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Loss and Risk Affecting Federally Insured Crops in the US

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An abstract of
a thesis submitted to the Faculty of Emory College of Arts and Sciences
of Emory University in partial fulfillment
of the requirements of the degree of
Bachelor of Science with Honors

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Abstract

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Agriculture in the United States (US) has been revolutionized over the past century. One of the most significant changes is the simplification, intensification, and mechanization of crop production. Climate change is one of the most significant threats to our agricultural productivity. It is increasingly imperative to switch from cultivation paradigms prioritizing productivity and efficiency at the expense of socio-environmental viability for new paradigms addressing the social and environmental externalities of current agricultural problems. Agricultural production is deeply influenced by the policies and incentives laid out in the US Farm Bill, an omnibus piece of legislation which strongly influences how and where food is produced in the US, and by the Federal Crop Insurance Program (FCIP). The United States is faced with a challenge: altering agricultural policies to encourage adaptation to climate change. Radical changes are necessary, and much of this responsibility falls upon the United States Department of Agriculture (USDA), which administers this program. In this paper, we provide an overview of the FCIP and past Farm Bills and investigate how they have shaped agricultural land use. We build upon prior research utilizing a measure of yield risk to make connections between the FCIP, land use change, and its influence on the riskiness of dominant crops cultivated over the past 30 years. Additionally, we use this measure of risk to identify the most pressing environmental threats to the agricultural productivity of major US crops and agricultural regions. Overall, the FCIP has a strong influence on US agriculture, and has the potential to mitigate the destruction of climate change.

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1.0 INTRODUCTION

Agriculture in the United States (US) has been revolutionized over the past century through new farming technologies, food manufacturing capabilities, dietary habits, and US agricultural policies. One of the most significant changes is the simplification, intensification, and mechanization of crop production over the past century. More than 64% of US cropland is now dominated by only three crops: corn, wheat and soybean (1). This decrease in crop diversity has granted us the caloric output to feed a rapidly growing nation, but at the expense of the sustainability and biodiversity of environmental ecosystems (2). US farmers have worked tirelessly to withstand major obstacles caused by environmental and economic stressors, and unfortunately our future holds further obstacles that will threaten the productivity and efficiency of agriculture in the US (3).

Climate change is one of the most significant threats to human life today (4). Much of this threat is due to the severe consequences of climate change on our agricultural productivity. Many regions are already experiencing increased average temperatures, chronic water shortages, and more severe natural disasters than ever before (4). In the past, economic profitability has been a dominant force shaping agricultural realities. However, it is increasingly imperative to switch from cultivation paradigms prioritizing productivity and efficiency at the expense of socio-environmental viability for new paradigms addressing the social and environmental externalities of current agricultural problems (5). This is both to mitigate the impacts of climate change on US agricultural systems, and to transition towards more resilient, just, and sustainable agricultural futures (2). We must prepare to mitigate the impacts that climate change will have on our agricultural productivity (6).

Agricultural production is deeply influenced by the policies and incentives laid out in the US Farm Bill, an omnibus piece of legislation which strongly influences how and where food is produced in the US, and is updated approximately every 5 years (7). One of the most influential federal incentive programs in the US Farm Bill is the Federal Crop Insurance Program (FCIP). The United States is faced with a challenge: altering agricultural policies to encourage adaptation to climate change. Radical changes are necessary, and much of this responsibility falls upon the United States Department of Agriculture (USDA), which administers this program.

In this paper, we provide an overview of the FCIP and past Farm Bills and investigate how they have shaped agricultural land use. We build upon prior research utilizing a measure of yield risk (8) to make connections between the FCIP, land use change, and its influence on the riskiness of dominant crops cultivated over the past 30 years. Additionally, we use this measure of risk to identify the most pressing environmental threats to the agricultural productivity of major US crops and agricultural regions. Overall, the FCIP has a strong influence on US agriculture, and has the potential to mitigate the destruction of climate change.

2.0 POLICY OVERVIEW

2.1 History of Agricultural Development and Policies in the US

US agriculture has changed dramatically over the past two centuries, and it is important to understand how policy has shaped the evolution of modern agriculture. By understanding the effects that policy has had on agriculture in the past, we can see the powerful potential it has to make the changes necessary to maintain agricultural viability during a new era of climate change.

Many technological and social elements contributed to the development of US agriculture. The late 18th century and early 19th century brought massive changes to US agricultural systems, which evolved over this period from primarily subsistence farming into a massive industry. Expansion into the western US, the development of irrigation canals, and the invention of steamboats allowed Americans to access millions of acres of fertile land, and ignited rapid population growth. Technological advancements such as the cotton gin in 1793 and cast-iron plows in 1797 advanced productivity and made cotton one of the first commodity crops to be exported, opening the US to international trade (3).

By the 20th century, agriculture experienced a massive expansion due to the implementation of railroads across the United States, inventions such as fertilizers, farming tools, and refrigeration, the switches from manpower to horsepower to fossil fuel power, and the Homestead Acts from 1862-1916 which gave farmland to settlers and offered education and research on agricultural knowledge and farming technology. In 1862, the Morrill Act expropriated indigenous land and established public higher education in agricultural and mechanical arts (9), and the Hatch Act of 1887 established agricultural research systems. By the beginning of the 20th century, gasoline engine tractors were being implemented which cut manual labor in half (3).

During World War I, the Food Control Act of 1917 gave farmers a fixed market price so they were encouraged to grow more and supply food, fuel, and fiber for the war effort. In 1918, the inventors of the Haber-Bosch process won a Nobel prize for its ability to convert atmospheric nitrogen into synthetic fertilizers. This process is claimed to have quadrupled grain production during the 20th century (10), and altered the perspective on agricultural production - it became viewed as importing nutrients and exporting crops. This process radically changed our ability to feed populations and spurred massive population growth (9).

After the war, supply of commodity crops exceeded demand, so prices fell and the Agricultural Marketing Act of 1929 (11) was implemented to stabilize prices by creating the Federal Farm Board which worked to reduce commodity crop surplus. 1933 marked the first Farm Bill, which created the Agricultural Adjustment Administration (12), whose job was to oversee the distribution of subsidies. This was the federal government's first significant effort to improve economic welfare for farmers by managing agricultural products, purchasing livestock, collecting taxes on commodity crops, and paying farmers in order to restrict their agricultural production (13). In the same year, the Commodity Credit Corporation (CCC) was created with the purpose of stabilizing, supporting, and protecting farm income and prices by withholding surplus commodities from the market and dispensing them strategically. Today, the CCC still exists and manages billions of dollars borrowed directly from the federal Treasury and is used for federal subsidies, conservation efforts, and international market development (14).

The Dust Bowl and Great Depression prompted a new phase of Farm Bills that included direct farm income payments. Amidst the Dust Bowl, the public grew extremely concerned about soil quality, and the Soil Conservation and Domestic Allotment Act was passed in 1935 to replace the Agricultural Adjustment Administration which was found to be unconstitutional because it allowed Congress to use taxing and spending powers to compel citizens to alter their farming practices (13). This act paid farmers subsidies to grow soil-conserving crops such as native grasses, trees, and vegetables, and turned into the Soil Conservation Act of 1935. This act addressed soil erosion in a few different ways, including flood control plans, drainage and irrigation support, and soil science research (15).

During World War II, American farmers expanded production but depleted soils, and this pattern continued with new technology that burned fossil fuels. In the 1950s tractors replaced horses on farms, leading to the mechanical harvesting of commodity crops. At the same time, anhydrous ammonia, made more abundant through the Haber-Bosch process, was sold cheaply which intensified yields (3). After World War II, Europe was able to increase agricultural production again, which created competition with American farmers. The Agricultural Act of 1954 began expansion into international trade and implemented export subsidies for US farmers.

After this period of increased production, there was a shift back towards soil preservation and food security. The Soil Bank program was created in 1956 and farmland with low productivity was turned into wildlife habitat. There were still huge amounts of commodity crop surpluses, and this prompted the Emergency Feed Grains Act of 1961 which paid farmers to reduce acres of commodity crops, and more importantly succeeded at motivating farmers to convert 30 million acres of cropland into the Soil Bank (16). The Agricultural Act of 1970 also aided in soil conservation by requiring farmers to set aside a percentage of their cropland in order to qualify for farm program benefits (16).

In 1972, the US exported 80% of wheat to the Soviet Union to support their livestock production. This was dubbed the "Russian grain robbery", and was not well received by the American public and led to increases in domestic crop prices. As a result, farmers were encouraged to plant "fencerow to fencerow" to increase domestic surpluses of corn, soybean, and wheat by practicing intensive agriculture that destroyed soil quality once again (17). Once crop supply was replenished, prices began to drop and the Agriculture and Consumer Protection Act of 1973 supported states with grants to develop consumer protection plans (18). 1982 brought a bumper crop that filled the Commodity Credit Corporation's (CCC) storage facilities. The Reagan administration created a Payment-in-Kind program which paid farmers in certificates for CCC stored grain if they reduced their own production of grain. They could redeem this grain and sell it, or simply sell the certificates to other farmers. This reduced the surplus, but also cost the government billions of dollars (19).

The 1985 Farm Bill highlighted conservation programs that created more wildlife habitats, protected grasslands and wetlands, and helped replenish degraded soils by paying farmers to retire erosion-prone croplands for 10-15 years. This bill also forced farmers to implement conservation techniques in order to be a part of federal farm programs. By the end of the century, the Federal Agriculture Improvement and Reform Act of 1996, also known as "Freedom to Farm", gave farmers back a lot of freedom in their farming by removing commodity crop acreage restrictions and replacing income support payments that were based on crop prices with direct compensatory payments that were paid regardless of market prices (17).

Agricultural policies since 2000 have followed four major trends. The first trend affected direct payments, which were fully eliminated by 2014 and replaced by payments based on market prices and revenues. The next trend has been the expansion of the FCIP - the amount of acres covered by the FCIP tripled from 2000 to 2020. Another trend has been expanding conservation programs, including the implementation of techniques such as nutrient management, conservation tillage, cover crops, and field-edge filter strips. The final trend is the increased ad hoc spending since the Trump Administration. This spending compensated farmers who lost export markets in response to international tariffs, and farmers who faced major losses due to COVID-19 and the government lock-down (20).

2.2 Summary Of FCIP

A major role of the Farm Bills is dictating the expenditures of the Federal Crop Insurance Program (FCIP) which reflects billions of dollars of taxpayer funds each year. From 1995-2020, over 200 billion taxpayer dollars were used to subsidize farmers' crop insurance and as indemnity payments for farms that experience low yields (21). So what is the Federal Crop Insurance Program, why is it important, and how has it been shaped by Farm Bills?

Crop yields are innately unstable given changes in climate, weather, pests, and diseases, and this prevents the assurance of a stable income. The inability of farmers to produce a set yield causes further variability in their income. These uncontrollable external factors are rooted in environmental changes. Yields vary annually due to the stochasticity of the weather and environmental factors. However, farmers serve a crucial role in society by providing energy and nutrients for all. But farming is an inherently risky profession, and without assurance of a stable income, many farmers would be forced to switch careers. Therefore, it is in society's best interest to cover the individual risk of farmers, and America's tax dollars pay for 60% of the cost of crop insurance policies (22).

The Federal Crop Insurance Corporation (FCIC) was first created in 1938 in response to major declines in crop yields due to the Dust Bowl. Originally, the program only offered coverage for major crops in major areas, and Farm Bills in the 1960s and 1970s offered free disaster coverage to farmers. The program gained popularity when the Federal Crop Insurance Act of 1980 expanded insurance options to include many additional regions and crops, and encouraged farmers to greatly expand their acreage. A drought in 1988 prompted ad hoc disaster assistance to farmers inside and outside the program, which prompted crop insurance to become mandatory for farmers to be a part of the program in order to receive assistance. The Federal Crop Insurance Reform Act of 1994 expanded coverage to include catastrophic (CAT) insurance which compensated farmers for losses over 50% of their average yield from the past several years (23).

1996 marked the creation of the USDA's Risk Management Agency (RMA) which administers the Federal Crop Insurance Program (FCIP) and is an extremely valuable resource for farmers that provides them with risk management tools and education. Through the RMA, the Risk Management Education Partnership Program (RMEP) works with farmers, particularly disadvantaged and underserved farmers and ranchers, to teach them about crop insurance and farm safety net tools, and hosts information sessions for farmers all over the country. The RMEP's trainings teach farmers how to access and utilize crop insurance and risk management training to effectively manage long term risks, and they also aid with financial, marketing, legal, and human resource education (24).

The most recent update to the FCIP came in the 2014 Farm Bill, which most notably introduced the Whole Farm Revenue Protection (WFRP) plan, a revenue-based plan that allows farmers to insure their whole farm, including crops and livestock. The plan uses past average revenue and current-year expected farm revenue to determine a coverage level. WFRP's convenience makes it easier for farmers to diversify their crops and make the switch from monocultures to polycultures (23).

Today, the FCIP functions to provide a specified level of coverage for both yield-based loss and revenue-based loss, in which the farmer pays a portion of the premium for the insurance policy and the federal government covers the rest of the cost. Yield-based plans offer indemnities to farmers in case of a lower than average yield due to environmental causes such as drought, excess precipitation, insects, and diseases. This 'average' yield is determined either by actual production history (APH) which is based on the past 4-10 years of that farmers' yield history, or by yield protection (YP) which uses future market prices. The farmer can choose a coverage level of 55-100%, and if the harvest falls below the covered yield, the farmer is paid an indemnity. There is also a Dollar Plan which provides protection against damage to yields for certain crops, and the Vegetation and Rainfall Indices, which are insurance plans that are best for farmers whose crop production follows average vegetation and rainfall patterns (23).

Revenue-based plans protect against both yield losses and changes in market prices that are lower than average. Similarly to yield-based plans, revenue-based plans use actual revenue of the farm operation history to determine the historical average market prices. Farmers can choose to insure 50-75% of the average yield and the amount of insurance protection is determined by whichever price is higher - the harvest price or the projected price of the crops. If the harvest price ends up lower than the projected price, the farmer is paid indemnities (23).

Finally, there is Catastrophic Coverage (CAT). This plan is paid for by the federal government and pays farmers 55% of the price for crop losses that are greater than 50%. Typically, CAT is used when unexpected natural disasters occur or disease and/or pests spread (23).

We know how the FCIP is intended to function, but how do these policies and programs actually play out? This paper serves to evaluate and answer important questions about the impact the FCIP has had on farmers' actual yields and losses. Our goals are to investigate how yields and losses have varied over time, how the level of risks vary by crops and regions, and what the most destructive causes of loss are. In particular, we are interested in how crop insurance policies have affected the planting and yields of commodity vs specialty crops (23).

3.0 METHODS

We utilized the software program R (version 2022.07.0, build 548) and open source datasets from the USDA to calculate yearly amounts of crops planted as well as a measure of yield risk. The main datasets used were from the USDA's Risk Management Association (RMA) and we combined these with data from yearly USDA crop production reports. We used these data to understand the trends of crop loss in the US, analyze agricultural insurance use, and interpret our measure of yield risk.

3.1 Datasets

The Cause of Loss (COL) (25) data were collected by the USDA RMA. We downloaded and compiled raw annual datasets from 1989 - 2020. The final dataset contains information about the type of crops that are planted, where they were planted, crop acreage, the insured acreage lost, whether that loss was due to economic or environmental reasons, and information about insurance policies used and indemnity payments. We note that due to data quality issues, we had to remove the crop peanuts planted from our analysis. Peanuts planted can be seen in SI Figure 1.

The Summary of Business (SOB) (26) dataset was built similarly to the COL, as it also included merging separate datasets from 1989 - 2020. SOB variables include the states and counties in which crops were grown, what crops were grown, detailed information about insurance policies used and coverage levels, as well as details about subsidies and indemnity payouts.

We merged the COL and SOB data to enable calculation of a loss-cost ratio (LCR), as developed by Perry et al. 2020 (8). This measure of yield risk is the ratio of losses to liabilities. Liabilities is the level of insurance coverage that farmers sign up for at the beginning of a season, and losses is how much of that covered crop is actually lost. In order to view our measure of risk as the percentage of the insured crop that is lost, we changed it from a ratio to a percentage. The larger the loss-cost percentage (LCP) is, the larger the risk is. The LCP is calculated by the following formula:

$$LCP_{it} = (\sum_j Losses_{it}^j)(Liabilities_{it})^{-1}(100)$$

Where $Losses_{it}^j$ is the dollar amount of realized indemnity payments, or insurance compensation, by county *i* and by year *t* due to a specific cause *j*. $Liabilities_{it}$ is the maximum possible dollar amount of indemnity payments, also by county and year (8). This creates a number from 0 to 1, which we multiplied by 100 to interpret as a percentage from 0 to 100. Zero percent indicates that none of the insured crops were lost so no indemnities were paid to the farmer, and 100% means that all of the insured crops were lost. A value above 100% would signify that the farmer received indemnities for more acres of crops than were insured.

Because we have over 100 cause of loss categories from the COL dataset, we can split LCP up into subcategories based on the causes. We chose to create four cause of loss subcategories related to weather stressors: causes due to heat, cold, drought, and excess moisture. The specific causes of loss are grouped and listed in Table 1. Our dataset also includes hundreds of crops, so we divided them into nine broader crop categories, which are described in Table 2. Throughout this paper, we also reference commodity and specialty crops. Commodity crops are crops that are 'commodified' and are grown in high intensities for public and global trade, like corn, wheat, and soybeans. Specialty crops include fruits, vegetables, nuts, and beans - these crops tend to be more nutritionally valuable and less destructive of soil due to less intensive planting.

Table 1: Causes of loss encompassed by each category of weather stressor.

Loss Category	**Specific Causes of Loss**
Heat	Heat, Insufficient Chilling Hours, Hot Wind, Fire, Excess Sun
Cold	Freeze, Frost, Cold Winter, Cold Wet Weather
Excess Moisture	Excess Moisture/Precipitation/Rain, Hurricane/Tropical Depression, Flood, Cold Wet Weather, Poor Drainage, Storm Surge, Tidal Wave/Tsunami
Drought	Drought, Drought Deviation, Failure of Irrigation Supplies, Failure of Irrigation Equipment, Erosion

Table 2: Crops encompassed by nine crop categories.

Crop Category	**Specific Crops Included**
Beans	Soybeans, Processing Beans, Fresh Market Beans
Citrus	Oranges, Tangelos, Grapefruit, Lemons, Limes, Mandarines, Tangerines, Tangors
Cotton	Cotton, Cotton Extra Long
Fruit	Blueberries, Strawberries, Raspberries, Blackberries, Peaches, Nectarines, Pears, Plums, Grapes, Apricots, Prunes, Raisins, Cherries, Avocados, Mangos, Stone fruit, Watermelon, Carambola, Figs, Papayas, Bananas
Grains	Sorghum, Millet, Rye, Rice, Wheat, Oats, Barley, Corn
Nuts	Almonds, Walnuts, Peanuts, Macadamia Nuts, Pecans
Other	Alfalfa, Sugar, Oils, Sunflowers, Forage, Coffee, Clams
Tobacco	Cigar Binder, Cigar Filler, Cigar Wrapper, etc
Vegetables	Cabbage, Cucumbers, Sweet Corn, Tomatoes, Green Peas, Olives, Onions, Peppers, Sweet Potatoes, Potatoes, Peas, Winter Squash

This paper examines the intersections of lost acres, LCR (or the riskiness of different crops), and cause of loss to understand the most severe threats posed to agricultural productivity.

We looked at these across the 31 year period of available data from 1989 to 2020. Our main questions were: (1) What crops are planted? (2) What crops are lost? (3) What is causing this loss? (4) Where is this loss occurring? (5) What is creating risk? (6) Which crops are most vulnerable to risk? (7) Which US states are most vulnerable to risk? (8) How has risk varied over time? (9) How have indemnity payments varied over time?

4.0 RESULTS

4.1 Planted Acres

Planted crop acreage has been highly variable over the past 30 years. In Figure 1, we break down acreage planted by specialty and commodity crops and see that commodity crops are planted in much larger quantities and account for much of the variability. Top commodities planted include wheat, corn, soybeans, tobacco, rice, and cotton. Top specialty crops planted include citrus fruits, stone fruits, pecans, and almonds.

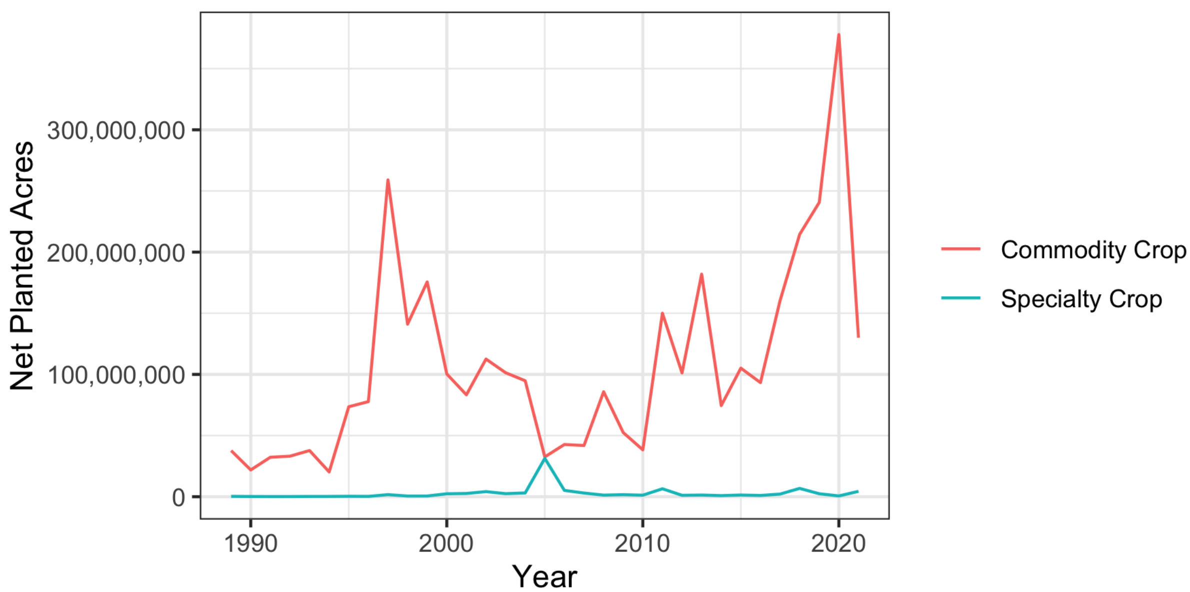


Figure 1: Net planted acres divided by commodity and specialty crops over time. Excluded peanuts due to outlier data.

4.2 Lost Acres

4.2.1 Loss Overall

Crop acreage can be lost - not survive to harvest - for a variety of reasons such as weather impacts, pests, the spread of diseases, and economic declines in market prices. By visualizing acreage lost over time, we can see the effects of major events on cultivation outcomes. In Figure

2, we see a general increase in both total crop loss and the variability of crop loss from the 1990s to the 2000s, which could be explained by an increase in overall acreage planted. The economic recession of 2008 correlates with a sharp decline in lost crops. After 2011, there was another drastic increase in loss. This is likely due to the 2011 drought brought upon the western US by ENSO circulation. This drought had major impacts on agriculture and agricultural land throughout the southern states, cost Texas farmers over $5 billion in losses in 2011, and continued to affect agriculture for years to come (27). The stark contrast between loss of commodity and specialty crops is because commodity crops are planted on a much larger amount of acres than specialty crops. In Figure 3 we break loss up by crop category, and we can see that grains consistently experience the most loss. This is due to the fact that grains include wheat and corn, which are grown on a larger scale than other categories of crops.

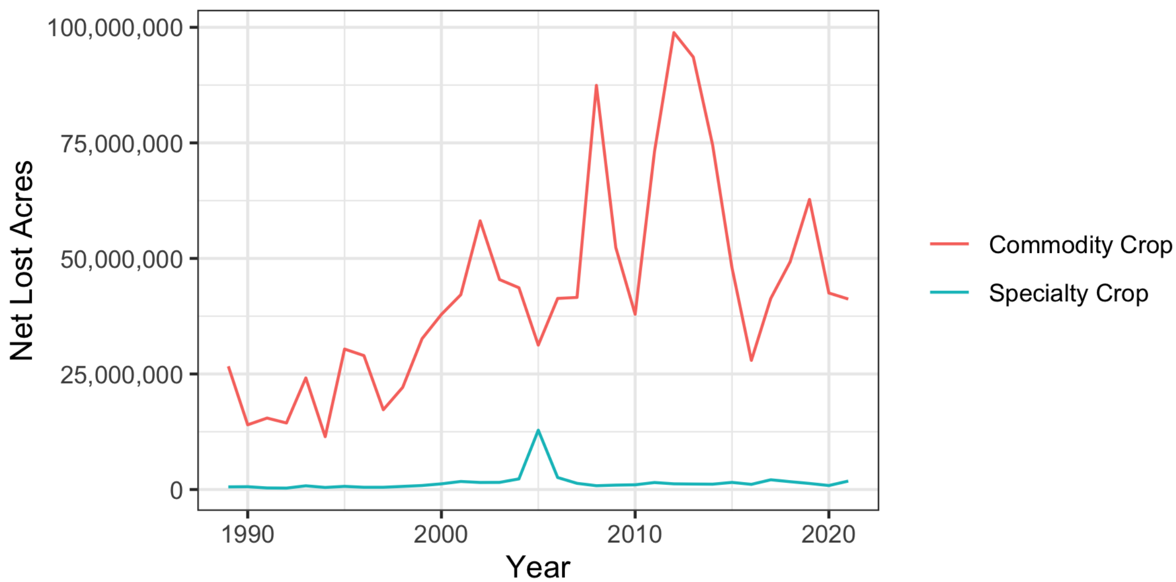


Figure 2: Net lost acres divided by commodity and specialty over time.

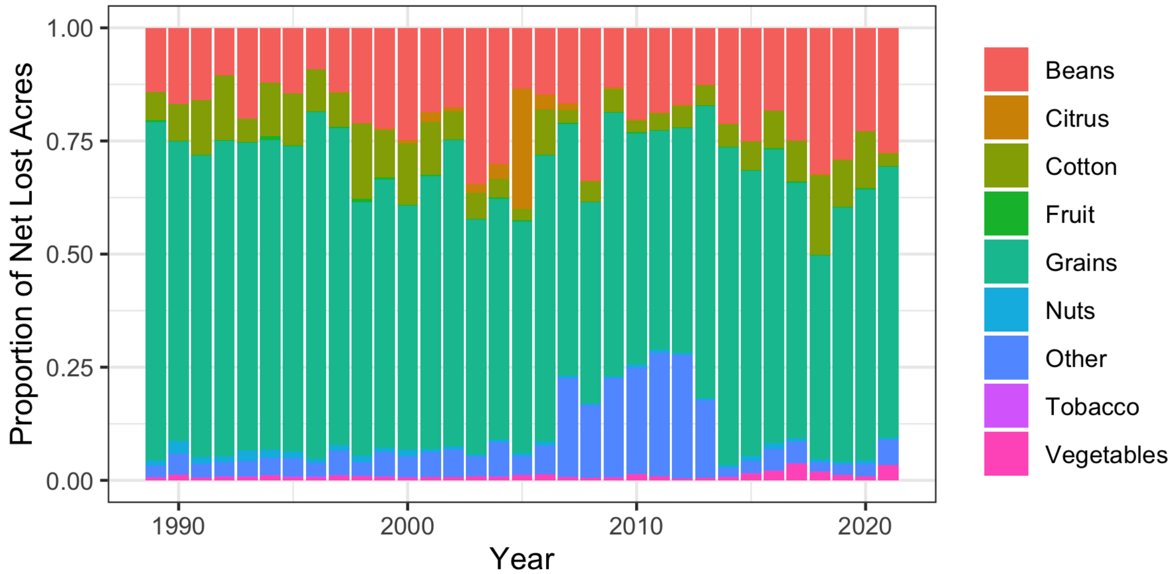


Figure 3: All loss broken down by crop categories.

4.2.2 Loss by Cause

Environmental and weather stressors - which are related to climate change - are causing the majority of crop loss. In Figure 4, we can see that the majority of loss is in fact due to these environmental causes compared to other (largely economic) causes. In this figure, environmental causes encompass weather events such as drought, heat, cold, excess moisture, and natural disasters. Other causes include fluctuations in market prices, diseases, and pests. In this case, lost acres can either be acres of crops that physically did not make it to harvest, or acres that were harvested but did not receive the expected price due to declines in market prices. Overall, weather stressors are responsible for much more loss compared to economic variability. Figure 5 breaks down these stressors further into our four main weather categories, in which we find that drought and excess precipitation are responsible for a vast amount of total lost acres. The figure shows us that drought and excess moisture have each caused over 400 million acres of crops to fail over the past 30 years. Figure 6 shows us the prevalence of the four causes of loss and how that has changed over time. We see a steady decrease in loss due to cold, while at the same time loss due to heat has increased.

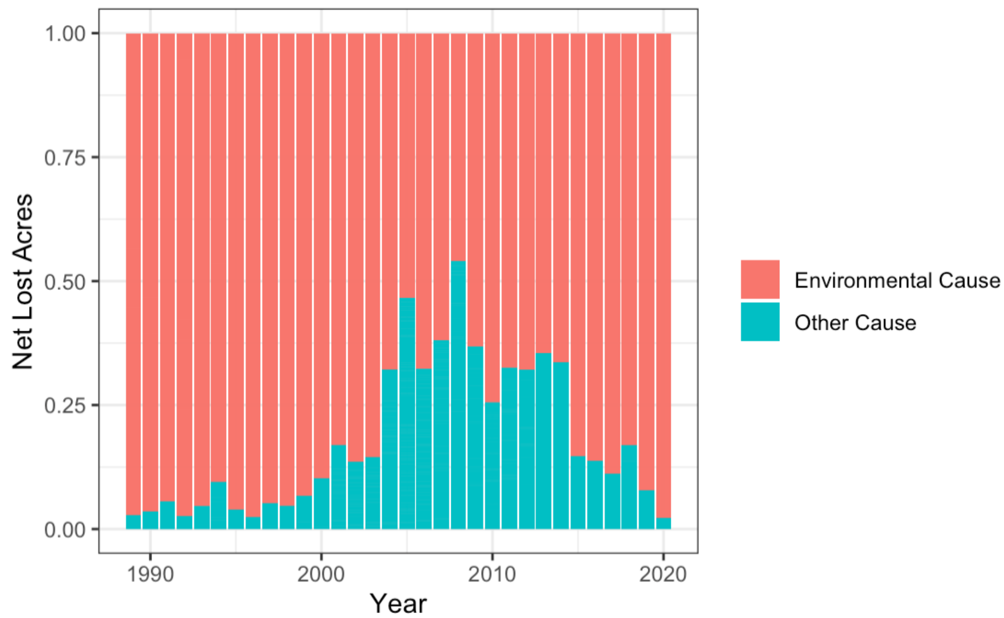


Figure 4: Net lost acres due to environmental or other causes.

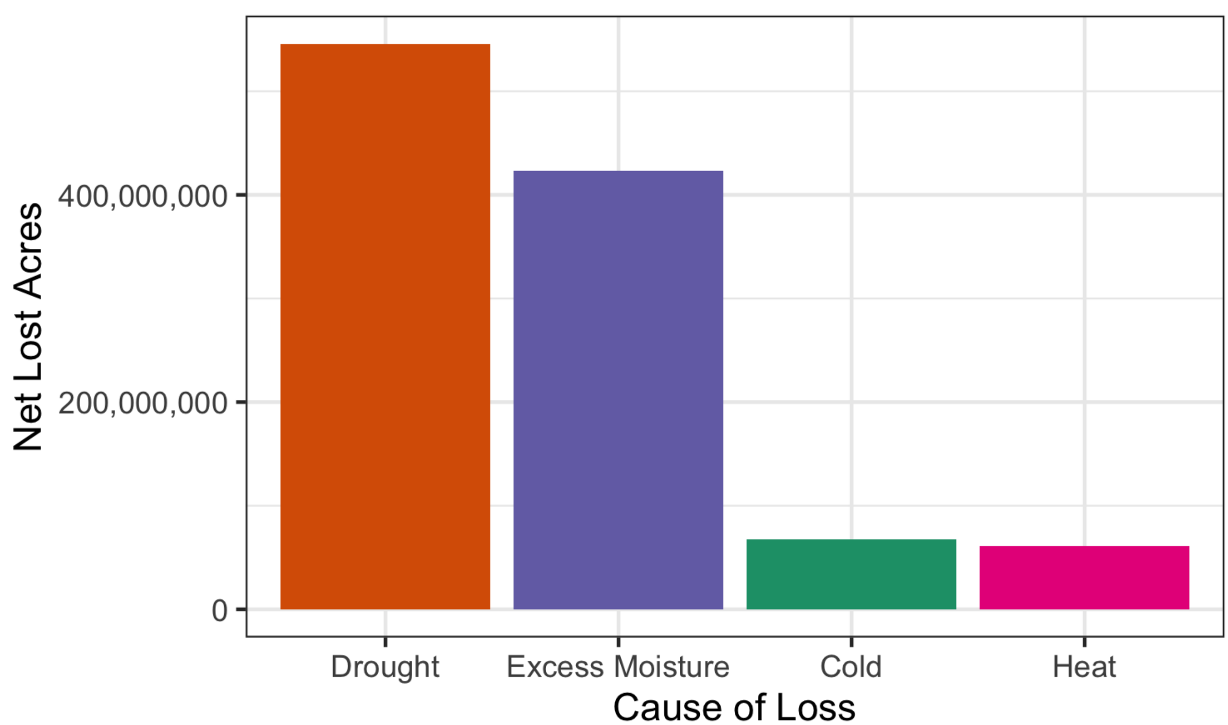


Figure 5: Net lost acres from 1989-2020 divided by the four main weather based causes of loss: drought, excess moisture, cold, and heat.

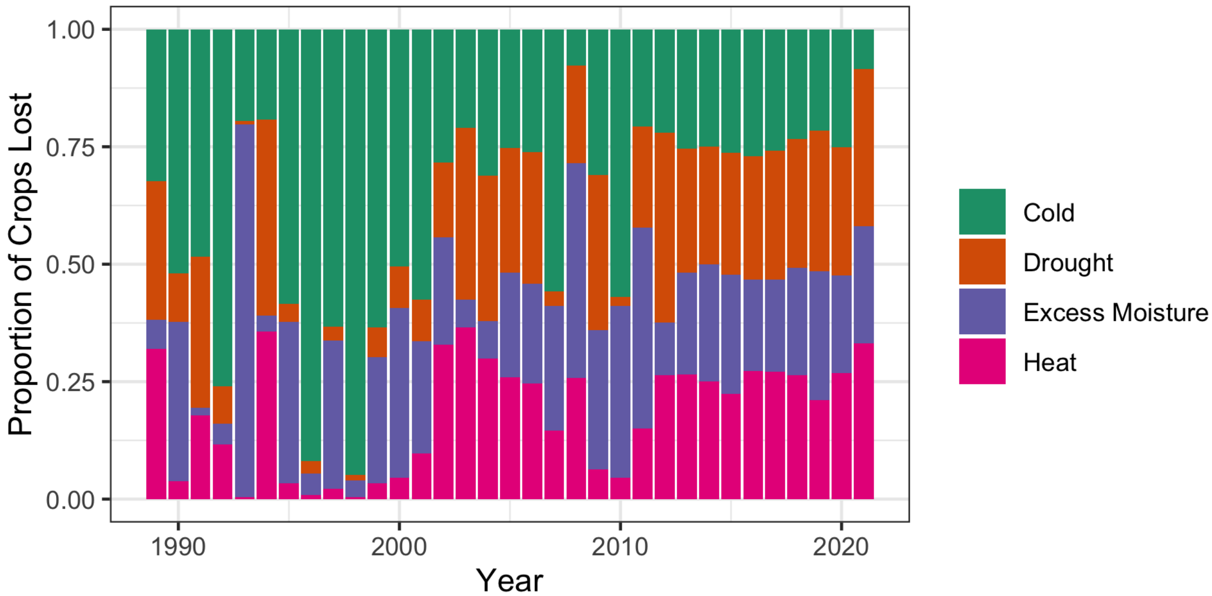


Figure 6: Crop loss divided by weather based causes of loss over time.

4.2.3 Loss by State

The three maps within Figure 7 display the predominant cause of loss, or cause of loss that has created the most loss by US state. In Figure 7A and 7B, we can see regional disparities between drought and excess moisture and precipitation. The East has been dominated by excess moisture while the West is plagued by drought. The strong similarities between Figures 7A and 7B show how so many states are dominated by commodity crops. Interestingly, cold weather is not the top cause of loss for commodity crops in any state. This is likely because most commodity crops are grown from spring to fall. However, cold has the strongest effect on specialty crops in 5 states.

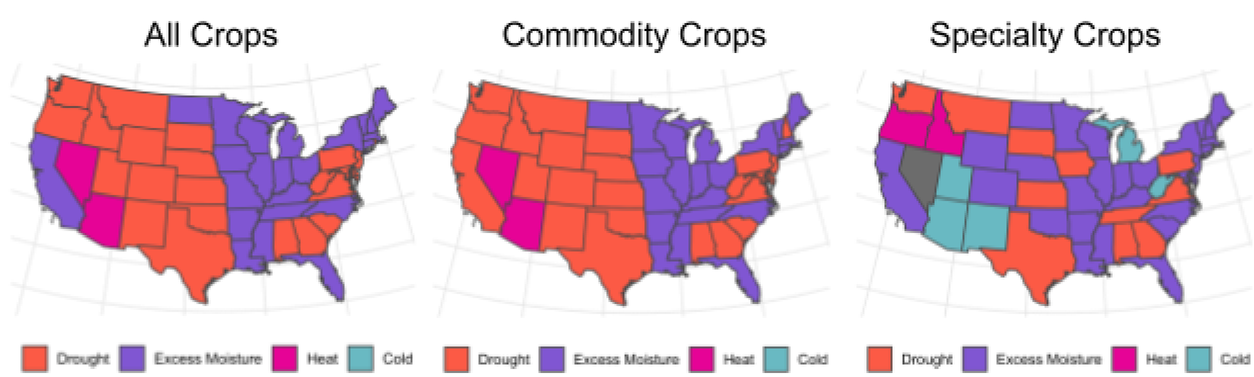


Figure 7 (A, B, C): Causes of loss that have created the most net lost acres from 1989-2020 by state. A is loss of total crops, B is loss of commodity crops, C is loss of specialty crops. In C, there was insufficient specialty crop data in Nevada to determine the top cause of loss.

4.3 Loss-Cost Percentage

Now that we have looked at loss in terms of total acres lost, we turn to the loss-cost percentage (LCP) to understand how this loss is related to crop insurance. The LCP is our calculated measure of yield risk, in which the higher the LCP, the more risk is associated with the crop. The range of the LCP should be 0% to 100%, in which 100% indicates that a farmer received indemnity payments for all the acres of crops they insured. However, some outliers were higher than 100%. This indicates that farmers received indemnity payments for some acres of crops that weren't insured, which might be possible if disaster assistance programs are in use, such as catastrophic coverage insurance plans that cover unexpected natural disasters, pests, and disease. The Noninsured Crop Disaster Assistance Program (NAP) also offers protection for crops that haven't been insured (28). Each data point represents coverage and loss of one crop, and the year and county in which the loss occurred.

4.3.1 LCP Over Time

First, we graphed median LCP over time for commodity crops and specialty crops. To do this, we took all the individual data points for each year and calculated the median. Specialty crops have a consistently higher median LCP value than commodity crops. We also see that while LCP has been highly variable over the past 30 years, there is no significant evidence of an overall increase of LCP.

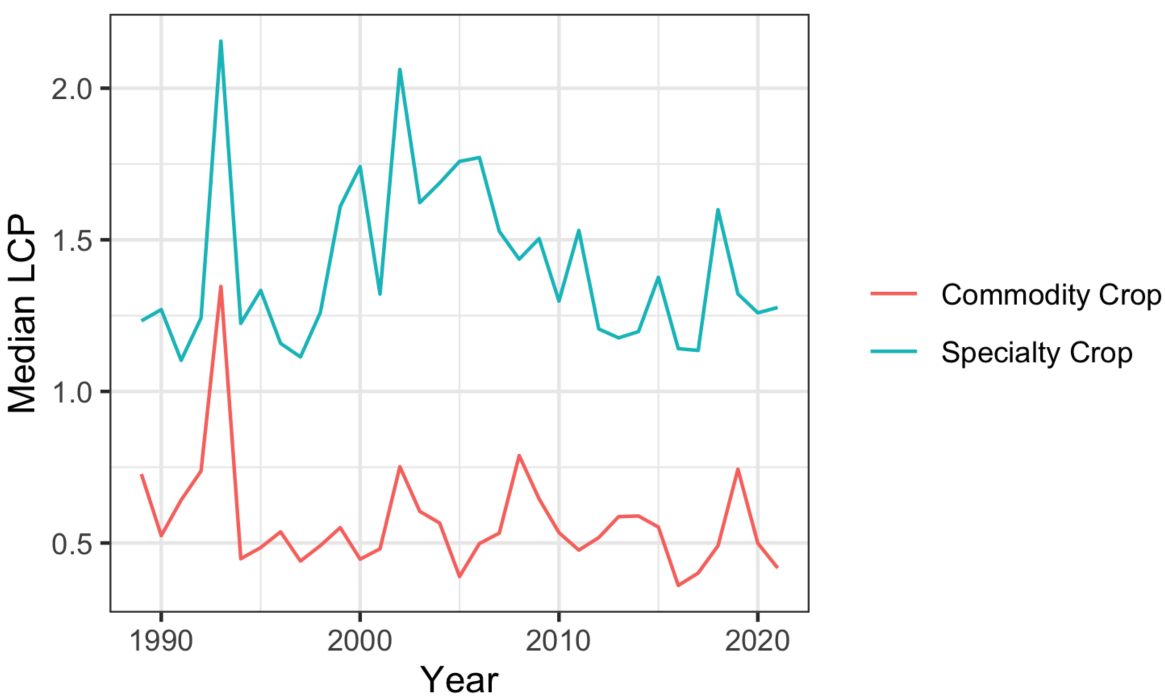


Figure 8: Median LCP for each year from 1989-2020 divided by commodity and specialty crops.

4.3.2 LCP by Cause

Next, we compare the LCP across the four main causes of loss: heat, cold, drought, and excess moisture to determine the amount of risk they each create. Farm level data points are divided by cause of loss and organized into box-whisker distributions. Our results in Figure 9 indicate that *across all crops,* drought creates the largest amount of risk. In all four categories, the median LCP falls below 3% indicating generally low levels of loss. However, all categories have many extreme positive outliers that indicate individual counties that experienced levels of high loss due to extreme weather events.

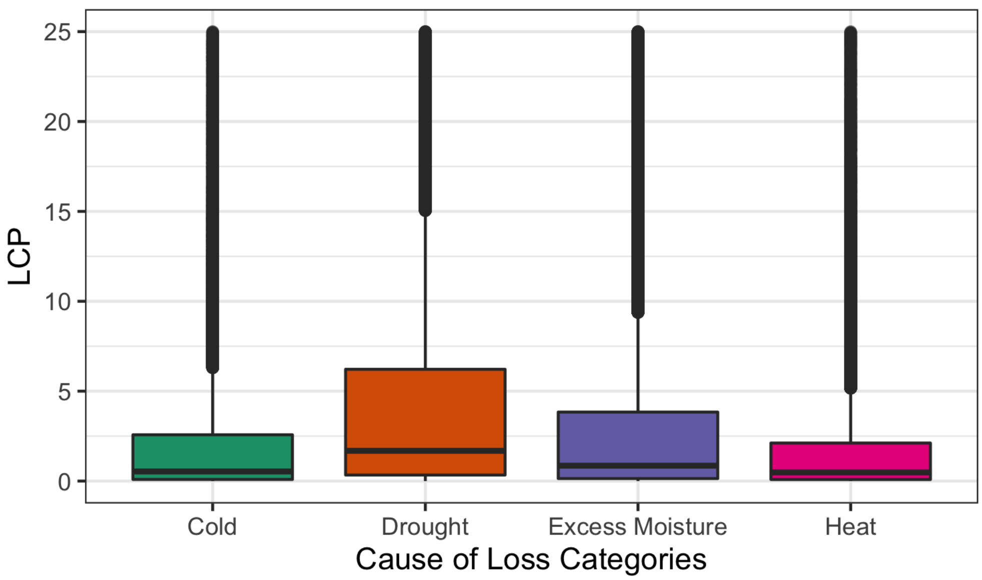


Figure 9: The LCP of farm level data divided by cause of loss categories. LCP has been capped at 25 in order to show where most data lies, however there are some positive outliers that are not shown.

4.3.3 LCP by Crops

We then broke down LCP by crop categories to determine which crops are most vulnerable to risk. The first division of crops was into commodity and specialty crops. Commodity crops have a mean LCP of 4.77 with a standard deviation of 11.81. Specialty crops have a mean of 6.24 with a standard deviation of 12.72.

We see in Figure 10 a wider spread in LCP due to the variability in vulnerability to weather stressors by crop categories. Vegetables appear to have the highest LCP from all causes combined. The “Other” category includes crops like coffee, oils, and flowers that are on the fringes of the FCIP and are more difficult to insure, also show a high amount of risk. Next, we visualized crop categories within each of the four causes of loss in Figure 11. By doing this, we can analyze how each cause of loss affects specific categories of crops. As we saw in Figure 9, drought causes the highest amounts of risks. Figure 11 shows that many crops are indeed highly vulnerable to drought. Excess moisture is our second highest contributor to crop risk, and also affects many crops, the most vulnerable being vegetables. Heat and cold weather have generally lower LCPs, with vegetables being the most vulnerable to heat and fruits being the most vulnerable to cold.

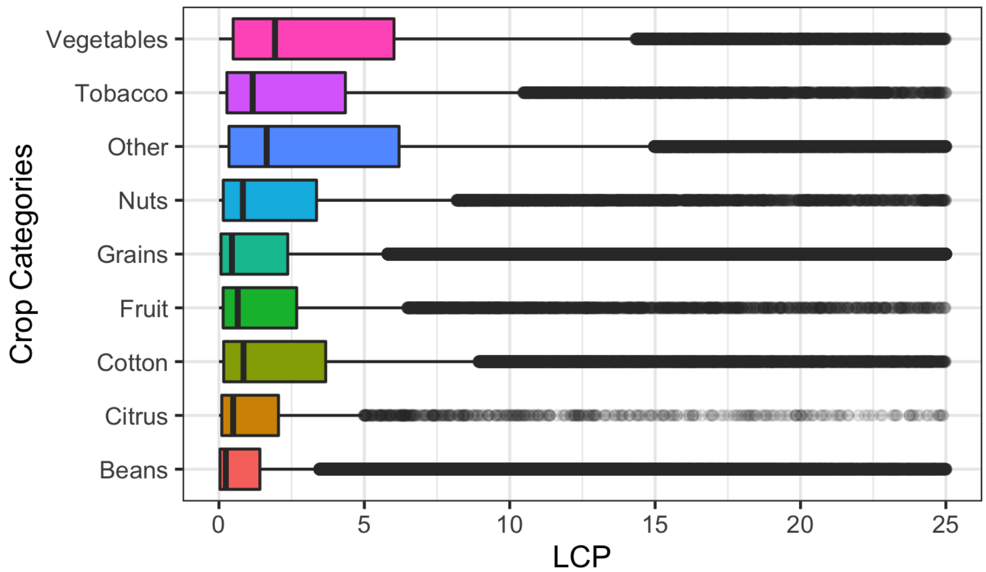


Figure 10: The LCP of county level data divided by crop category. LCP has been capped at 25 in order to show where most data lies, however there are some positive outliers that are not shown.

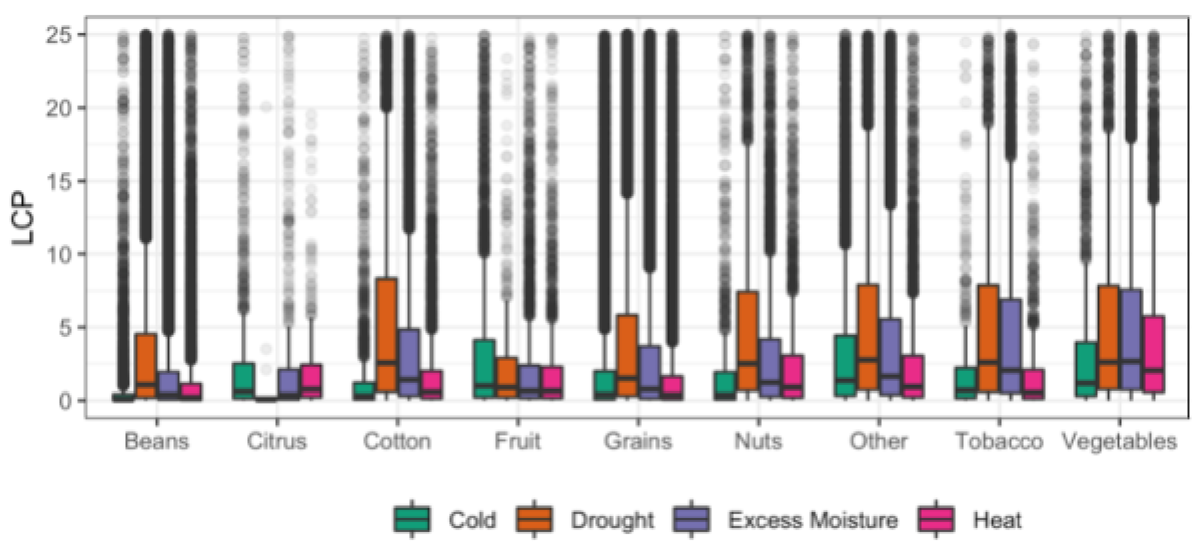


Figure 11: LCP of county level data, divided by crop category and by cause of loss categories. Drought, excess moisture, heat, and cold, respectively. For citrus, there are only 13 county-year observations for drought.

4.3.4 LCP by State

Figure 12 shows the mean LCP by cause of loss in each state. Due to the fact that many counties are not agriculturally productive, county level data was divided by state. Map A displays the deepest colors, indicating the highest mean LCP values are caused by drought. In particular, the most risk created by drought is found in the South and Southwestern states such as Texas, New Mexico, California, and Nevada. Texas is also moderately affected by excess precipitation as shown in Map B, and slightly affected by heat and cold weather in Maps C and D. Generally, excess precipitation affects states in the East and Southeast most. Heat and cold have contributed less intensely to risk, but they do affect broad ranges of states.

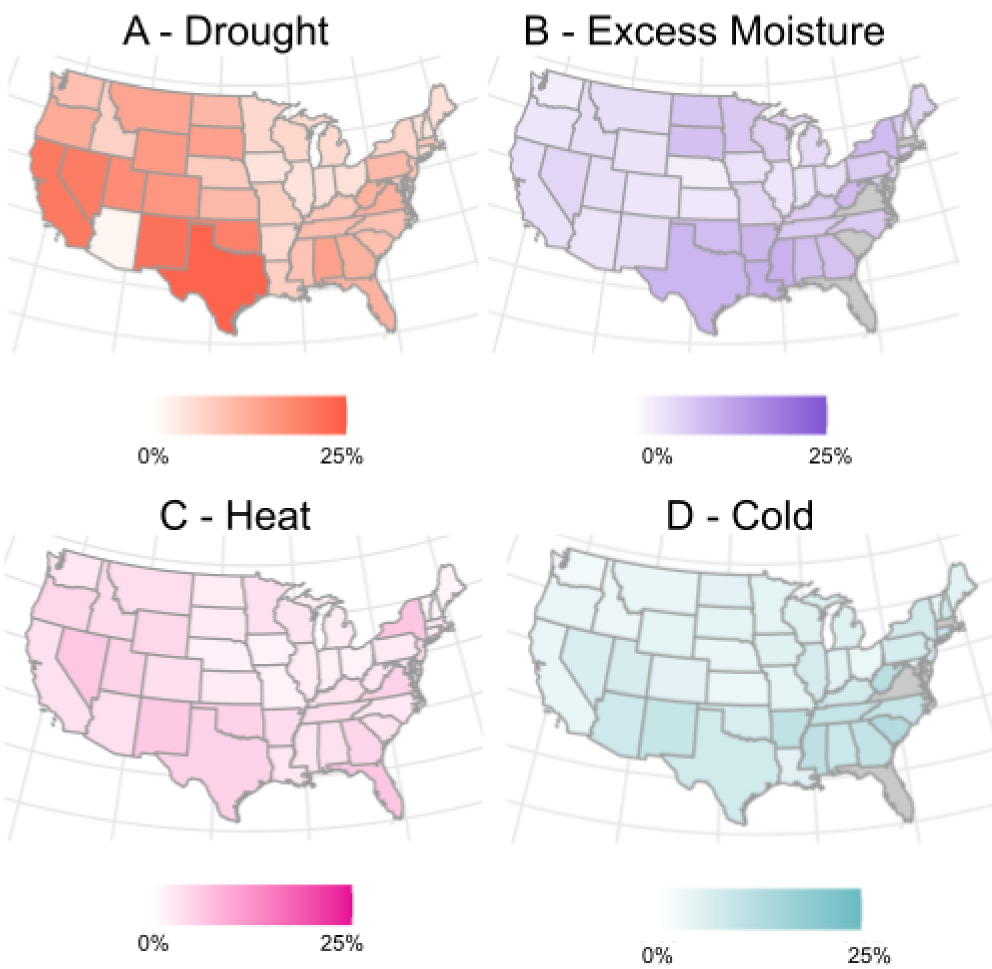


Figure 12 (A, B, C, D): Mean state LCP from county level data from 1989-2020 by state divided by cause of loss categories: drought, excess precipitation, heat, cold, respectively. Range of LCP

is from 0% to 25%. States in gray had insufficient data. Arizona in 12A only has one point of data

4.4 Indemnity Payments

Finally, we looked at the distribution of indemnity payments by commodity and specialty crops, and then by all crop categories. Despite specialty crops experiencing more risk and having a higher LCP, commodity crop farmers consistently receive more money from indemnity payments, as shown in Figure 13. This is likely due to the increased volume of acres planted with commodity crops. By dividing the data further into crop categories in Figure 14, we reveal the crop category to receive the largest sums of indemnity payments is grains. The grains category peaked in 2012 when the indemnity payments totaled just about 100 billion dollars. In 2012, an intense drought decimated corn crops and increased the indemnity payment for one bushel of corn due to increased loss and demand (29). Figure 15 shows us that billions of dollars were lost due to environmental factors. Drought and excess moisture are the top 2 most expensive causes of loss, totalling about 100 billion dollars in loss from 1989-2020.

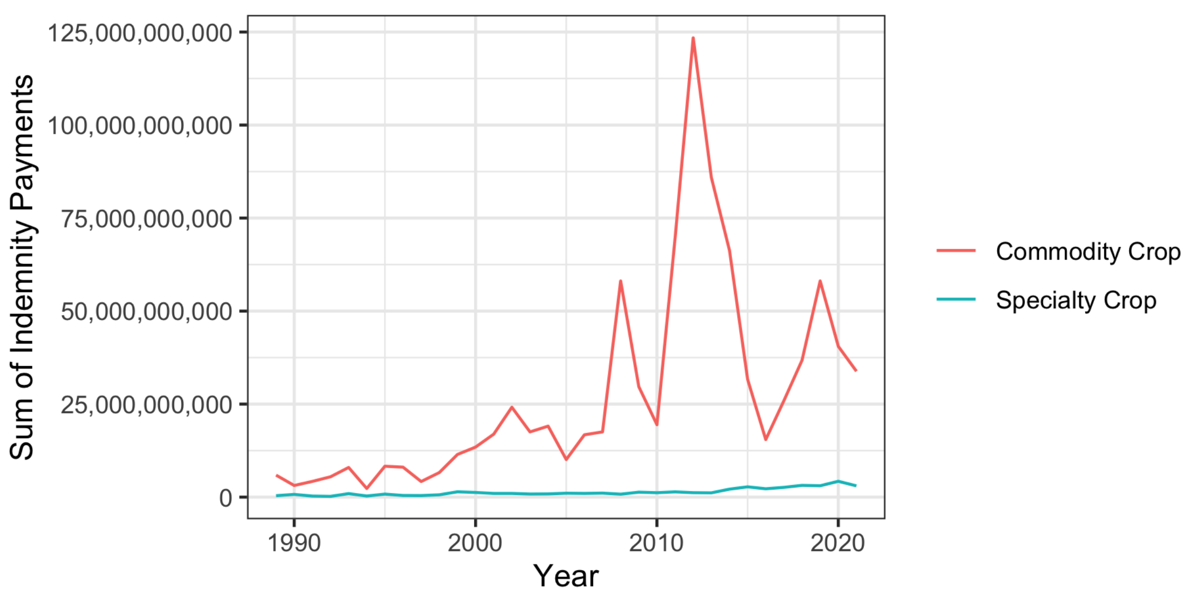


Figure 13: Sum of all indemnity payments each year from 1989-2020 divided by commodity and specialty crops.

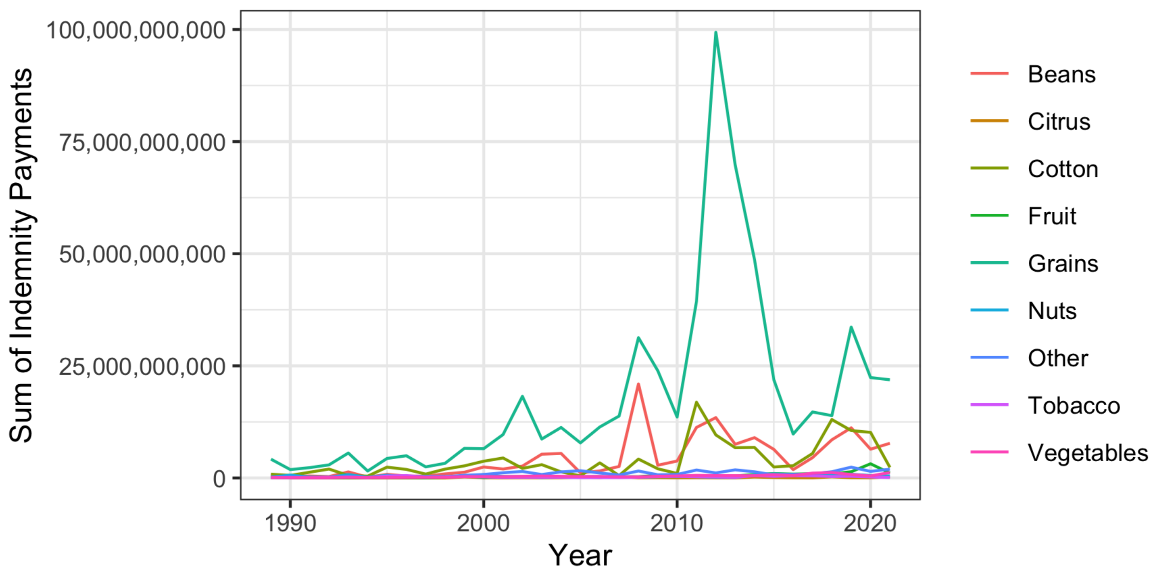


Figure 14: Sum of all indemnity payments each year from 1989-2020 divided by crop category.

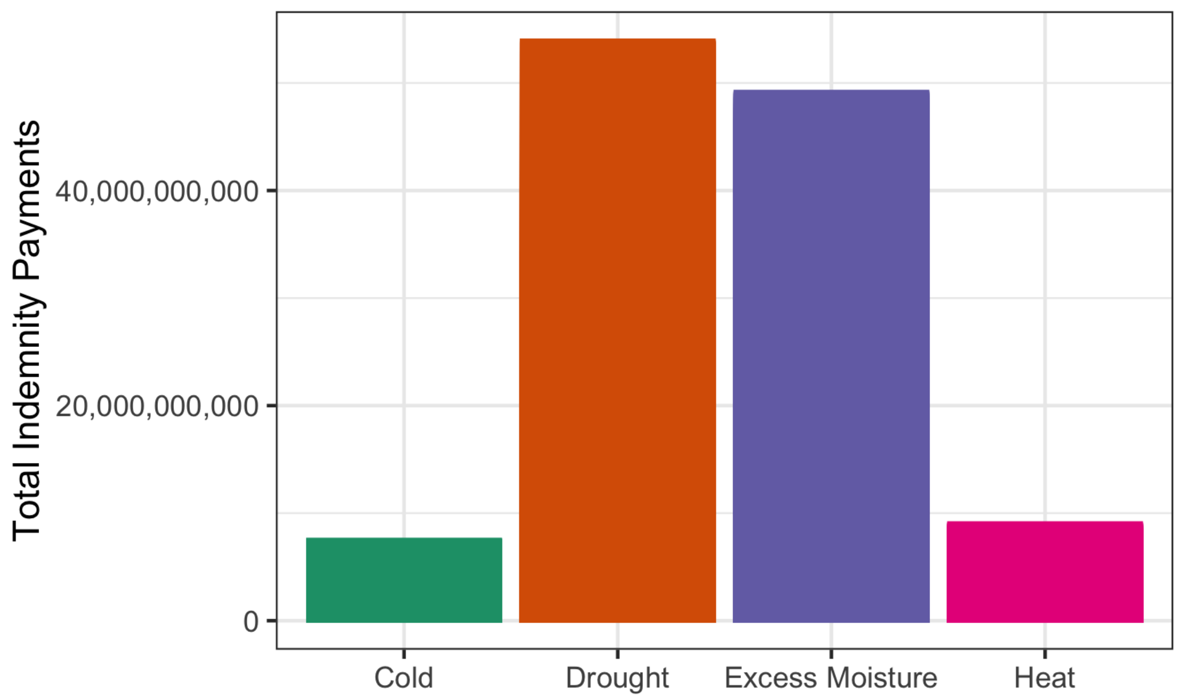


Figure 15: Sum of all indemnity payments due to loss caused by cold, drought, excess moisture, or heat.

5.0 Discussion

Over the last two centuries, American agriculture has transformed from subsistence farming into a highly mechanized industry in order to increase efficiency and productivity. However, our data reveals how inefficient our system may actually be. We see millions of acres of crops being lost annually due to environmental stressors, and billions of tax dollars supporting this loss. This highlights an increasing vulnerability to further loss and underlines the importance of billions of dollars in federal aid to support current agricultural systems.

Our results highlight the dominance of commodity crops, as well as the significant annual loss for these crops. These massive amounts of loss indicate a major flaw and inefficiency in our agricultural system. In the past, increased agriculture output and caloric production was necessary to support rapid population growth. This prompted intensification of high calorie monocultures of grains to feed both humans and livestock. However, despite our increased agricultural productivity, malnutrition is still widespread in America and can be accompanied by obesity. Governmental subsidies have encouraged the overproduction of high energy, low nutrient commodity crops and added hundreds of calories of fats, oils, and sugars to the American Diet (30). We have a need for nutrient-dense specialty crops, but as long as commodity crops are subsidized, farmers will continue to grow them despite the fact that they are losing a large amount of their crops.

What is causing all of this loss? Our results inform us that environmental stressors, specifically weather stressors, are destroying significant swaths of cropland, and that drought and excess moisture are simultaneously posing the largest threats to our agricultural production. These established weather trends should help farmers prepare to fight loss since they have predictions as to what will threaten their yields.

We see that LCP is most heavily exacerbated by the same top causes of loss: drought and excess moisture. This means that the most indemnity payments go to farmers who have lost crops due to drought and excess moisture. Our results show which crops are most vulnerable to loss, and specifically what those causes of loss are. Generally we see that fruits and vegetables have the highest LCPs, indicating that these key specialty crops are the most vulnerable to weather stressors. On the other hand, some of the top commodity crop categories like grains and beans have much lower LCPs. Overall, we found that specialty crops have higher LCP levels than commodity crops. So specialty crops are more vulnerable to risk than commodity crops. However, the intensification of commodity crops leads to them receiving billions more in indemnity payments annually.

Crop insurance and subsidies have been established so that farmers can grow crops and not fear losing revenue to risk. However, long established coverage programs have been targeted towards commodity crops. Specialty crops experience higher levels of risk, so crop insurance for specialty crops is much needed to reduce the fear of growing and losing some specialty crops. Agricultural insurance in general has been shown to increase cultivation of commodity crops at the expense of drought-resistant crops, and typically commodity crop planting practices provide very little resistance to drought (31). The Whole Farm Revenue Program (WFRP) is a step in the right direction, since it is a plan that discounts premium rates when farms insure multiple types of crops. This is because they acknowledge that farm diversification and intercropping leads to a lower risk of revenue loss (32).

The goal of insurance, in any scenario, is to mitigate risk and minimize losses. So why is the FCIP failing to cease all this loss? We can use our measure of yield risk, LCP, to interpret the relationship between loss and insurance coverage. LCP indicates increasing risk, but also means that this risk doesn't pose a financial threat to the farmers that are experiencing the loss. The indemnity payments from the FCIP fill any shortcomings in expected incomes, and due to this, farmers have little incentive to mitigate future risk. This is where moral hazard comes into play and why crop insurance could be considered maladaptive. Moral hazard refers to the idea that when someone's property is insured, they are more likely to expose it to risk because they aren't liable for any losses or damage (33). We consider crop insurance to be maladaptive because it doesn't encourage farmers to adapt their practices to our changing environment. In studies comparing the sensitivity to extreme heat of commodity crops that are insured to those that are not insured, the insured crops are found to have a much higher vulnerability to heat due to a lack of protective measures against the heat (33).

5.1 Future Directions

Climate change in the next few decades will bring hotter average temperatures, dryer soil, longer times between rainfall, and changes in precipitation (34). This means exacerbated drought, heat, and excess precipitation - which are already major causes of loss of crops. We know the direction our climate is heading; it is time to prepare to face the upcoming threats. This is where the RMA can help. Their duty is to ensure market and yield stability by educating farmers on insurance plans and risk mitigation. They do have established educational programs, but could benefit from offering further free education on resilience and risk prevention. Farmers need to know how climate change will affect the US county to county, and the best methods to adapt to it. As farming has become industrialized and scaled up, farms become businesses. Further education on aspects of business, as well as how to best utilize crop insurance, would be useful. This expansion of education could include more direct engagement with farmers by working with land extension universities.

Further changes to the way the FCIP works would also be beneficial. An increase in utilization of Actual Production History (APH) in insurance coverage could reduce moral hazard. This would require farmers to recalculate their APH annually and set that as their maximum coverage. This way, farmers have incentive to keep their yields high year to year. In order to maintain high yields, farms will have to undertake sustainable cropping practices or shift to growing different crops. Another beneficial change would be to base the price of premiums on the sustainability levels of individual farms. The WFRP encourages farm diversification due to ease of bundling insurances for multiple crops, and lower premium rates than if a farmer was insuring a single monocrop (32). Farms that have unsustainable management practices, such as monocropping a single commodity crop, should pay a higher premium rate that reflects their increased risk of loss (31). The USDA is taking steps in the right direction with a pilot Climate-Smart Commodity program. This program is investing 3 billion dollars to help farmers implement climate-smart practices that are estimated to take over 50 million metric tons of carbon dioxide out of the atmosphere (35). Programs like this will reduce individual farm risk, and work to mitigate the impact of climate change on destructive weather stressors.

5.2 Limitations

There are a few limitations we faced due to unavailability of data. Some crop data was excluded due to being connected to invalid commodity codes. Due to the long time span our data is from, there was some variance in what and how the USDA recorded all data year to year. We also would have liked to look at data on access to insurance over demographics and how insurance coverage varies by farm size, but this was not included in our datasets.

6.0 Conclusion

Our rapidly changing world has required agriculture to evolve with it over the past few centuries, and this will continue into the future. Climate change poses a great threat to humanity and agricultural production, and it is crucial that we adapt new climate-smart practices to meet these threats head on. Our current agricultural system is maladaptive to climate change and the crops grown are extremely simplified. This is due in large part to what our established insurance programs encourage. In this paper, we outlined past agricultural policies, the current state of the FCIP, and the trends in crop loss and risk over the past 30 years. Improvements within the RMA and FCIP have the potential to mitigate future climate related threats, which needs to be a top priority as environmental and weather stressors increase.

7.0 References

1. USDA NASS (2019a). 2017 Census of Agriculture Report: United States Summary and State Data. AC-17-A-51. Geography Area Series, Part 51. Washington, DC: United States

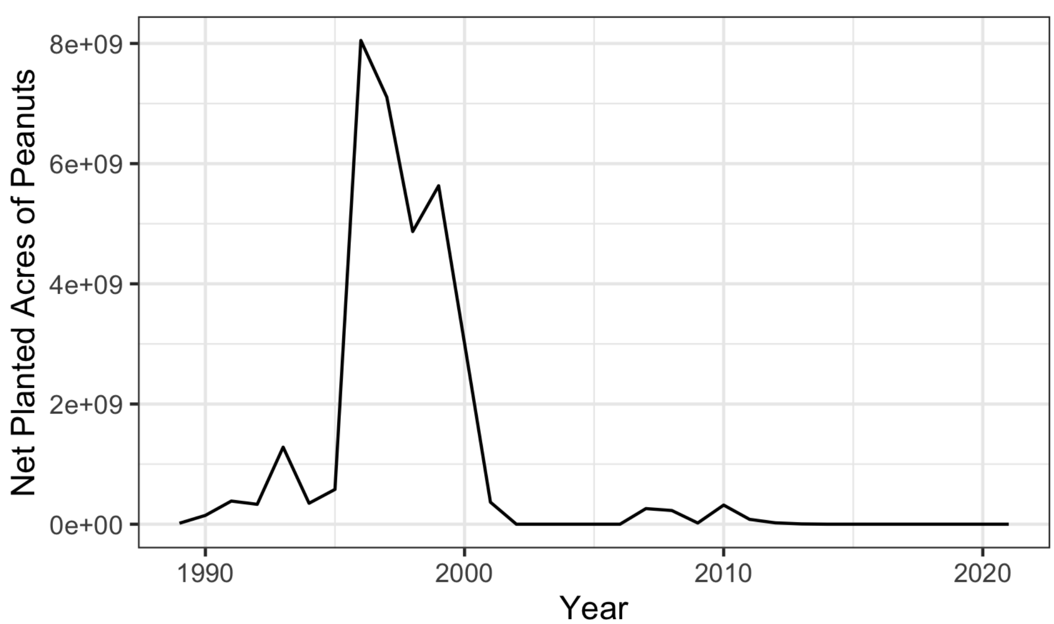
Department of Agriculture.
https://www.nass.usda.gov/Publications/AgCensus/2017/Full_Report/Volume_1,_Chapter_1_US/usv1.pdf

2. Spangler, K., Burchfield, E., & Schumacher, B. (2020). Past and Current Dynamics of US Agricultural Land Use and Policy. Frontiers in Sustainable Food Systems. https://www.frontiersin.org/articles/10.3389/fsufs.2020.00098/full
3. Bellis, M. (2021a, February 6). American Farm Machinery and Technology Changes from 1776-1990. ThoughtCo. https://www.thoughtco.com/american-farm-tech-development-4083328
4. Spratt, D., & Dunlop, I. (2019). Existential climate-related security risk: A scenario approach. Breakthrough - National Centre for Climate Restoration. https://docs.wixstatic.com/ugd/148cb0_a1406e0143ac4c469196d3003bc1e687.pdf
5. Frederick H. Buttel, Internalizing the Societal Costs of Agricultural Production, *Plant Physiology*, Volume 133, Issue 4, December 2003, Pages 1656–1665, https://doi.org/10.1104/pp.103.030312
6. Liang X-Z, Wu Y, Chambers R G, Schmoldt D L, Gao W, Liu C, Liu Y-A, Sun C and Kennedy J A 2017 Determining climate effects on US total agricultural productivity Proc. Natl Acad. Sci. 114 E2285–92 https://www.pnas.org/doi/full/10.1073/pnas.1615922114
7. The farm bill | union of concerned scientists. (2018, February 17). https://www.ucsusa.org/resources/farm-bill
8. Perry, E. D., Yu, J., & Tack, J. (2020). Using insurance data to quantify the multidimensional impacts of warming temperatures on yield risk. Nature Communications, 11(1), 4542. https://doi.org/10.1038/s41467-020-17707-2
9. Lee, R., & Ahtone, T. (2020, March 30). *Land-grab universities*. High Country News. https://www.hcn.org/issues/52.4/indigenous-affairs-education-land-grab-universities
10. Schneider, S. (n.d.). The haber-bosch process. Institute for Mindful Agriculture. https://www.instituteformindfulagriculture.org/writings-1/2016/3/24/the-haber-bosch-process-1
11. USLegal. Soil conservation and domestic allotment act. https://naturalresourceslaw.uslegal.com/wildlife-conservation/scdaa/
12. Agricultural adjustment act. US Conlawpedia; Georgia State University. https://sites.gsu.edu/us-constipedia/agricultural-adjustment-act/
13. United states v. Butler. Bloomberg Law. https://www.casebriefs.com/blog/law/constitutional-law/constitutional-law-keyed-to-stone/the-powers-of-congress/united-states-v-butler-2/
14. Commodity credit corporation. (n.d.). Retrieved September 12, 2022, from https://www.usda.gov/ccc
15. Soil conservation service. (2016, November 18). Living New Deal. https://livingnewdeal.org/glossary/soil-conservation-service-scs-1935

16. Outlaw, J., & Klose, S. (n.d.). Supply management. https://www.iatp.org/sites/default/files/Supply_Management.htm
17. McGranahan, D. A., Brown, P. W., Schulte, L. A., & Tyndall, J. C. (2013). A historical primer on the US farm bill: Supply management and conservation policy. Journal of Soil and Water Conservation, 68(3), 67A-73A. https://doi.org/10.2489/jswc.68.3.67A
18. S.1160—Consumer Protection Act. (n.d.). Congress.Gov. https://www.congress.gov/bill/93rd-congress/senate-bill/1160
19. Olson, A.H. 2001. Federal farm programs-past, present and future-will we learn from our mistakes. Great Plains Natural Resources Journal 6:1. https://nationalaglawcenter.org/publication/olson-federal-farm-programs-past-present-and-future-will-we-learn-from-our-mistakes-6-great-plains-natural-resources-j-1-29-2001/
20. Glauber, J., & Smith, V. (2021). Trends in US agricultural policy since 2000 and implications for the next twenty years. EuroChoices, 20(2), 58–63. https://doi.org/10.1111/1746-692X.12329
21. Crop Insurance in the US. Environmental Working Group. http://farm.ewg.org/cropinsurance.php?_ga=2.138453363.1583806103.1663456413-407383298.1663456413
22. Schechinger, A. (2022, January 27). Crop losses from climate crisis cost billions of dollars in insurance payouts. Environmental Working Group. https://www.ewg.org/research/crop-losses-climate-crisis-cost-billions-dollars-insurance-payouts
23. Shields, D. (2015). Federal Crop Insurance: Background. Congressional Research Service. https://sgp.fas.org/crs/misc/R40532.pdf
24. Risk management education. RMA USDA https://legacy.rma.usda.gov/aboutrma/who/aboutrme.html
25. Cause of loss historical data files. (1989-2020). https://legacy.rma.usda.gov/data/cause.html
26. Summary of Business RMA. (1989-2020). https://www.rma.usda.gov/Information-Tools/Summary-of-Business/Cause-of-Loss
27. The great drought of 2011—The impact of the 2011 drought. (2014, February 22). https://web.archive.org/web/20140222144813/http://www.window.state.tx.us/specialrpt/drought/drought2011.php
28. Crop Commodity Programs. USDA Economic Research Service. https://www.ers.usda.gov/agriculture-improvement-act-of-2018-highlights-and-implications/crop-commodity-programs/
29. Final harvest prices announced for 2012 crop insurance. (2012, November 6). Farm Progress. https://www.farmprogress.com/story-final-harvest-prices-announced-2012-crop-insurance-9-64726

30. Franck, C., Grandi, S. M., & Eisenberg, M. J. (2013). Agricultural subsidies and the American obesity epidemic. *American journal of preventive medicine*, *45*(3), 327–333. https://doi.org/10.1016/j.amepre.2013.04.010
31. Müller, B., Johnson, L., & Kreuer, D. (2017). Maladaptive outcomes of climate insurance in agriculture. Global Environmental Change, 46, 23–33. https://doi.org/10.1016/j.gloenvcha.2017.06.010
32. Whole-Farm Revenue Protection. ProAg. https://www.proag.com/products/mpci/whole-farm-revenue-protection-wfrp/
33. Annan, F., & Schlenker, W. (2015). Federal Crop Insurance and the Disincentive to Adapt to Extreme Heat. The American Economic Review, 105. https://www.jstor.org/stable/43821890
34. Fourth National Climate Assessment. (2018). US Global Change Research Program. https://nca2018.globalchange.gov
35. *Partnerships for climate-smart commodities*. USDA. https://www.usda.gov/climate-solutions/climate-smart-commodities

8.0 Supplemental Material



SI Figure 1: Peanuts planted outlier data