Estimating the Effect of Easements on Agricultural Production

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Abstract

Many US crops face higher agricultural risk as growing season temperatures rise, and destructive disasters such as excess precipitation and flooding become commonplace. The Natural Resources Conservation Service (NRCS) easement programs may offer an adaptation strategy that improve the resilience of agricultural systems. Easements impact agricultural production both directly by reducing planting on marginal land and indirectly by changing flood patterns that improve yields on surrounding cropland. I model the decision-making process of the producer and conservation agent to better understand the tradeoffs in the easement process and the implications of easement spillovers. To test the hypotheses of the theoretical model empirically, I use national data on agricultural production and easement programs for the past three decades. I employ a regression model with two-way fixed effects to quantify how easement land share impacts county-level yields, risk, as well as acres planted, failed, and prevented planted. I find that a 100% increase in land share of wetland easements increases yields by 0.34%, 0.77% and 0.46% for corn, soybeans, and wheat. Soybean crops seem to be the most impacted by easement land share. Wetland easements reduce soybean losses from excess moisture, heat, and disease by \$3.59, \$6.07 and \$11.23 for each dollar of liability. I study the mechanisms through which improved production occurs and find evidence of a slippage effect in which producers reduce soybean and wheat acreage but increase corn production. While some results suggest that easements lead to less failed and prevented planting for soybeans and wheat, I find increases of these types of losses for corn and some cases of higher drought risk. My results have policy implications for future NRCS funding and targeting strategies.

1 Introduction

Our agricultural systems and food production are vulnerable to temperature, rainfall, and weather extremes. Studies show lower crop yields and higher losses attributed to a changing climate (Schlenker & Roberts, 2009; Deschênes & Greenstone, 2012; Rosenzweig et al., 2014; Perry et al., 2020). This loss is expected to continue continue as growing season temperatures risk and destructive disasters increase in frequency and severity (IPCC, 2012; NOAA, 2020b).

Increased flooding and heavy precipitation events pose a particular risk for agricultural production. Heavy precipitation and floods have caused catastrophic damage to US crop production and profits (Rosenzweig et al., 2002; NOAA, 2020b). There is significant evidence of regional alterations in rainfall patterns, more frequent occurrences of climate extremes, and ultimately, higher flood risk in certain regions. A recent example of this occurred in 2019 when above average precipitation fell across most of the eastern half of the country, making it the record-wettest year to date (NOAA, 2020a). The central US experienced a series of severe storms preventing farmers from planting, flooding crops, and accruing debilitating losses in the billions for agrarian communities across the Corn Belt and Mid-South (English et al., 2021). Such extreme precipitation is projected to be more frequent across the States and cause additional disruption in agricultural production(Urban et al., 2015).

Here I study the impact of one potential adaptation strategy: withdrawing frequently inundated cropland from production and restore it to its original condition. The Natural Resources Conservation Services (NRCS) of the United States Department of Agriculture (USDA) offers voluntary buyouts through the Emergency Watershed Protection Program (floodplain easements) and Wetlands Reserve Program (wetland easements). An easement contract restores the land to its natural floodplain state or enhances its wetland functions. The farmer retains ownership of the land and receives a lump-sum transfer to forgo the right to plant crops on that field permanently. Floodplains and wetlands have the potential to serve as flood protection by storing water and acting as natural buffers. Restoration includes planting native species, breaking or removing tiling, and building topographical features (for example, creating a berm or filling a ditch) to redirect water onto the eased land.

Using thirty years of national data, I quantify the impacts of the wetland and floodplain easement programs on agricultural yields and risk. I study the direct effect of removing low-yielding land out of production as well as the easement indirect yield effects. I delve into how easements impact lost cost ratios and different causes of indemnity losses. I investigate the mechanisms through which the programs have an effect, including acres planted, prevented planted, and failed. My results shed light on the ex-post effects of the easements programs as well as the potential effects of such programs in a world with higher temperatures and more frequent, extreme weather events.

NRCS floodplain and wetland easements account for only 0.01% of land in the US, while 40% of land is used for agricultural purposes. From 2002-2020, the NRCS spent $4.9 billion and $3.4 billion USD on the wetland and floodplain programs respectively (USDA, 2021). In comparison, indemnity spending for corn, soybean, and wheat losses in that same period reached over $85.9 billion USD. Figure 1 emphasizes the difference in NRCS and indemnity spending over time. Putting land into easement may be a cost-effective adaptation strategy for agricultural resiliency.

Although the acreage of land under easement seems minimal, easements impact agricultural production through a number of pathways. These easement programs eliminate the moral hazard associated with insured farmers planting on marginal fields, decrease indemnities and taxpayer spending on agricultural losses, and offer other ecological advantages, such as improving yields on neighboring cropland. Wetlands and floodplains have the capacity to act as "sinks" and retain water within the watershed in ways that impact the flood patterns on surrounding fields.

This research explores how easements impact agricultural systems at the county level. First, I ask whether wetland and floodplain easements increase average yields and decrease risk. Second, I explore the mechanisms through which easements impact agricultural production by studying changes in acres planted, failed, and prevented from planting. I find evidence that easements impact agricultural production in three main ways: 1) directly by removing marginal land from production, 2) indirectly by improving yields on surrounding cropland, and 3) changing the cultivation choices of producers (also known as a slippage effect).

I use a theoretical framework to model the easement decision-making processes and examine the objectives of the producers and conservation agents. The producer, a profit-maximizing agent, will ease a field when the payment to ease the land exceeds expected agricultural profits. The conservation agent maximizes environmental benefits subject to their budget constraint. The model hypothesizes that land is more likely to be eased when it is lower yielding, more costly to plant, and higher in environmental benefits. Additionally, a producer that internalizes the easement benefits on surrounding fields is more willing to ease land. My model informs my testable hypotheses and the potential mechanisms of my findings.

To test these hypotheses empirically, I compile data from a range of sources. I pair a national easement database with county-level USDA data from the Risk Management Agency (RMA), Farm Service Agency (FSA), and National Agricultural Statistics Services (NASS) to build a panel of data from 1989-2020. The NRCS houses a database on all completed easements. In 2020, there were approximately 3 million acres of eased wetlands and 185,000 acres of floodplain easements in the US. Crop yield and acreage stock data come from the NASS. The RMA Cause of Loss Data and Summary of Business (SOB) data provide details on agricultural insurance and risk. The FSA has data on acres prevented planted and failed. PRISM data source the weather controls such as precipitation, temperature, and degree days. I limit my main sample to 1,700 counties east of the 100th meridian to focus on rainfed and non-irrigated counties. The main commodities focused on in this study include corn, soybeans, and wheat. The observations in my sample size range from 35,000 to 50,000 depending on the commodity and outcome variable of interest.

I use a panel model with two-way fixed effects (TWFE) to estimate how easements impact agricultural production.[1] My identifying assumption is that treatment (easement closing) is random conditional on county and year fixed effects. I take the inverse hyperbolic sine of my independent and dependent variables and use a mean transformation of my estimates (Bellemare & Wichman, 2019) to better understand the elasticity response. I identify how increasing easement land share impacts crop yields (bushels/acre), loss-cost ratios (the proportion of indemnities to liabilities), and loss ratios (the proportion of indemnities to premiums). I also identify the potential channels through which easements impact agricultural outcomes. I estimate the effect of easements on acres planted, acres prevented planted, and acres failed to understand the underlying mechanisms. This research finds evidence that easements have a direct effect, indirect effect, and a slippage effect. I also interact easement acreage with measures of precipitation and degree days to understand the weather pathways through which easements provide adaptive benefits. Finally, I explore the heterogeneity of easement effects by examining how easements impact yields for the twelve major NASS regions of the US.

Wetland easements have a significant, positive effect on yields for all three commodities and reduce agricultural risk for soybeans. I find that a 100% increase in wetland easement land share increases county yields by 0.34%, 0.77%, and 0.46% for corn, soybeans, and wheat. There is also some evidence that shows easing non-cropland improves crop yields indirectly. Moreover, I find that wetland easements have a negative and significant impact on the loss cost ratio for soybeans–especially when considering losses due to excess moisture, heat, and disease. Doubling wetland easement land share reduces losses from excess moisture by \$3.59, from heat by \$6.07, and from disease by \$11.23 for each dollar of soybean liability. Corn crops also see less insect losses by \$8.50 per dollar of liability. My results also suggest that increasing land share in floodplain and wetland easements leads to escalated drought risk for all three crops.

Easements lead to the retirement of marginal soybean and wheat cropland from production. I also find that producers switch their production away from soybean and wheat and towards corn. Easing land may encourage farmers to continuously crop corn. A question that remains is whether easements reduce incidences of prevented and failed planting. There exist mixed results regarding how easements impact acres prevented planted and failed. However, it does seem that wetland easement land share mitigates the impact of extreme degree days for soybeans and excess precipitation for corn.

[1] It is worth noting the limitations of using a panel model with two-way fixed effects. Many issues with this methodology have recently been brought to the forefront of the econometric literature (Goodman-Bacon, 2021; Callaway et al., 2021; Callaway & Sant'Anna, 2020; De Chaisemartin, D'haultfoeuille, & Haultfoeuille, 2019). As of now, dealing with the cases of staggered and continuous treatment is still being investigated.

This paper documents the effects and externalities of the easement programs on agricultural systems. It adds to the literature on the relationship between agricultural systems and climate change. I provide evidence that these conservation policies allow farmers to adapt in ways that have a concrete and meaningful impact on the resilience of our agricultural systems. This paper also complements the cost-benefit conservation literature that quantifies the impact of conserved land habitats. My paper provides an economic estimate of some of the non-market values that wetlands and floodplains provide. This can have policy implications on the future funding and targeting strategies of the NRCS easement programs.

This paper is relevant to the literature on adaptation to heightened agronomic yield risk. Burke and Emerick (2016) find evidence suggesting that long-run adaptation has been limited and insignificant. However, more recent work by Mérel and Gammans (2021) suggests that panel models may not be reflective of climate adaptation in the long-term and alternate specifications do find evidence of long-run climate adaptation for crop yields. Other researchers take a different approach and instead focus on the effects of specific adaptation measures; there is evidence that various adaptation practices can be effective at increasing resiliency. Producers can manage risk through insurance (Annan & Schlenker, 2015), technology (Goodwin & Piggott, 2020), planting date adjustments (Zipper et al., 2016; Kucharik, 2008), cultivar selection (Hagerty, 2021; Sloat et al., 2020), irrigation (Hornbeck & Keskin, 2014), and conservation practices (Schulte et al., 2017; Fleckenstein et al., 2020). My work adds to our understanding of the adaptation benefits of easements in an agricultural setting.

A vein of the conservation literature examines easement value. Many studies measure the impact of easements on land sales prices (R. J. Brown, 1976; Kousky & Walls, 2014; Lawley & Towe, 2014; Nickerson & Lynch, 2001; Shoemaker, 1989; Shultz & Taff, 2004). These works consistently find that the land discount on eased land adequately captures the foregone agricultural profits. A complementary literature uses auction modeling techniques to estimate the reservation value of retiring land from agricultural production (Boxall et al., 2017; L. K. Brown et al., 2011; Ferraro, 2008; Hellerstein et al., 2015; Kirwan et al., 2005; Narloch et al., 2013). Another section of the literature focuses on comparing the costs and benefits of conservation efforts. The cost-benefit papers seek to identify optimal parcels and best targeting strategies to meet desired conservation goals (Costello & Polasky, 2004; Fleming et al., 2018; Gelso et al., 2008; Heimlich, 1994; Newburn et al., 2006; J. J. Wu et al., 2001). Others quantify benefits by estimating how additional wetland and floodplain acreage impact property damages from flooding (Taylor & Druckenmiller, 2022; Gourevitch et al., 2020; Watson et al., 2016).

Yet there remains a gap in our understanding of the effects of these easement programs on agricultural outcomes. There are some smaller field-level/regional studies as well as anecdotal evidence of the benefits of these programs (NRCS, 2011; Mushet & Roth, 2020). I contribute the first work at a national-scale over the entire duration of the program life span. Quantifying the effect of easements on agricultural systems has implications for land value estimates, conservation cost-benefit analyses, and easement program goals for policymakers. Perhaps most importantly, my results offer insights into how easements offer a strategy to remove marginal land from production, improve crop yields, and decrease risk in the face of a changing climate.

The remainder of the paper proceeds as follows: Section 2 provides program background as well as a discussion on the relationship between climate and agriculture, as well as the role of insurance. Section 3 lays out the theoretical framework. Sections 4 and 5 present the data and empirical models respectively. Section 6 covers empirical results and discusses their implications. Section 7 concludes and summarizes my main findings.

2 Background

What is an easement?

The NRCS floodplain easement and wetland restoration programs allow agricultural producers to retire frequently flooded land from agricultural use. Information about these programs is distributed to communities through local USDA Service Centers. Easements alleviates the stress of operating in a high-risk flood area while still retaining ownership of the land. It eliminates the need for futile future farmer spending and insurance spending on that acreage. The NRCS restoration process includes removing structures that impede water flow, building topographic features such as ridges and swales, and planting native vegetation. The transaction is permanent and grants the NRCS surface rights and the right to restore the land. The landowners retain ownership and pay property taxes on the land. They are also granted the rights to control public access, quiet enjoyment, and recreational use such as hunting and fishing. [2]

The NRCS states that the main purpose of the wetland restoration program is to "achieve the greatest wetland function and values, along with optimum wildlife habitat, on every acre enrolled in the program"(NRCS, 2021d). The NRCS goal of the floodplain easement program is to "restore, protect, maintain and enhance the functions of floodplains while conserving their natural values such as serving fish and wildlife habitat, improving water quality, retaining flood water, and recharging groundwater(NRCS, 2021a)". The inception of these restoration program dates back to the early 1990s. Almost half of the natural wetlands in the US had been drained and filled for agricultural and development purposes by 1984 (NRCS, 2021c). To slow the destruction of wetlands, Congress added wetland and conservation protection to the 1985 and 1990 Farm Bill. In 1985, the Swampbuster provision prohibited farmers from draining wetlands while participating in USDA programs and receiving any type of aid. This offered some of the first protections to wetlands. Then

[2] There is also a possibility of authorizing compatible use activities such as timber harvest, grazing or periodic haying when consistent with long-term enhancement of the floodplain functions and values.

in 1990, the first wetland restoration program was authorized as an option for farmers to retire land that had been drained and to conserve eligible wetlands. Wetland restoration led to a reversal of wetland losses and often led to net increases in wetland coverage. The Emergency WRP was established in 1993 and became today's floodplain easement program (Hebblethwaite & Somody, 2008). The Emergency WRP Program was funded after receiving emergency appropriations following severe flooding in the Midwest in the 1990s.

My sample includes all the easements conducted under different iterations of the wetland easement program. Wetland restorations offered by the NRCS have evolved over time and been offered under the Emergency Wetlands Reserve Program and Wetlands Reserve Program. As of 2014, wetland restorations are offered by the Agricultural Conservation Easement Program for Wetlands Reserve Easements. Most of the basics underlying the floodplain and wetland programs remain the same, but wetland projects tend to require higher investment and more management. To be eligible for a wetland easement, land needs to be farmed wetland or converted wetland with the potential to be restored in a cost-effective manner; priorities are put on easements with high potential for protecting and enhancing the habitat. Wetland easements can be permanent, 30-year easements, 30-year contracts or 10-year cost-share agreements. The most common type of wetland restoration are permanent.

The floodplain easement process varies slightly from the wetland easement process. In order to be eligible for a floodplain easement, the proposed acreage must be in a floodplain that has been damaged by a flood once in the calendar year or flooded at least twice in the past decade. Land that is in danger of being adversely impacted by a dam breach is also eligible. Other parcels may also be eligible if they enhance the floodplain system, improve erosion control, or promote easement management. Criteria include flooding history, proximity to other protected land or public access points, adjacency to existing easements, acreage of proposed easement in the flood zone and associated flood hazard, percentage of acreage in different land use classes, estimated restoration costs, other parties' contribution of the cost, and existence of rare species within a certain buffer. All floodplain easements are permanent.

The amount of easement projects and acres that are selected depends on the individual state budget for each program. The easement program is funded federally but each state NRCS department oversees its implementation. The wetland restoration program receives regular funding from Farm Bill appropriation. Funding for floodplain easements is provided by a Congressional Act, often after large-scale flooding in the US. Easement compensation for the producer is based on the lowest of three values: fair market appraisal, geographic area rate cap, and a voluntary offer by a landowner. Most often, compensation is based on the geographic area rate which stems from a market survey of cropland in the area. Rarely does a landowner posit a voluntary offer. Based on interviews with policy directors, it is most often the case that farmers that are not selected continue to crop on the land. From this I learn that enrolling these fields in easement programs directly reduces future crop losses since farmers would have continued farming otherwise.

How does climate/weather impact crop production?

There is a large body of knowledge explaining how weather patterns and underlying climate impact crop production(Ortiz-Bobea, 2021; Wing et al., 2021).

Extreme temperatures associated with climate change are projected to become more intense and frequent in upcoming years. Extreme heat exposure beyond a certain threshold reduces the quality and yields of agricultural crops(Schlenker & Roberts, 2009). Heat stress adversely affect plant development, pollination, and reproductive processes (Hatfield & Prueger, 2015). Extreme temperatures coupled with water scarcity, or drought conditions, can also lead to reduced productivity. Decreased soil moisture reduces stunts crop growth and increases vulnerability to pests. Drought conditions are especially prevalent in the Western half of the country.

While some areas are faced with worsening drought conditions, extreme precipitation is projected to be more frequent in other areas of the United States, especially the central Midwest(Rosenzweig et al., 2002; Shirzaei et al., 2021). Excess precipitation coupled with higher temperatures are detrimental climate patterns for crop production (Eck et al., 2020). Flooding impacts agriculture by delaying or preventing planting, damaging standing crops, and carrying away topsoil and nutrients.

When flooding occurs during planting season in the spring, farmers may be delayed or prevented from planting since their machines are unable to work on the inundated soil (Urban et al., 2015; Boyer et al., 2022). Farmers may need to switch to a seed variety with a shorter growing season or be unable to plant anything at all. Flooding in the early season is costly to farmers since they are unable to plant at the optimal time and will most likely see reduced yield and profit for that season. Excess rain can also be harmful later in the season when the crops are growing. If there is an abundance of water, flooding can destroy crops by washing them away, decreasing oxygen intake and respiration, building up toxic compounds in the soil, inhibiting plant growth, and making plants prone to disease, insects, or mold (Hatfield et al., 2011). This type of water stress increase uncertainty, and reduce profits. Extreme precipitation can also have more long-term impacts by reducing the soil quality over time by draining nutrients out of the soil or washing away the top soil altogether.

Both heat and water stress can indirectly lead to losses by making crops prone to disease and insects (Jabran et al., 2020; Deutsch et al., 2018). Higher temperatures and varying moisture levels have expanded the breeding ground of certain insects and changed their feeding habits: increased metabolisms lead to larger appetites and lower yields. Changing weather conditions have led to a wider range and distribution of pathogens that have increase the risk of plant diseases. There is large variation in top pest concerns dependent on crop type, geography, timing, and weather conditions(Savary et al., 2019).

How do floodplains and wetlands impact the land?

Wetlands and floodplains—both natural and manmade—are associated with many ecological and hydrological benefits that have been studied by economists, ecologists, hydrologists, and conservationists. Floodplains and wetlands have the potential to serve as flood protection by storing water and acting as natural buffers in the event of extreme flooding. Wetlands reduce damage from floods by lowering flood heights and reducing the water's destructive potential (Gleason et al., 2008). Restored floodplains and wetlands are also associated with improved water quality, ground water reservoir replacement vital for irrigation systems, carbon sequestration, reduced greenhouse gases, and wildlife habitat (Bostian & Herlihy, 2014; De Steven & Lowrance, 2011; Roley et al., 2016; Sonnier et al., 2018; Speir et al., 2020).

Wetlands serve a role in improving watershed health, adding to the vitality of agricultural land, and enhancing the aesthetic value of the surrounding community (NRCS, 2012). There have been a few studies of NRCS wetland restoration projects, such as regional studies from the USDA's Conservation Effects Assessment Project (CEAP). These studies provide a foundation on the easement success and study a broad set of outcomes, including habitat and biodiversity, pollution management, surface water and floodwater containment, greenhouse gas emission management, and water sustainability (NRCS, 2011; Mushet & Roth, 2020). A piece that is missing, however, is a better understanding of the relationship between easement habitat and agricultural land.

What is the role of insurance?

Crop insurance can be purchased to protect agricultural producers against the loss of crops from natural disasters such as excess heat, flooding, fire, drought, disease, insect damage, and destructive weather. Multiple peril crop insurance (MPCI) protects producers against lower than expected yields and revenues. MPCI is serviced by private sector insurance companies which the USDA subsidizes, regulates, and re-insures. The history of crop insurance is laid out nicely in (Glauber, 2013). The government typically subsidizes 60% of a producer's premiums in addition to offering assistance after natural disasters (Congressional Budget Office (CBO), 2019). There are more than 290 million acres insured in the US, which account for more than 80% of acres planted. In 2020, MPCI insured nearly $110 billion in liability and cost taxpayers $6.4 billion in premium subsidies and $1.5 in delivery costs (Goodwin & Piggott, 2020).

Producers can choose from a variety of policies and coverage options. Yield-based policies insure producers against crop-specific yield losses. Revenue-based policies protect against volatility in yields and also prices and are more expensive since they protect against an additional risk. Yield-based policies are the most accessible and have existed the longest. A producer pays a premium to the insurance company in order to purchase coverage on their commodities. Yield-based policies are based on the actual production history

(APH) of a parcel and pay an indemnity for low yields. The APH is an average of the past four to ten years of yields on a parcel and represents the expected yields of that parcel. The APH is used to determine the liability. The liability represents the expected value of a commodity and the maximum value that is insured by a policy. In the event of a loss, the indemnity payment is determined by taking the difference between the liability and the actual value of production.

The liability and any potential indemnity values depends on the coverage level selected by a producer. Coverage levels vary from 50-85% in 5% increments. A minimal amount of acreage in the USA is covered at the 50% level.[3] A majority of producers choose to pay a premium and purchase additional coverage, called Buy-up coverage. A producer is able to choose the percentage of the commodity value to insure. The coverage level can be thought of like a deductible. For example, a policy with an 80% coverage level insures against yield losses greater than 20% of the liability but does not provide indemnities for losses that total less than 20% of the liability.

To set insurance rates and premiums, the RMA uses a loss cost ratio (LCR) approach. The history and details of how rates and premiums are devised are laid out in detail in the Federal Crop Insurance Primer (Congressional Reseach Service, 2021) and other academic papers (Schnapp et al., 2000; Woodard et al., 2019). Basically, the RMA uses historical data on individual producers and calculates LCRs for each year and each producer. They do this by dividing a producer's indemnities by their liabilities. Then, the RMA averages the LCRs across the the county-level and over time. This resulting county-level average LCR is the base rate the RMA charges producers for coverage in that area.[4] The LCR represents the yield risk of a commodity in that county. The RMA sets the premium rate equal to the rate of expected losses over the total value of commodities. The loss ratio represents the actuarial fairness of the insurance policy. The loss ratio is the proportion of indemnities to the premiums paid by a producer. When the indemnities equate the premium paid (and the loss ratio is equal to one), expected losses are equal to the payment of the coverage for that specified risk.

Most previous work primarily links climate to crop yields. This is something that is done in this paper as well but I believe that limiting the analysis to this approach has shortfalls. Looking strictly at yields does not capture whether production is becoming more or less risky. This may underestimate the impact of climate and any potential adaptation measures on yield sensitivity. For this reason, I also estimate the effect of easements on the loss cost ratio and loss ratio. Some researchers have used the variance of yields but this measure is deficient since the distribution of yields is ever evolving and changes in this coefficient

[3]On the low end of coverage, there exists a specific policy called catastrophic crop insurance (CAT). CAT reimburses farmers for severe crop losses exceeding 50% of average historical yields at a payment rate of 55% of the established commodity price. No premium is required for this type of coverage except for an administrative fee–which has increased from $60 to $655 per crop per county in the past twenty years.

[4]There are also other adjustments made for the base rate. Usually, the RMA also applies a spatially smoothing procedure, caps and cups rate changes, and applies a state excess load.

are hard to interpret. Using the LCR and LR has been gaining popularity because these measures capture the risks of individual producers. For example, Perry et al. (2020) uses the loss cost ratio when estimating how warming impact the agricultural risk of corn and soybeans. Goodwin and Piggott (2020) use the loss cost ratio and loss ratio in their analysis of how seed innovations impact agricultural risk and insurance rate-making behavior.

It is also interesting to consider the role that insurance may have on the easement decision-making process. A common concern with insurance products is the moral hazard that they introduce. There are a number of studies that evaluate the moral hazard implications of subsidized multiperil crop insurance in agriculture (Horowitz & Lichtenberg, 1993; Coble et al., 1997; S. Wu et al., 2020; Yu & Sumner, 2018; Kim & Kim, 2018; Smith & Goodwin, 1996; Glauber, 2004; Yu & Hendricks, 2020). Moral hazard occurs since producers act in ways that are more risky since they do not take on the full cost of the risks. For easements, this means that insurance present an additional hurdle to retiring agricultural land that would perhaps be better suited for easement. Not only does insurance impact the decision to ease a field, once a producer eases some land, the insurance decisions for surrouding land may change as well. If a farmer takes their most risky land out of production, they may be more willing to take on additional risks in other ways. This could occur through changes in coverage levels for their remaining agricultural land. Other potential risk-altering behavior could include changes in cultivation decisions, changes in acres planted, or changes in fertilizer, pesticide, and herbicide application.

3 Theoretical Model

I develop a theoretical model to draw intuition about why, when, and where easements are implemented and at what price. I consider the decision-making process for both parties involved: the farmer and the conservation agent. The farmer is trying to determine the share of land to enroll in an easement program in order to maximize their utility function. The conservation agent chooses which land to ease and implicitly sets the price of easements. The conservation agent is trying to maximize the environmental benefits of the land. I add to the model by considering the unintended impact of easements on surrounding fields. This a one-period model that does not consider waiting to ease and option value. For a more comprehensive theoretical framework on the easement decision-making process that considers dynamics see Miao, Hennessy, and Feng (2016).

I start by considering land area L which is divided into different field parcels, l_i. Each field is the same size and $i = 1, 2, , ..., L$ Each field differs in its agricultural yields (y_i), costs of planting (c_i), and environmental benefits (b_i). I assume there is one commodity type that can be produced and the price of the commodity p is determined by the market.

Farmer's Problem

The farmer aims to increase their utility by making land use decisions that will maximize their profits. The farmer with land area L determines what to do with each field l_i. The farmer can put field l_i into agricultural production (a_i) or they can enroll the land into the easement program (e_i).

For each field in agriculture, the farmer makes a profit based on the commodity price (p), yield (y_i), and cost (c_i) where $\pi_i = py_i - c_i$. When a field is eased, the farmer receives a payment of r_i for retiring the land from agricultural production. The farmer is subject to their land constraint, $l_i = a_i + e_i$ and non-negativity constraints, $a_i \geq 0$ $e_i \geq 0$. The farmer chooses a_i and e_i for each l_i to maximize profits and utility. To solve the farmer's problem, we can set up a Lagrangean and take first order conditions.

$$max_{a_i,e_i} \ \sum_i^L (py_i - c_i)a_i + \sum_i^L r_i e_i \ \ s.t. \ \ \forall i : a_i + e_i \leq l_i \ , \ a_i \geq 0, e_i \geq 0$$

$$\mathcal{L} = \sum_i^L (py_i - c_i)a_i + \sum_i^L r_i e_i + \sum_i^L \mu_i(l_i - a_i - e_i) + \sum_i^L \theta_i e_i + \sum_i^L \sigma_i a_i$$

$$[a_i] : py_i - c_i - \mu_i - \sigma_i = 0$$

$$[e_i] : r_i - \mu_i - \theta_i = 0$$

$$[\mu_i] : l_i - a_i - e_i = 0$$

$$[\theta_i] : \theta_i e_i = 0$$

$$[\sigma_i] : \sigma_i a_i = 0$$

The Kuhn-Tucker conditions tell us that we are at the solution when the first-order conditions are satisfied (1), the original constraints hold (2), the Lagrange multipliers are non-negative (3), and complementary slackness holds (4).

1. $py_i - c_i = \mu_i + \sigma_i, \ r_i = \mu_i + \theta_i$
2. $a_i + e_i = l_i, \ a_i \geq 0, \ e_i \geq 0$
3. $\mu_i \geq 0, \ \theta_i \geq 0, \ \sigma_i \geq 0$
4. $\mu_i(l_i - a_i - e_i) = 0, \ \theta_i e_i = 0, \ \sigma_i a_i = 0$

We can use the complementary slackness conditions to explicitly define the optimal e_i and a_i. The farmer will ease field i when the retirement payment is greater than or equal to the agricultural profits of a field. When the retirement payment is less than the agricultural profits, the farmer will put that entire field towards agricultural production. This model also informs us of the qualities of land that are more likely to be eased. Land with lower yields, higher costs of planting, and higher environmental benefits are more likely to be put under easement.

$$e_i^f = \begin{cases} l_i & \text{if } py_i - c_i \leq r_i \\ 0 & \text{if } py_i - c_i > r_i \end{cases}$$

$$a_i^f = \begin{cases} l_i & \text{if } py_i - c_i > r_i \\ 0 & \text{if } py_i - c_i \leq r_i \end{cases}$$

Conservation Agent's Problem

Babcock, Lakshminarayan, Wu, and Zilberman (1996) compare different targeting strategies for conservation policy makers: maximizing the benefit-to-cost ratio, maximizing total benefits, and minimizing total costs. I use their model as a baseline when considering the conservation agent's problem.

The conservation agent is trying to maximize environmental benefits subject to their budget constraint. These benefits are idiosyncratic to a field and can include ecological benefits such as reduced soil erosion, sequestered carbon, reduced greenhouse gases, provided wildlife habitat, increased wildlife diversity, and improved local water quality. The conservation agent chooses which fields to enroll e_i while simultaneously choosing the price to offer a farmer to retire that field r_i. It is most often the case that the easement payment is equal to the geographical area rate cap. This can be interpreted as the average land value in a county. In my model, the agent sets the price equal to the average land value in L. I call this price $\bar{r}$. The conservation agent uses the average expected agricultural profits for all L fields to determine $\bar{r} = \frac{1}{L}\sum_i^L py_i - c_i$. The conservation agent is also subject to a total budget we call T. I assume that the budget is positive $T > 0$ and that the conservation agent can not exceed their budget $\sum_i^L \bar{r}e_i \leq T$. I also include the condition that the easement can not be larger then the field itself $e_i \leq l_i$. I can write out the conservation agent's objective function as a constrained maximization problem.

$$max_{e_i} \sum_i^L b_i e_i \ st. \ \sum_i^L \bar{r}e_i \leq T, \ \forall i: \ 0 \leq e_i \leq l_i$$

To solve for the optimal e_i for the conservation agent, I set up a Lagrangean as well. I ignore the non-negativity constraint since I know that it is not optimal for the conservation agents to have zero easements.

$$\mathcal{L} = \sum_i^L b_i e_i + \lambda(T - \sum_i^L \bar{r}e_i) + \sum_i^L \omega_i(l_i - e_i)$$

$$[e_i] : b_i - \lambda\bar{r} - \omega_i = 0$$

$$[\lambda] = T - \sum_i^L \bar{r}e_i = 0$$

$$[\omega_i] : l_i - e_i = 0$$

Again, I write out our Kuhn-Tucker conditions that hold when the agent is at the optimal solution.

$$1.\ b_i - \lambda\bar{r} - \omega_i = 0$$

$$2.\ \sum_i^L \bar{r}e_i \leq T,\ e_i \leq l_i$$

$$3.\ \lambda \geq 0,\ \omega_i \geq 0$$

$$4.\ \lambda(T - \sum_i^L \bar{r}e_i) = 0,\ \omega_i(l_i - e_i) = 0$$

I use the KT conditions to derive the explicit solution of the conservation agent. The conservation agent will ease field i when the benefit to cost ratio of that field exceeds the shadow price. The shadow price λ^c represents the marginal benefit of relaxing the budget constraint, or the associated change in environmental benefits when the budget is increased by one unit. As long as the ratio of field easement benefits over the cost of acquisition exceeds the shadow value, the conservation agent will ease the parcel. The conservation agent will enroll the fields with the highest benefit-cost ratio first and will continue to enroll the most beneficial fields until the budget T is depleted.

$$e_i^c = \begin{cases} l_i & \text{if } \frac{b_i}{\bar{r}} \geq \lambda^c \\ 0 & \text{if } \frac{b_i}{\bar{r}} < \lambda^c \end{cases}$$

Solving for Equilibrium

I can combine our findings from when both the farmer and conservation agent are acting optimally to find the equilibrium. This will allow us to better understand which land goes into easement. From the farmer's model, I know that the farmer will not ease a field unless the easement payment from the conservation agent exceeds the expected agricultural profits. When the conservation agent sets the price equal to average expected profits of all the land, the fields that are lower in agricultural profits are the ones that farmers will ease. Mathematically, this means that $e_i = l_i$ if $py_i - c_i \leq \bar{r}$. Meanwhile, the conservation agent wants to ease land when the environmental benefits over the shadow price is greater than the easement payment price: $e_i = l_i$ if $\bar{r} \leq \frac{b_i}{\lambda}$. We can conclude that land will be eased when both these conditions are met. A field will be eased when the benefit to cost ratio, or in this case, the opportunity cost of agricultural profits on a field, exceed the shadow price. Otherwise, the land will stay in agricultural production.

$$e_i^* = \begin{cases} l_i & \text{if } \frac{b_i}{py_i - c_i} \geq \lambda^* \\ 0 & \text{if } \frac{b_i}{py_i - c_i} < \lambda^* \end{cases}$$

I can take away from this model that fields with ample environmental benefits and low agricultural productivity are the most likely to be eased. The fields with high benefit-cost ratios will be eased. If the price of the commodity increases, then fields are less likely to be eased since the opportunity cost is higher. Or if the cost of production increases, for example, if the input or labor prices increase, then I would expect more fields go into the easement program. I can also consider the impact of climate change. If there is frequent flooding or extreme heat, one would expect lower yields and profits. Expectations of lower yields would lead to more easements. Another facet to consider is the role of insurance. If the potential agricultural profits of a field were guaranteed due to insurance coverage, it would be less likely for land to go into easement. This would mean that a field would continue being used for agricultural production even though without insurance, it would have been eased. This emphasizes some of the moral hazard issues that insurance introduces to the easement process.

Considering Externalities

The baseline model I have set up implicitly assumes that eased land does not impact its surrounding agricultural fields. However, research suggests that easements may impact nearby fields through their water storing capacity. Restoring land into a wetland or floodplain changes the watershed topography and can lead to the easement acting as a "sink". Water pools onto the eased land. Excess water upstream from the easement, instead of pooling on agricultural lands, now streams to the restored wetland or floodplain. This can lead to reduced erosion and less instances of water pooling on those surrouding croplands. This could lead to improved yields on agricultural lands near easements. I expand on the farmer's objective model by considering how easements impact surrouding field yields as well as the easement decision-making process.

I model this spillover effect as $s(e_i)y_j$ where $j \neq i$. I assume the spillover effect is monotone and non-negative. I also assume here that easements do not impact the costs of producing on other fields.[5] In this set up, I ignore the non-negativity constraints since I know that it is not optimal for the farmer to choose negative e_i or a_i. Here, I lay out how easing field i has an impact on the other non-i fields, which I subscript with j.

$$max_{a_i,e_i,a_j,e_j} \underbrace{(py_i - c_i)a_i + r_ie_i + \mu_i(l_i - a_i - e_i)}_{\text{objective for field i}} + \underbrace{\sum_{j\neq i}^{L}((p + s(e_i))y_j - c_j)a_j + \sum_{j\neq i}^{L} r_je_j + \sum_{j\neq i}^{L} \mu_j(l_j - a_j - e_j)}_{\text{objective for fields j with spillover}}$$

$$\mathcal{L} = (py_i - c_i)a_i + r_ie_i + \mu_i(l_i - a_i - e_i) + \sum_{j\neq i}^{L}((p + s(e_i))y_j - c_j)a_j + \sum_{j\neq i}^{L} r_je_j + \sum_{j\neq i}^{L} \mu_j(l_j - a_j - e_j)$$

$$[a_i] : py_i - c_i - \mu_i = 0$$

$$[e_i] : r_i - \mu_i + s'(e_i)y_ja_j = 0$$

$$[a_j] : (p + s(e_i))y_j - c_j - \mu_j = 0$$

$$[e_j] : r_j - \mu_j = 0$$

$$[\mu_i] : l_i - a_i - e_i = 0$$

[5] I abstract away from potential cases in which adding an easement increases the cost of accessing neighboring fields, for example.

$$[\mu_j] : l_j - a_j - e_j = 0$$

Next, I derive the new Kuhn-Tucker conditions.

$$1.\ py_i - c_i = \mu_i,\ r_i + s'(e_i)y_j a_j = \mu_i,\ (p + s(e_i))y_j - c_j = \mu_j,\ r_j = \mu_j$$

$$2.\ a_i + e_i = l_i, a_j + e_j = l_j$$

$$3.\ \mu_i \geq 0,\ \mu_j \geq 0$$

$$4.\ \mu_i(l_i - a_i - e_i) = 0,\ \mu_j(l_j - a_j - e_j) = 0$$

Then, I solve for the explicit solutions for e_i and e_j.

$$e_i^s = \begin{cases} l_i & \text{if } py_i - c_i \leq r_i + s'(e_i)y_j a_j \\ 0 & \text{if } py_i - c_i > r_i + s'(e_i)y_j a_j \end{cases}$$

$$e_j^s = \begin{cases} l_j & \text{if } py_j + s(e_i)y_j - c_j \leq r_j \\ 0 & \text{if } py_j + s(e_i)y_j - c_j > r_j \end{cases}$$

When the farmer takes into account spillover effects of eased lands, their easement threshold changes. If there are zero spillovers, then our equations revert back to our original solution. If the spillover is positive ($s'(e_i) > 0$), then easement enrollment would be more likely. Now, there is a new easement benefit to consider in the objective function besides just the easement retirement payment. These yield spillovers would increase the number of fields that go into easement. However, looking at e_j^s provides insights into an alternative effect. If there are some easements on the land and spillovers are large enough, it may be the case that easement enrollment decreases. Specifically, the increased yields from spillovers make expected agricultural profits higher than the easement price and land is then more likely to stay in agricultural production. I focus on the case in which spillovers are large enough to encourage more fields to go into easement but not so large that fields becomes so much more productive that it actually discourages easing.

If the conservation agent ignores the spillover effects, and continues paying $\bar{r}$, the conservation agent will be paying more than is necessary to purchase the easement. The farmer should be willing to accept a lower price since they now take into consideration the added profit benefits to the surrouding fields. If the conservation agent could set the new price equal to the expected agricultural profits less the spillover benefits, they could still ensure a producer would be willing to ease while having more budget left over to ease more land and increase the total environmental benefits.

An interesting thought exercise is to consider the case when there are multiple land owners. If there is a producer downstream from another's easement that sees yield spillovers, they benefit from the easement without paying the costs (or opportunity costs) of putting in an easement. This situation exemplifies a market failure in which there is a positive environmental externality. In some ways, an wetland and floodplain easement serves as a public good even though they are privately owned. My model highlights the positive externality of agricultural production benefits; other potential externalities include the aesthetic value of the conserved land, as well as the water quality improvements of these types of habitats.

How could these spillovers be internalized when the easement landowners differ from the agricultural land owners experiencing the yield spillovers? Local NRCS, FSA, RMA offices in a county could measure these spillover benefits and communicate them to stakeholder producers. If the producers coordinated such as through a cooperative, easement benefits and easement costs could more equitably be distributed. This could lead to more easements being introduced in an area, and lower agricultural risks for the members in the cooperative. This could mitigate the market failure and lead to more resilient agricultural systems.

4 Data

I compile from a wide array of sources to build a comprehensive data set to address my research questions. Administrative data is collected from various branches at the USDA: the NRCS, NASS, RMA, and FSA. The remote sensing Parameter-elevation Regressions on Independent Slopes Model (PRISM) data is the source of the weather and climate controls. Each observation is aggregated to the county-year level. The data spans from 1989-2020 and includes over 2,000 farming counties. The commodities of focus are corn, soybeans, and wheat. This section outlines each data set used in this research and points out important variables and trends. Key summary statistics for the main counties east of the 100th meridian are presented in Tables 1 and 2.

4.1 NRCS Easements

The NRCS has a database for all the information on floodplain easements and wetland restorations completed in the United States (NRCS, 2021b). These data are collected by NRCS agents across the country. The data spans from program inception in 1992 to 2020. There are 1,613 completed floodplain easement and 17,751 completed wetland restorations in the data. Variables include program type, total acres enrolled, cropland acres enrolled, key dates in the process, condition of easements, HUC number, corresponding national initiative, and geospatial data identifying where the easement exists. The main explanatory variables of interest include the cumulative acres closed in the floodplain and wetland easements programs divided by the county land area. On average, there are 615 acres of wetland easement and 56 acres of floodplain easement in a county over the sample period. The mean landshare in a county of wetland easement is 0.00160 and 0.00012 for floodplain easements. I also differentiate between the cropland and non-cropland easement acres in order to parse out the direct and indirect effects.

Figure 2 depicts the cumulative acres enrolled in wetland and floodplain easements over time. Wetland enrollment increased very slowly at first and then spiked in the late 1990s and into the early 2000s. The growth rate plateaued until the passage of the American Recovery and Reinsurance Act in 2008 which provided the NRCS with additional funding. I see wetland enrollment increasing for a few years after ARRA before flattening again. Floodplain easement enrollment has been much milder. Floodplain easements, unlike wetland easements which are supported by Farm Bills that occur every five years, are funded though Congressional Acts that are infrequent. Funding for floodplains spiked after severe agricultural flooding events such as in the late 1990s and 2008. This additional funding corresponds to floodplain enrollment.

It is also important to consider the timing of easements. The NRCS Easement data records dates of importance such as application date, agreement start date, enrollment date, closing date, recorded date, and restoration completion dates. Each event in the process is defined in detail in Table 4. Whether a producer can crop on the land or insure the land with the USDA is also noted. Producers are actually encouraged to crop on the land until the NRCS is ready to actively restore the land. From application to restoration completion, a floodplain can take an average of 2.8 years to be finished. The wetland restoration process tends to be more intensive and takes 4.1 years on average to complete. A breakdown of each step's duration is presented in the box plot in Figure 3. There is a large range in terms of how long it takes to finish the easement process—there are cases in which it takes less than a year and others than span closer to 10 years to be considered officially complete.

The date of importance for our analysis is the closing date. The closing date represents the point that the contract becomes official. The conservation agent has approval to purchase the easement and the landlord is paid. After this date, farmers can no longer receive benefits on that parcel nor insure the eased parcel. They may still be able to plant crops on the parcel with a compatible use authorization. It is not until the restoration is complete that producers are prohibited from cropping on the easement. I choose the closing date as the time that an easement is counted in the county running total of acres—the main explanatory variable of interest. I believe at this point that I will see changes in risk reflected at the county-level since the land is no longer insured at this point. I might expect to see indirect effects on neighboring parcels at this time as well. It is also possible that at the restoration completion date the indirect effects may be amplified.

At what time in the year do easements occur? I break down the key steps in the easement process by month of occurrence in Figure 4. I notice that applications and restoration completions tend to occur during certain months. On the other hand, I notice that the timing is distributed evenly during the year for NRCS management specific steps such as closing and recording.

Application timing is likely to be endogenous. The decision to apply to an easement program is not random. A producer may be motivated to apply after facing agricultural losses. It appears that wetland applications are more likely to occur in heavy-flooding months, March and June. Floodplain applications are more likely to occur during the spring and summer season as well. Over thirty-six percent of floodplain applications are received in July and August. At this point in the year, producers have realized whether their yields will be less than expected. A willingness to retire marginal cropland after facing flood losses may have incited an increase in the frequency of applications during these months.

The work completed by the NRCS seems to be distributed in a uniform distribution across the year, especially for closings and court recordings. There does seem to be patterns worth mentioning for when restorations are completed. Restorations require removing tiling or planting native flora on the eased parcel. It is understandable that wetlands tend to be finished by the end of summer around September. Floodplains generally take less effort and planting to complete. Floodplain restorations tend to take place in late summer and also the month of December. I investigate the timing of the easement process in order to better understand when I may begin to see effects on agricultural production and risk. These exercises informs the decisions of which date to consider when studying easement effects. The main specifications presented here correspond to the closing date.

4.2 NASS Crop Yields

The central data set used to study agricultural outcomes is the NASS. The NASS uses survey data to provide estimates of county level yields, acres planted, and acres harvested. I also create a measure of acreage failed to harvest by subtracting the acres planted by acres harvested for each county year. There are data for each of these variables for corn, soybeans and wheat from 1989-2020. Yields for each crop are measured in terms of bushels per acre. I create maps of the average yields over from 1989-2020 to allow us to observe variation in the bushels per acre for each crop in each county. Figures 5, 6, and 7 show the average yields for corn, soybeans, and wheat respectively. These maps also help us understand which counties are in each of our specifications for each commodity. For corn, we notice that corn production is centralized in the "corn belt" states, Nebraska, Iowa, Illinois, and Indiana. However, there is corn production apparent in the western half of the US as well. The mean corn yield during these three decades is 122 bushels/acre. Soybean production is more focused in the eastern half of the United States. Soybean yields average 38 bushels per acre. Wheat production occurs in the Midwest of the US but the highest yielding wheat counties are in the Western states. Wheat yields average around 49 bushels per acre.

4.3 RMA Cause of Loss and Summary of Business

The Cause of Loss (COL) dataset from the RMA (Risk Managment Agency, 2021) provides valuable information on monthly indemnities for each county from 1989-2020. Each observation gives us county-month-commodity-cause of loss information. Outcome variables of interest include the acres lost as well as indemnity totals for specific loss types. I reorganize the causes-of-loss data and calculate the total indemnities for each category to better understand the magnitude of losses (Figure 8). The biggest cause-of-loss is drought, with indemnities totaling over $35 trillion over the period 1989-2020. The second biggest cause of loss is Excess Moisture, with indemnities close to $30 trillion. The causes of loss that I am specifically interested in are for events related to flooding and excess water. I focus on these types of losses since I believe that floodplain and wetlands will have the biggest impact on agricultural risk concerning excess water. However, I also consider the overall causes of losses as well since crops may be indirectly impacted by other types of losses at a greater rate after suffering water damage. Crops that face water damage are also more liable to damages caused by disease, insects, and wildlife.

The Cause of Loss Data are merged with another RMA data resource, the Summary of Business (SOB) data file. The SOB data record the acres planted, liabilities, premiums, subsidies, coverage levels, and chosen policies. The SOB data allow us to build our outcomes of focus, the Loss Ratio and Loss Cost Ratio. We aggregate the data to a yearly total for each county to create panel data. To create a balanced panel, we assume that reported indemnities and losses are zero for county-years with no reported losses. However, our analysis only consists of the subset of counties that faced losses (ie counties that had non-zero losses in that year as is standard practice). The maps in Figures 9, 10, and 11 show the extent of indemnities per acre planted for corn, soybeans and wheat. When looking at losses for corn, I note that the highest losses are scattered throughout the country but there are concentrations in the Dakotas as well as along the coasts. Indemnities per acre are a lot lower for soybeans but follow similar patterns to the losses for corn. The wheat map in Figure 11 displays the most striking losses. High indemnities for wheat run along the northern edge of the United States. These also overlap with a high number of easements.

It is also interesting to consider the timing of these damages. To explore when indemnities occur, I graph changes in indemnities for corn, soybeans and wheat during our sample period in Figure 12. I notice that indemnities remain relatively low and stable for the first decade in our sample. I then notice more frequent upswings in losses for crops. I notice losses around $3 billion for each crop in 2008. This year is notorious for severe flooding and the associated ARRA funding uptick. I also see severe losses for corn in 2012 after another bad year of flooding that amount to almost $12 billions in indemnities paid out to farmers.

4.4 FSA Crop Acreage

The FSA has collected data on acreage planted, prevented planted, and failed from 2009-2020 (FSA 2020). Producers who participate in FSA programs are required to self-report on acreage outcomes each year to the FSA. Records include the sum of planted acres, volunteer acres, failed acres, prevented acres, and net planted acres. These reports are used to calculate losses for various disaster assistance programs. Observations are then aggregated to the county-level for each year and then made publicly available.

The main outcomes that I use from the FSA data are the prevented planting and failed planting variables. Prevented planting is the inability to plant the intended crop acreage with proper equipment by the final planting date for a specific crop type. Failed acreage is acreage that is planted with the intent to harvest but is unable to be brought to harvest. The average number of acres that are prevented from planting in a county is 1,619, 723, and 590 for corn, soybeans and wheat. Failure is less common with an average of 119, 35 and 116 acres failed for corn, soybeans and wheat. The FSA data allows for an investigation of the timing of easements effects. Do easements reduce agricultural risk by reducing acres prevented planted during planting season? Or is it the case that easements reduce risk later on in the season by reducing acres failed?

4.5 PRISM Weather and Climate

I follow the approach of ? (?) and Ortiz-Bobea (2021) when including weather data in my models. I use PRISM data that is aggregated at the county-level. Notably, I only include the raster weather data on parcels that are classified as cropland or pastureland by the USGS National Land Cover Data Base. Since the original PRSIM dataset is at the monthly level and my data are at the year level, I also aggregate over the growing season from April to September to create a yearly panel. For example, my precipitation measure represents the total millimeters of precipitation that a county receives in a growing season. I also include a squared precipitation term since precipitation has a non-linear effect on the agricultural outcomes of interest. My data set also includes heat exposure by considering the average growing season temperature as well as the average monthly minimum and maximum temperatures. Instead of focusing on the temperature variables, I consider the exposure of varying temperature levels by binning the hours spent at each Celsius degree. Similar to Annan and Schlenker (2015), my model includes moderate temperature exposure (total exposure from 10-29 degrees Celsius) and extreme temperature exposure (total exposure at and above 30 degrees Celsius).

5 Empirical Model

Panel model with two-way fixed effects

The main specification in this paper uses a panel model with two-way fixed effects (TWFE) to estimate how easements impact agricultural outcomes. The panel spans from 1989 to 2020, encompassing 32 years of data. My equation takes the form of

$$Y_{ict} = \beta_1 Wetland_{it} + \beta_2 Floodplain_{it} + \Gamma X_{it} + \alpha_i + \delta_t + \epsilon_{ict} \tag{1}$$

The outcome variables of interest, Y, that I examine are the crop yields, lost cost ratio, and loss ratio in county i in year t for crop c. The crops of interest in this study are corn, soybeans, and wheat. When studying potential mechanisms, I also look at the acres planted, prevented planted, failed, and failed to harvest as outcomes of interest. I cluster my standard errors at the county level. I take the inverse hyperbolic sine transformation (IHS) of all the outcome variables except for the risk ratios. This transformation allows estimated effects in the outcomes to be interpreted as percent changes. The IHS is preferred to the natural log transformation since there are many cases of zero values in the data. I also apply a mean transformation to correct the magnitudes of the coefficients so I can interpret them as elasticities.When both the outcome(y) and treatment(x) are IHS, the elasticity equals $(b * \overline{x} * \sqrt{(\overline{y}^2 + 1)})/(\overline{y} * \sqrt{(\overline{x}^2 + 1)})$ where b is the coefficient after regressing IHS(y) on IHS(x), $\overline{x}$ is the mean of x, and $\overline{y}$ is the mean of y. When the treatment x is IHS but the outcome y is not, the semi-elasticity is $(b * \overline{x} * \sqrt{(\overline{y}^2 + 1)})/\overline{y}$. The standard errors for the elasticities are then calculated using the delta method. A more detailed explanation of this process is laid out in Bellemare and Wichman (2019).

I include fixed effects at the county-level to account for the average differences across counties. The county-level fixed effect controls for observed and unobserved county factors that are time invariant. This allows me to use within county variation to reduce the threat of omitted variable bias. I also include year fixed effects. These control for both observable and unobservable factors changing across time that are consistent across counties. The underlying assumption that is being made is that conditional on the county and year, treatment is exogenous.

The main treatment variables, $Floodplain$ and $Wetland$, represent the floodplain and wetland eased land as a proportion of a county's total land area. The IHS of the treatment variables is taken as well for ease of interpretation and since there are many counties with zero easement acreage. The main source of identifying variation stems from variation across time and space in the closing of easement acres. The coefficient of interest β_1 measures the elasticity response of the chosen agricultural outcomes to a 100% increase in land under wetland easement. The coefficient β_2 represents the elasticity response after a 100% increase in land under floodplain easement. For ease of legibility, instead of measuring the response to a 1% increase in easement land share, I consider a "doubling" of land share in wetland and floodplain acre, or a 100% increase.

To reduce the threat of omitted variable bias, I include relevant controls in my model. I account for planting-relevant variables that are common in the literature such as precipitation, temperature, and degree days. My main specification includes moderate and extreme degree exposure as well as precipitation and precipitation squared. Moderate degree exposure is the sum of hours spent between 10-29 degrees Celsius. Extreme degree exposure is the sum of hours above 30 degrees Celsius. Finally, I adjust the standard error by clustering at the state-level. I cluster at the state since the programs are funded and administered by each state NRCS department.

I use the closing year in my preferred specification since this date is the most reasonably exogenous and the point in time that is associated with reduced risk. This is also the point at which a producer can no longer insure the parcel. The application date is heavily influenced by recent flooding and previous indemnities. This means that our treatment and outcome variables are co-determined. However, once a farmer decides to apply and enroll into the program, the rest of the process is in the hands of the NRCS. Meetings with NRCS directors and agents have shed light on the fact that the NRCS steps including closing, court recording, and restoration completion are somewhat random. Many potential hurdles may delay the process. It is often the case that various legal issues make the closing and restoration process last longer. For example, a previous utility contract may be unearthed and an agreement must be worked out. Alternatively, sometimes there is trouble with accessing the parcel of land for the NRCS because of legalities with rail roads and private roadways. There are many legal documents and processes that take an quasi-random amount of time to complete. For these reasons, I believe the timing of closing is reasonably exogenous.

In my results here, I include counties in the sample when that county plants that commodity at least once during my time horizon. I use the NASS acreage and FSA acreage variable to create these sample groups. [6] So, for example, counties that plant corn at least once during the 30 years are included in the corn sample. Counties that never plant soybeans are omitted from the soybean sample. When calculating the mean of the treatment and outcome variables for the elasticity transformation, I use means specific to each commodity sub-sample. The mean of easement land share may vary depending on the commodity sub-sample for instance.

[6] For NASS outcome variables, I use the NASS acreage commodity subsamples. For the FSA outcomes, I use the FSA acreage commodity sub-samples. There is not perfect overlap between the FSA and NASS groups. This is because the FSA sample is shorter and covers a shorter time span. But there are about 200 observations that belong in the FSA sample but are not in the NASS sample. I use the NASS sample of counties for the FSA outcomes and find similar results as a robustness check.

Limitations and Trends in TWFE and DiD Models

It is worth noting the limitations and current updates regarding panel models with two-way fixed effects. The two-way fixed effect strategy can also be interpreted as a difference-in-differences(DiD) set up but with a staggered, continuous treatment variable. There has been a lot of recent work in the DiD setting: decomposing the treatment effects, discerning how they are weighted, and understanding the underlying assumptions(Goodman-Bacon, 2018; De Chaisemartin, D'haultfoeuille, & Haultfoeuille, 2019; Callaway & Sant'Anna, 2020). Alternative estimators have been specified to create the correct counterfactual groups and accurately weigh observations to find the average treatment effect in a variety of settings, especially in the canonical two-period DiD setting. Currently, the literature is applying this logic to multi-period settings and cases when treatment is staggered and continuous(De Chaisemartin, Haultfoeuille, & Guyonvarch, 2019; Callaway et al., 2021).

How can we interpret the main treatment coefficients? There are two causal effects of interest: a treatment effect and causal response effect (Callaway et al., 2021). The treatment (level) effect measures the difference between a unit's potential treated outcome and potential untreated outcome. The causal response (slope) effect captures the response to an incremental change in the treatment level. To identify the treatment effect, a comparison must be made between treated and untreated units with the assumption of parallel trends on untreated potential outcomes. The causal response effect comes from comparisons between units that have more treatment relative to other treated units and requires a much stronger parallel trends assumption. There can also be selection bias that is captured in the parameter since there may be non-random differences between units with different treatment intensity. As Callaway et al. (2021) notes, the original TWFE estimator is composed of four different types of comparisons: 1) between units treated at the same time with different treatment levels, 2) between units in early-treated groups relative to later-treated groups, 3) between later-treated groups relative to already-treated groups, and 4) between early-treated and later-treated groups in common periods. To identify the treatment effect and causal response effect, the correct comparison groups must be selected. Callaway et al. (2021) propose a specification to correctly identify the causal effects of interest in a multi-period setting with variation in treatment timing and intensity as well as the needed parallel trend assumptions. The code for this alternate specification is still being developed.

6 Results

This section reviews my findings from using a TWFE model. I present both coefficient plots and regression tables to make the results easy to follow. Each regression includes fixed effects at the county and year level. Each model also includes precipitation, precipitation squared, moderate degree exposure, and extreme degree exposure. The sample is restricted to counties that are east of the 100th meridian except for when I look at region heterogeneity.

How do easements impact crop yields?

Results table 1 shows how wetland and floodplain easements impact corn, soybean and wheat yields. A clear pattern emerges, especially for wetland easements. As hypothesized, easements positively impact yields. For wetland easements, a 100% increase in land share of wetland easement is associated with 0.34%, 0.77% and 0.46% increase in yields for corn, soybeans, and wheat. The estimates on floodplain easements are also positive but no longer statistically significant for corn and soybeans. There is evidence of significant increases in wheat yields of 0.13% after an increase in floodplain easement land share.

Results table 2 differentiates by the original land use of the easement. A majority of the land put under easement is cropland. There are cases when adjacent non-cropland (land not used in production) is put under easement as well. Non-cropland is eased in order to to connect eased cropland, improve drainage outcomes, and create more robust ecosystems. Differentiating by the original land use uncovers the direct and indirect effect of easements. The estimates on cropland wetland and floodplain acres represent the direct and indirect effect of easements. The direct effect is the mechanical effect of taking land out of production. The indirect effect captures the effect of restoring land into a wetland and floodplain. The estimates on the non-cropland wetland and floodplain easements represent just the indirect effects of easements.

Results table 2 shows that doubling wetland crop acres has a positive, significant effect for soybeans and wheat. Doubling cropland in wetland easement increases corn yields by 0.14%, soybeans by 0.82%, and wheat by 0.33%. Doubling the land share of non-cropland into wetlands has a 0.22%, 0.29% and 0.11% increase in yields for corn, soybeans and wheat; however, only the estimate for soybeans is significant. Soybeans seem to be the commodity most impacted by wetland easements. The results for floodplains differ in the fact that they are smaller in magnitude, and even negative at times. I believe the small magnitude is due to the fact that there is such a small amount of floodplain easements. Easing cropland into a floodplain has an insignificant effect for corn and wheat yields. Unexpectedly, doubling land share of cropland in floodplains decreases soybean yields by 0.06%. However, the indirect effect of floodplain easements is positive and significant for all three commodities. Doubling the share of land in non-cropland floodplain easements leads to a 0.14%, 0.06% and 0.09% increase in corn, soybean and wheat yields. This evidence lends support to the hypothesis that easements have an overall positive effect on agricultural production by increasing the average yields within a county. There seems to be different effects based on the easement type and the original use of the land.

How do easements impact crop yield risk?

The next set of results evaluate how easements impact agricultural risk. I measure yield risk as the ratio of indemnities to liabilities as well as the ratio of indemnities to premiums paid. I do not take the inverse hyperbolic sine of the risk ratios so these results are interpreted as semi-elasticities. The subset of data here include only county observations that have a non-zero indemnity in that year. [7] Results table 3 show how floodplain easements and wetland easements impact the lost cost ratio. Unlike with yields, I do not find a strong relationship between easement closing and reduced risk. I find no significant effects of wetland and floodplain easement land share on corn and wheat loss cost ratios. However, I do find that an increase in easement wetland acres reduces the loss cost ratio for soybeans. Increasing wetland easements by 100% decreases soybeans losses by $2.26 per dollar of liability. This suggest that there is not as robust of a relationship between easements and crop yield risk. There is some evidence showing that soybean production is less risky post easement implementation.

To try to understand the types of agricultural losses that may be prevented by easements, I calculate the loss cost ratio for different subsets of indemnity types. Specifically, I create a separate lost cost ratio for excess moisture, flooding, drought, heat, disease, and insect losses. Results table 4 explores how the lost cost ratio for these different climate-related indemnities changes after an increase in easements. Even though disease and insects are not directly related to weather, research shows the changing climate has exacerbated pest problems. Moreover, crops that experience extreme weather stress are more susceptible to disease and insect losses.

I find evidence that wetland easements significantly impact indemnity losses from excess moisture, heat, disease, and insects. For soybeans, increasing wetland easements decreases losses from excess moisture by $ 3.59, from heat by $6.07, and from disease by $11.23 per dollar of liability. Doubling wetland easements significantly reduces insect losses by $8.50 per dollar of liability for corn; the coefficient for soybeans is almost identical but insignificant. These findings suggest that wetland easements could be used to improve agricultural resiliency, especially for soybean crops. Considering that climate change research predicts worsening excess moisture, heat, and disease conditions, easements provide a potential solution to mitigate costly crop losses.

I also find evidence of increased drought risk associated with higher easement land share. Increasing wetland easements by 100% is associated with $3.80 more losses per dollar of wheat liability. Increasing floodplain easements by 100% leads to $0.46 and $0.32 more indemnities per dollar of corn and soybean liability, respectively. I posit that easements changing the water patterns within a watershed may be leading to less water on remaining agricultural fields. This could increases the risk of drought for some fields.

[7] If a county has zero indemnities in a year, the loss cost ratio and loss ratio are undefined. Moreover, sticking to the subset of observations that regularly face losses will give a better idea of the true effect of easements.

To investigate how producer risk is impacted by easements, I regress the loss ratio on wetland and floodplain acres in results table 5. All the estimates are insignificant. This may suggest that producers are not experiencing any changes in risk post easement closings in the county. To try and understand factors driving the yield and risk results, I explore potential mechanisms in the section.

What are the potential mechanisms?

This section explores the potential mechanisms through which easements may be impacting agricultural production. I look at how an increase in wetland and floodplain easement acres impact acres planted, harvested, failed, and prevented planted.

I start by looking at how planting behavior changes and examining how easement land share impacts acres planted. Results table 6 uses NASS data on acreage planted that stem the entire panel period. The estimates for floodplain easements are small and insignificant. The results for wetland easements are much more telling. I find that increasing wetland land share by 100% decreases acres planted of soybeans by 2% and acres planted of wheat by 1%. This is consistent with my hypotheses since easements take land out of production. Surprisingly, doubling wetland easement acres is associated with a 3% increase in corn acreage.

Evidence of a similar spillover effect, called slippage, has been associated with the Conservation Reserve Program (J. Wu, 2000). I believe the narrative here is that producers are switching their production on remaining agricultural fields toward corn. Another possibility is that non-cropland is being converted into corn cropland. Producers often rotate a field between corn and soybeans to diversify their commodities, improve production, renew the soil nutrients, reduce erosion, balance the pest and weed communities, and reduce the need for fertilizers and herbicides. After easement, a producer has less acreage to plant on and it is likely that the producers retired their riskiest fields. Because of these changes in their production systems, it could be the case that farmers try to maximize profits by planting a more profitable commodity on their remaining fields. There is also some evidence suggesting that corn is more resilient against excess moisture and flooding. Producers that put land into easement may be taking other adaptive steps by producing more corn over soybeans. Continually cropping corn is more profitable but also more risky. Continuous corn cropping is also associated with some negative environmental externalities that could be counterproductive to easement goals.

Results table 7 uses FSA acreage data, which has a shorter panel of data from 2009-2020. I run this specification for robustness. The findings are similar but often smaller in magnitude and less significant. The results for floodplains are again insignificant and close to zero. I find that doubling wetland easement land share leads to a -16% change in wheat acreage planted. I suspect that easements were focused on the wheat-growing regions from 2010-2020 and that led to a sizeable reduction in wheat acreage planted. Results table 8 show how doubling easement land share impacts acres harvested. The acres harvested findings are almost identical to the acres planted results.

The next potential mechanism that I explore is looking at acres failed to harvest (from the NASS data) and acres failed (according to the FSA data). Results table 9 highlight that doubling wetland easement land share reduces acres failed to harvest for soybeans and wheat by approximately 1%. I take away from these results that land that is more prone to harvest failure is taken out of production through easement. This is part of the direct effect of easements. I also find that doubling floodplain easement leads to a significant reduction in acres failed to harvest for wheat by about 1%. Unexpectedly, a 100% increase in wetland acres leads to a 3% increase in corn acres failed to harvest. This finding is consistent with the spillage narrative. More corn is planted, and this leads to a higher failure to harvest of corn. Results table 10 shows patterns that are similar to the previous table. From 2009-2020, increasing wetland land share decreased acres failed for soybeans by 10% and acres failed for wheat by 21%. These findings suggest that easements were successfully targeting marginal land during this time and effectively reducing acreage failure.

Since I am interested in the excess water and flood prevention capacities of easements, I also look at how easement land share impacts acres prevented planted. For wetland easements, I find that increasing land share by 100% decreases acres prevented planted of soybeans and increases acres prevented planted of wheat but these estimates are insignificant. Again, unexpectedly, I find that doubling wetland easement land share increases acres prevented planted for corn by 43%. I think this deepens our understanding of the slippage effect. From 2009 to 2020, it seems that more land is being put towards corn production post-easement and this may be leading to higher corn losses. I also find that floodplain easements are associated with large reductions in acres prevented planted. Doubling land share in floodplain easement reduces prevented planting acreage for corn by 14% and soybeans by 9%. It seems that floodplain easements are successful at reducing the risks associated with prevented planting.

Finally, I explore the potential weather pathways by taking an approach similar to Annan and Schlenker (2015) in which they look at how the portion of land that is insured impact the effect of precipitation and degree days on crop yields. I interact the share of wetland easements with moderate degree days, extreme degree days, precipitation, and precipitation squared. This allows me to see through which type of weather pathways easements impact crop yields. I find that for corn, wetland easements reduce the effect of moderate degree days. This makes sense since moderate degree days positively impact yields, so more land in easement will reduce the effect of moderate degree days. There is a similar story explaining the negative and significant interaction between wetland easement land share and precipitation. I also find that the interaction between wetland easements and precipitation squared is positive and significant for corn (although smaller then the interaction coefficient with just precipitation). This could emphasize that easements are effective at improving corn yields when precipitation is further from the optimal level and more extreme. For soybeans, I find that wetland easement land share mitigates the effect of extreme degree days on yields. Extreme degree days decrease soybean yields, and doubling wetland easements reduces this negative effect. Soybean fields are being taken out of production post-easement and yields are improving due to less damages from extreme degree days. For wheat, I do not find a significant effect of easements interacted with the weather pathways.

How do easements impact each region?

Finally, I take some time to explore heterogeneity in easement effects by region in Results Table 13. I look at how wetland easement and floodplain easement land share impact corn, soybean and what yields by region. The NASS has 12 regional offices that are responsible for the statistical work of their area. These are often grouped by similarities in production. A map in Figure 13 shows which are included in each region. This regional analysis can help me better understand which areas of the USA are driving the results. I note some interesting findings. The Southern region and Northwest region of the US actually sees decreased soybean and wheat yields associated with increased easement land share. However, most regions find positive or insignificant impacts of easement land share on yields. The Heartland, Northern Plains and Southern Plains seem to be the most impacted by easement land share and see the biggest increases in yields. It may be interesting to further explore these states that see significant easement effects. This regional analysis may point policy makers towards which regions derive the highest agricultural benefits from easements.

7 Conclusion

This paper presents novel evidence of how easing land affects agricultural production. I quantify the impact of easements, both floodplain and wetland, on county level yields and risk using a TWFE model. I find that wetland and floodplain easements increase the crop yields for corn, soybeans, and wheat. I parse out the direct and indirect effect of easements by distinguishing by original land use. Easing cropland directly improves yields by removing lower yielding land from production. I also find that easing non-cropland improves agricultural outcomes by indirectly improving surrounding production. I also study the mechanisms through which easements impact production. I find some evidence suggesting that easements reduce losses due to excess-moisture, heat, disease and insects but increase drought risk. There are also less incidences of prevented and failed planting for soybean and wheat in counties with higher easement land share. Unexpectedly, I also find evidence of a slippage effect in which producers switch to more corn production following easement closing. This slippage effect may actually increase agricultural risk and be associated with more corn prevented planting acreage. This study is a step towards a better understanding the NRCS easement programs. Accounting for these spillover effects may be important when considering future field selection into the program. Quantifying these benefits may impact how policy-makers fund future conservation efforts to adapt to a changing climate.

8 Appendix: Figures and Tables

Treatment and Control Variables Summary Statistics	Mean	SD	Min	Max	N
Wetland Acres	615.9	2,234	0	46,608	53,241
Crop Wetland Acres	356.9	1,535	0	30,394	53,241
Floodplain Acres	55.95	488.0	0	12,651	53,241
Crop Floodplain Acres	20.38	180.1	0	6,250	53,241
Wetland Acres/County Acres	0.00160	0.00577	0	0.117	53,241
Crop Wetland Acres/County Acres	0.000939	0.00399	0	0.0787	53,241
Floodplain Acres/County Acres	0.000120	0.000837	0	0.0192	53,241
Crop Floodplain Acres/County Acres	4.89e-05	0.000385	0	0.0118	53,241
Max. Temperature (C)	26.18	3.060	17.74	36.88	53,241
Min. Temperature (C)	13.97	3.152	5.495	23.67	53,241
Average Temperature (C)	20.08	3.063	11.85	29.79	53,241
Precipitation (total mm)	623.4	168.0	75.77	1,697	53,241
Moderate degree exposure (hours)	3,508	229.4	2,198	4,170	53,241
Extreme degree exposure (hours)	463.1	356.5	0	2,194	53,241

Note: Unit of observation is a county-year. Values are for counties in the main sample and from 1989-2020.

Table 1: Summary Statistics for treatment and control variables

Outcome Variables Summary Statistics	Mean	SD	Min	Max	N
Corn yield (bushel/acre)	122.2	38.55	0	246.7	50,343
Soybean yield (bushel/acre)	37.57	11.07	0	80.40	45,877
Wheat yield (bushel/acre)	48.90	14.76	0	109.7	34,867
Corn Lost Cost Ratio	0.0996	0.158	-5.73e-05	1.245	44,950
Soybean Lost Cost Ratio	0.0927	0.138	0	1.354	42,906
Wheat Lost Cost Ratio	0.123	0.180	0	1.366	37,859
Corn Loss Ratio	0.887	1.386	-0.00101	20.03	44,950
Soybean Loss Ratio	0.769	1.052	0	15.41	42,906
Wheat Loss Ratio	1.050	1.692	0	34.45	37,859
Corn Planted Acres (FSA)	49,547	58,567	0	378,953	18,303
Soybean Planted Acres (FSA)	48,889	53,528	0	536,339	18,303
Wheat Planted Acres (FSA)	11,599	32,113	0	374,145	18,303
Corn Planted Acres (NASS)	46,580	56,077	50	397,000	50,358
Soybean Planted Acres (NASS)	48,673	51,985	10	541,000	45,879
Wheat Planted Acres (NASS)	17,493	38,208	50	500,000	34,880
Corn Harvested Acres	43,223	54,505	20	394,000	50,325
Soybean Harvested Acres	47,981	51,595	10	539,000	45,877
Wheat Harvested Acres	15,057	33,367	30	480,000	34,842
Corn Failed Harvest Acres	3,387	5,771	0	124,500	50,324
Soybean Failed Harvest Acres	694.3	1,555	0	71,000	45,877
Wheat Failed Harvest Acres	2,455	8,092	0	253,000	34,842
Corn Prevented Planted Acres (FSA)	1,619	7,820	0	260,914	18,303
Soybean Prevented Planted Acres (FSA)	723.0	3,083	0	89,229	18,303
Wheat Prevented Planted Acres (FSA)	590.7	3,095	0	122,702	18,303
Corn Failed Acres (FSA)	119.1	644.6	0	22,474	18,303
Soybean Failed Acres (FSA)	34.98	334.9	0	19,759	18,303
Wheat Failed Acres (FSA)	116.2	774.9	0	42,701	18,303

Note: Unit of observation is a county-year. Values are for counties in the main sample and from 1989-2020, except for FSA variables which stem from 2009-2020.

Table 2: Summary Statistics for outcome variables (levels)

Event	Definition	Can the producer farm the land?	Can the producer insure the land?
Application	Application received by the NRCS from producer.	Yes.	Yes.
Agreement Start	Parcel selected and producer agrees to continue in process.	Yes.	Yes
Enrollment	Parcel enrolls in program.	Yes.	Yes.
Closing	Conservation agent has approval. Attorneys sign off. Landlord paid money.	Only with Compatible Use Authorization (CUA).	No. After this date, farmer can no longer receive FSA benefits nor crop insurance.
Recorded	Transaction recorded in court. Officially NRCS easement.	Only with CUA.	No.
Restoration Complete	Parcel has been restored	No.	No.

Table 3: Table outlining each step in easement process

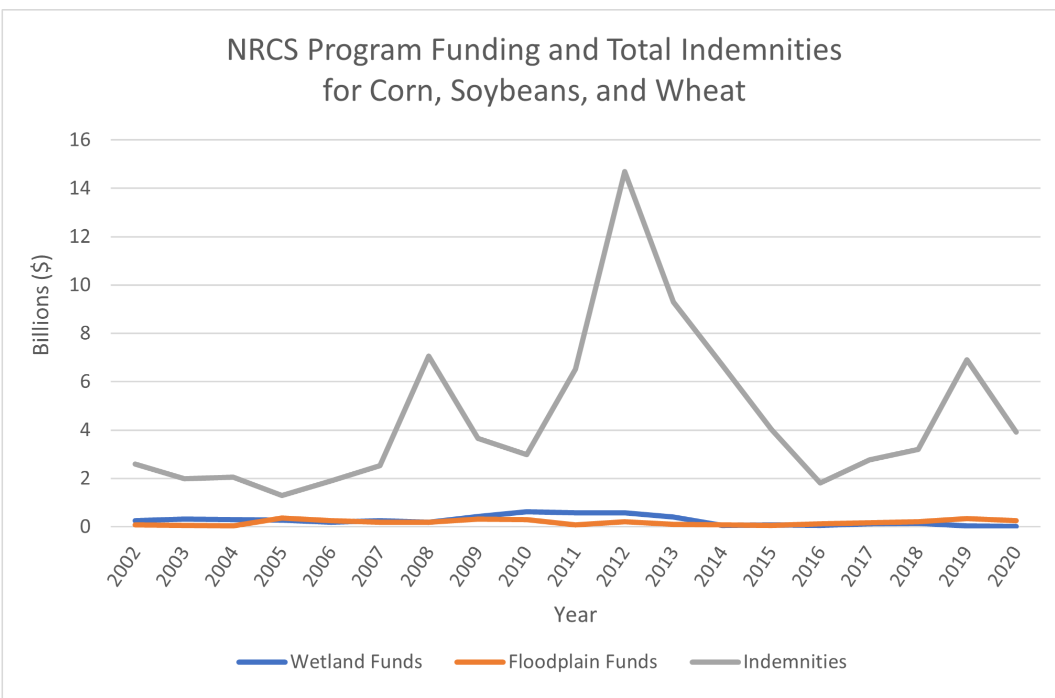


Figure 1: Spending comparison of NRCS easement program and crop indemnities

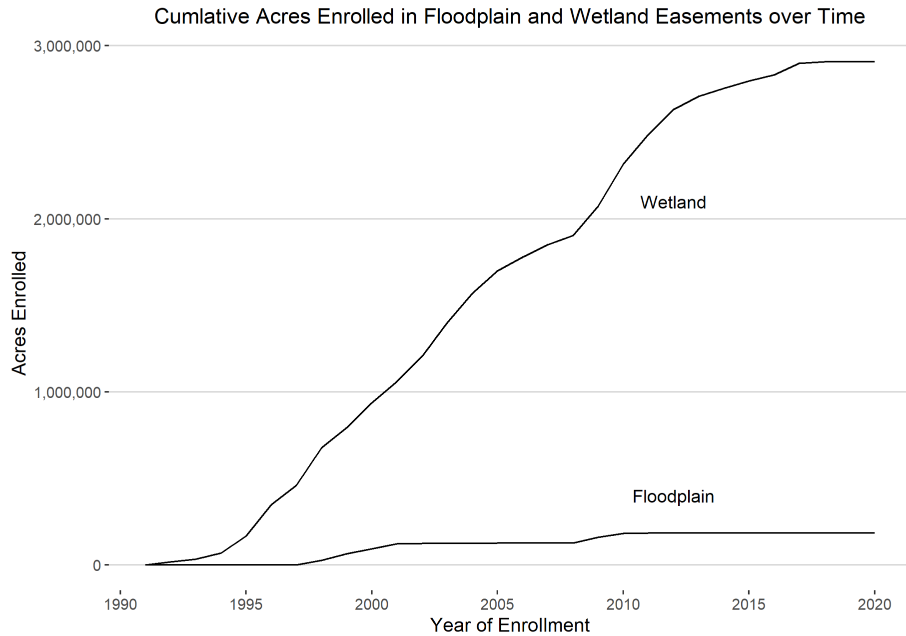


Figure 2: Acres enrolled in wetland and floodplain program

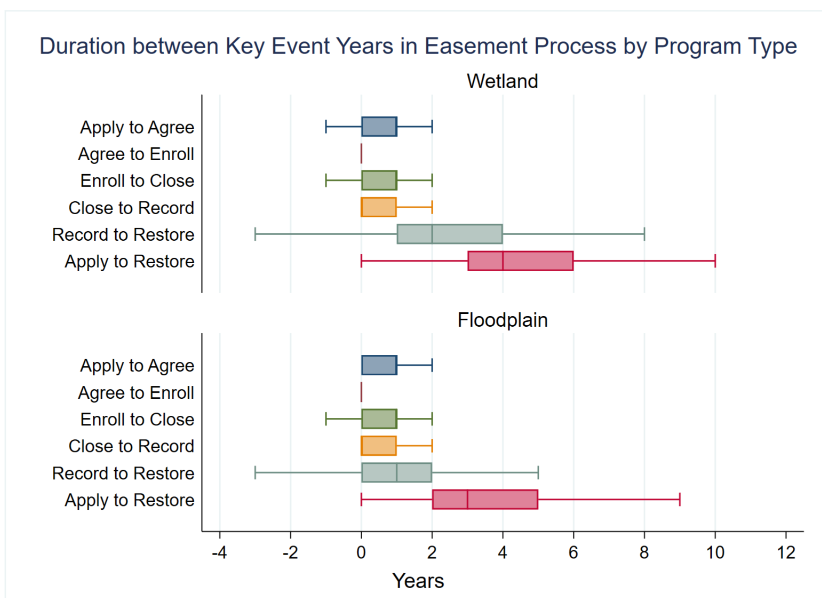


Figure 3: Duration in each phase by program type

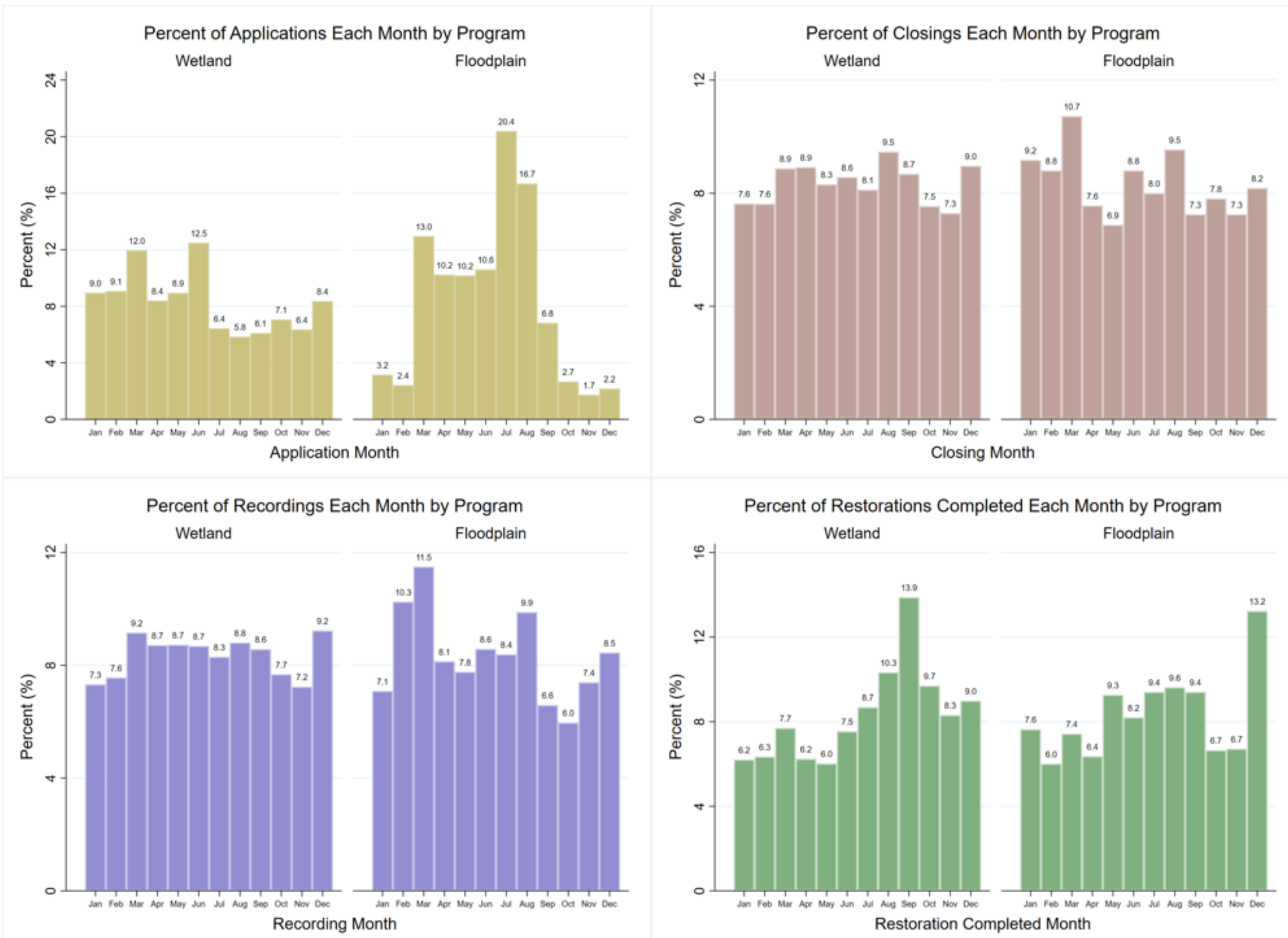


Figure 4: Monthly Breakdown of Main Easement Steps

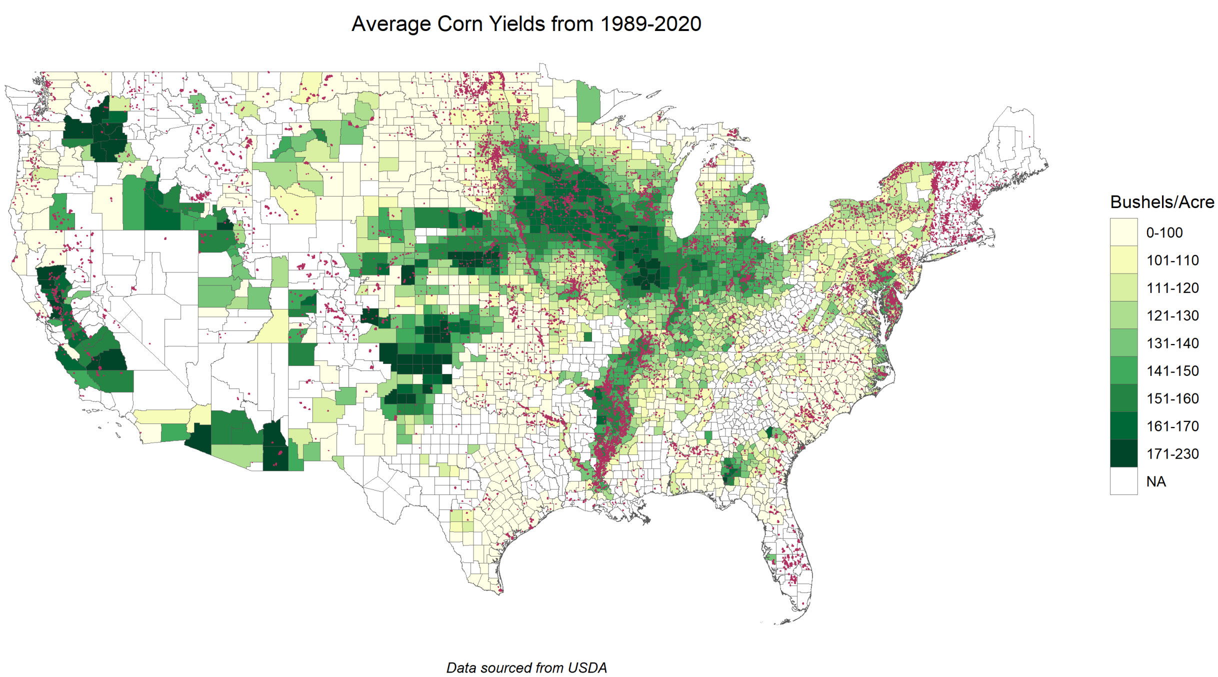


Figure 5: Map of corn average yields and easements

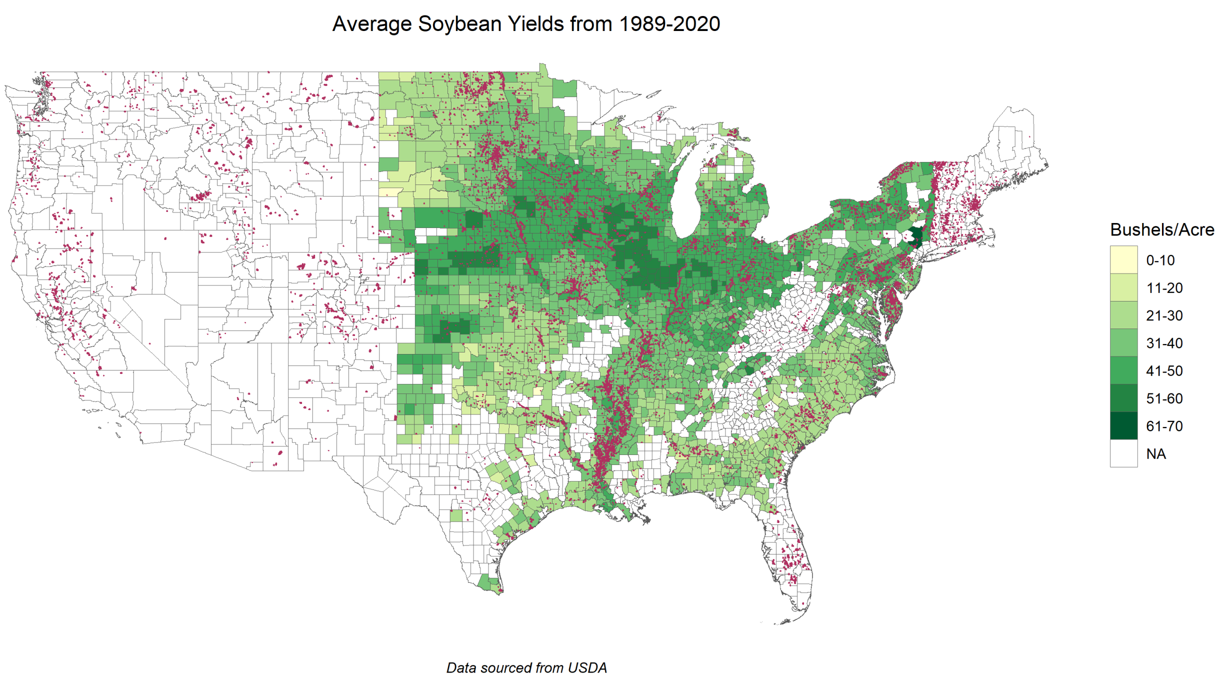


Figure 6: Map of soybean average yields and easements

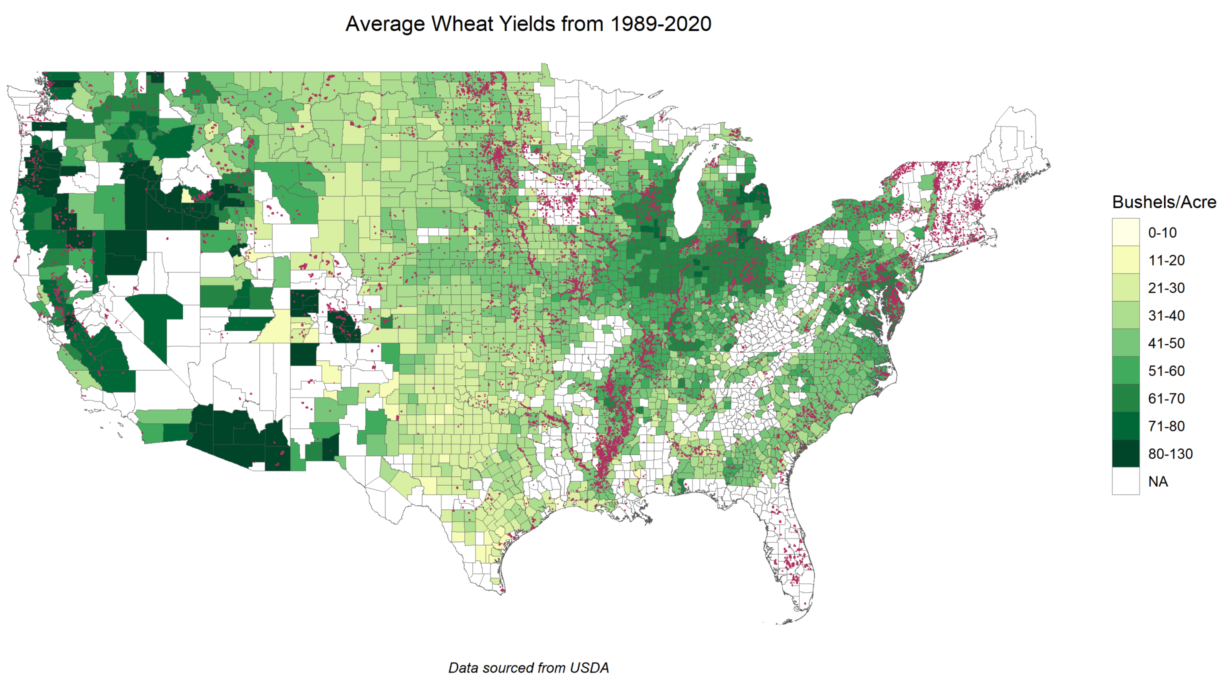


Figure 7: Map of wheat average yields and easements

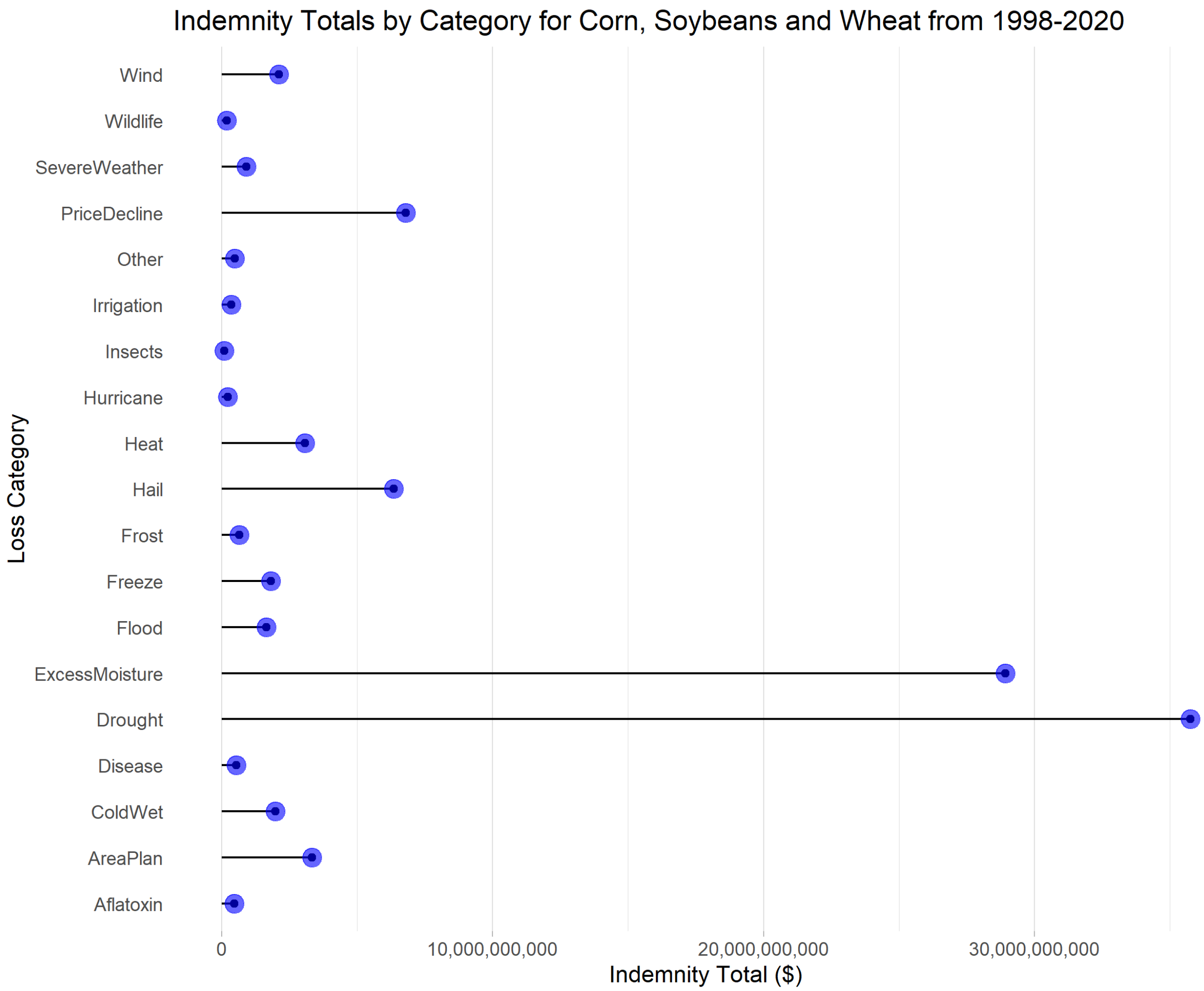


Figure 8: Indemnity Totals from 1989-2020

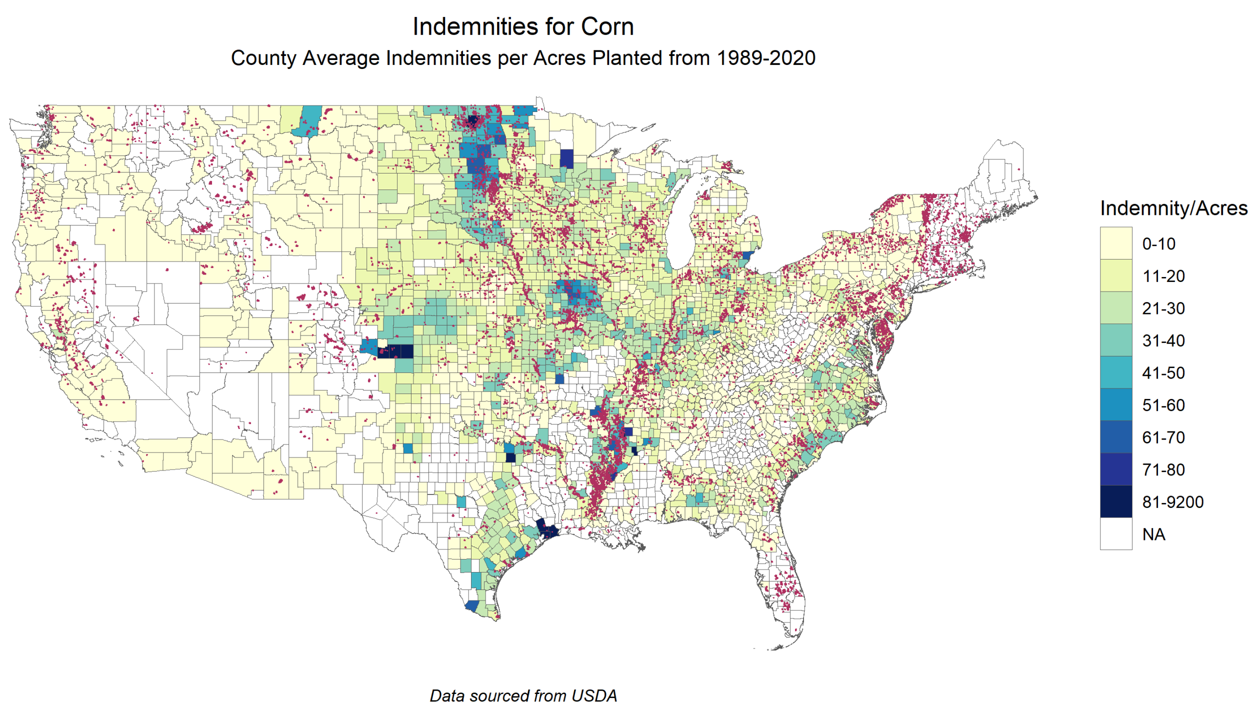


Figure 9: Indemnities per acre planted for corn and easements

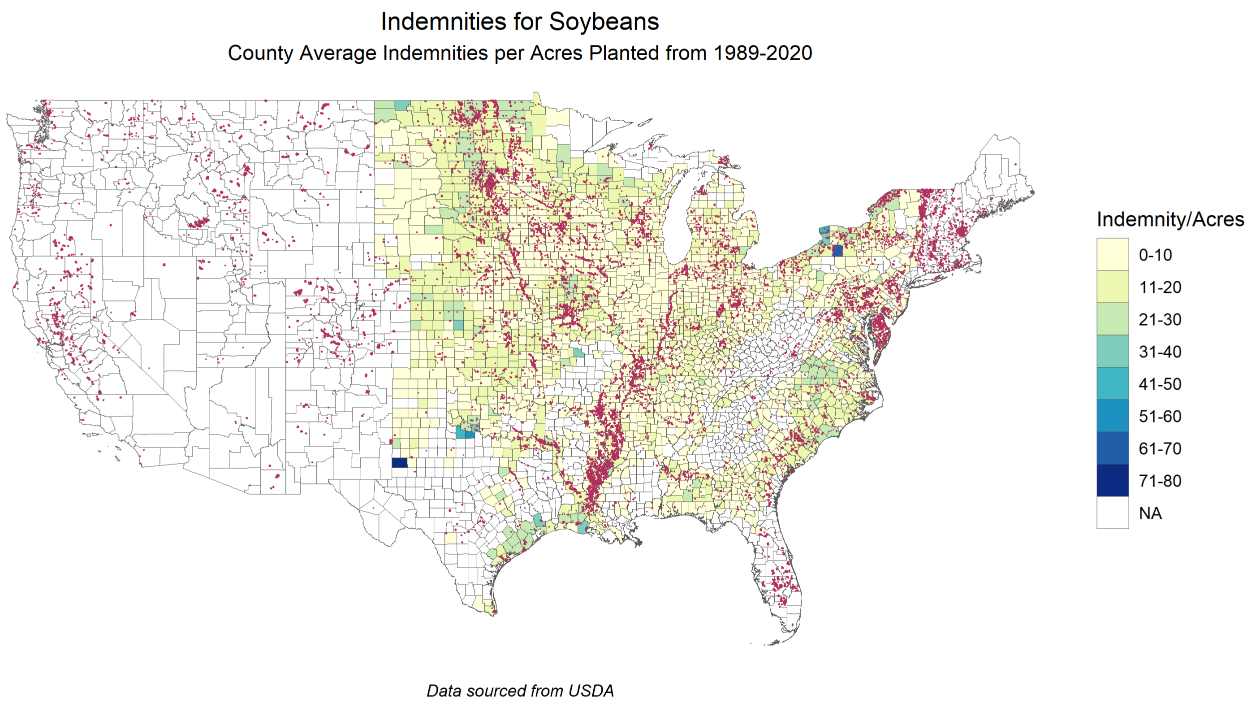


Figure 10: Indemnities per acre planted for soybeans and easements

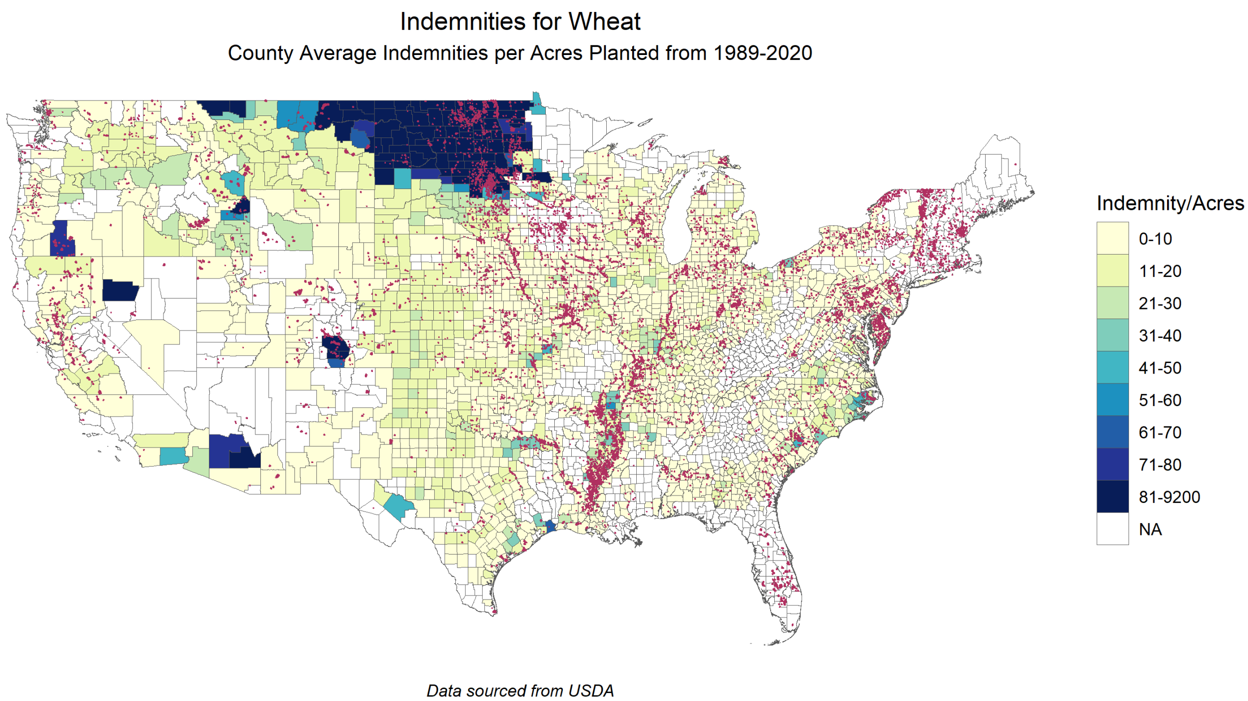


Figure 11: Indemnities per acre planted for wheat and easements

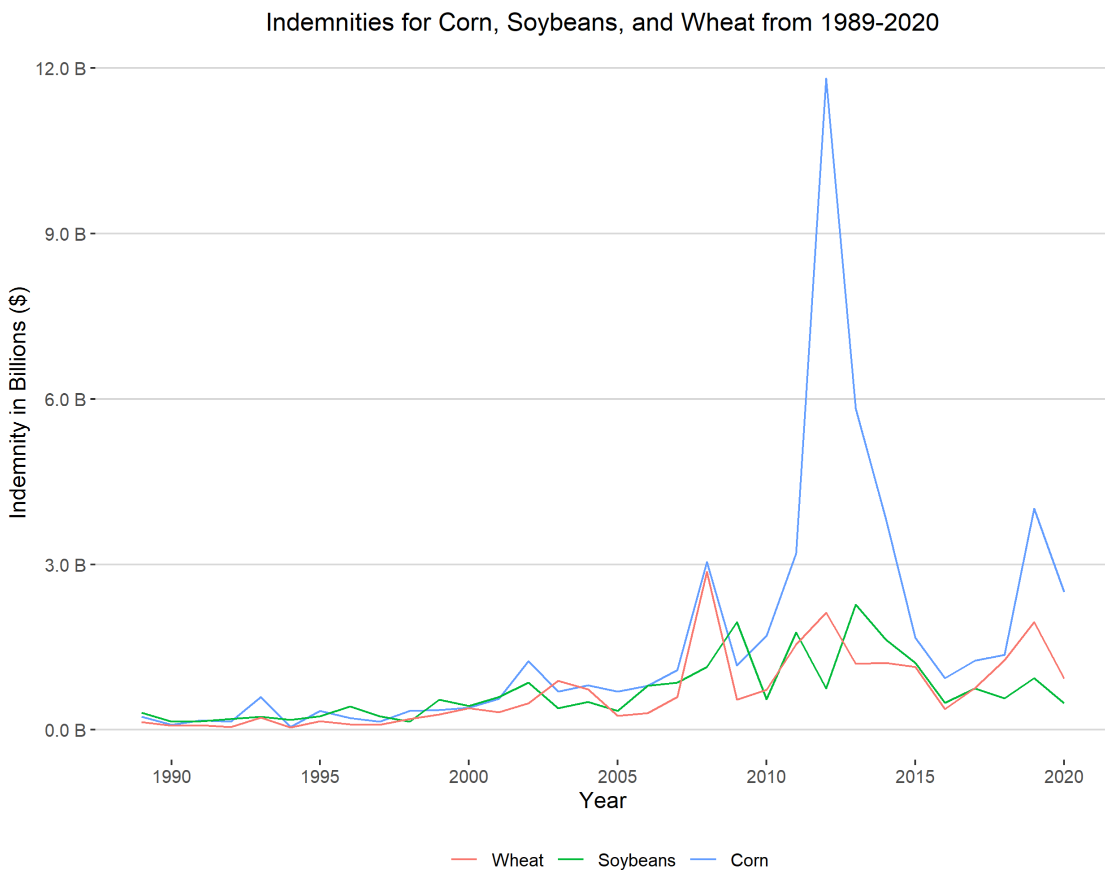


Figure 12: Indemnities over time by crop

Map of NASS Regions

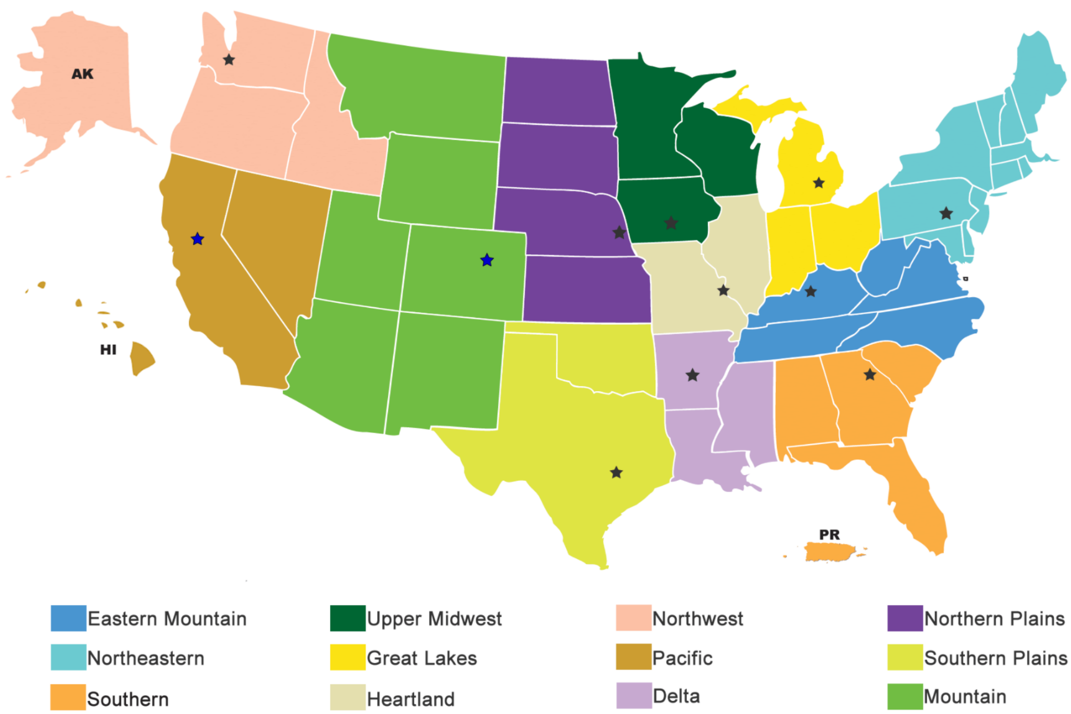
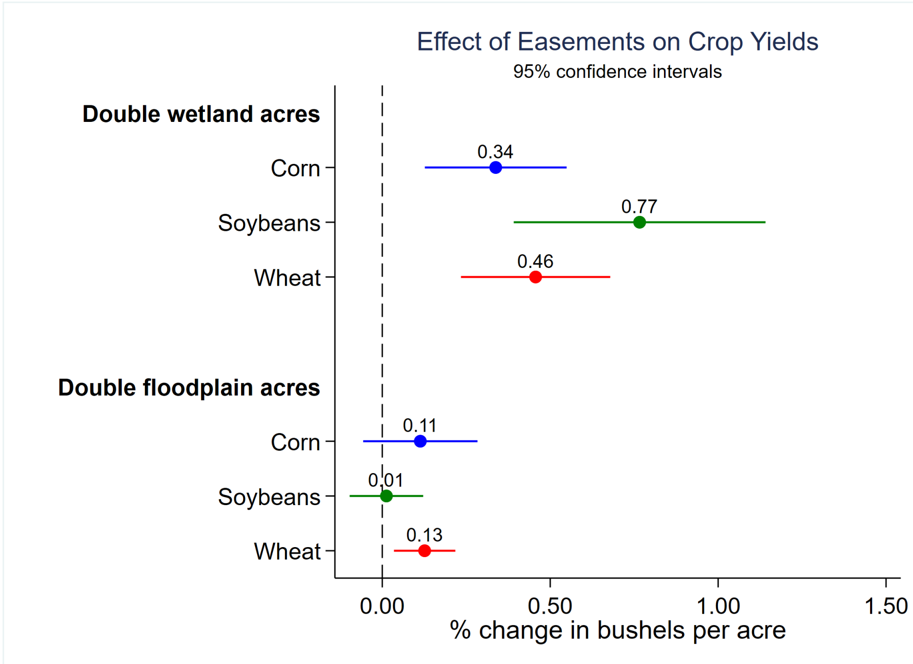
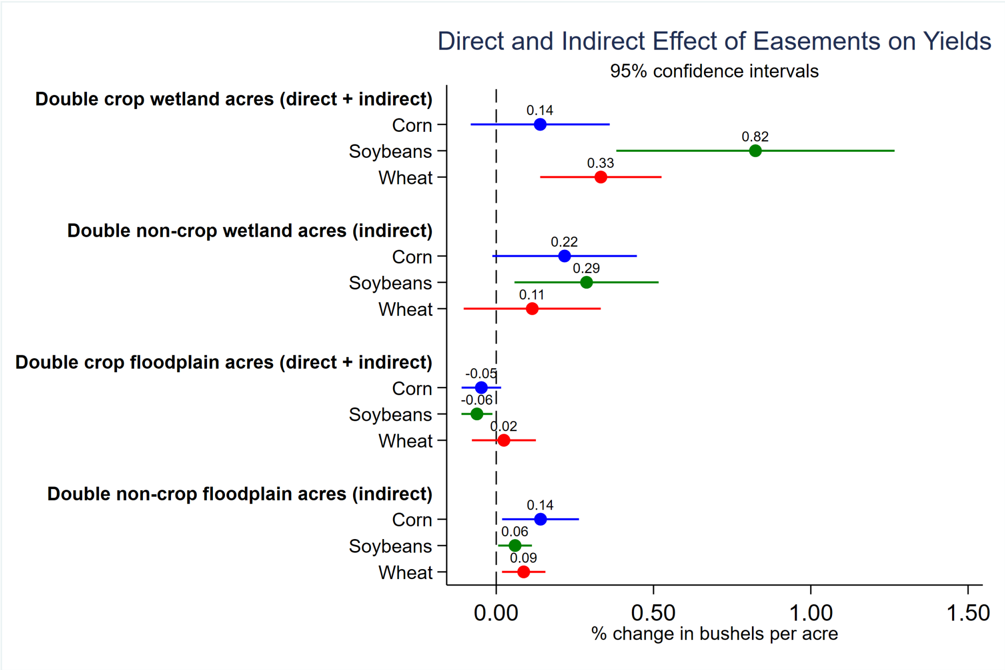


Figure 13: Map from USDA NASS of each region

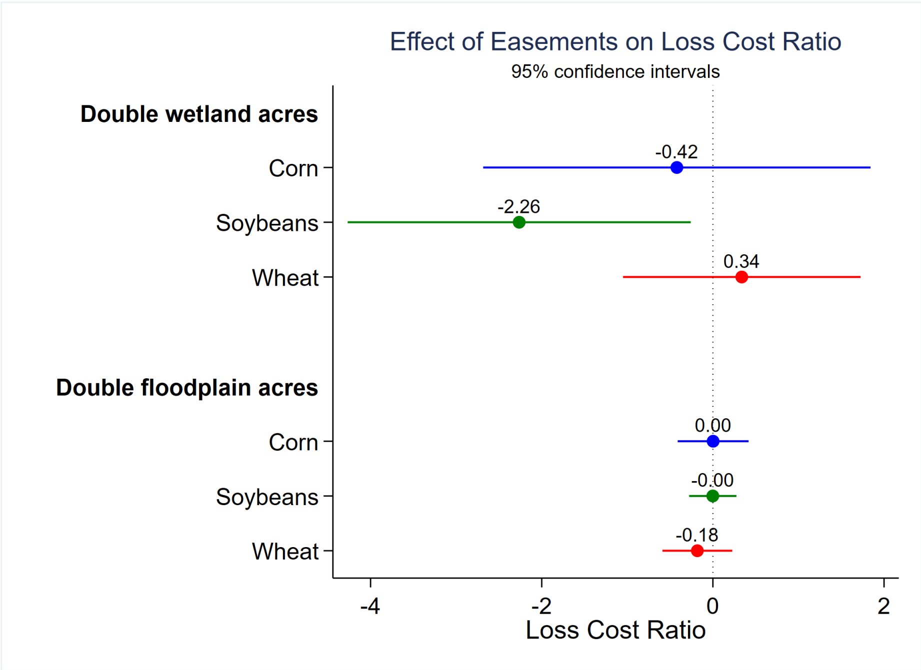
Results Plot 1



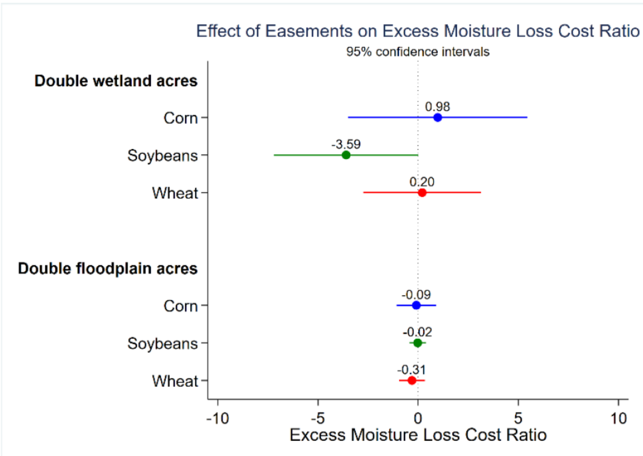
Results Plot 2

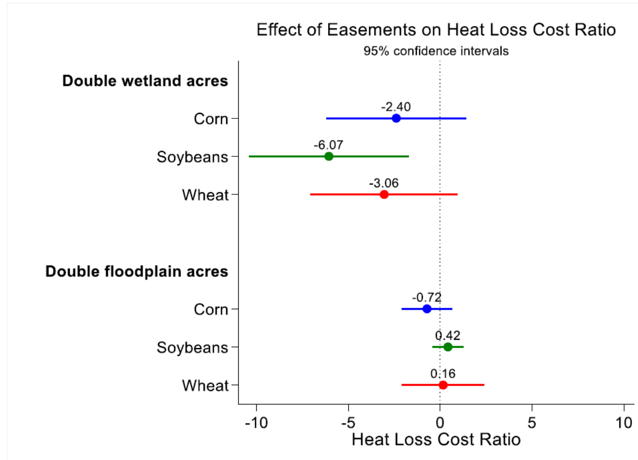


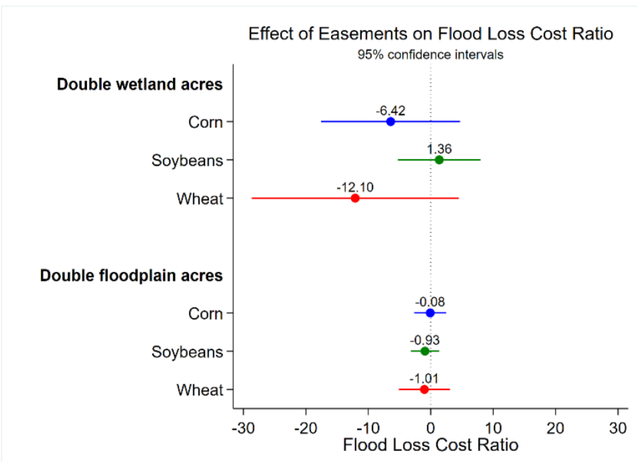
Results Plot 3

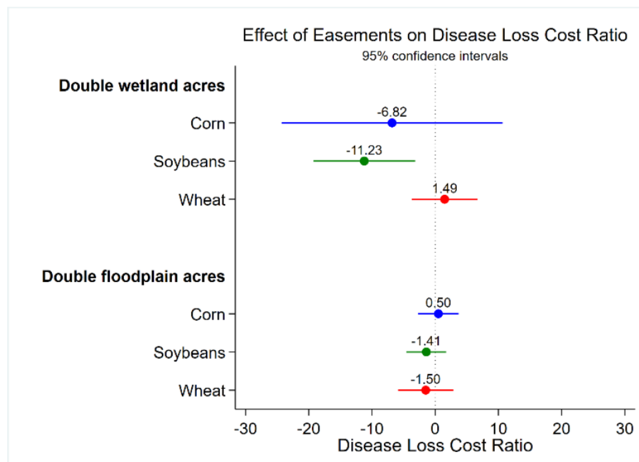


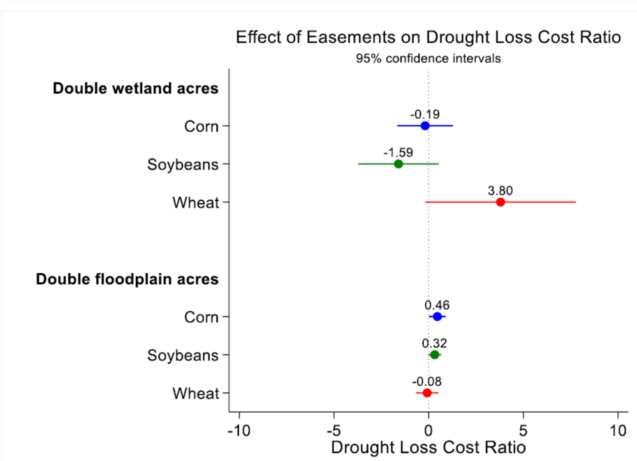
Results Plots 4

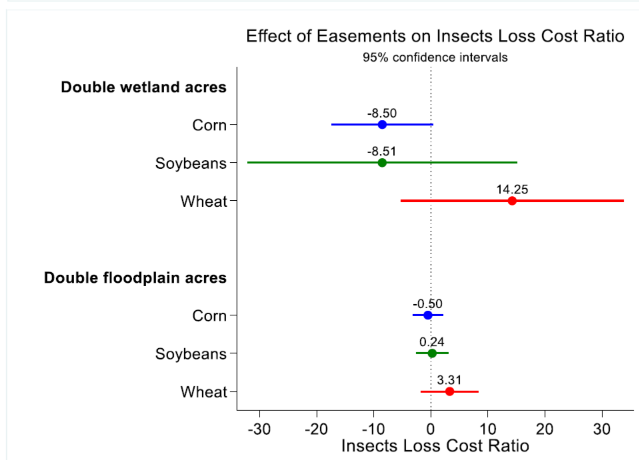




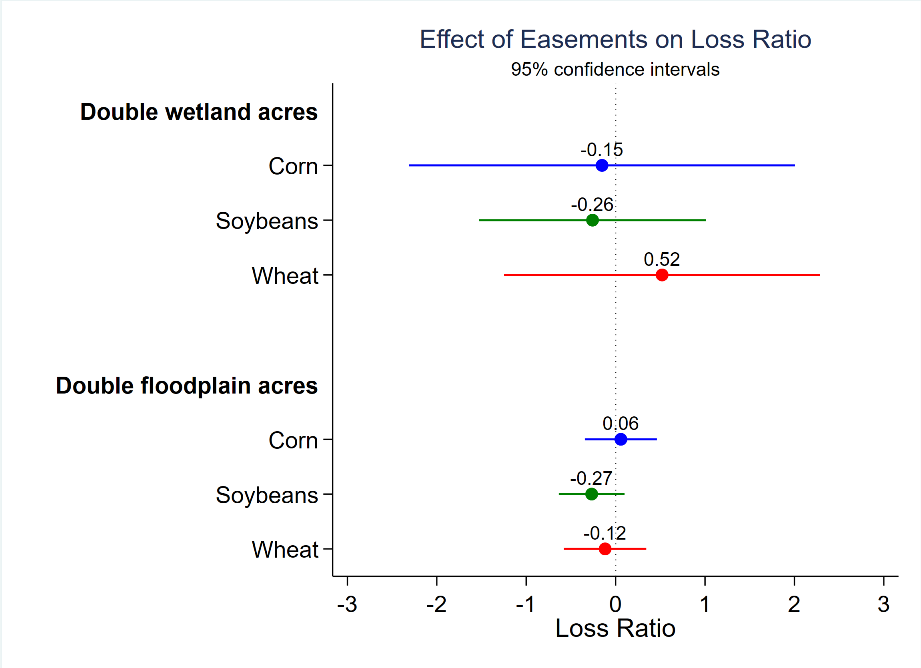




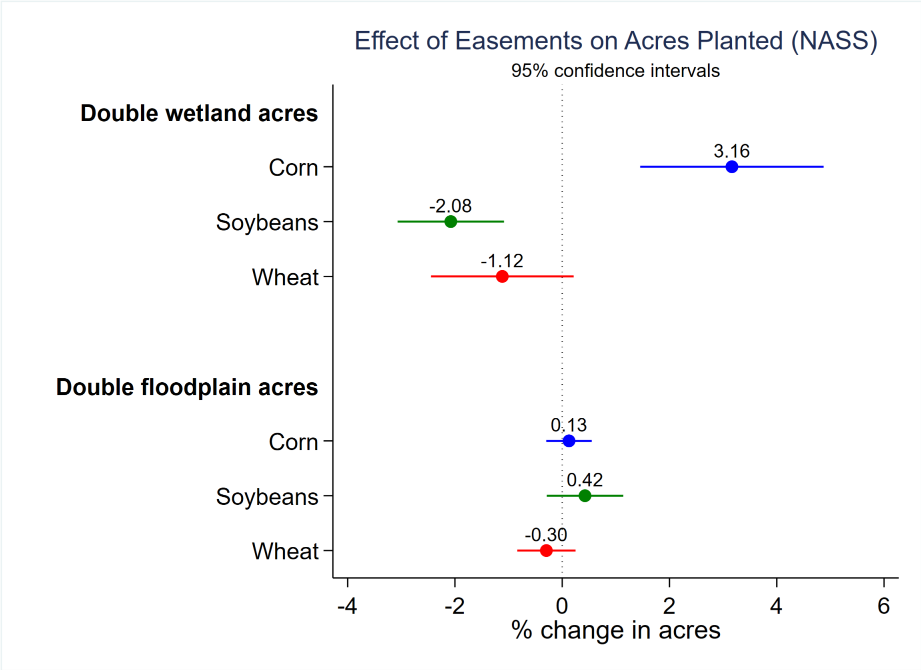




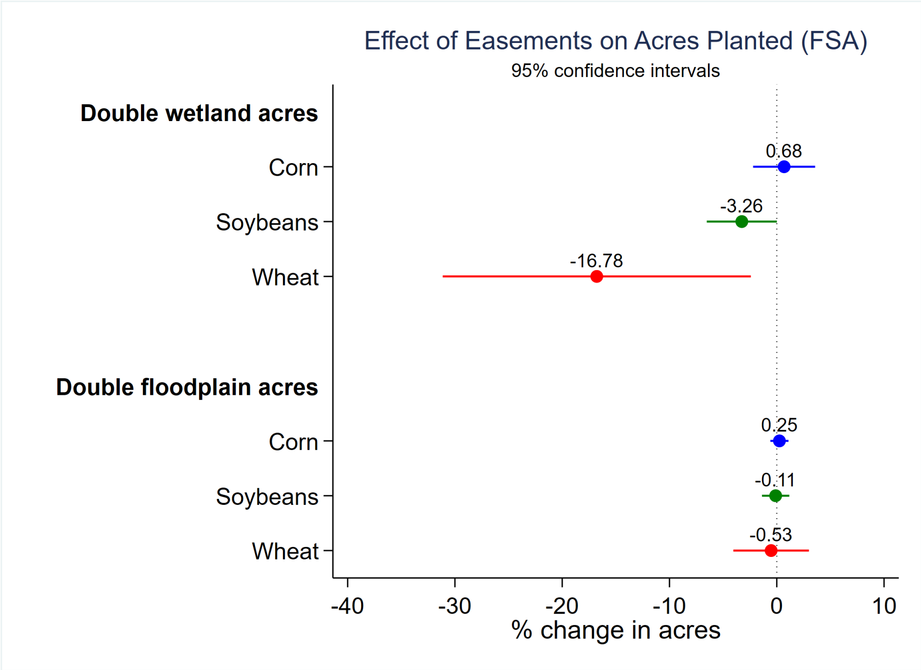
Results Plot 5



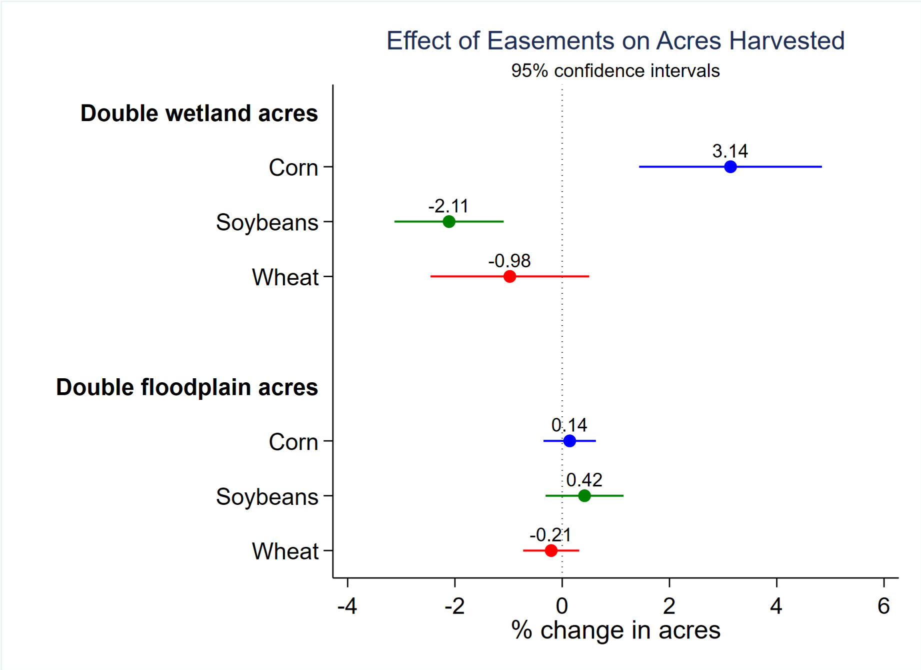
Results Plot 6



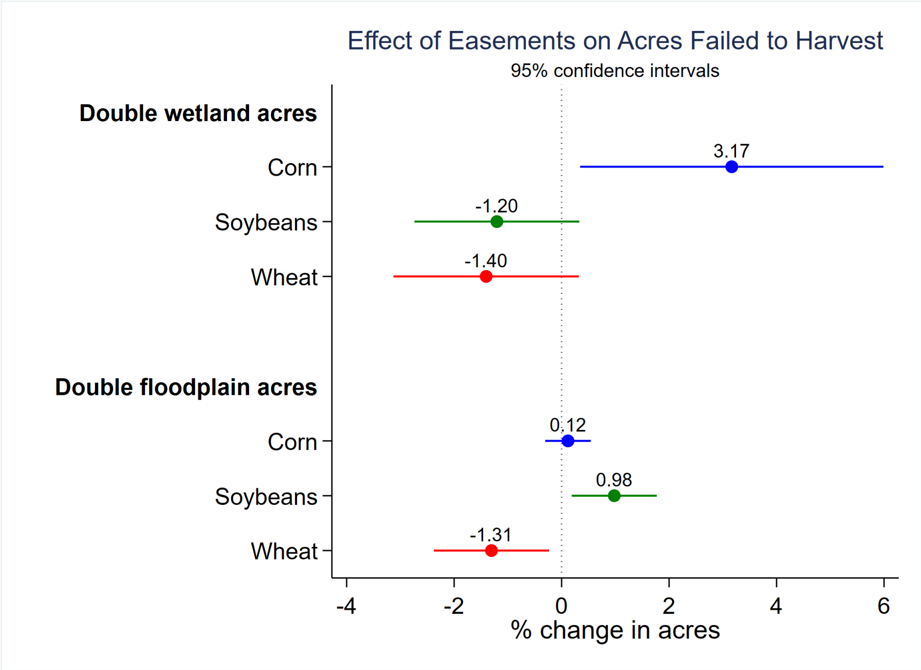
Results Plot 7



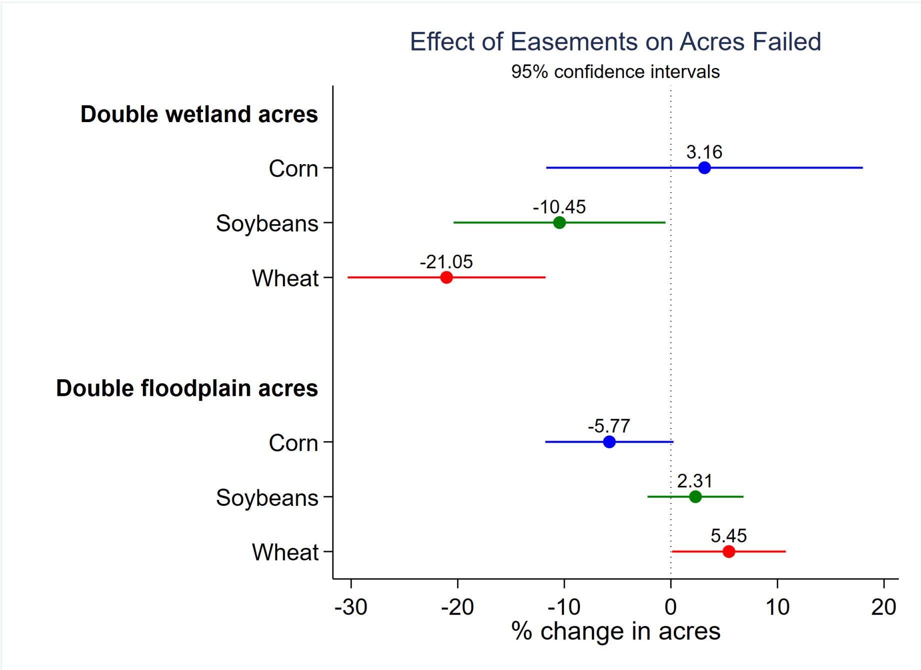
Results Plot 8



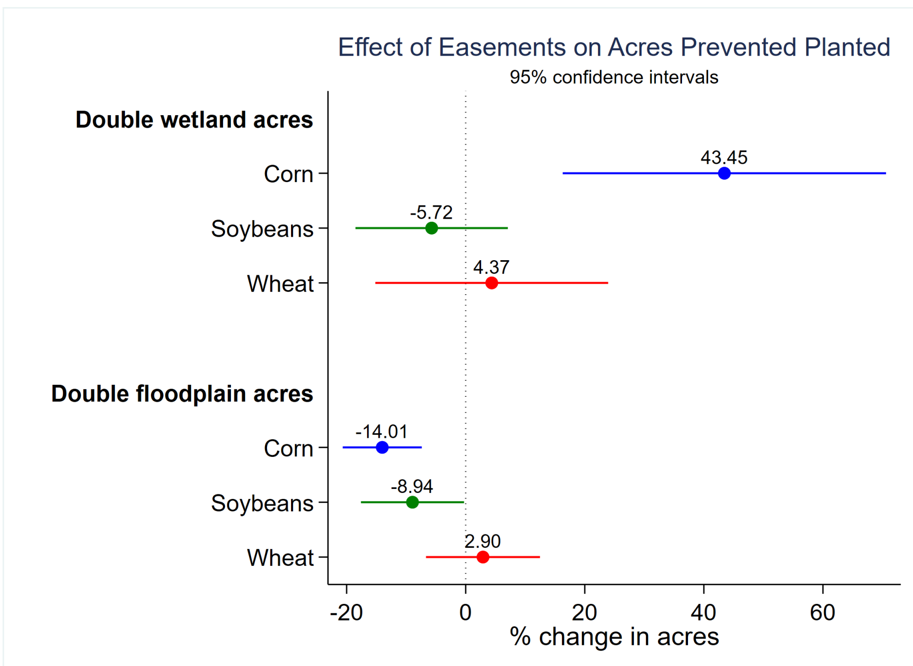
Results Plot 9



Results Plot 10



Results Plot 11



Results Table 1: Effect of Easements on Crop Yields (bushels/acre)

	(1)	(2)	(3)
	Corn yield	Soybean yield	Wheat yield
100% Wetland Easement Acres	0.338***	0.766***	0.457***
	(0.108)	(0.191)	(0.113)
100% Floodplain Easement Acres	0.113	0.012	0.126***
	(0.087)	(0.056)	(0.047)
Observations	50,261	45,836	34,818
Number of Counties	1,871	1,762	1,716
R-squared	0.449	0.486	0.315
County FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Controls	Yes	Yes	Yes

Note: Estimates are transformed to interpret results as elasticities.

Delta method used to calculate standard errors. *** p<0.01; ** p<0.05; * p<0.10

Results Table 2: Effect of Cropland/Non-cropland Easements on Crop Yields (bushels/acre)

	(1)	(2)	(3)
	Corn Yield	Soybean Yield	Wheat Yield
100% Crop Wetland Easement Acres	0.140	0.824***	0.333***
	(0.113)	(0.226)	(0.098)
100% Non-crop Wetland Easement Acres	0.217*	0.287**	0.115
	(0.117)	(0.117)	(0.111)
100% Crop Floodplain Easement Acres	-0.047	-0.061**	0.024
	(0.032)	(0.025)	(0.052)
100% Non-crop Floodplain Easement Acres	0.141**	0.060**	0.087**
	(0.062)	(0.027)	(0.035)
Observations	50,261	45,836	34,818
Number of Counties	1,871	1,762	1,716
R-squared	0.450	0.486	0.315
County FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Controls	Yes	Yes	Yes

Note: Estimates are transformed to interpret results as elasticities.

Delta method used to calculate standard errors. *** p<0.01; ** p<0.05; * p<0.10

Results Table 3: Effect of Easements on Loss Cost Ratio

	(1) Corn Loss Cost Ratio	(2) Soybean Loss Cost Ratio	(3) Wheat Loss Cost Ratio
100% Wetland Easement Acres	-0.421	-2.264**	0.337
	(1.155)	(1.023)	(0.708)
100% Floodplain Easement Acres	0.003	-0.001	-0.182
	(0.211)	(0.141)	(0.208)
Observations	44,905	42,869	37,830
R-squared	0.202	0.172	0.131
Number of Counties	1,775	1,664	1,603
County FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Controls	Yes	Yes	Yes

Note: Estimates are transformed to interpret results as semi-elasticities.

Delta method used to calculate standard errors. *** $p<0.01$; ** $p<0.05$; * $p<0.10$

Results Table 4: Effect of Easements on Loss Cost Ratios with Different Indemnity Causes

	(1) Corn Loss Cost Ratio	(2) Soybean Loss Cost Ratio	(3) Wheat Loss Cost Ratio
Excess Moisture			
100% Wetland Easement Acres	0.978	-3.594*	0.203
	(2.282)	(1.843)	(1.501)
100% Floodplain Easement Acres	-0.092	-0.023	-0.306
	(0.504)	(0.209)	(0.329)
R-squared	0.149	0.137	0.168
Flood			
100% Wetland Easement Acres	-6.415	1.359	-12.098
	(5.681)	(3.376)	(8.468)
100% Floodplain Easement Acres	-0.081	-0.929	-1.008
	(1.308)	(1.158)	(2.091)
R-squared	0.034	0.054	0.018
Drought			
100% Wetland Easement Acres	-0.188	-1.594	3.797*
	(0.751)	(1.084)	(2.029)
100% Floodplain Easement Acres	0.458**	0.317*	-0.082
	(0.221)	(0.175)	(0.303)
R-squared	0.300	0.291	0.063
Observations	44,905	42,869	37,830
Number of Counties	1,775	1,664	1,603
County FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Controls	Yes	Yes	Yes

Note: Estimates are transformed to interpret results as semi-elasticities.

Delta method used to calculate standard errors. *** p<0.01; ** p<0.05; * p<0.10

Results Table 4: Effect of Easements on Loss Cost Ratios with Different Indemnity Causes (Continued)

	(1)	(2)	(3)
	Corn	Soybean	Wheat
	Loss Cost Ratio	Loss Cost Ratio	Loss Cost Ratio
Heat			
100% Wetland Easement Acres	-2.397	-6.070***	-3.056
	(1.941)	(2.222)	(2.041)
100% Floodplain Easement Acres	-0.724	0.418	0.159
	(0.692)	(0.431)	(1.140)
R-squared	0.087	0.055	0.010
Disease			
100% Wetland Easement Acres	-6.822	-11.228***	1.488
	(8.920)	(4.116)	(2.649)
100% Floodplain Easement Acres	0.500	-1.409	-1.501
	(1.633)	(1.601)	(2.226)
R-squared	0.009	0.003	0.082
Insects			
100% Wetland Easement Acres	-8.502*	-8.512	14.251
	(4.555)	(12.054)	(9.961)
100% Floodplain Easement Acres	-0.504	0.244	3.312
	(1.321)	(1.419)	(2.556)
R-squared	0.005	0.004	0.019
Observations	44,905	42,869	37,830
Number of Counties	1,775	1,664	1,603
County FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Controls	Yes	Yes	Yes

Note: Estimates are transformed to interpret results as semi-elasticities.

Delta method used to calculate standard errors. *** p<0.01; ** p<0.05; * p<0.10

Results Table 5: Effect of Easements on Loss Ratio

	(1) Corn Loss Ratio	(2) Soybean Loss Ratio	(3) Wheat Loss Ratio
100% Wetland Easement Acres	-0.152	-0.258	0.520
	(1.101)	(0.648)	(0.902)
100% Floodplain Easement Acres	0.059	-0.267	-0.117
	(0.205)	(0.188)	(0.235)
Observations	44,905	42,869	37,830
Number of Counties	1,775	1,664	1,603
R-squared	0.225	0.194	0.150
County FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Controls	Yes	Yes	Yes

Note: Estimates are transformed to interpret results as semi-elasticities.
Delta method used to calculate standard errors. *** p<0.01; ** p<0.05; * p<0.10

Results Table 6: Effect of Easements on Planted Acres (NASS)

	(1)	(2)	(3)
	Corn Planted Acres	Soybean Planted Acres	Wheat Planted Acres
100% Wetland Easement Acres	3.164***	-2.076***	-1.117*
	(0.872)	(0.506)	(0.679)
100% Floodplain Easement Acres	0.127	0.425	-0.295
	(0.216)	(0.364)	(0.277)
Observations	50,276	45,838	34,831
Number of Counties	1,871	1,762	1,717
R-squared	0.092	0.152	0.236
County FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Controls	Yes	Yes	Yes

Note: Estimates are transformed to interpret results as elasticities.

Delta method used to calculate standard errors. *** p<0.01; ** p<0.05; * p<0.10

Results Table 7: Effect of Easements on Planted Acres (FSA)

	(1)	(2)	(3)
	Corn Planted Acres	Soybean Planted Acres	Wheat Planted Acres
100% Wetland Easement Acres	0.683	-3.260*	-16.777**
	(1.475)	(1.667)	(7.327)
100% Floodplain Easement Acres	0.246	-0.107	-0.526
	(0.431)	(0.650)	(1.797)
Observations	18,243	17,799	17,156
Number of Counties	1,785	1,706	1,653
R-squared	0.041	0.039	0.174
County FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Controls	Yes	Yes	Yes

Note: Estimates are transformed to interpret results as elasticities.

Delta method used to calculate standard errors. *** p<0.01; ** p<0.05; * p<0.10

Results Table 8: Effect of Easements on Harvested Acres (NASS)

	(1) Corn Harvested Acres	(2) Soybean Harvested Acres	(3) Wheat Harvested Acres
100% Wetland Easement Acres	3.138***	-2.109***	-0.976
	(0.870)	(0.520)	(0.755)
100% Floodplain Easement Acres	0.140	0.417	-0.205
	(0.249)	(0.371)	(0.267)
Observations	50,243	45,836	34,793
Number of Counties	1,871	1,762	1,713
R-squared	0.095	0.158	0.237
County FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Controls	Yes	Yes	Yes

Note: Estimates are transformed to interpret results as elasticities.

Delta method used to calculate standard errors. *** p<0.01; ** p<0.05; * p<0.10

Results Table 9: Effect of Easements on Failed Harvest Acres (NASS)

	(1) Corn Failed Harvest Acres	(2) Soybean Failed Harvest Acres	(3) Wheat Failed Harvest Acres
100% Wetland Easement Acres	3.166**	-1.204	-1.404
	(1.440)	(0.782)	(0.880)
100% Floodplain Easement Acres	0.119	0.979**	-1.305**
	(0.216)	(0.404)	(0.547)
Observations	50,242	45,836	34,79
Number of Counties	1,871	1,762	1,713
R-squared	0.046	0.053	0.054
County FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Controls	Yes	Yes	Yes

Note: Estimates are transformed to interpret results as elasticities.
Delta method used to calculate standard errors. *** p<0.01; ** p<0.05; * p<0.10

Results Table 10: Effect of Easements on Failed Acres (FSA)

	(1) Corn Failed Acres	(2) Soybean Failed Acres	(3) Wheat Failed Acres
100% Wetland Easement Acres	3.159	-10.445**	-21.045***
	(7.581)	(5.073)	(4.738)
100% Floodplain Easement Acres	-5.770*	2.309	5.447**
	(3.069)	(2.299)	(2.724)
Observations	18,243	17,799	17,156
Number of Counties	1,785	1,706	1,653
R-squared	0.074	0.026	0.066
County FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Controls	Yes	Yes	Yes

Note: Estimates are transformed to interpret results as elasticities.

Delta method used to calculate standard errors. *** $p<0.01$; ** $p<0.05$; * $p<0.10$

Results Table 11: Effect of Easements on Prevented Planted Acres (FSA)

	(1) Corn Prevented Planted Acres	(2) Soybean Prevented Planted Acres	(3) Wheat Prevented Planted Acres
100% Wetland Easement Acres	43.446***	-5.716	4.373
	(13.855)	(6.529)	(9.977)
100% Floodplain Easement Acres	-14.014***	-8.936**	2.904
	(3.387)	(4.418)	(4.885)
Observations	18,243	17,799	17,156
Number of Counties	1,785	1,706	1,653
R-squared	0.278	0.282	0.154
County FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Controls	Yes	Yes	Yes

Note: Estimates are transformed to interpret results as elasticities.

Delta method used to calculate standard errors. *** p<0.01; ** p<0.05; * p<0.10

Results Table 12: Effect of Easements on Yields through Weather Pathways

	(1)	(2)	(3)
	Corn Yield	Soybean yield	Wheat Yield
100% Wetland	5.4413**	-0.6018	0.7384
	(2.4398)	(1.9986)	(3.4051)
Moderate degree days	0.0066***	0.0061***	0.0029
	(0.0013)	(0.0017)	(0.0024)
x 100% Wetland	-0.0206*	-0.0002	-0.0019
	(0.0118)	(0.0087)	(0.0152)
Extreme degree days	-0.0145***	-0.0135***	-0.0006
	(0.0023)	(0.0025)	(0.0033)
x 100% Wetland	0.0035	0.0391***	0.0060
	(0.0110)	(0.0091)	(0.0145)
Precipitation (100mm)	0.0901***	0.1108***	0.0407**
	(0.0174)	(0.0180)	(0.0156)
x 100% Wetland	-0.5553***	0.0188	-0.0749
	(0.1941)	(0.1908)	(0.3379)
Precipitation squared (100mm)	-0.0066***	-0.0071***	-0.0051***
	(0.0012)	(0.0011)	(0.0012)
x 100% Wetland	0.0316**	-0.0019	0.0069
	(0.0124)	(0.0117)	(0.0261)
Observations	50,261	45,836	34,818
Number of Counties	1,871	1,762	1,716
R-squared	0.451	0.489	0.314
County FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

Note: Wetland easement estimates and interactions are transformed to interpret results as elasticities. Delta method used to calculate standard errors. *** p<0.01; ** p<0.05; * p<0.10

Results Table 13: Effect of Easements on Crop Yields by NASS Region

	Corn yield	Soybean yield	Wheat yield
Northeastern			
100% Wetland	-0.037	-0.003	-0.162
	(0.119)	(0.060)	(0.145)
100% Floodplain	-0.026	-0.013	-0.093***
	(0.026)	(0.016)	(0.015)
N	4,157	2,945	2,600
Eastern Mountain			
100% Wetland	0.038	0.058*	0.144**
	(0.046)	(0.034)	(0.061)
100% Floodplain	-0.046	0.041	0.113***
	(0.049)	(0.033)	(0.036)
N	9,362	8,069	6,890
Southern			
100%	-0.379	-0.288**	-0.059
	(0.328)	(0.117)	(0.154)
100% Floodplain	-0.096	0.005	-0.562***
	(0.064)	(0.007)	(0.030)
N	4,566	3,691	2,997
Great Lakes			
100% Wetland	-0.166	-0.047	0.113
	(0.132)	(0.104)	(0.190)
100% Floodplain	0.026	0.104***	0.040
	(0.032)	(0.018)	(0.052)
N	7,228	6,694	5,943
Upper Midwest			
100% Wetland	0.219	0.029	0.064
	(0.197)	(0.158)	(0.285)
100% Floodplain	0.092	0.033	0.164
	(0.089)	(0.041)	(0.206)
N	7,528	7,339	2,215
Heartland			
100% Wetland	0.378**	0.406**	0.301
	(0.147)	(0.169)	(0.309)
100% Floodplain	0.050	0.065**	-0.001
	(0.045)	(0.033)	(0.049)
N	5,791	5,787	5,023

Note: Estimates are transformed to interpret results as elasticities. Mean of each region is used. Delta method used to calculate standard errors. *** p<0.01; ** p<0.05; * p<0.10

Results Table 13: Effect of Easements on Crop Yields by NASS Region (Continued)

	Corn yield	Soybean yield	Wheat yield
Delta			
100% Wetland	0.034	1.839***	0.692
	(0.259)	(0.399)	(0.489)
100% Floodplain	-0.084	0.010	-0.063
	(0.084)	(0.151)	(0.101)
N	2,845	3,488	2,128
Northern Plains			
100% Wetland	0.969***	0.291*	1.367***
	(0.191)	(0.152)	(0.294)
100% Floodplain	0.395***	0.079	0.232***
	(0.111)	(0.066)	(0.083)
N	8,820	7,536	7,567
Southern Plains			
100% Wetland	-0.003	-0.237	1.037***
	(0.070)	(0.294)	(0.316)
100% Floodplain	0.031***	0.077***	0.003
	(0.005)	(0.009)	(0.029)
N	3,764	2,012	6,229
Mountain			
100% Wetland	1.076**	-	0.240
	(0.504)		(0.218)
100% Floodplain	0.319***	-	-0.033
	(0.079)		(0.057)
N	1,742	-	2,845
Northwest			
100% Wetland	-35.659**	-	0.369
	(15.949)		(0.399)
100% Floodplain	-2.974***	-	0.077
	(0.900)		(0.059)
N	721	-	2,088
Pacific			
100% Wetland	7.064*	-	0.021
	(4.053)		(0.954)
100% Floodplain	1.184	-	0.681**
	(0.854)		(0.286)
N	517	-	724

Note: Estimates are transformed to interpret results as elasticities. Mean of each region is used. Delta method used to calculate standard errors. *** p<0.01; ** p<0.05; * p<0.10

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