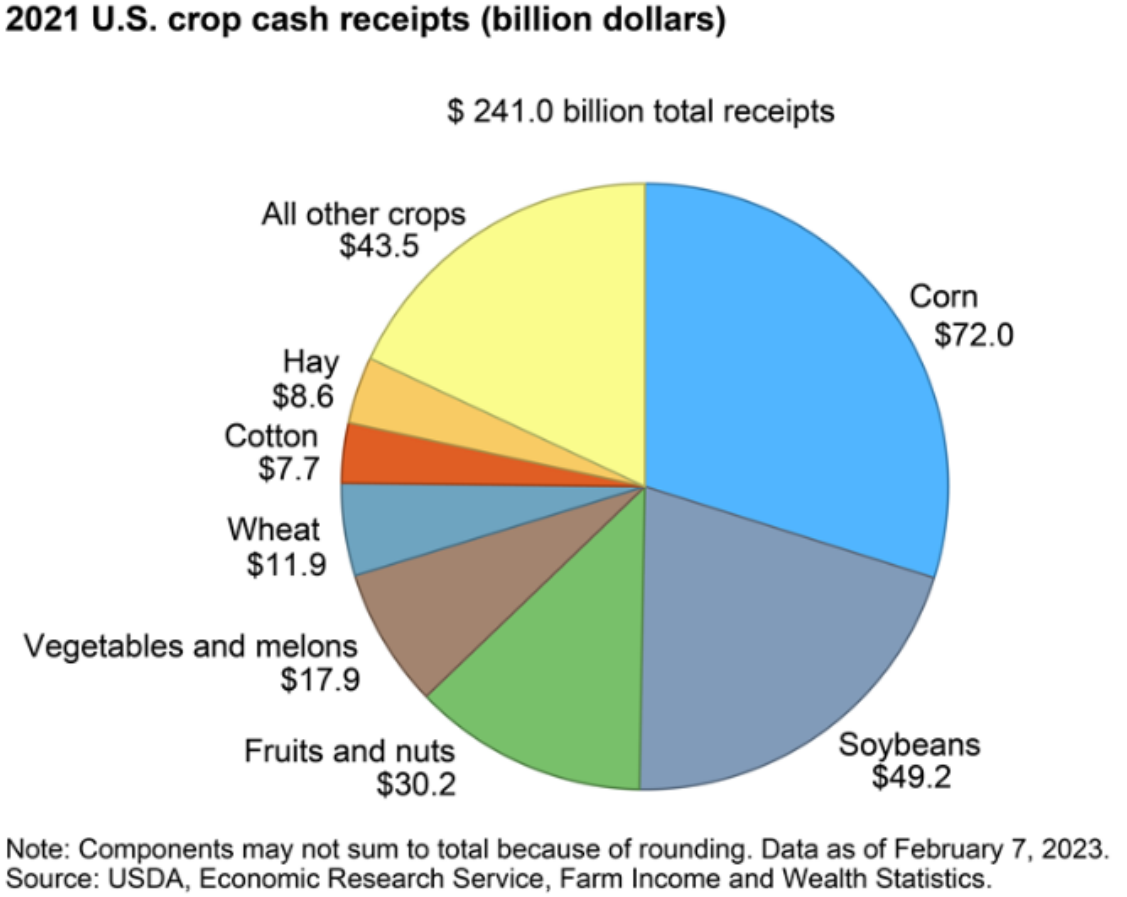


[1]

[1] USDA, ERS, "Land and Natural Resources"

U.S. Crop Commodities

- The United States is the **largest producer of corn and soy**, providing 35% of world's supply [1]
- The United States is the **fourth largest producer of wheat,** providing 7% of the world's supply [1]
- 53% of wheat grown is exported [1]
- 57% of soybeans are exported [1]
- 14% of corn is exported [1]



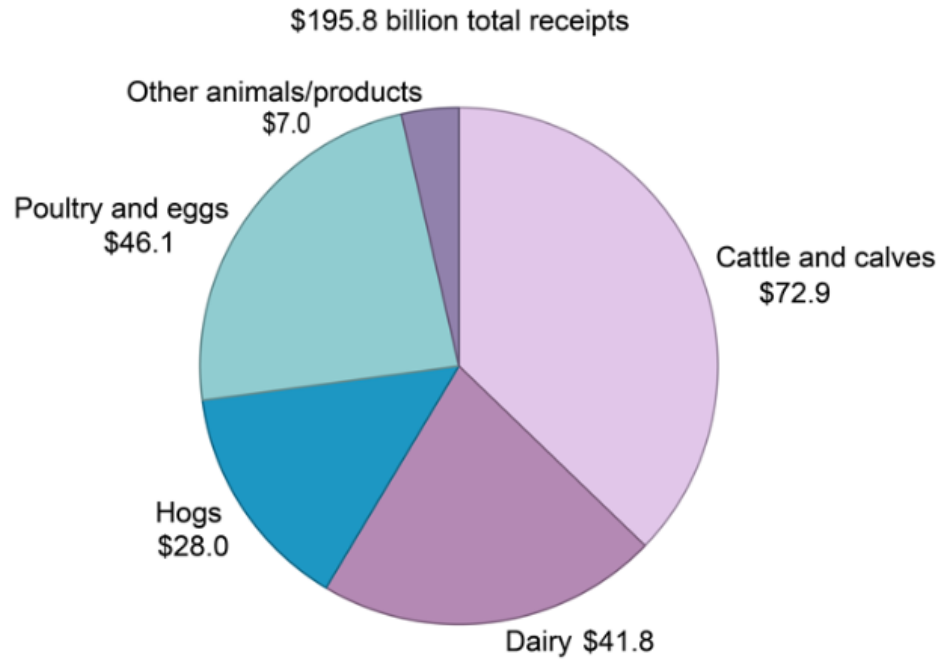
Crop cash receipts totaled $241.0 billion in calendar year 2021. Receipts [2]

[1] Food and Agriculture Organization (FAO) of the United States, "Food and Agriculture Data"
[2] USDA, ERS, "Farming and Farm Income"

U.S. Livestock Commodities

- Beef
  - The United States is the **world's largest producer** of beef
  - **15.2%** of U.S. beef was **exported** in 2022
  - The United States is a net beef importer [1]
- Pork
  - The United States is the **world's third largest producer of pork**
  - The United States has been either the **world's largest or second largest exporter** of pork and pork products
  - U.S. **exports** average over **20%** of commercial pork production in most years [2]
- Poultry
  - The U.S. poultry industry is the **world's largest producer** and a major egg producer
  - The United States is the **second largest exporter** of poultry meat
  - Almost **18%** of total poultry production is **exported** [3]

2021 U.S. animal and animal product cash receipts (billion dollars)



Note: Components may not sum to total because of rounding. Data as of February 7, 2023.
Source: USDA, Economic Research Service, Farm Income and Wealth Statistics.

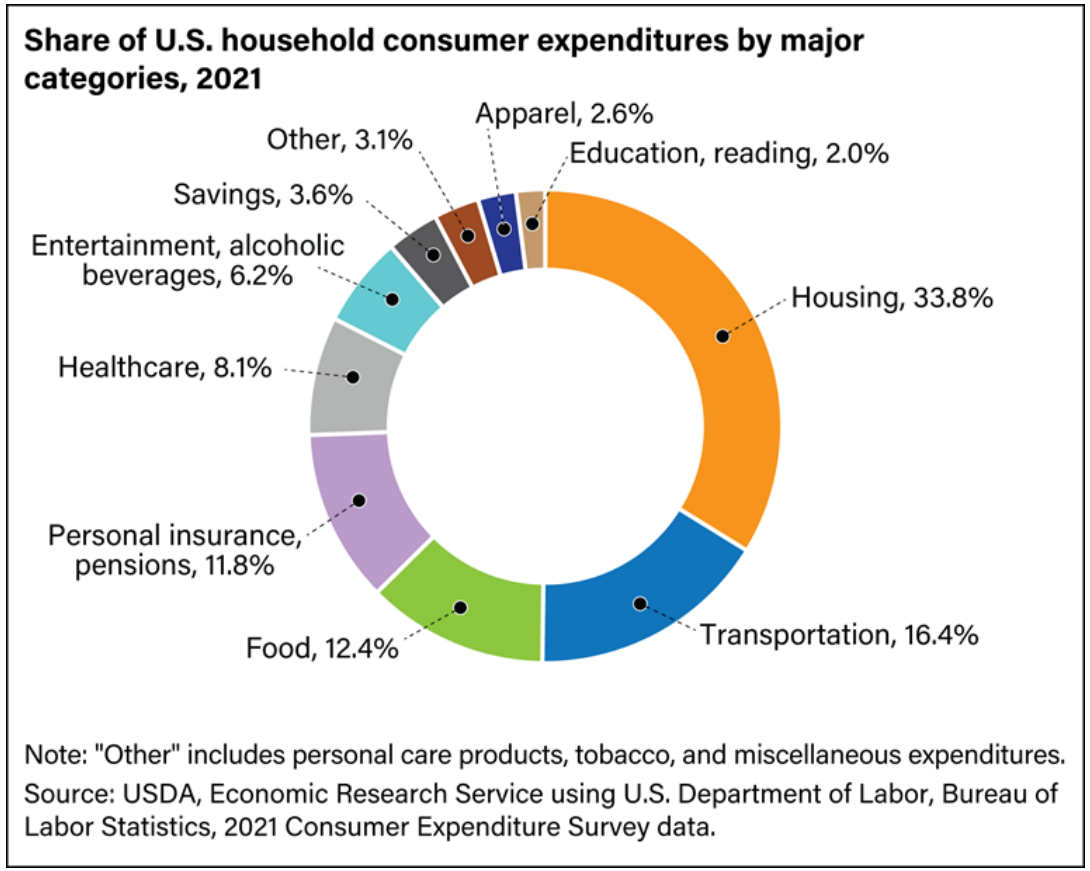
[4]

[1] USDA, ERS, "Cattle & Beef"
[2] USDA, ERS, "Hogs & Pork"
[3] USDA, ERS, "Poultry & Eggs"
[4] USDA, ERS, "Farming and Farm Income"

U.S. Food Insecurity Overview

Food Expenses for Consumers

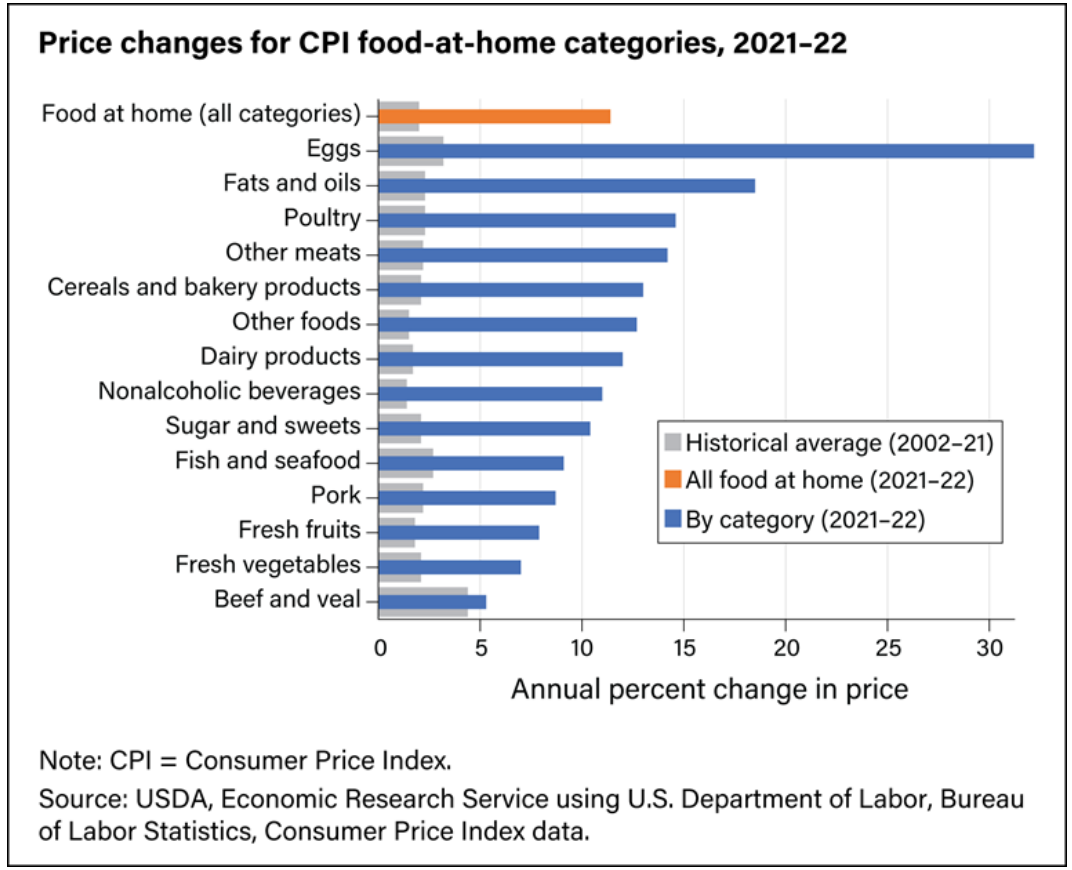
Expenditures on food accounted for 12.4% of U.S. household spending in 2021, an increase from 11.9% in 2020 [1]



[1] USDA, ERS, "Food Prices and Spending"

Food Inflation

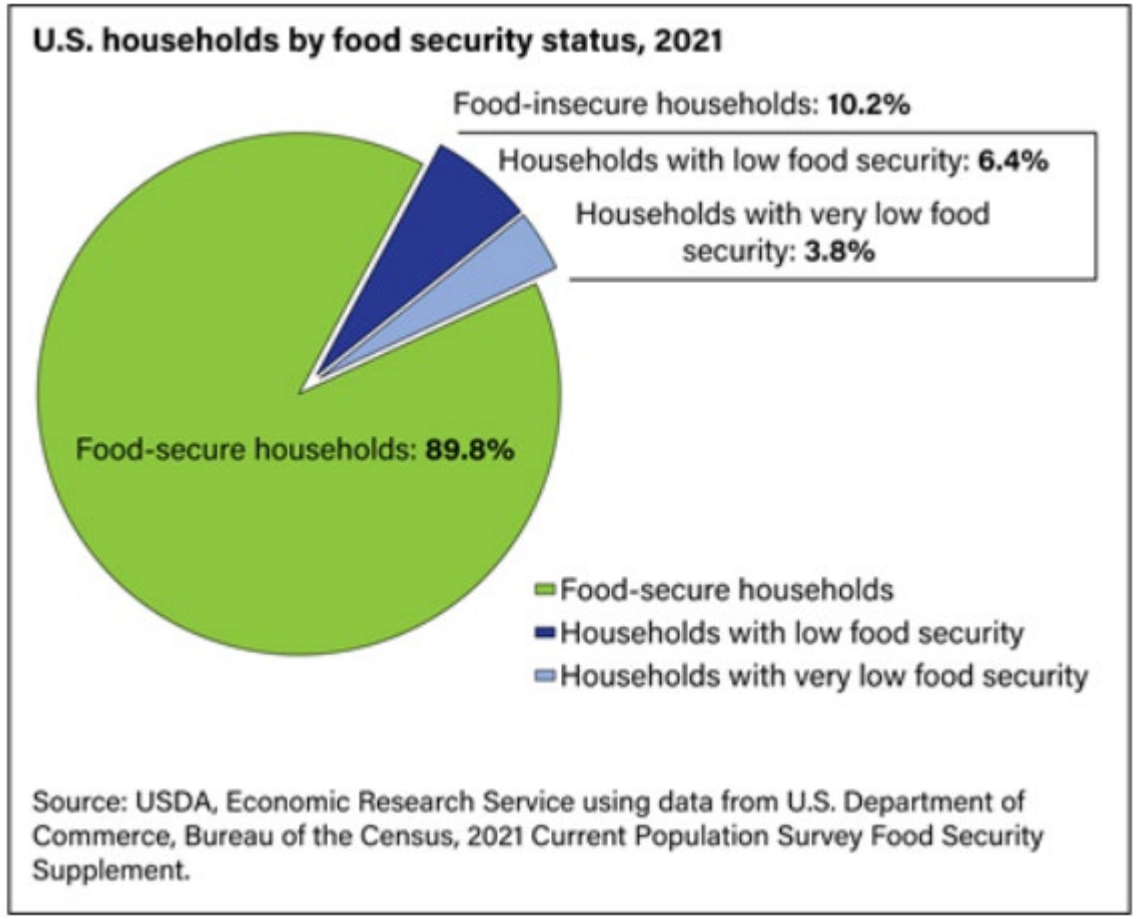
- Negative impact to income and price increases on food will impact food security for Americans
- Annual food-at-home prices were **11.4% higher in 2022 than in 2021 [1]**
- Prices for 9 food categories **increased by more than 10%** in 2022 [1]



[1] USDA, ERS, "Food Prices and Spending"

U.S. Food Insecurity

- **Food insecurity**: "A lack of consistent access to enough food for every person in a household to live an active, healthy life" [1]
- **Low food security:** "Households reduce the quality, variety, and desirability of their diets, but the quantity of food intake and normal eating patterns are not substantially disrupted" [1]
- **Very low food security:** "At times during the year, eating patterns of one or more household members are disrupted and food intake reduced because the household lacks money and other resources for food" [1]



[2]

[1] USDA, ERS, "Measurement"
[2] USDA, ERS, "Key Statistics & Graphics"

Military Food Insecurity

Active-Duty Food Insecurity [1]

- **24%** of active-duty service **members lack consistent access to enough food** for their households
- **15.4%** of troops could be classified by the USDA as having **low food security** in 2018
- **10.4%** could be classified as having very **low food security**

Causes of Food Insecurity in Military Families [1]

- Lower salaries at lower ranks
- High unemployment rates for military spouses
- High cost of living near military bases
- Ineligibility for food-assistance programs

[1] Rand Corporation, "Food Insecurity Affects Many Active-Duty U.S. Military Families, but Root Causes Remain Unclear"

Food Insecurity

- **Physical and mental tolls** on service members can affect their mission readiness [1]
- Food insecurity has been associated with negative impacts on **recruitment and retention** for military personnel [1]

[2]

[3]

[1] https://www.csis.org/analysis/solving-food-insecurity-among-us-veterans-and-military-families#:~:text=Hunger%20can%20negatively%20affect%20service,fit%20and%20perform%20their%20duties.
[2] https://www.dvidshub.net/image/3624634/swear
[3] Joint Base San Antonio, *JBSA News,* "Army Combat Fitness Test Changes Affect All Soldiers"

2022 National Security Memorandum 16

Purpose: Strengthen the security and resilience of U.S. food and agriculture to ensure that American families have access to safe and affordable food [1]

Identified threats to food and agriculture

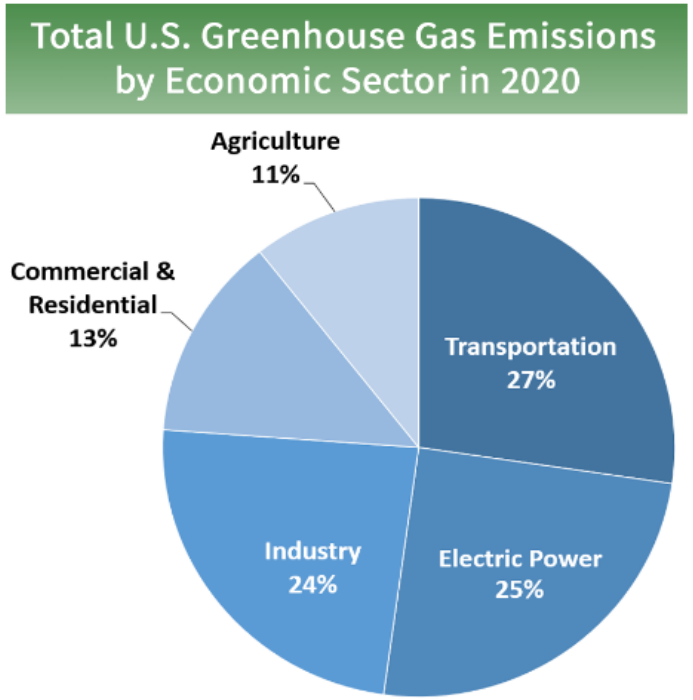
- **Introduction of hazardous contaminants such as poisonous agents, natural or genetically engineered pests and pathogens**, and physical effects of nuclear detonations or dispersion of radioactive materials
- **Consequences of climate change**
- **Threats in the cyber domain**
- Theft of intellectual property
- Current and future pandemics that could impact the sector's critical infrastructure and essential workforce

[1] The White House, "National Security Memorandum on Strengthening the Security and Resilience of United States Food and Agriculture"

Impact of Climate Change to Agricultural Security

Greenhouse Gases

- The main greenhouse gases are carbon dioxide, methane, and nitrous oxide
- Agriculture industry contributes to the production of greenhouse gases

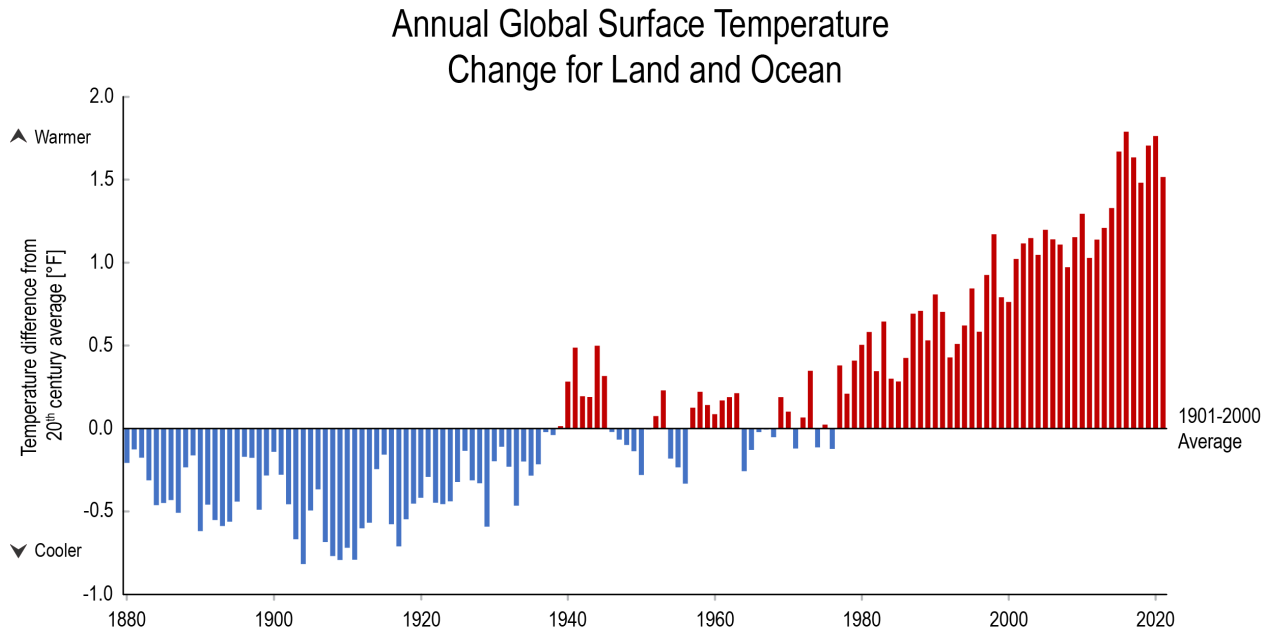


[1]

[1] U.S. Environmental Protection Agency (EPA), "Sources of Greenhouse Gas Emissions"

Global Warming

- Global warming refers to the rise in global temperatures due mainly to the increasing concentrations of greenhouse gases in the atmosphere
- Agriculture industry is both impacted by and contributes to global warming



[1]

[1] U.S. Global Change Research Program, "Global Surface Temperatures"

Climate Change

- Climate change refers to **long-term changes** in global or regional climate patterns [1]
- Human activities have been the main driver of climate change since the 1800s, as they increase the levels of greenhouse gases in the atmosphere [1]
- Climate change can **impact the intensity and frequency of weather events** including participation and heat extremes

[2]

[1] United Nations, "What Is Climate Change?"
[2] National Oceanic and Atmospheric Administration (NOAA), "Climate Change Impacts"

Severe Weather Events

- Severe weather is a term used to describe weather conditions that are unusually intense, destructive, or hazardous [1]; examples of severe weather include heatwaves, droughts, hurricanes, tornadoes, and blizzards
- Trends of extreme weather events
  - **Extreme temperature** events averaged roughly 40 events per year in the 1970s but nearly **quadrupled** to over 150 annually in the 2010s [2].
  - **Floods**, which averaged **30 events per year** in the 1970s, doubled to over 60 in the 1980s and **skyrocketed** to an average of 180 in the 2000s, with a peak of **246 flood events in 2006** [2].

[1] EPA, *Climate Change Science,* "Understanding the Link Between Climate Change and Extreme Weather"
[2] *National Geographic*, "The Influence of Climate Change on Extreme Environmental Events"

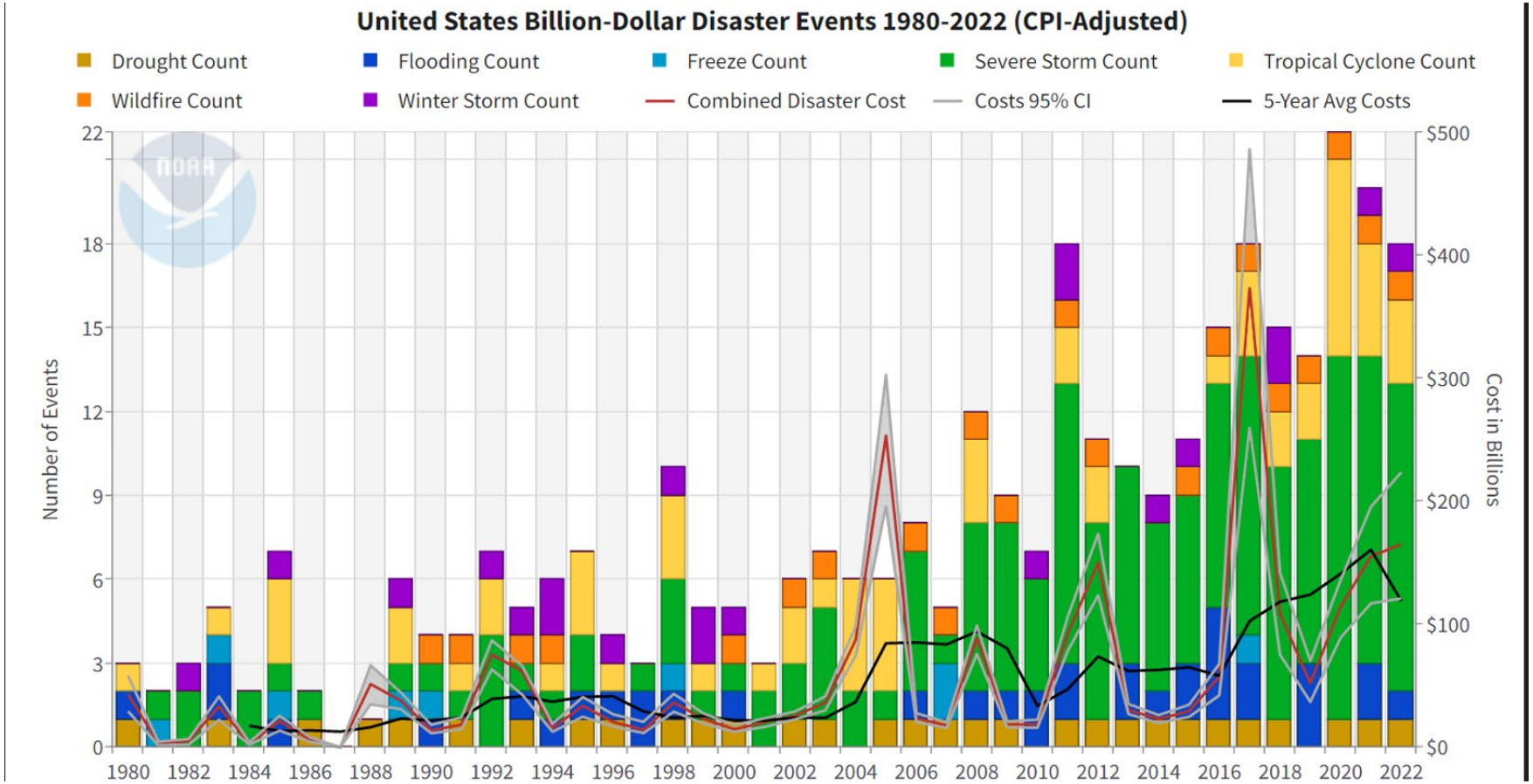
Recent Severe Weather Events and Impacts on U.S. Agriculture

- 2012 Great Plains and Midwest Drought
- 2015 California Drought
- 2018 California Wildfires
- 2022 Florida Hurricane Ian

Image shows an Air National Guard unit based at Hunter Army Airfield in Savannah, GA, providing air support with a CH-47 Chinook rigged with a bucket capable of scooping up to 2,000 gallons of water every few minutes to help douse fires in the area. (U.S. Navy photo by Mass Communication Specialist Seaman Recruit Dmitry Chepusov) [1]

[1] https://www.dvidshub.net/image/608541/kansas-national-guard-supports-colorado-high-park-firefight

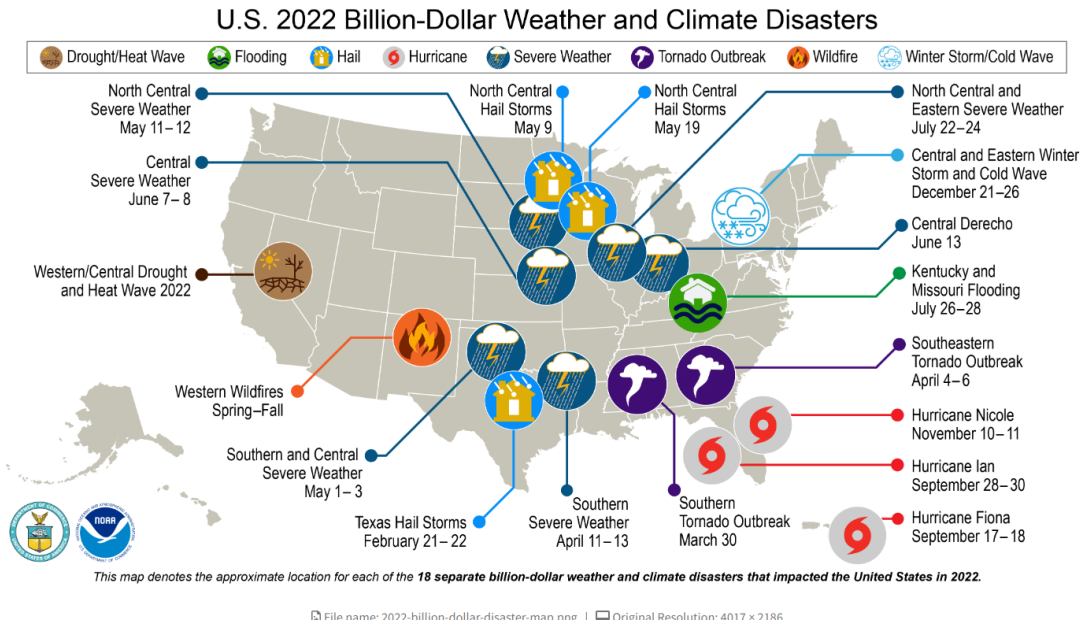
Trends of Billion-Dollar Weather Disaster Events



[1] National Centers for Environmental Information (NCEI), NOAA, "Billion-Dollar Weather and Climate Disasters: Time Series" [1]

2022 Billion-Dollar Weather and Climate Disasters

- One winter storm/cold wave event (across the central and eastern United States)
- One wildfire event (wildfires across the western United States including Alaska)
- One drought and heat wave event (across the western and central United States)
- One flooding event (in Missouri and Kentucky)
- Two tornado outbreaks (across the southern and southeastern United States)
- Three tropical cyclones (Fiona, Ian, and Nicole)
- Nine severe weather/hail events (across many parts of the country, including a derecho in the central United States)

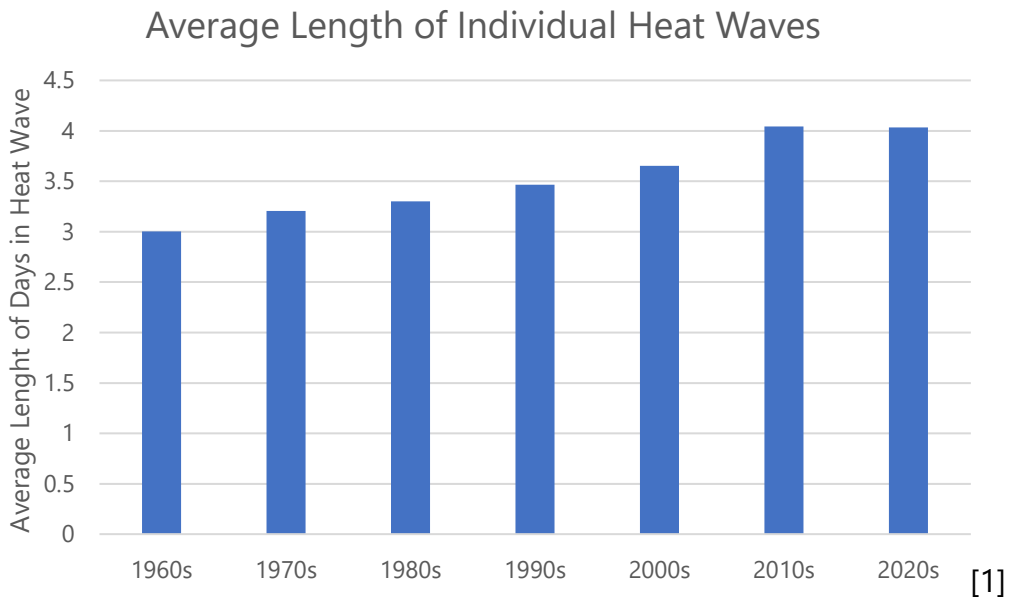


[1]

[1] NCEI, NOAA, "Billion-Dollar Weather and Climate Disasters: Overview"

Heatwaves

- The 2022 global annual surface temperature was the sixth highest since recordkeeping began in 1880
- 2022 North America's annual temperature tied with 2011 and 2019 as the fifteenth warmest year on record
- **The frequency and duration of heatwaves are increasing**



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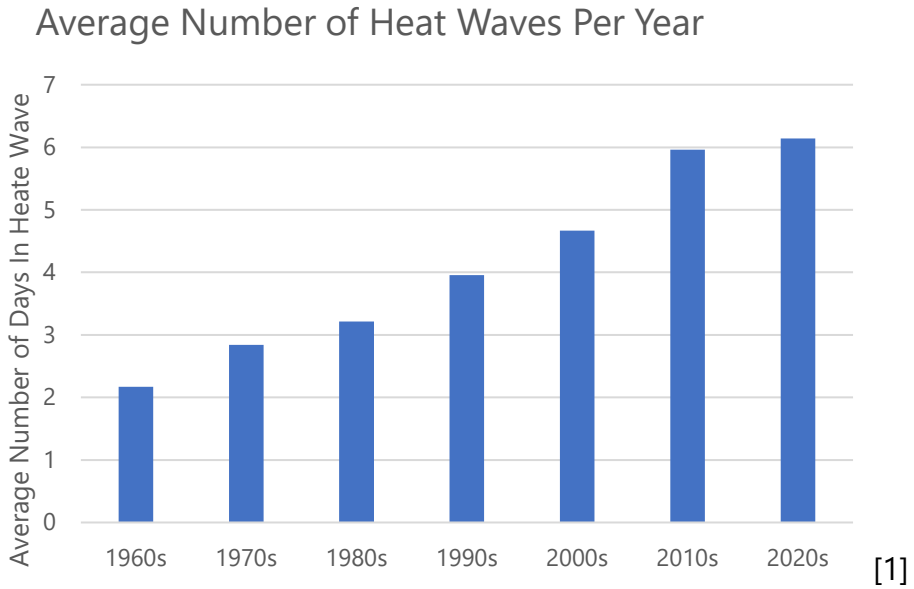


[1]

[1] NCEI, NOAA, "Annual 2022 National Climate Report"

Droughts

- The NOAA ranks drought as **third among extreme weather events associated with billion-dollar weather disasters**, behind tropical cyclones and severe storms [1]
- In January 2023, the USDA declared **597 counties across 14 states natural disaster areas** as a result of the ongoing drought that threatens the winter wheat crop; this declaration was **the second year in a row** that a declaration had been made, which has not been declared since the 1950s [2]
- Drought, in addition to water use, contributes to the **depletion of U.S. groundwater systems**
- Groundwater that supplies the irrigated water for agriculture is supplied by two primary groundwater systems in the United States—**California's Central Valley Aquifer** and the **Ogallala Aquifer** beneath the Great Plains**, both at historic lows** [3]
- **Water from these aquifers supplies 20% of the world's grain crop; more than 40% percent of U.S. beef production; and about 40% of the vegetables, nuts, and fruits consumed in the United States [4]**

[1] National Integrated Drought Information System, NOAA, "Agriculture"
[2] USDA , "USDA Designates 597 Counties in 2013 as Disaster Areas Due to Drought"
[3] Springer Nature, *nature communications,* "Groundwater Depletion in California's Central Valley Accelerates During Megadrought
[4] *The Atlantic,* "The West's Unprecedented Water Crisis Is Worsening"

Wildfires

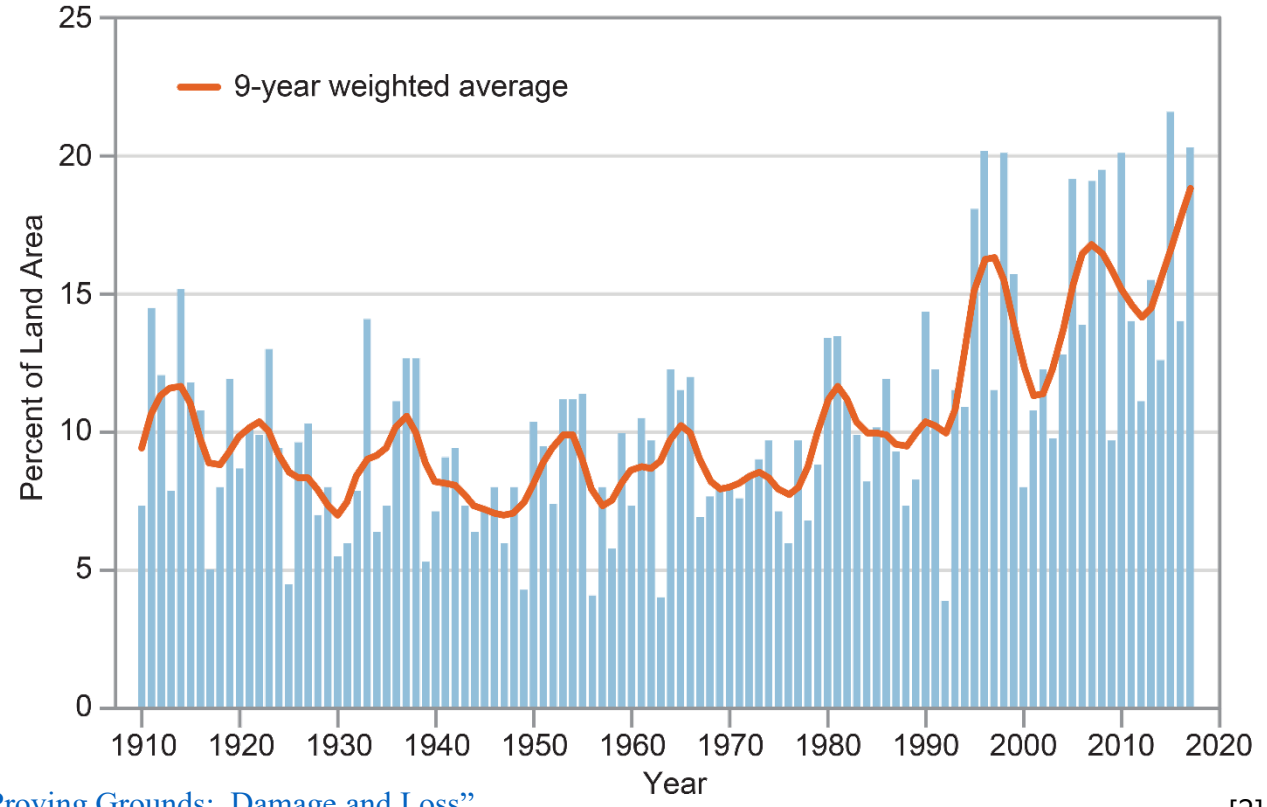
- The **number of days with high fire danger** occurring at the same time across large areas in the western United States has **increased by 25 since 1979** [1]
- The average **length of wildfire season** across the United States is **105 days longer**, with **3 times as many large fires** (greater than 1,000 acres) as in the 1970s [1]
  - 2020 was the most active wildfire year on record; Colorado had three of its worst wildfires in history, and California recorded five of the six largest wildfires in history [2]
  - 75% of the area consumed by wildfires across the United Stares is in nonforested ecosystems, much covering rangelands and crops [2]

[1] Agriculture Climate Network, "Agriculture Is Feeling the Flames and the Smoke"
[2] *Progressive Farmer,* "Ag Weather Forum: *Record* Billion-Dollar Weather Damage in 2020"

Flooding

Flooding is the second most devasting effect on agriculture loss worldwide [1]

- Extreme precipitation **events remained steady until the 1980s** but have significantly risen since then [2]
- There have **been 36 weather events since 1980** where flooding (nonhurricane related) has inflicted at least $1 billion of damage in the United States [2]
- The **rising sea levels** are due to a combination of melting glaciers and ice sheets and to the expansion of seawater from increasing water temperatures [3]
- In **2021**, sea levels reached 3.8 in above the average level of 1993, which makes it **the highest annual average** since 1993 [3]

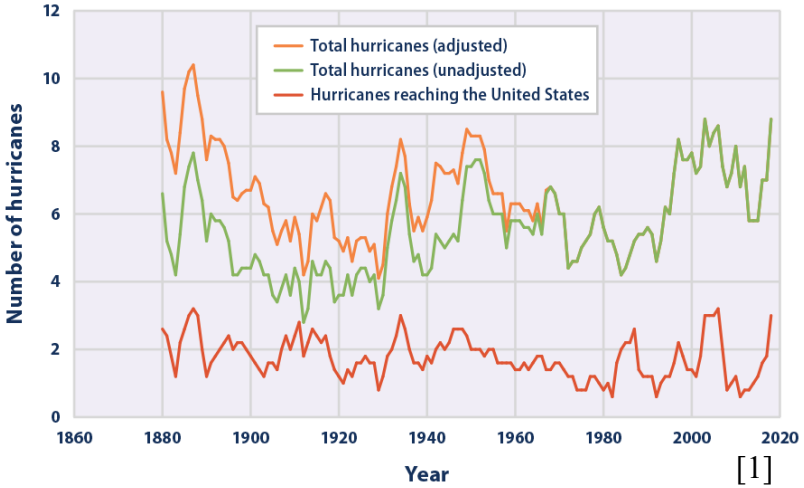


[2]

[1] Food and Agriculture Organization of the United States, "Agriculture on the Proving Grounds: Damage and Loss"
[2] U.S. Global Change Research Program, *Fourth National Climate Assessment,* "Chapter 10: Agriculture and Rural Communities"
[3] NOAA, "Climate Change: Global Sea Level"

Hurricanes

- Since 1878, on **average, two hurricanes** have made landfall in the United States [1]
- In 2022, three hurricanes (Fiona, Ian, and Nicole) made landfall
- The total number of hurricanes and the number reaching the United States **do not indicate a clear overall trend since 1878** [1]
- Hurricane **intensity has risen noticeably** over the past 20 years, and 8 of the 10 most active years since 1950 have occurred since the mid-1990s [1]



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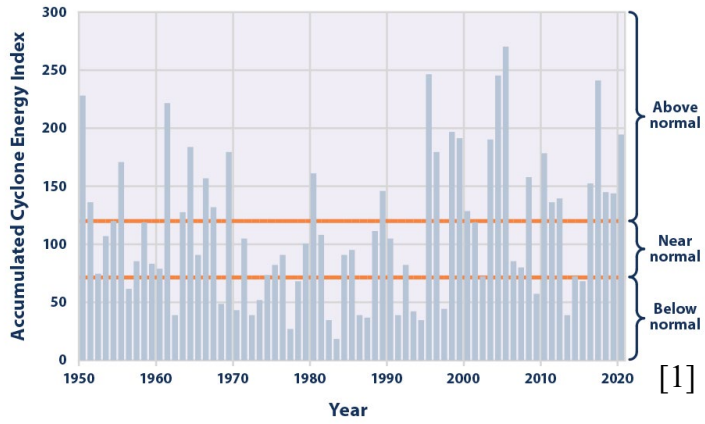


[1]

[1] EPA, "Climate Change Indicators: Tropical Cyclone Activity"

Impact of Climate Change on the U.S. Department of Defense (DoD)

Secretary of Defense Lloyd Austin has stated that

“to keep the nation secure, the DoD must tackle the existential threat of climate change” [1]

[1] https://apps.dtic.mil/sti/pdfs/AD1174099.pdf

DoD Documents and Plans to Adapt to and Address Climate Change

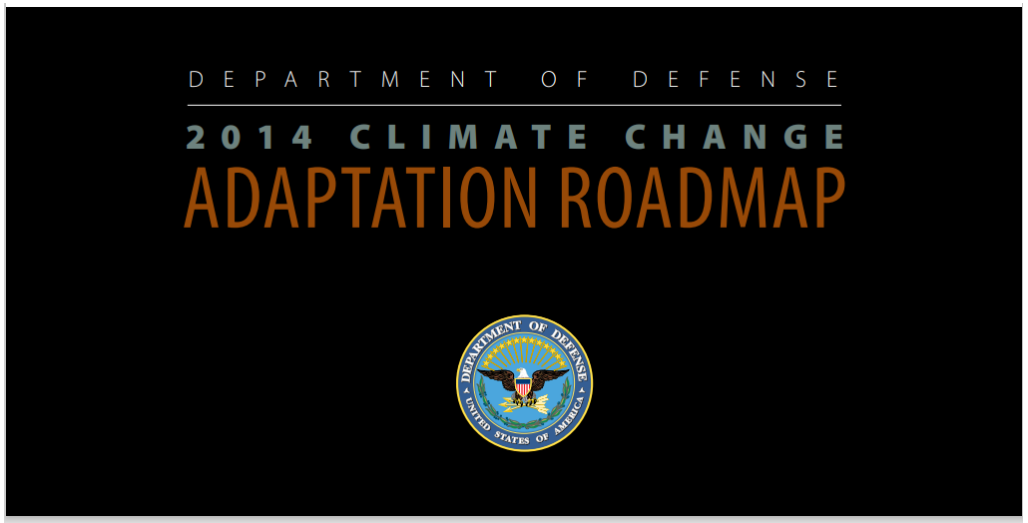
- 2014 DoD Climate Change Adaptation Roadmap: focuses on various actions and planning the DoD is taking to increase its resilience to the impacts of climate change [1]
- 2021 DoD Climate Risk Analysis: highlights the risks of climate change and how the DoD will use the best available science and data to prevent, mitigate, account for, and respond to defense-related climate change impacts [2]
- 2021 DoD Climate Adaptation Plan: outlines the DoD's projects and activities focused on addressing climate change [3]
- 2021 Highlights and Examples for the DoD Climate Adaptation Plan: was published on 1 September 2021, and is a companion report to the DoD Climate Adaption Plan providing examples of how the DoD is addressing climate change [4]

[1] DoD, "Department of Defense Climate Change Adaptation Roadmap"
[2] DoD, "Department of Defense Climate Risk Analysis"
[3] https://apps.dtic.mil/sti/pdfs/AD1174099.pdf
[4] https://media.defense.gov/2021/Nov/03/2002886171/-1/-1/0/HIGHLIGHTS-AND-EXAMPLES-FOR-DOD-CLIMATE-ADAPTATION-PLAN.PDF

2014 Climate Change Adaptation Roadmap

Climate Change Impact on DoD Operations [1]

- **"Increased demand for Defense Support of Civil Authorities (DSCA)"**
- **"Increased demand for disaster relief and humanitarian assistance overseas"**
- "Increased need for air, sea, and land capabilities and capacity in the Arctic region"
- "Altered, limited, or constrained environment for military operations"
- **"Instability within and among other nations"**



[1] DoD, "Department of Defense Climate Change Adaptation Roadmap"

DoD Climate Adaptation Plan

- Potential effects of climate change on Department training and testing [1]
  - **“Increased number of ‘black flag’ (suspended outdoor training) or fire hazard days”**
  - “Decreased training/testing land-carrying capacity to support current testing and training rotation types or levels, and some training/testing lands may lose their carrying capacity altogether”
  - “Increased dust generation during training activities, which may interfere with sensitive equipment, resulting in greater repairs, or may require more extensive dust control measures to meet environmental compliance requirements”
  - “Stressed, threatened, and endangered species and related ecosystems, on and adjacent to DoD installations, resulting in increased endangered species and land management requirements”
  - **“Increased operational health surveillance and health and safety risks to the Department’s personnel”**
  - **“Increased maintenance/repair requirements for training/testing lands and associated infrastructure and equipment (e.g., training roads, targets)”**

[1] DoD, “Department of Defense Climate Change Adaptation Roadmap”

DoD Climate Adaptation Plan (cont.)

- Potential effects of climate change on Department-built and natural infrastructure [1]
  - "**Increased inundation, erosion, and flooding damage**"
  - "Changing building heating and cooling demand, impacting installation energy intensity and operating costs"
  - "Disruption to and competition for reliable energy and fresh water supplies"
  - "Damage from thawing permafrost and sea ice in Alaska and the Arctic region"
  - "Increased ecosystem, wetland, sensitive species, and non-native invasive species management challenges"
  - "**Increased maintenance requirements for runways or roads to remain operable during extreme hot days**"
  - **"Changed disease vector distribution, increasing the complexity and cost of ongoing disease management efforts"**

[1] DoD, "Department of Defense Climate Change Adaptation Roadmap"

DoD Climate Adaptation Plan (cont.)

- Potential effects of climate change on Department acquisition and supply chain [1]
  - "Changed operational parameters for current and planned weapons and equipment, resulting in increased associated maintenance requirements or requirements for new equipment"
  - "Reduced availability of or access to the materials, resources, and industrial infrastructure needed to manufacture the Department's weapon systems and supplies"
  - **"Interrupted shipment, delivery, or storage/stockpile of materials or manufactured equipment and supplies"**
  - "Alterations in storage and stockpile activities"
  - **"Reduced or changed availability and access to food and water sources to support personnel"**

[1] DoD, "Department of Defense Climate Change Adaptation Roadmap"

Biosecurity and Agroterrorism

Background

- Foreign, emerging, or zoonotic animal diseases, exotic plant diseases or pests, and contaminants can be introduced by natural incursion, accidental introduction, or as an intentional act [1]
- Biosecurity measures have been developed to prevent and limit agroterrorism severity, but it still remains a challenge
  - **Federal Select Agent Program:** is jointly comprised of the Centers for Disease Control and Prevention/Division of Select Agents and Toxins and the Animal and Plant Health Inspection Service/Division of Agricultural Select Agents and Toxins [2]
    - The select agents and toxins listed in code of federal regulations (CFR) 7 CFR 331.3, are those that have been determined to have the potential to pose a severe threat to plant health or plant products
  - **Animal and Plant Health Inspection Service (APHIS):** has developed a list of 59 pests and diseases that could pose a significant risk and have the most impact to U.S. food and agriculture resources [3]

[1] U.S. Department of Justice, Federal Bureau of Investigation, "Animal-Plant Health Sector Defense: Awareness and Outreach"
[2] https://www.selectagents.gov/
[3] https://www.aphis.usda.gov/aphis/resources/farmbill/fb-pests/farmbill-pest-list

Systematic Risk

- There are various types of systemic risks that could interrupt the flow of agricultural inputs and outputs and dramatically affect the status of these systems with massive and immediate impacts on force readiness
  - "Pre-harvest" agriculture could be compromised by the intentional use of hazardous materials, which would target field level production of livestock and crops up to the point of delivery for processing into food [1]
  - "Post-harvest" food commodities could be intentionally contaminated, which would target public health and the human population consuming the affected food products; there is also a threat of imported foods being contaminated prior to arriving at a port of entry [1]

[1] U.S. Department of Justice, Federal Bureau of Investigation, "Animal-Plant Health Sector Defense: Awareness and Outreach"
[2] https://www.cdc.gov/foodsafety/outbreaks/prevention-education/future.html

[2]

Methods of Introductions

- Multiple methods of delivery
- High concentrations of animals [1]
- Auction markets [1]
- Transportation of animals [1]
- Limited immunity to foreign animal diseases [1]
- Centralized feed supply and distribution [1]
- Difficult to detect (an attack can go unnoticed for days or weeks)

[2]

[1] Center for Food Security and Public Health, Iowa State University, "Safeguarding American Agriculture From Foreign Animal Diseases," 2004
[2] https://www.dvidshub.net/image/5625755/veterinarian-detachment-observes-cows-feeding

Agroterrorism

- **What is agroterrorism?**
  Agroterrorism is a subset of bioterrorism and is defined as a "deliberate introduction of an animal or plant disease with the goal of generating fear, causing economic losses, and/or undermining stability" [1]

- **Motivation and goal:** generation of fear, economic espionage, disruption of operations/trade, and a gain of access to agricultural commodity production and capacity [2, 3]

- **Most likely perpetrators:** "(1) domestic/international terrorists, (2) state-sponsored insurgent/extremist elements, (3) state-sponsored weapons of mass destruction programs, (4) economic espionage by corporate or state-sponsored competitors, (5) insider threats, or (6) an individual 'lone wolf'" [3]

[1] https://irp.fas.org/crs/RL32521.pdf
[2] Center for Food Security and Public Health, Iowa State University, "Agroterrorism Awareness: Safeguarding American Agriculture," 2003
[3] U.S. Department of Justice, Federal Bureau of Investigation, "Animal-Plant Health Sector Defense: Awareness and Outreach"

Historical Agroterrorism Examples

- WWI: Germany infected horses with anthrax or glanders [1]
- 1984 Dalles, OR: religious cult infected salad bars with salmonella [2]
- 1996 Wisconsin: liquid fat contaminated with chlordane [3]

[1] https://www.sciencedirect.com/science/article/pii/S1198743X14626343#:~:text=During%20World%20War%20I%2C%20Germany,did%20not%20have%20military%20consequences.
[2] https://leb.fbi.gov/articles/featured-articles/agroterrorism-threats-to-americas-economy-and-food-supply#:~:text=Agroterrorism%20is%20not%20new.,across%20the%20Atlantic%20to%20France
[3] Center for Food Security and Public Health, Iowa State University, "Agroterrorism Awareness: Safeguarding American Agriculture," 2003

Historical Unintentional Examples

- 1997 Taiwan: outbreak of foot and mouth disease (FMD), which cost farmers $4 billion and an estimated $15 billion from trade embargos [1]
- 2001 Great Britain: outbreak of FMD, which cost farmers $1.6 billion and cost Great Britain $4 billion in lost tourism revenue [1]
- 2002 California: outbreak of Newcastle disease (led to the quarantine of the U.S. Army National Training Center at Fort Irwin) [1]

It is important to look at these examples to see how easily a terrorist would be able to replicate similar events

[1] https://www.govinfo.gov/content/pkg/CHRG-108shrg91045/html/CHRG-108shrg91045.htm

Heightened Pathogens to U.S. Agriculture

- FMD, African swine fever (ASF), and classical swine fever (CSF) are three of the most detrimental animal diseases and are currently foreign to the United States [1]
- FMD is a viral disease that affects cattle, pigs, sheep, goats, deer, and other animals with split hooves; does not affect horses, dogs, cats, or humans; is a severe and highly contagious disease that can cause blisters, fever, lameness, and reduced milk production; but is not a food safety concern [2]
- ASF is a viral disease that affects domestic and wild pigs; can cause high fever, hemorrhage, loss of appetite, and death; does not affect humans or other animals; and is not a food safety issue [3]
- CSF is a viral disease that affects domestic and wild pigs; can cause fever, hemorrhage, diarrhea, vomiting, skin discoloration, nervous signs, and death; can also cause reproductive failures and abortion; and is not a threat to human health or other animals [4]
- FMD [5], ASF [6], and CSF are a threat to U.S. agriculture because there could be significant economic losses due to reduced production, trade restrictions, and control costs

[1] National Library of Medicine, *PubMed*, "Risks of Introduction and Economic Consequences Associated With African Swine Fever, Classical Swine Fever, and Foot-and-Mouth Disease: A Review of the Literature"
[2] Iowa Department of Agriculture and Land Stewardship, "Foot and mouth Disease"
[3] USDA, APHIS,"African Swine Fever (ASF)"
[4] *MSD Veterinary Manual*, "Classical Swine Fever"
[5] USDA, APHIS, "Protect Our Pigs: Fight African Swine Fever"
[6] USDA, APHIS, "Foot and Mouth Disease"

Synthetic Biology

Synthetic biology is the engineering of biology: the synthesis of complex, biologically based (or inspired) systems, which display functions that do not naturally exist in nature [1]

- **Techniques used in synthetic biology**
  - Clustered regularly interspaced short palindromic repeats (CRISPR)
  - Genetically modified organism (GMO)
- **Benefits of synthetic biology**
  - Engineered crops to be more resistant to pest and diseases, resistance to climate change, increased crop yield, and improvement of food security
- **Examples of synthetic biology**
  - Crops that are resistant to specific herbicides
  - Crops engineered to be drought resistant
  - Crops resistant to pests and diseases

[2]

[1] Vancompernolle & Ball, "Synthetic Biology: Applying Engineering to Biology," Report of a NEST High Level Expert Group, https://onlinelibrary.wiley.com/doi/full/10.1002/sae2.12014 , 2005
[2] https://jgi.doe.gov/our-science/science-programs/synthetic-biology/

Synthetic Biology Uses for Agroterrorism

- **Recreating known pathogenic viruses:** synthetic biology can enable the synthesis of viruses that cause diseases such as influenza, smallpox, or Ebola from scratch or from available genetic sequences [1]
- **Making existing bacteria more dangerous:** synthetic biology can enhance the virulence, antibiotic resistance, or environmental persistence of bacteria that cause diseases such as anthrax, plague, or cholera [1]
- **Using microbes to produce harmful biochemicals in humans:** synthetic biology can engineer microbes to produce toxins, hormones, or drugs that can interfere with human physiology or behavior [1]

[1] National Academic Press, "Biodefense in the Age of Synthetic Biology"

Outcomes

- Possible crop failures or necessary slaughter of millions of infected livestock [1]
- Serious economic effects locally and nationally [1]
- Potential for mass disruption in food production [1]
- Higher food prices [1]
- Food shortages [1]
- Loss in trade [1]
- Human casualties [1]
- Loss in confidence of government [1]
- Quarantine [1]

The outcome of a biological outbreak to the agriculture sector whether intentional or not will be similar

[1] Center for Food Security and Public Health, Iowa State University, "Safeguarding American Agriculture From Foreign Animal Diseases, 2004

Cybersecurity Vulnerabilities in Agriculture

Background of U.S. Farms

- There are currently 2 million farms in the United States [1]
- Family farms remain a key part in U.S. agriculture and account for 98% of all U.S. farms and 88% of total production [1]
- Almost half of the total production comes from 3% of large-scale family farms [1]

A cyberattack on one of these large food corporations could shut down food production and cause food insecurities and major economic losses

[1] https://www.ers.usda.gov/data-products/chart-gallery/gallery/chart-detail/?chartId=58288

Historical Overview

- The industry of agriculture has been around for centuries, and its history has been shaped by technological advancements
- The United States is currently in the fourth revolution of agriculture, which is referred to as "smart or digital agriculture;" represents the use of digital technologies; and is moving toward a smarter, more efficient, environmentally responsible agriculture sector [1]
- As the advancements in technologies have shaped the agriculture industry, the importance of security against cyberattacks has often been overlooked because, historically, the agricultural sector has not been a notable target for cyberattacks [2]

[1] Mohd, J., "Enhancing Smart Farming Through the Applications of Agriculture 4.0 Technologies," 2022
[2] https://cybersecurityguide.org/industries/food-and-agriculture/

Background

- The United Nations' Food and Agriculture Organization (FAO) estimates that global food production needs to increase 60% by 2050 in order to meet the demand of the global population [1]
- Climate change, natural resource depletion, and soil erosion also make meeting the demands more challenging
- This has led agriculture to implement modern technologies and the internet of things (IoT), which is often referred to as **"smart farming"**

[1] https://www.mdpi.com/2076-3417/11/16/7518

Introduction to Smart Farming

- May use several types of sensors to collect data (e.g., temperature, humidity, light, pressure, presence, etc.), and use communication networks to send and receive data, which is then managed and analyzed by management information systems and data analysis solutions [1]
- Has allowed farmers to optimize their agricultural production systems while improving the economic, environmental, and manual labor outcome [2]

[3]

[1] https://www.mdpi.com/1424-8220/20/15/4231
[2] https://smartertechnologies.com/guides/the-complete-guide-to-smart-agriculture-farming/#chapter-1
[3] https://www.nifa.usda.gov/grants/funding-opportunities/farm-future

Multilayer Smart-Farming Architecture

Made up of multiple layers of data collection, processing, handling, and storage that are susceptible to data loss

- The **perception layer** relates to the physical devices such as sensors, actuators, Global Positioning System (GPS), radio frequency identification, tags (RFID), and other devices that are used to collect both field environment and crop growth information [1]
- The **network layer** consists of connection technologies and devices, usually a wireless sensor network, and is used to transfer the data [2]
- The **edge layer** consists of multiple edge nodes, with each node representing a gateway that includes a variety of resources such as security features, data filtering, software features applied to decision-making and data processing, and storing small amounts of data [3]
- The **application layer**, which is located in the cloud, consists of all applications that are used by the end user [4]

[1] https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=9269526
[2] https://www.mdpi.com/2071-1050/13/4/1821/htm
[3] https://ieeexplore.ieee.org/document/9003290
[4] https://www.sciencedirect.com/science/article/pii/S2590005620300333#:~:text=The%20perception%20layer%20includes%20sensors,the%20edge%20or%20the%20cloud

Cyberattack

The National Institute of Standards and Technology Computer Security Resource Center defines a cyberattack as “any kind of malicious activity that attempts to collect, disrupt, deny, degrade, or destroy information system resources or the information itself” [1]

Vulnerabilities are any smart technologies left unsecured or unmonitored that increase the vulnerability to malicious hackers, leaving global supply chains exposed to risk [3]

A cyberattack can happen at any layer, which can threaten the integrity, availability, confidentiality, authentication, and nonrepudiation of a smart farm system

[2]

[1] https://csrc.nist.gov/
[2] https://www.nist.gov/news-events/events/2016/04/climate-smart-precision-agriculture
[3] https://www.bbc.com/news/science-environment-61336659

Examples of Cyberattacks

- Malware attack: corrupts firmware, which can destroy farm control systems and result in over/underwatering of a crop to destroy it [1]
- False data injection: feeds intentional falsification of data into the sensor network, which are connected via Wi-Fi/Bluetooth/cellular and can result in over/underwatering of crops [1]
- Radio frequency jamming attack: attacks Wi-Fi channels, which are open in nature to jam the wireless networking system [1]
- Ransomware attack: Type of malware that is designed to encrypt files on the organization's network, make the files or system unusable, and demand a ransom to receive the encryption key [2]
- Data leakage attack: unauthorized transmission of data from an organization to any external source violates confidentiality of the data [1]
- Side-channel attack: gathers unauthorized information pertaining to implementation description of a system by monitoring physical parameters such as electrical current or voltage [1]
- Spoofing attack: fakes the media access control address of gateway; convinces victim to send frames of fake address in place of destined address; has no way to verify sender; or permits data traffic to be recorded or manipulated or the session could be hijacked [1]
- Cloud-computing attacks: misuse cloud features such as self-provisioning, on-demand services, and autoscaling to take advantage of cloud resources (e.g., an infected virtual machine can quickly spread the infecting malware to other virtual machines via the cloud) [3]

[1] https://assets.researchsquare.com/files/rs-2042812/v1_covered.pdf?c=1663097448
[2] Yazdinejad, A., et. al, 2021, and Basharat, A., et. al, 2022
[3] https://www.mdpi.com/2076-3417/11/16/7518

Examples of Cyberattacks on Agriculture in 2021

- 2021: Florida water treatment facility hacked, raising the levels of sodium hydroxide [1]
- 2021: U.S. baking company lost access to its server [2]
- 2021: Ransomware attack on JBS (world's largest producer of beef, chicken, and pork), shutting down its facilities and resulting in JBS paying $11 million [3]

[1] https://abcnews.go.com/US/florida-citys-water-treatment-system-hacked-intruder-investigators/story?id=75763680
[2] https://www.ic3.gov/Media/News/2022/220420-2.pdf
[3] https://www.cbsnews.com/news/jbs-ransom-11-million/

Recognition of Cyberthreats to Agriculture

- In April of 2022, the cyberdivision of the Federal Bureau of Investigation released a notice alerting the food and agriculture sector that it could become a target of ransomware attacks during the busiest time of year [1]
- The USDA has some mandates and resources to provide agricultural security; however, the complexity of emerging technology is creating new hazards that increase the need for interagency cooperation, which is lacking [2]

[3]

[1] https://www.ic3.gov/Media/News/2022/220420-2.pdf
[2] Booghossian, A, Personal communication, U.S. Department of Agriculture, Washington, DC, 1 April 2022
[3] https://www.cisa.gov/stopransomware

Security Threats in Smart Farming

- The complex ecosystem creates a broad attack surface that needs to be protected to ensure data integrity
- Cyberattacks that are neither well timed nor coordinated have caused mass disruptions, and well-coordinated attacks could be devastating

Cyberterrorism is low-cost venture with potentially high payoff

State-of-the-Art Technologies

Climate Change

Sustainable agriculture: science-based practices to maximize productivity and profit while minimizing environmental damage, which can help reduce greenhouse gas emissions, conserve water and soil quality, and enhance biodiversity and resilience

- Crop rotation: a practice of planting different crops in a sequence on the same field, which can help prevent soil erosion, improve soil fertility, reduce pest and disease pressure, and diversify farm income [1]
- Permaculture: a design system that mimics natural ecosystems and creates productive landscapes that are self-sustaining, which can help conserve water, enhance biodiversity, recycle nutrients, and provide food security [1]
- Agroforestry: a practice of integrating trees with crops or livestock on the same land, which can help provide shade, timber, fuelwood, fodder, fruits, etc., and can also help reduce greenhouse gas emissions, improve soil quality, conserve water resources, etc. [1]

[1] Utopia, "What Is Sustainable Agriculture? 5 Examples and Its Benefits"

Gene Editing

Gene editing: **t**his is a technique that allows precise modifications of plant or animal DNA; can help create crops or livestock that are more resistant to pests, diseases, drought, heat, or salinity; and can also help improve nutritional quality yield or shelf life [1]

- Capturing carbon in crop roots: gene editing can enable crop plants to grow bigger and deeper roots that are effective in capturing carbon and storing it in the soil for extended periods of time [1]
- Replenishing carbon-absorbing trees: gene editing can help restore forests by creating trees that are more resistant to pests, diseases, droughts, etc., and can also help increase tree growth and biomass [1]
- Providing sources of low-carbon biofuel: gene editing can help create crops or algae that produce more oil or sugar that can be converted into biofuel and can also help reduce land use and water consumption for biofuel production [1]
- Reducing food waste: gene editing can help food stay fresh longer by making fruits and vegetables more resistant to browning or bruising and can also help improve shelf life, taste, texture, etc. [1]
- Enhancing nutrient density and quality: gene editing can help create crops or animals that have higher levels of vitamins, minerals, proteins, etc., and can also help reduce allergens, toxins, etc. [1]

[1] Innovature, "Gene Editing Is a Key to Environmental Sustainability"

Food Security for the Military

Defense Advanced Research Projects Agency (DARPA)

- Resource Program: "Performer teams are tasked with developing systems to break down mixed waste, including common plastics; reformulate the waste at the molecular level into strategic materials and chemicals; and recover purified, usable products such as oils, lubricants, and edible macronutrients" [1]
- Cornucopia Program: "DARPA's Cornucopia program aims to create a variety of healthy new microbial-based foods using three ingredients (air, water, and electricity) with minimal or no supplementation; if successful, troops could one day deploy with a transportable system that makes nourishing and appetizing food on demand in remote locations, obviating costly and brittle food supply chains" [2]

[1] https://www.darpa.mil/news-events/2021-11-29
[2] https://www.darpa.mil/news-events/2023-02-03

Conclusion