This PDF is a selection from a published volume from the National Bureau of Economic Research

Volume Title: American Agriculture, Water Resources, and Climate Change

Volume Authors/Editors: Gary D. Libecap and Ariel Dinar, editors

Volume Publisher: University of Chicago Press

Volume ISBNs: 978-0-226-83061-2 (cloth); 978-0-226-83062-9 (electronic)

Volume URL: https://www.nber.org/books-and-chapters/american-agriculture-water-resources-and-climate-change

Conference Date: May 12-13, 2022

Publication Date: December 2023

Chapter Title: Estimating the Effect of Easements on Agricultural Production

Chapter Author(s): Nicole Karwowski

Chapter URL: https://www.nber.org/books-and-chapters/american-agriculture-water-resources-and-climate-change/estimating-effect-easements-agricultural-production

Chapter pages in book: p. 53 – 105

2

Estimating the Effect of Easements on Agricultural Production

Nicole Karwowski

2.1 Introduction

Agricultural systems and food production are vulnerable to climate. Excess water poses a particular risk for agricultural production. In 2019, when above average precipitation inundated the eastern half of the country, the US experienced its record-wettest year to date (NOAA 2020). 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). Heavy precipitation and floods have caused catastrophic damage to US crop production and profits (Rosenzweig et al. 2002; NOAA 2023). The scientific literature has identified that regional rainfall patterns are already changing, and that we can expect more frequent occurrences of climate extremes, and ultimately, higher flood risk in certain regions (Urban et al. 2015). Studies consistently show lower crop yields and higher losses attributed to a changing climate, and that these losses are expected to increase in frequency and severity (Schlenker and Roberts 2009; Deschênes and Greenstone 2012; IPCC 2012; Rosenzweig et al. 2014; NOAA 2023; Perry et al. 2020). Finding strategies to deal with increased precipitation and flooding under future climate change is critical for mitigating climate risks.

Here, I evaluate the adaptation benefits of some of the largest conservation programs in the United States. The Natural Resources Conservation

Nicole Karwowski is a PhD candidate in Agricultural and Applied Economics at the University of Wisconsin-Madison.

For acknowledgments, sources of research support, and disclosure of the author's material financial relationships, if any, please see https://www.nber.org/books-and-chapters/american-agriculture-water-resources-and-climate-change/estimating-effect-easements-agricultural-production.

Services (NRCS) of the US Department of Agriculture (USDA) offers voluntary buyouts through the Wetlands Reserve Program (wetland easements) and Emergency Watershed Protection Program (floodplain easements). In 2020, there were approximately 3 million acres of eased wetlands and 185,000 acres of eased floodplains in the US. These programs buy out land from farmers through easements contracts. The farmer retains ownership of the land and receives a lump-sum transfer to forgo the right to plant crops on that field in perpetuity. Eased land is then restored to its natural floodplain or wetland state. 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. Land restoration is hypothesized to provide flood protection by storing water and acting as natural buffers for nearby developed land.

Using over 30 years of national data and a two-way fixed effects strategy, I quantify the impacts of the wetland and floodplain easement programs on agricultural production at the county level. I focus on rainfed, non-irrigated counties producing corn, soybeans, and wheat. I discover that a 100 percent increase in wetland easement land share increases county yields by 0.34 percent, 0.77 percent, and 0.46 percent for corn, soybeans, and wheat. I find that easements decrease risk for soybeans: doubling wetland easement land share reduces indemnities 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. To better understand the drivers of these effects, I interact easement acreage with measures of precipitation and degree days to understand the weather pathways through which easements provide adaptive benefits. Wetland easement land share attenuates the impact of extreme degree days for soybeans and excess precipitation for corn. My results indicate that these easement conservation programs can serve a critical role in mitigating climate risk.

I also identify the potential channels through which easements impact agricultural outcomes. I estimate the effect of easements on acres planted, acres failed, and acres prevented planted to understand the underlying mechanisms changing yields and risk. Easements impact agricultural production in three main ways: removing marginal land from production (direct effect), improving yields on surrounding cropland (indirect effect), and by changing the cultivation choices of producers (slippage effect).

Easements lead to the retirement of cropland from production permanently. Easements also include non-cropland to create a more effective habitat. Easing cropland mechanically improves the average county-level yields for commodities, since the lowest yielding land is no longer cropped. There is also some evidence of a positive yield externality: wetland and floodplain habitats improve yields on surrounding croplands. I parse out the direct and indirect effect in my data by estimating how cropland and non-cropland easement land share impacts yields. Doubling cropland in the wetland program directly improves soybean yields by 0.82 percent and wheat yields by 0.33 percent, while doubling non-cropland indirectly improves corn yields by 0.22 percent and soybean yields by 0.29 percent. There is also evidence of an indirect floodplain yield effect: doubling non-cropland in the floodplain program increases corn, soybean, and wheat yields by 0.14 percent, 0.06 percent, and 0.09 percent. Easement habitats offer flood buffer protection to surrounding agricultural fields. It may also be the case that producers re-optimize their inputs and production strategies on their non-eased land and this improves producer-level yields.

Producers switch their production away from soybean and wheat toward corn. Easing land may encourage farmers to continuously crop corn on their remaining fields or alternatively convert non-cropland into corn cropland. There is a 2 percent decrease in soybean acres planted and 1 percent decrease in wheat acres planted as expected with a doubling of wetland easement land share. Surprisingly, planted acreage for corn increases by 3 percent after a 100 percent increase in wetland easement land share. A similar slippage effect has been found for the Conservation Reserve Program (CRP) (Wu 2000; Fleming 2014; Uchida 2014) and other conservation programs (Lichtenberg and Smith-Ramírez 2011; Pfaff and Robalino 2017). Learning that easements impact cultivation choices for producers may have implications for the sustainability benefits of the program. Continuous corn cropping tends to be more profitable for farmers but also associated with yield penalties and worse environmental outcomes (Seifert, Roberts, and Lobell 2017). This slippage effect may offset some of the ecosystem benefits of easements.

I find mixed results regarding how easements impact acres failed to harvest, failed, and prevented planted. The slippage story may help explain why easements have an insignificant or even positive impact at times on harvest failure and prevented planting. Based on National Agricultural Statistics Survey (NASS) data analysis, conditional on failure occurring, increasing wetland acres by 100 percent in a county is associated with a 1.67 percent increase in corn harvest failure, and −1.19 percent and −1.38 percent change in soybean and wheat acres failed to harvest. Meanwhile, doubling floodplain easement acreage results in a 1.66 percent increase in acres failed to harvest for soybean crops and 0.83 percent decrease for wheat crops. Using a decadal panel of data from the Farm Service Agency (FSA), I find that wetland acres decrease acres failed for soybeans by over 10 percent and for wheat by over 21 percent. Floodplain easements during this time reduce corn acres failed by 5.77 percent yet increase wheat acres failed by 5.45 percent. When examining incidences of acres prevented planted, wetland acres actually increase corn acres prevented planted by 43 percent. On the other hand, floodplain easement doubling reduces corn acres prevented planted by 14 percent and soybean acres prevented planted by 8.94 percent. These mixed findings suggest that further examination of how easements impact acreage outcomes is warranted.

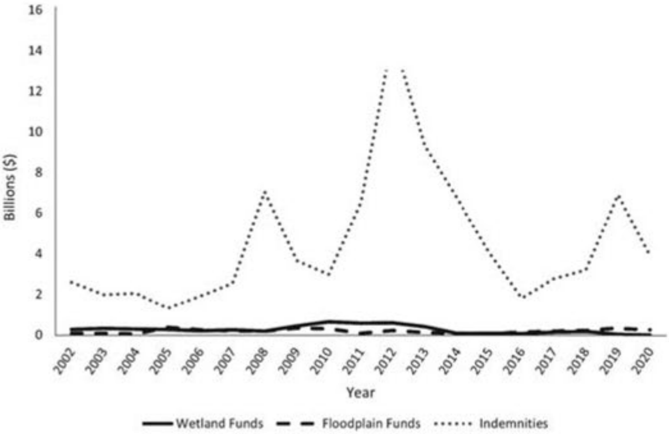

Fig. 2.1 Spending comparison of NRCS easement programs and crop indemnities

NRCS floodplain and wetland easements account for only 0.01 percent of land in the US, while 40 percent of land is used for agricultural purposes. From 2002 to 2020, the NRCS spent US$4.9 billion and US$3.4 billion 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 US$85.9 billion. Figure 2.1 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 economic 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. There may also be changes in producer input allocation and cultivation strategies that lead to yield gains.

This paper documents the effects and externalities of the easement programs on agricultural production. 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 agricultural resilience. 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. In a back-of-the-envelope cost-benefit analysis, I find that doubling wetland easement land share is cost effective and yield benefits exceed US$7 billion.

My work contributes 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 and Schlenker 2015); technology (Goodwin and Piggott 2020); planting date adjustments (Kucharik 2008; Zipper, Qiu, and Kucharik 2016); cultivar selection (Sloat et al. 2020; Hagerty 2021); irrigation (Hornbeck and Keskin 2014); and conservation practices (Schulte et al. 2017; Fleckenstein et al. 2020). My work adds to this literature by shedding light on the ex-post effects of easements as well as the implications of conservation programs in a world with higher temperatures and more frequent, extreme weather events.

There is a burgeoning literature focused 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 (Heimlich 1994; Wu, Zilberman, and Babcock 2001; Costello and Polasky 2004; Newburn, Berck, and Merenlender 2006; Gelso, Fox, and Peterson 2008; Fleming, Lichtenberg, and Newburn 2018). Others quantify benefits by estimating how additional wetland and floodplain acreage impact property damages from flooding (Watson et al. 2016; Gourevitch et al. 2020; Taylor and Druckenmiller 2022). There are some smaller field-level/regional studies as well as anecdotal evidence of the ecosystem benefits of the NRCS easement programs (NRCS 2011; Mushet and Roth 2020). Yet there remains a gap in understanding the effects of these easement programs on agricultural outcomes at a broader level. I contribute the first work at a national scale over the entire duration of the program life span.

Another vein of the conservation literature examines the relationship between prices and easement quantity and quality. Many studies measure the impact of easements on land sales prices (Brown 1976; Shoemaker 1989; Nickerson and Lynch 2001; Shultz and Taff 2004; Kousky and Walls 2014; Lawley and Towe 2014). These works consistently find that the land discount on eased land adequately captures the forgone agricultural profits. A complementary literature uses auction modeling techniques to estimate the reservation value of retiring land from agricultural production (Kirwan, Lubowski, and Roberts 2005; Ferraro 2008; Brown et al. 2011; Narloch, Pascual, and Drucker 2013; Hellerstein, Higgins, and Roberts 2015; Boxall et al. 2017). These studies look at how easements impact prices; Parker and Thurman (2018) quantify how tax incentives (price benefits) influence easement growth and conservation land quality. My paper looks beyond the easement quantity-price relations and reveals program externalities including yield spillovers and changes in cultivation choices.

Quantifying the effect of easements on agricultural systems has implications for climate change adaptation policy, land value estimates, and conservation cost-benefit analyses. 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 2.2 includes a discussion on program background, the relationship between climate and agriculture, and the role of insurance. Section 2.3 lays out the theoretical framework. Sections 2.4 and 2.5 present the data and empirical models respectively. Section 2.6 covers empirical results and discusses their implications. Section 2.7 summarizes the main findings. The results tables are in the appendix, and the coefficient plots are in an online appendix.[1]

2.2 Background

2.2.1 What Is an Easement?

The NRCS floodplain easement and wetland restoration programs allow agricultural producers to retire frequently flooded land from agricultural use. Producers apply to the program and, if selected, receive a lump-sum payment to forgo the right to crop on that field. The easement contract grants the NRCS surface rights and the right to restore the land. The landowners retain ownership and pay property taxes on the land. Landowners are also granted the rights to control public access, quiet enjoyment, and recreational use such as hunting and fishing.There is also a possibility of authorizing compatible use activities (CUA) such as cropping certain commodities, timber harvest, grazing or periodic haying when consistent with long-term enhancement of the easement functions and values. Easements often occur on lower-yielding land that is costly to manage and at higher risk of losses. Easements remove marginal land from production by increasing the opportunity cost of operating in high-risk areas for producers.

The NRCS strives to maximize the environmental benefits of easements. 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 2021c). 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 NRCS pays for the majority of the restoration and carries it out themselves.

1. See http://www.nber.org/data-appendix/c14694/appendix.pdf

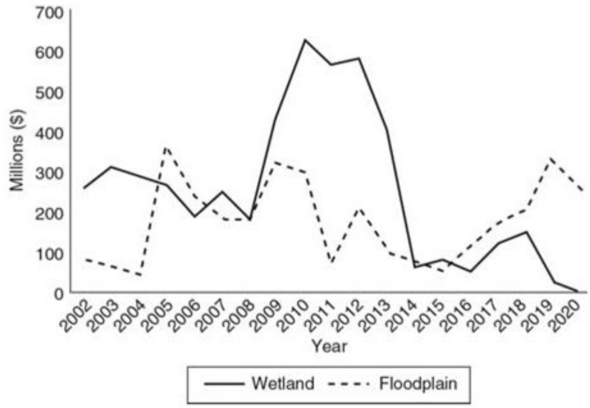

Fig. 2.2 NRCS wetland and floodplain program funding over time

The restoration process includes removing structures that impede water flow, removing or breaking tiling, building topographic features such as ridges and swales, and planting native vegetation. Wetland and floodplain easements retain water within a watershed and impact flood patterns in the area.

The NRCS pays the landowner for the right to restore the land. After ranking and selecting the optimal parcels, the NRCS offers the producer compensation that the producer can choose to accept or not. Easement compensation 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 cap (GARC), which stems from a market survey of cropland in the area. Landowners rarely posit a voluntary offer. Based on interviews with policy directors, it is most often the case that farmers who are not selected continue to crop on the land. Easement programs directly reduce insurance spending on future crop losses, since farmers would have continued farming otherwise.

The amount of easement projects selected depends on the individual state budget for each program. The easement programs are funded federally, but each state NRCS department oversees 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. Figure 2.2 demonstrates trends in funding from 2002 to 2020. Wetland and floodplain funding experience a sharp increase in 2009 and for a few years afterwards; the American Recovery and Reinvestment Act included stimulus spending for agricultural programs to counter the 2008 recession.

These easement programs date 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 2021b). 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 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.

Easement programs have gone through multiple names and iterations. NRCS wetland restorations have been offered under the Emergency Wetlands Reserve Program, Wetlands Reserve Program, and Agricultural Conservation Easement Program for Wetlands Reserve Easements. The Emergency WRP was established in 1993 and became today's floodplain easement program (Hebblethwaite and Somody 2008). The Emergency WRP Program was funded after receiving emergency appropriations following severe flooding in the Midwest in the 1990s. This study includes all these easement types.

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. Ranking criteria include drainage conditions, portion of hydric acres, protection potential of certain species, adjacency to other conserved areas and wetlands, and water quality improvement estimates. 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. Ranking 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.

Wetlands and floodplains—both natural and man-made—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, Laubhan, and Euliss 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 and Herlihy 2014; Roley et al. 2016; Sonnier et al. 2018; Speir, Tank, and Mahl 2020). 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 show that easements have been successful in supporting habitat and biodiversity, pollution management, surface water and floodwater containment, greenhouse gas emission management, and water sustainability (NRCS 2011, 2012; Hansen et al. 2015; Mushet and Roth 2020).

2.2.2 How Do Climate and Weather Impact Crop Production?

There is a large body of knowledge explaining how weather patterns and underlying climate impact crop production (Wing, De Cian, and Mistry 2021; Ortiz-Bobea 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 and Roberts 2009). Heat stress adversely affects plant development, pollination, and reproductive processes (Hatfield and Prueger 2015). Extreme temperatures coupled with water scarcity—drought conditions—can also reduce productivity. Decreased soil moisture 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 US, 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). Excess spring moisture reduces yields by 1–3 percent yearly, but these losses can range up to 10 percent during extremely wet springs (Urban et al. 2015). 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, Park, and Yun 2022). Delayed planting increases production costs and risk by shortening the growing season as well as exposing crops to late-season freezes. In 2019, heavy precipitation led to a record 19 million acres prevented planted (English et al. 2021). Excess rain can also be harmful later in the season. If there is an abundance of water, flooding destroys 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 increases uncertainty and reduces 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 topsoil altogether.

Both heat and water stress can indirectly lead to losses by making crops prone to disease and insects (Deutsch et al. 2018; Jabran, Florentine, and Chauhan 2020). 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 increased 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).

Easements have the adaptation potential to improve agricultural resiliency, especially in the face of a changing climate. Escalating temperatures and extreme weather events make easing land a more lucrative option for producers. Easing marginal land that is at high risk of losses offsets climate-caused indemnities. Insurance premiums, subsidies, and indemnities are expected to increase (Tack, Coble, and Barnett 2018). Easements provide one potential pathway to reducing agricultural risk by reallocating land and improving the resiliency of land remaining in agricultural production.

2.2.3 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. Glauber (2013) provides a thorough history of crop insurance. The government typically subsidizes 60 percent of a producer's premiums in addition to offering assistance after natural disasters (Congressional Budget Office 2019). There are more than 290 million acres insured in the US, which account for more than 80 percent of acres planted. In 2020, MPCI insured nearly US$110 billion in liability and cost taxpayers US$6.4 billion in premium subsidies and US$1.5 billion in delivery costs (Goodwin and 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 prices, but are more expensive. 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 yield states. 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 percent in 5 percent increments. A minimal amount of acreage in the US is covered at the 50 percent level.[2] 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 as a deductible. For example, a policy with an 80 percent coverage level insures against yield losses greater than 20 percent of the liability but does not provide indemnities for losses that total less than 20 percent of the liability.

To set insurance rates and premiums, the Risk Management Agency (RMA) uses a loss cost ratio (LCR) approach.[3] 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 (LR) is the proportion of indemnities to the premiums paid by a producer. The loss ratio represents the actuarial fairness of the insurance policy. 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

2. 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 percent of average historical yields at a payment rate of 55 percent 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 20 years.

3. The history and details of how rates and premiums are devised are laid out in detail in the Federal Crop Insurance Primer (Congressional Research Service 2021) and other academic papers (Schnapp et al. 2000; Woodard, Sherrick, and Schnitkey 2011).

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 a state excess load.

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 are hard to interpret. Using the loss cost ratio and loss ratio has been gaining popularity because these measures capture the risks of individual producers. For example, Perry, Yu, and Tack (2020) use the loss cost ratio when estimating how warming impacts the agricultural risk of corn and soybeans. Goodwin and Piggott (2020) use the loss cost ratio and loss ratio when analyzing 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 and Lichtenberg 1993; Smith and Goodwin 1996; Coble et al. 1997; Glauber 2004; Kim and Kim 2018; Yu and Sumner 2018; Yu and Hendricks 2020; Wu, Goodwin, and Coble 2020). Moral hazard occurs since producers act in ways that are more risky, as they do not take on the full cost of the risks. In the easements context, insurance presents 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 but 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. The farmer could change the coverage levels on their remaining agricultural fields. Other potential risk-altering behavior could include changes in cultivation decisions, changes in acres planted, or changes in fertilizer, pesticide, and herbicide application.

2.3 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 the farmer and the conservation agent. The farmer chooses the share of land to enroll in an easement program in order to maximize profits. The conservation agent chooses which land to ease and implicitly sets the price of easements. The conservation agent maximizes the environmental benefits of the land. I add to the framework by considering the role of insurance. This is a one-period model that does not consider leaving the land fallow or the option value of waiting to ease. For a more comprehensive theoretical framework on the easement decision-making process that considers dynamics, see Miao et al. (2016).

I start by considering L field parcels that are denoted by l_i. Each field is the same size and $i = 1, 2, \ldots, L$. 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.

2.3.1 Farmer's Problem

The farmer aims to increase profits by making land use decisions that will maximize income. The farmer with L land parcels determines what to do with each field l_i. The farmer can put field l_i into agricultural production ($a_i = 1$) or enroll the land into the easement program ($e_i = 1$).

For each field in agricultural production, the farmer makes a profit based on the commodity price (p), yield (y_i), and cost (c_i), where $\pi_i = py_i - c_i$. The yield can be high or low depending on whether an extreme weather event occurs. The probability of a disaster occurring on a field is f_i. If there is no disaster, yields are y_i. If there is a disaster such as a flood or drought, yields are $\delta_i y_i$ where $\delta_i \in (0, 1)$. The producer insures their fields against the risk of a disaster by paying a premium that is included in the cost function, c_i. The producer pays the cost of insurance in the event that there is a flood or not. The insurance company covers α of the expected yield value, and the coverage level is the same for each field $\alpha \in (0.5, 0.9)$. When a disaster does occur, the producer receives an indemnity payment: $m_i = p(\alpha y_i - \delta_i y_i)$. The indemnity payment is the commodity price multiplied by the difference between the covered yields in the non-disaster state and the yields in the disaster state. The expected agricultural profits on field i for the producer is the weighted sum of the income in the non-disaster and disaster state.

(1) $$\mathbb{E}(\pi_i) = \underbrace{(1 - f_i)(py_i - c_i)a_i}_{\textit{profit in non-disaster state}} + \underbrace{f_i(p\delta_i y_i + m_i - c_i)a_i}_{\textit{profit in disaster state}}$$

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, $a_i + e_i \leq 1$ 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. To solve the farmer's problem, I set up a Lagrangean and take first-order conditions.

(2) $$\max_{a_i, e_i} \sum_i^L (1 - f_i)(py_i - c_i)a_i + f_i(p\delta_i y_i + m_i - c_i)a_i + \sum_i^L r_i e_i$$

$$s.t.\ \forall i : a_i + e_i \leq 1,\ a_i \geq 0, e_i \geq 0$$

$$\mathcal{L} = \sum_i^L (1 - f_i)(py_i - c_i)a_i + f_i(p\delta_i y_i + m_i - c_i)a_i + \sum_i^L r_i e_i$$

$$+ \sum_i^L \mu_i(1 - a_i - e_i) + \sum_i^L \theta_i e_i + \sum_i^L \sigma_i a_i$$

$$[a_i] : (1 - f_i)(py_i - c_i) + f_i(p\delta y_i + m_i - c_i) - \mu_i - \sigma_i = 0$$

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

$$[\mu_i] : 1 - a_i - e_i = 0$$

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

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

At the solution, the Kuhn-Tucker conditions show that 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. $(1 - f_i)(py_i - c_i) + f_i(p\delta_i y_i + m_i - c_i) = \mu_i + \sigma_i, r_i = \mu_i + \theta_i$
2. $a_i + e_i = 1, a_i \geq 0, e_i \geq 0$
3. $\mu_i \geq 0, \theta_i \geq 0, \sigma_i \geq 0$
4. $\mu_i(1 - a_i - e_i) = 0, \theta_i e_i = 0, \sigma_i a_i = 0$

I 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 expected agricultural profits of a field. When the retirement payment is less than the agricultural profits, the farmer will put that entire field toward agricultural production. This model also informs us of the qualities of land that are more likely to be eased. Land with lower yields, higher risk of flooding, lower flood-damage yields, higher costs of planting, and higher environmental benefits are more likely to be put under easement.

$$e_i^* = \begin{cases} 1 \text{ if } (1 - f_i)(py_i - c_i) + f_i(p\delta_i y_i + m_i - c_i) \leq r_i \\ 0 \text{ if } (1 - f_i)(py_i - c_i) + f_i(p\delta_i y_i + m_i - c_i) > r_i \end{cases}$$

$$a_i^* = \begin{cases} 1 \text{ if } (1 - f_i)(py_i - c_i) + f_i(p\delta_i y_i + m_i - c_i) > r_i \\ 0 \text{ if } (1 - f_i)(py_i - c_i) + f_i(p\delta_i y_i + m_i - c_i) \leq r_i \end{cases}$$

2.3.2 Conservation Agent's Problem

Babcock et al. (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. 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 of the L fields. I call this price $\bar{r}$. The conservation agent uses the average expected agricultural profits for all L fields to determine $\bar{r} = 1/L \sum_i^L (1 - f_i)(py_i - c_i) + f_i(p\delta y_i + m_i - c_i)$. The conservation agent is also subject to total budget T. I assume that the budget is positive $T > 0$ and that the conservation agent cannot exceed the budget $\sum_i^L \bar{r}e_i \leq T$. I also include the condition that the easement cannot be larger then the field itself $e_i \leq 1$. I can write out the conservation agent's objective function as a constrained maximization problem.

(3) $$\max_{e_i} \sum_i^L b_i e_i \; st. \sum_i^L \bar{r}e_i \leq T, \forall i : 0 \leq e_i \leq 1$$

To solve for the optimal e_i for the conservation agent, I set up another Lagrangean. I ignore the non-negativity constraint since it is not optimal for the conservation agent to have zero easements.

$$\mathcal{L} = \sum_i^L b_i e_i + \lambda\left(T - \sum_i^L \bar{r}e_i\right) + \sum_i^L \omega_i(1 - e_i)$$

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

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

$$[\omega_i] : 1 - e_i = 0$$

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

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

$$2. \; \sum_i^L \bar{r}e_i \leq T, e_i \leq 1$$

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

$$4. \; \lambda\left(T - \sum_i^L \bar{r}e_i\right) = 0, \omega_i(1 - e_i) = 0$$

I use the Kuhn-Tucker 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 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.

$$e_i^{\#} = \begin{cases} 1 \text{ if } \dfrac{b_i}{\bar{r}} \geq \lambda \\ 0 \text{ if } \dfrac{b_i}{\bar{r}} < \lambda \end{cases}$$

2.3.3 Solving for Equilibrium

I combine the solutions of the farmer and conservation agent to find the equilibrium. 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 $e_i = 1$ if $(1 - f_i)(py_i - c_i) + f_i(p\delta y_i + m_i - c_i) \leq \bar{r}$. The conservation agent eases land when the environmental benefits over the shadow price are greater than the easement payment price: $e_i = 1$ if $\bar{r} \leq b_i / \lambda$. Land will be eased when both these conditions are met. A field will be eased when the benefit to cost ratio exceed the shadow price. Otherwise, the land will stay in agricultural production.

$$e_i^* = \begin{cases} l_i \text{ if } \dfrac{b_i}{(1 - f_i)(py_i - c_i) + f_i(p\delta_i y_i + m_i - c_i)} \geq \lambda^* \\ 0 \text{ if } \dfrac{b_i}{(1 - f_i)(py_i - c_i) + f_i(p\delta_i y_i + m_i - c_i)} < \lambda^* \end{cases}$$

$$e_i^* = \begin{cases} l_i \text{ if } \dfrac{b_i}{(1 - f_i)(py_i - c_i) + f_i(p\alpha y_i - c_i)} \geq \lambda^* \\ 0 \text{ if } \dfrac{b_i}{(1 - f_i)(py_i - c_i) + f_i(p\alpha y_i - c_i)} < \lambda^* \end{cases}$$

2.3.4 Comparative Statics and Hypotheses

This model predicts that fields with ample environmental benefits and low agricultural productivity are the most likely to be eased. The fields with high benefit to 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. If the cost of production increases—for example, if insurance premiums increase—then more fields would go into the easement program.

I can also consider the impact of climate change. If there is frequent flooding or more frequent drought conditions, expected yields would be lower, making easing land more attractive. Or if damages from disasters were higher, easing fields would also be more likely to occur. If the expected agricultural profits of a field were higher due to increased insurance coverage, it would be less likely for land to go into easement. A field that may have been better off eased may remain in production because of the guaranteed income from the insurance coverage. This emphasizes some of the moral hazard issues that insurance introduces to the easement process. This also highlights that insurance and easements are substitute adaptation strategies, not complementary.

Consider the effect of easements on the overall land, total indemnities, and average yields. Increasing easements will decrease the acres in agricultural production. This is a mechanical result. If lower-yielding and high-risk land is eased as our model predicts, then average expected losses for the land will decrease. Decreasing acres in production will decrease indemnities paid out $\sum_i^L m_i$ and acres damaged $\sum_i^L \delta_i y_i a_i$. The average yields on the remaining land in production $\bar{y} = 1/L \sum_i^L y_i$ are expected to increase.

The hypotheses tested empirically are as follows:

I. Easements increase average yields.
II. Easements decrease indemnities.
III. Easements decrease acres in agricultural production.
IV. Easements decrease acres failed and prevented planted.

2.4 Data

I compile from a wide array of sources to build a comprehensive data set to address my research questions. Administrative data are collected from various branches at the USDA: 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 at the county-year level. The data spans from 1989–2020 and includes about 1,700 farming counties. The commodities of focus are corn, soybeans, and wheat. Key summary statistics for the main counties east of the 100th meridian are presented in table 2.1.

2.4.1 NRCS Easements

The NRCS has a detailed database with information on completed floodplain easements and wetland restorations. There are 1,613 completed floodplain easements and 17,751 completed wetland restorations as of 2020. On average, there are 615.9 acres of wetland easement and 56 acres of floodplain easement in a county over the sample period. The mean land share in a county of wetland easement is 0.00160 and 0.00012 for floodplain easements. I differentiate between the cropland and non-cropland easement acres in order to parse out the direct and indirect effects. I also integrate the data on the geographical area rate cap to estimate the approximate per acre easement cost. The geographical area rate cap is the rate that most often corresponds to the per acre purchasing cost of easements and averages around \$3,126 per acre. I estimate the average floodplain easement cost for new

Table 2.1 **Summary statistics**

Variable	Mean	SD	Min	Max	N
NRCS					
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
Geographical Area Rate Cap	3,162	9,953	0	792,500	72,424
Wetland Easement Cost Per Acre (est)	2,657	1,840	232	20,064	6,044
Floodplain Easement Cost Per Acre (est)	2,691	2,035	319	15,774	475
NASS					
Corn yield (bushel/acre)	122.2	38.55	0	246.7	50,343
Soybean yield (bushel/acre)	37.57	11.07	0.700	80.40	45,877
Wheat yield (bushel/acre)	48.90	14.76	0	109.7	34,867
Corn Planted Acres	46,580	56,077	50	397,000	50,358
Soybean Planted Acres	48,673	51,985	10	541,000	45,879
Wheat Planted	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
RMA					
Corn Indemnity	845,110	3.427e+06	0	1.396e+08	53,241
Soybean Indemnity	388,800	1.120e+06	0	3.692e+07	53,241
Wheat Indemnity	143,686	790,740	0	3.550e+07	53,241
Corn Liability	1.248e+07	2.549e+07	0	2.860e+08	53,241
Soybean Liability	7.642e+06	1.378e+07	0	1.689e+08	53,241
Wheat Liability	1.314e+06	4.589e+06	0	1.234e+08	53,241
Corn Premium	1.040e+06	2.000e+06	0	3.207e+07	53,241
Soybean Premium	651,643	1.199e+06	0	2.240e+07	53,241
Wheat Premium	176,620	722,158	0	2.883e+07	53,241
Corn Loss Cost Ratio	0.0996	0.158	–5.73e-05	1.245	44,950
Soybean Loss Cost Ratio	0.0927	0.138	0	1.354	42,906
Wheat Loss 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

Table 2.1 (cont.)

Variable	Mean	SD	Min	Max	N
FSA					
Corn Planted Acres	49,547	58,567	0	378,953	18,303
Soybean Planted Acres	48,889	53,528	0	536,339	18,303
Wheat Planted Acres	11,599	32,113	0	374,145	18,303
Corn Prevented Planted Acres	1,619	7,820	0	260,914	18,303
Soybean Prevented Planted Acres	723.0	3,083	0	89,229	18,303
Wheat Prevented Planted Acres	590.7	3,095	0	122,702	18,303
Corn Failed Acres	119.1	644.6	0	22,474	18,303
Soybean Failed Acres	34.98	334.9	0	19,759	18,303
Wheat Failed Acres	116.2	774.9	0	42,701	18,303
PRISM					
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 days (hrs)	3,508	229.4	2,198	4,170	53,241
Extreme degree days (hrs)	463.1	356.5	0	2,194	53,241

easements in the sample period to be $2,691 while wetland easement costs are a little higher at $2,657.

Figure 2.3 depicts the cumulative acres enrolled in wetland and floodplain easements over time. Wetland enrollment increases slowly at first and then spikes in the late 1990s and early 2000s. The growth rate plateaus until the passage of the American Recovery and Reinsurance Act in 2008, which provides the NRCS with additional funding. Wetland enrollment increases for a few years after ARRA before flattening again. Floodplain easement enrollment is milder. Floodplain easements are funded though congressional acts that are infrequent. Funding for floodplains spikes after severe agricultural flooding events such as in the late 1990s and 2008. This additional funding corresponds to high floodplain enrollment. The NRCS Easement data record dates of importance such as application date, agreement start date, enrollment date, closing date, recording date, and restoration completion dates. Each step in the process is defined in detail in table 2.2. Whether a producer can crop on the land or insure the land with the USDA during that time is also noted. Producers are encouraged to crop on the land until the NRCS is ready to actively restore the land. A floodplain takes an average of 2.8 years to go from application to restoration completion. The wetland restoration process is more intensive and takes 4.1 years on average to complete. Figure 2.4 shows a breakdown of each step's duration. 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 that take closer to nine years.

I focus my analysis on the closing date, the day the easement contract becomes official. The conservation agent has approval to purchase the ease-

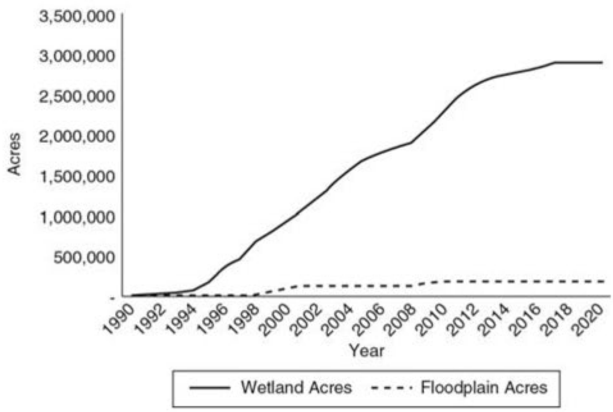

Fig. 2.3 Cumulative acres in wetland and floodplain easement program

Table 2.2 Steps in the easement process

Step	Description	Cropable?	Insurable?
Application	Application received by NRCS from producer.	Yes.	Yes
Agreement Start	Parcel selected and producer agrees to continue.	Yes.	Yes.
Enrollment	Parcel enrolls in program.	Yes.	Yes.
Closing	Attorneys sign off. Landowner receives payment.	CUA only.	No.
Recording	Transaction recorded in court.	CUA only.	No
Restoration Complete	Parcel restored.	No.	No.

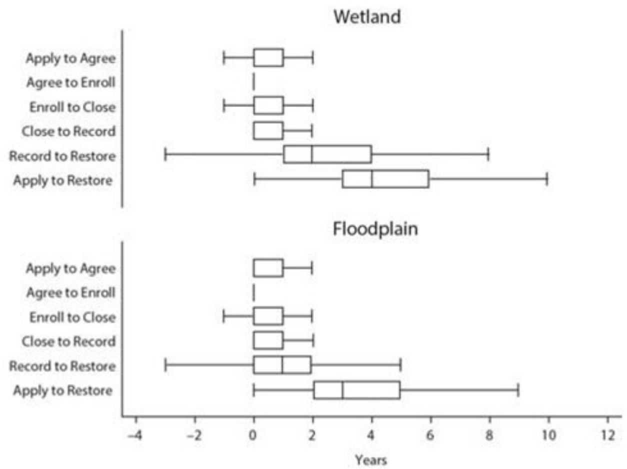

Fig. 2.4 Duration in each easement step by program type

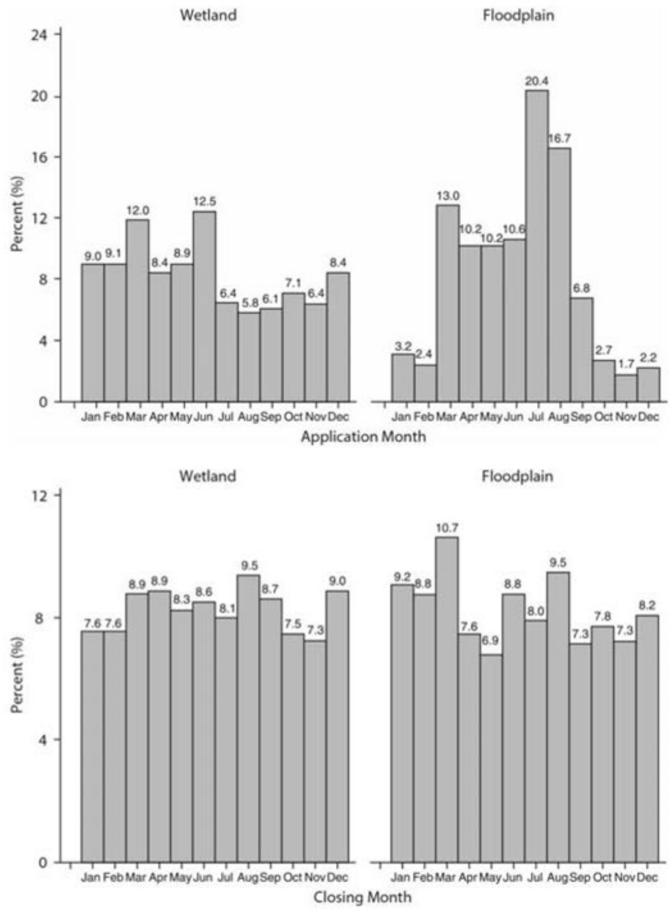

Fig. 2.5 Monthly breakdown of main easement steps

ment and the landowner is paid. After this date, farmers can no longer receive benefits on that field or insure the eased field. Notably, the farmer may still be able to plant on the field with a compatible use authorization until the restoration is complete, although they bear the full risk of production during that period. It is not until the restoration is complete that producers are prohibited from cropping on the easement. I therefore expect to observe direct and indirect effects of the easement decision beginning at the contract closing. Although, it is also possible that the indirect effects may increase after the restoration completion date.

I investigate the timing of the easement process in order to better understand when changes in agricultural production and risk may occur. I plot the distribution of the key steps in the easement process by month of occurrence in figure 2.5. Application timing is likely to be endogenous, as the decision to

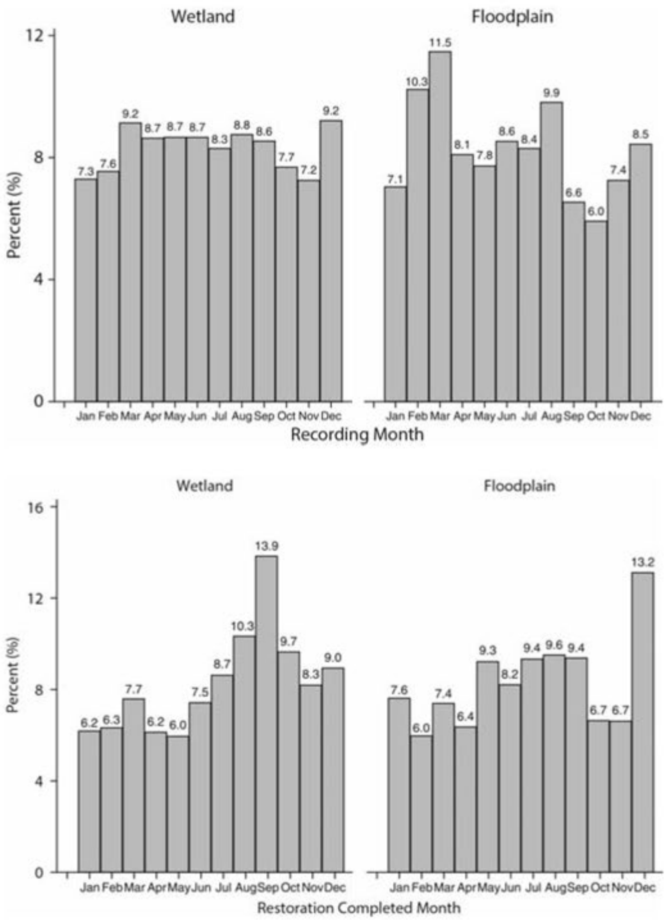

Fig. 2.5 (cont.)

apply to an easement program may be driven by agricultural losses. Wetland applications are more frequent in heavy precipitation months, March and June. Over 36 percent of floodplain applications are received in July and August, after producers have realized their yields. The uptick in applications is likely driven by farmers retiring marginal cropland after facing losses. The work completed by the NRCS, closings and recordings, is relatively evenly distributed across the year. There are seasonal patterns in restoration completion, since restorations require planting native flora. Wetlands tend to be finished by the end of summer around September. Floodplain restorations most commonly take place in late summer and December. The closing date seems to be reasonably exogenous and the best predictor of when easement effects are expected to occur.

2.4.2 National Agricultural Statistics Survey

Data on most agricultural outcomes stem from the USDA National Agricultural Statistics Survey (NASS). NASS includes yearly estimates of county-level yields. Figures 2.6, 2.7, and 2.8 map the average yields for corn, soybeans, and wheat, respectively. Corn production is centralized in

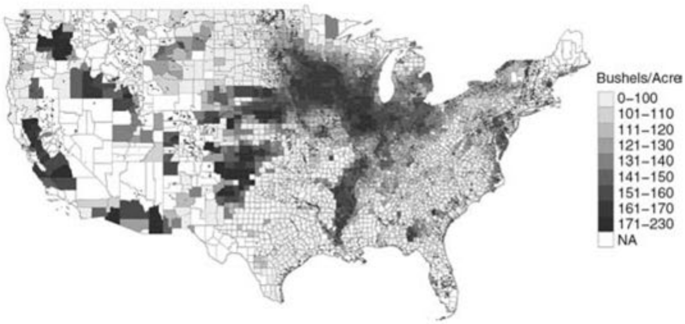

Fig. 2.6 Map of corn average yields and easements from 1989–2020

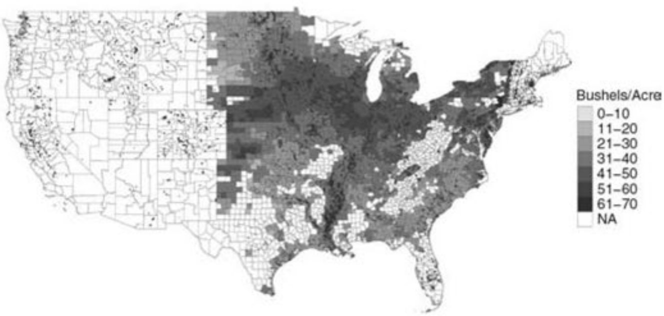

Fig. 2.7 Map of soybean average yields and easements from 1989–2020

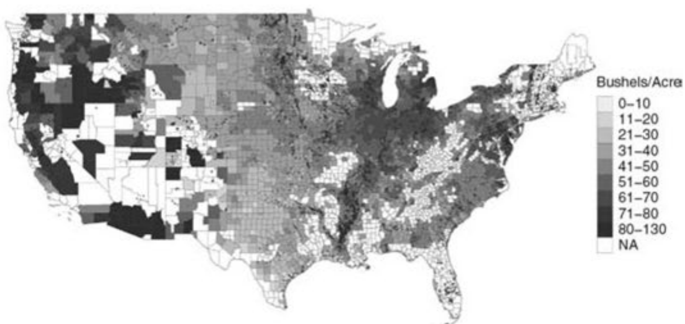

Fig. 2.8 Map of wheat average yields and easements from 1989–2020

the "corn belt" states: Nebraska, Iowa, Illinois, and Indiana. The mean corn yield during these three decades is 122 bushels per acre. Soybean production is more focused in the eastern half of the US. 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. The yield maps are overlaid with the easement locations to see the correlation between where production occurs and where easements take place.

NASS also provides statistics on acres planted and harvested since 1989. I create a measure of acres failed to harvest by subtracting the acres planted by acres harvested. On average, a county plants 46,000–48,000 acres of corn and soybean in a year. Wheat acreage is much lower at 17,000 acres per year in a county. Most of the acreage is harvested and the proportion of acres failed to harvest is low; usually a couple thousand acres are failed to harvest.

2.4.3 RMA Cause of Loss and Summary of Business

The Cause of Loss (COL) data set from the RMA (Risk Management Agency) provides valuable information on monthly indemnities for each county from 1989 to 2020. I aggregate each type of loss to the county-year level. Figure 2.9 compares the magnitude of losses by cause of loss. The biggest cause of loss is drought, with indemnities totaling over $35 billion. The second biggest cause of loss is excess moisture, with indemnities close to $30 billion. I expect easements to mitigate losses related to excess water and flooding. However, I also consider the overall loss cost ratio and other losses as well, since crops that face water stress are more liable to damages caused by disease, insects, and wildlife.

The Cause of Loss data are merged with the Summary of Business (SOB) data file. The SOB data record the acres planted, liabilities, premiums, subsidies, coverage levels, and chosen policies. I calculate the loss cost ratio by divid-

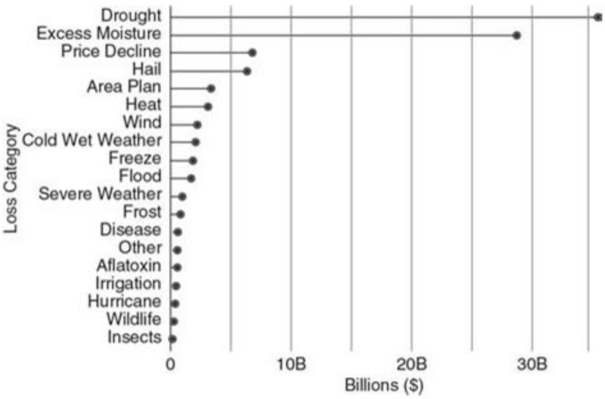

Fig. 2.9 Indemnity totals for corn, soybeans, and wheat by category from 1989 to 2020

ing the COL indemnity by the SOB liabilities. I do the same for the loss ratio by dividing the indemnities by the total premium amount. To create a balanced panel, I assume that reported indemnities are zero for county-years with no reported losses. I focus on the subset of counties that face indemnities (counties that have non-zero indemnities in that year). Figures 2.10, 2.11, and 2.12

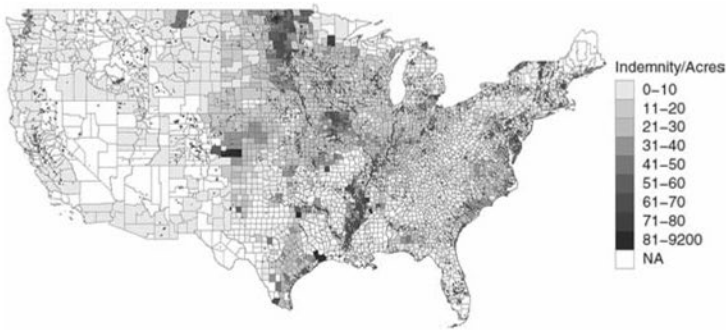

Fig. 2.10 Map of average indemnities per acre planted for corn and easements from 1989 to 2020

Fig. 2.11 Map of average indemnities per acre planted for soybeans and easements from 1989 to 2020

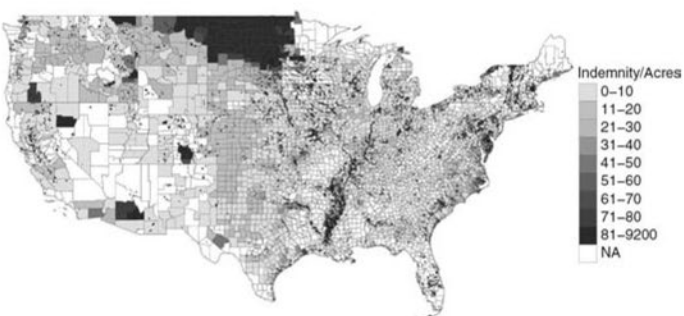

Fig. 2.12 Map of average indemnities per acre planted for wheat and easements from 1989 to 2020

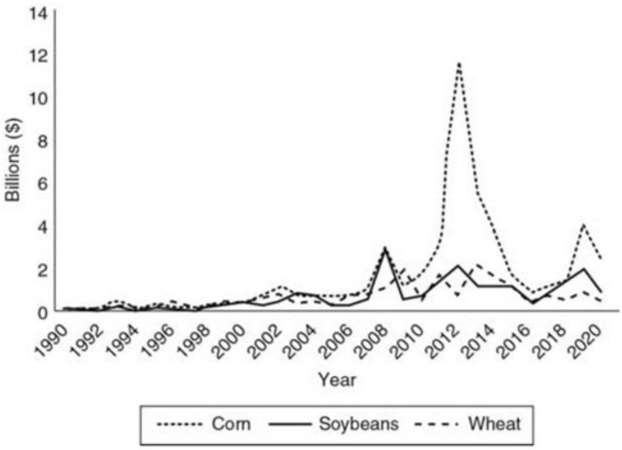

Fig. 2.13 Indemnities by commodity over time

show the extent of indemnities per acre planted for corn, soybeans, and wheat. There are corn indemnities scattered throughout the country, but there are high losses in the Dakotas and along the coasts. Soybean indemnities follow a similar spatial pattern but have lower average indemnities per acre compared to corn. Wheat indemnities are the highest of the three crops, especially in the northern edge of the United States. Easements seem to be concentrated in counties with high losses.

To explore when indemnities occur, I graph changes in total indemnities for corn, soybeans, and wheat in figure 2.13. Indemnities are relatively low and stable in the first decade of my sample. Spikes in losses become more frequent in the mid-2000s. It is important to note that acres enrolled and liability totals change drastically during this period. But some of these increases are also due to the changing climate. Losses are notable in 2008 (US$6 billion for wheat and corn combined) and 2012 (US$12 billion for corn), two years remembered for their extreme weather events. Extreme flooding throughout the Midwest in 2008 is associated with increased easement funding through ARRA. Record-breaking heat and limited precipitation led to a severe drought in 2012 in two-thirds of the US. It is expected that these billion-dollar weather disasters will increase in frequency.

2.4.4 FSA Crop Acreage

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 aggregated to the county level for each year and are publicly available. Unlike the other USDA data, the FSA only spans from 2009 to 2020.

I consider how easements impact acres prevented planted and failed. 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. I use these data to test whether easements reduce agricultural risk by reducing acres prevented planted during planting season or if easements reduce risk later on in the season by reducing acres failed.

2.4.5 PRISM Weather and Climate

Following the approach of Schlenker and Roberts (2009) and Ortiz-Bobea (2021), I control for weather variables in my models using PRISM data. I filter pixels that are classified as cropland or pastureland by the USGS National Land Cover Data Base. I aggregate monthly weather data over the growing season (April to September) to create a yearly panel. 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 nonlinear effect on the agricultural outcomes of interest (Schlenker and Roberts 2009). Instead of focusing on average temperatures, I include 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°C to 29°C) and extreme temperature exposure (total exposure at or above 30°C).

2.5 Empirical Model

2.5.1 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. My equation takes the form

$$Y_{it} = \beta_1 Wetland_{it} + \beta_2 Floodplain_{it} + \Gamma X_{it} + \alpha_i + \delta_t + \varepsilon_{it}.$$

The outcome variable of interest, Y, is the yield, loss cost ratio, and loss ratio for county i in year t. The crops of interest in this study are corn, soybeans, and wheat. When studying potential mechanisms, Y takes the value of acres planted, prevented planted, failed, and failed to harvest. I cluster standard errors at the state level, since state NRCS departments administer these programs. I take the inverse hyperbolic sine (IHS) of all the outcome variables except for the risk ratios. I prefer this transformation, as there are many zero-valued observations in the data and coefficients can then be interpreted as percent changes. I also apply a mean transformation to correct the magnitudes of the coefficients so I can interpret them as elasticities (Bellemare and Wichman 2020). When both the outcome (y) and treatment (x) are IHS, the elasticity equals $\left(b * \bar{x} * \sqrt{(\bar{y}^2 + 1)}\right) / \left(\bar{y} * \sqrt{(\bar{x}^2 + 1)}\right)$, where b is the coefficient after regressing IHS(y) on IHS(x), $\bar{x}$ is the mean of x, and $\bar{y}$ is the mean of y. When the treatment x is IHS but the outcome y is not, the semi-elasticity is $\left(b * \bar{x} * \sqrt{(\bar{y}^2 + 1)}\right) / \bar{y}$. The standard errors for the elasticities are then calculated using the delta method.

I include county-level fixed effects to account 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. My identification strategy relies on the underlying assumption that conditional on the county and year, treatment is exogenous. 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, precipitation squared, moderate degree days, and extreme degree days.

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 used for ease of interpretation as 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 percent increase in land share of wetland easement. The coefficient β_2 represents the elasticity response to a 100 percent increase in land share of floodplain easement. For ease of legibility, instead of measuring the response to a 1 percent increase in easement land share, I consider a "doubling" of land share in wetland and floodplain easement, or a 100 percent increase. Since land in easement is such a small percentage of acreage on average, a 100 percent increase in easement land share for a county is reasonable.

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 the 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 delay the closing and restoration process. For example, a previous utility contract may be unearthed and an agreement must be worked out between the different parties. Alternatively, sometimes there is trouble with accessing the parcel of land for the NRCS because of legalities with railroads and private roadways. There are many legal documents and processes that take a quasi-random amount of time to complete. For these reasons, I believe the timing of closing is reasonably exogenous.

The sample is restricted to counties that are east of the 100th meridian except for when I look at region heterogeneity. I include a county in the sample when that commodity is planted at least once during my time horizon. I use the NASS acreage and FSA acreage variable to create these sample groups.[5] 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 varies depending on the commodity sub-sample.

2.5.2 Limitations and Trends in TWFE 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) setup 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 2021; De Chaisemartin and D'haultfoeuille 2020; Callaway and Sant'Anna 2021). 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, D'haultfoeuille, and Guyonvarch 2019; Callaway et al. 2021). Callaway, Goodman-Bacon, and Sant'Anna (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. I use the traditional TWFE model here.

5. 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.

2.6 Results

This section reviews my findings from using a TWFE model. Tables 2A.1–2A.13 present regressions, and the online appendix presents coefficient plots to make the results easy to follow.[6]

2.6.1 How Do Easements Impact Crop Yields?

Table 2A.1 shows how wetland and floodplain easements impact corn, soybean, and wheat yields. As hypothesized by the theoretical model (hypothesis I), easements positively impact yields. For wetland easements, a 100 percent increase in land share of wetland easement is associated with 0.34 percent, 0.77 percent, and 0.46 percent 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 percent after an increase in floodplain easement land share.

Table 2A.2 differentiates by the original land use of the easement. Eased land can be classified as cropland or non-cropland. Non-cropland is eased in order to connect eased cropland, improve drainage outcomes, and create more robust ecosystems. In 2020 in the main sample, there are 173,088 acres under floodplain easement of which 70,995 acres were originally cropland (41 percent). There are 2,133,094 wetland easement total acres closed and 1,198,473 acres were cropland (56 percent). 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 and producers re-allocating their remaining resources. 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.

Table 2A.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 percent, soybeans by 0.82 percent, and wheat by 0.33 percent. Doubling the land share of non-cropland into wetlands has a 0.22 percent, 0.29 percent, and 0.11 percent increase in yields for corn, soybeans and wheat; however, only the estimate for soybeans is significant. 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 because of low variation and acreage in floodplain easement. 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 percent. However, the indirect effect of floodplain easements is posi-

6. See http://www.nber.org/data-appendix/c14694/appendix.pdf

tive and significant for all three commodities. Doubling the share of land in non-cropland floodplain easements leads to a 0.14 percent, 0.06 percent, and 0.09 percent increase in corn, soybean, and wheat yields. This evidence lends support to hypothesis I 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.

Next, in table 2A.12, I explore the potential weather pathways by taking an approach similar to Annan and Schlenker (2015). The researchers look at how the portion of land that is insured impacts the effect of precipitation and degree days on crop yields. Similarly, 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. For corn, wetland easements reduce the effect of moderate degree days. 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. The interaction between wetland easements and precipitation squared is positive and significant for corn (although smaller than 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.

2.6.2 How Do Easements Impact Indemnities and Risk?

The next set of results evaluates how easements impact indemnities and agricultural risk (hypothesis II). 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] Table 2A.3 shows how floodplain easements and wetland easements impact the loss 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

7. If a county has zero indemnities in a year, the loss cost ratio and loss ratio are undefined.

soybeans. Increasing wetland easements by 100 percent decreases soybean losses by \$2.26 per dollar of liability. 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 loss cost ratio for excess moisture, flooding, drought, heat, disease, and insect losses. Table 2A.4 explores how the loss 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 and pathogen issues. Moreover, crops that experience extreme weather stress are more susceptible to disease and insect losses.

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

To investigate how producer risk is impacted by easements, I regress the loss ratio on wetland and floodplain acres in table 2A.5. All the estimates are insignificant and noisy.

2.6.3 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. My model predicts that acres planted will decrease after an increase in easement land share (hypothesis III). Table 2A.6 uses NASS data on acreage planted that span the entire panel period. The estimates for floodplain easements are small and insignificant. I find that increasing wetland land share by 100 percent decreases acres planted of soybeans by 2 percent and acres planted of wheat by 1 percent. This is consistent with my hypothesis since easements take land out of production. Surprisingly, doubling wetland easement acres is associated with a 3 percent increase in corn acreage.

Table 2A.7 uses FSA acreage data, which have a shorter panel of data from 2009 to 2020, as a robustness check. The findings for wetland easements are similar but often smaller in magnitude and less significant. The results for floodplains are again insignificant and close to zero. Notably, doubling wetland easement land share leads to a −17 percent change in wheat acreage planted. Easements were focused on the wheat-growing regions from 2010 to 2020 and that led to a sizeable reduction in wheat acreage planted. The results in Table 2A.8 show that doubling easement land share impacts acres harvested. The acres harvested findings are almost identical to the acres planted results.

To test hypothesis IV, I estimate how easements affect acres failed to harvest, acres failed, and acres prevented planted. In table 2A.9a, I find that easements are associated with positive and negative changes in acres failed to harvest. Doubling wetland acres leads to a 3.17 percent increase in corn acres failed to harvest. This finding is consistent with the slippage narrative. More corn is planted, and this leads to higher corn harvest failure. Wetland easement land share has a negative but insignificant effect on soybean and wheat acres failed to harvest. Doubling floodplain acres has no significant effect on corn acres failed to harvest, increases soybean acres failed to harvest by 0.98 percent, and decreases wheat acres to harvest by −1.31 percent.

Table 2A.9b shows the results from the same regression as in table 2A.9a, but conditional on counties experiencing non-zero acres failed to harvest. The patterns are similar to the findings in table 2.9a. Increasing wetland easements land share increases corn acres failed to harvest by 1.66 percent. But, now doubling wetland easement land share significantly reduces acres failed to harvest for both soybeans and wheat by approximately 1 percent. Doubling floodplain easement still has no significant effect on corn, but continues to increase soybeans acres failed to harvest by less than 1 percent and decrease wheat acres failed to harvest by 0.83 percent.

In table 2A.10, I estimate how easement land share impacts acres failed using FSA data. Increasing wetland easements in a county by 100 percent decreases soybean acres failed by 10 percent and wheat acres failed by 21 percent. Increasing floodplain acres also decreases corn acres failed by about 5 percent while increasing wheat acres failed by 5 percent. There is some support for the hypothesis that easements reduces acres failed in some contexts, but also some contradictory findings. It is unclear from these results whether easements are associated with a reduction in acres failed.

Since easements are most likely to reduce losses from excess water and floods, I look at how easement land share impacts acres prevented planted using FSA data from 2009 to 2020. For wetland easements, increasing land share by 100 percent decreases acres prevented planted of soybeans and increases acres prevented planted of wheat, but these estimates are insignificant. Again, unexpectedly, doubling wetland easement land share increases acres prevented planted for corn by 43 percent. This deepens the implications of the slippage effect. It seems that more land is being put toward corn production post-easement and this may be leading to higher corn losses. Floodplain easements are associated with reductions in acres prevented planted. Doubling land share in floodplain easement reduces prevented planted acreage for corn by 14 percent and soybeans by 9 percent. It seems that floodplain easements are successful at reducing the risks associated with prevented planting.

My results show that increasing wetland easement land share increases corn acreage planted, corn acreage failed to harvest, and corn acreage prevented planted. These findings run counter to my hypotheses, but evidence of a similar spillover effect, called slippage, has been associated with other conservation programs. Wu (2000) finds that a 100-acre increase in the Conservation Reserve Program (CRP) leads to the conversion of 20 acres from non-cropland into cropland, which offsets the ecosystem benefits of the program by 9–14 percent. The slippage effect is driven by increased output prices from the reduced supply as well as substitution effects in which producers begin producing on lower quality land. However, Roberts and Bucholtz (2005) replicate Wu's findings and do not find conclusive evidence of a slippage effect. More recently, Fleming (2014) uses satellite data and finds evidence of a mild slippage effect: an additional 100 acres of land enrolled in CRP leads to the conversion of 4 acres to cropland. Uchida (2014) uses Census of Agriculture panel data and also finds robust evidence of farm-level slippage effects of about 14 percent. Lichtenberg and Smith-Ramírez (2011) find evidence that land is reallocated to crop production when there are increases in participation in cost-sharing conservation programs. Pfaff and Robalino (2017) provide an overview of the slippage literature and a deeper discussion of the mechanisms behind it.

There are a few potential explanations for why the wetland easement program is associated with producers switching their production toward corn. This could be a case of input reallocation (Pfaff and Robalino 2017). Easements free up inputs such as labor and capital and producers look for new ways to raise profits on their lands. 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 decrease the need for fertilizers and herbicides. It is likely that the producers retired their riskiest fields and have less land to plant on post-easement. Because of these changes in their production choice set, it could be the case that farmers try to maximize profits by planting a more

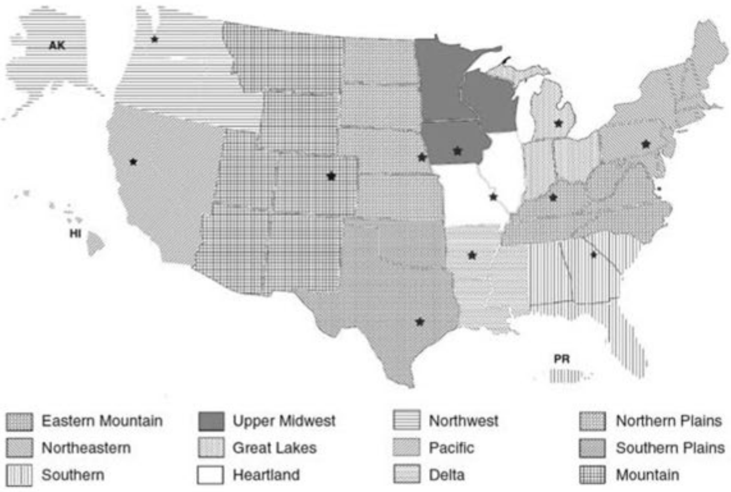

Fig. 2.14 Map of NASS regions from USDA

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. This mechanism is referred to as *learning* in Pfaff and Robalino (2017); conservation programs may encourage producers and their neighbors to engage in new practices. 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.

2.6.4 How Do Easements Impact Each Region?

Finally, I explore heterogeneity in easement effects by region in table 2A.13. I look at how wetland easement and floodplain easement land share impact corn, soybean, and wheat yields by region. The NASS has 12 regional offices that are responsible for the statistical work of an area. These are often grouped by similarities in production. A map in figure 2.14 shows which are included in each region. This regional analysis deepens our understanding of which areas of the US are driving the results. The Southern region and Northwest region of the US actually experience decreased soybean and wheat yields after 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 toward which regions derive the highest agricultural benefits from easements.

2.6.5 How Do Benefits and Costs Compare?

I use the yield estimates from table 2A.1 to conduct a simple cost-benefit analysis of wetland easements. I calculate the ratio of yield benefits to the cost of easing land (analogous to the solution for the conservation agent's problem laid out in my theoretical model). This analysis does not include all ecosystem benefits associated with easements, nor does it include the administrative, maintenance, or enforcement costs of the program. However, the back-of-the-envelope accounting exercise is beneficial in understanding the potential scope of wetland easement effects as well as their cost-effectiveness.

Table 2.3 depicts the benefits and costs of doubling a county's land share in wetland easement by 100 percent and then aggregates to all counties in the main sample. The benefit equals the change in average revenue for a county from corn, soybeans, and wheat crops. Average revenue is the product of the average price per bushel, the average yield, and average acres planted of each commodity (averaged over 1989–2020). The change in revenue post-

Table 2.3 **Cost benefit analysis of wetland easements**

	Corn	Soybeans	Wheat	Total
Benefit				
Average price per bushel	3.36	8.18	4.50	
Average yield (bushels per acre)	122.20	37.57	48.90	
Average acres planted	46,580	48,673	17,493	
Average county revenue	19,125,375	14,958,313	3,849,335	
Estimate of yield increase after 100% increase in wetland easements	0.00338	0.00766	0.00457	
Increase in revenue after 100% increase in wetland easements	64,644	114,581	17,591	196,816
Present value of increased revenue at 5% interest rate	1,292,875	2,291,614	351,829	3,936,318
Number of counties in sample	1,871	1,762	1,716	
Total increase in revenue	2,419,969,825	4,037,823,054	603,738,885	7,060,531,764
Cost				
Average county wetland easement acres				616
Average per acre cost of wetland easement				2,657
Cost of 100% increase in wetland easements in a county				1,636,446
Number of counties in sample				1,871
Total cost				3,061,791,027
Benefit to cost ratio				
One county				2.41
All counties in sample				2.31

easement is the product of the average revenue and the yield estimates. Next, I find the present value (in perpetuity) by dividing by a 5 percent interest rate. The present value of benefits for one county is \$3,936,318. After aggregating for all the counties in the sample, the present value of yield benefits is over US\$7 billion.

To increase wetland acres by 100 percent, it would cost on average \$1,636,446 for one county and \$3 billion for all the counties in the main sample. To find the cost of doubling wetland easements, I find the product of the average acres in wetland easement and the average cost of purchasing easement acreage. The overall benefit to cost ratio is 2.41 for a county and 2.31 overall, which means the program is cost-effective. With an interest rate of 3 percent the benefit cost ratio becomes 4.01 (3.84). An interest rate of 10 percent brings the benefit cost ratio down to 1.20 (1.15). There is currently a small share of land in wetland easements, and these estimated benefits may represent the point that the highest marginal benefits are achieved. In the future, if there is more land in easement and less in cropland, the marginal benefit would be expected to diminish.

I find that my cost-benefit estimates are within range of other cost-benefit analyses estimates completed on the Conservation Reserve Programs and Wetland Restoration Programs. Miao et al. (2016) finds that CRP is not cost-effective when comparing the environmental benefits index to the contract rental rates. In the Indian Creek watershed of Iowa, Johnson et al. (2016) calculate a cost-benefit ratio of 1.3–4.8 after estimating the water quality, flood mitigation, air quality, and climate benefits. In a CEAP study, Hansen (2007) calculates a cost-benefit ratio of 0.70–0.85 for CRP lands when considering the soil erosion and wildlife habitat benefits. In a report on wetland ecosystems, Hansen et al. (2015) summarizes some cost-benefit analyses of wetland restorations. They predict average easement costs are between \$160 and \$6,100 per acre. Duck hunting benefits range from \$0–\$143 per acre, while reduced greenhouse gas emission benefits range from \$0–\$129 per acre. The review on flood mitigation benefits had high variance in reported benefits and did not lead to any conclusive estimates of avoided damages on croplands. My estimates of yield benefits may prove useful in future program cost-benefit analyses by capturing an additional ecosystem benefit of wetlands.

2.7 Conclusion

This paper presents novel evidence that wetland and floodplain easements increase crop yields for corn, soybeans, and wheat. I parse out the direct and indirect effect of easements by distinguishing by original land use. As expected, easing cropland directly improves yields by removing lower yielding land from production and reallocating inputs and labor toward surrounding cropland. Importantly, I also find that easing non-cropland increases some crop yields indirectly by improving production on non-eased fields. I study the mechanisms through which easements impact agricultural production. I find some evidence suggesting that easements reduce losses due to excess moisture, heat, disease, and insects. Easements increase yields by mitigating the effect of extreme precipitation and extreme degree days. There are mixed findings regarding how easements affect acres prevented and failed. 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 increased drought risk and more corn acreage prevented planting. This study is a step toward a better understanding of 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.

Appendix

Table 2A.1 **Effect of easements on crop yields (bushels/acre)**

	Corn yield (1)	Soybean yield (2)	Wheat yield (3)
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. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.

Table 2A.2 **Effect of cropland/non-cropland easements on crop yields (bushels/acre)**

	Corn Yield (1)	Soybean Yield (2)	Wheat Yield (3)
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. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.

Table 2A.3 **Effect of easements on loss cost ratio**

	Corn Loss Cost Ratio (1)	Soybean Loss Cost Ratio (2)	Wheat Loss Cost Ratio (3)
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. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.

Table 2A.4 Effect of easements on loss cost ratios with different indemnity causes

	Corn Loss Cost Ratio (1)	Soybean Loss Cost Ratio (2)	Wheat Loss Cost Ratio (3)
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
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. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.

Table 2A.5 Effect of easements on loss ratio

	Corn Loss Ratio (1)	Soybean Loss Ratio (2)	Wheat Loss Ratio (3)
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. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.

Table 2A.6 Effect of easements on acres planted (NASS)

	Corn Acres Planted (1)	Soybean Acres Planted (2)	Wheat Acres Planted (3)
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. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.

Table 2A.7 **Effect of easements on acres planted (FSA)**

	Corn Acres Planted (1)	Soybean Acres Planted (2)	Wheat Acres Planted (3)
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. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.

Table 2A.8 **Effect of easements on acres harvested (NASS)**

	Corn Acres Harvested (1)	Soybean Acres Harvested (2)	Wheat Acres Harvested (3)
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. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.

Table 2A.9a **Effect of easements on acres failed to harvest (NASS)**

	Corn Acres Failed to Harvest (1)	Soybean Acres Failed to Harvest (2)	Wheat Acres Failed to Harvest (3)
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	34,793
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. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.

Table 2A.9b **Effect of easements on non-zero acres failed to harvest (NASS)**

	Corn Acres Failed to Harvest (1)	Soybean Acres Failed to Harvest (2)	Wheat Acres Failed to Harvest (3)
100% Wetland Easement Acres	1.656*	–1.186***	–1.380*
	(0.915)	(0.357)	(0.716)
100% Floodplain Easement Acres	0.055	0.662**	–0.826***
	(0.163)	(0.264)	(0.261)
Observations	49,112	42,006	33,050
Number of Counties	1,865	1,745	1,695
R-squared	0.075	0.116	0.095
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. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.

Table 2A.10 **Effect of easements on acres failed (FSA)**

	Corn Acres Failed (1)	Soybean Acres Failed (2)	Wheat Acres Failed (3)
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. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.

Table 2A.11 **Effect of easements on acres prevented planted (FSA)**

	Corn Acres Prevented Planted (1)	Soybean Acres Prevented Planted (2)	Wheat Acres Prevented Planted (3)
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. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.

Table 2A.12 **Effect of easements on yields through weather pathways**

	Corn Yield (1)	Soybean yield (2)	Wheat Yield (3)
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)
× 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)
× 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)
× 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)
× 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. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.

Table 2A.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
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

Table 2A.13 (cont.)

	Corn yield	Soybean yield	Wheat yield
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. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.

References

Annan, F., and W. Schlenker. 2015. "Federal Crop Insurance and the Disincentive to Adapt to Extreme Heat." *American Economic Review* 105 (5): 262–66.

Babcock, B., P. Lakshminarayan, J. Wu, and D. Zilberman. 1996. "The Economics of a Public Fund for Environmental Amenities: A Study of CRP Contracts." *American Journal of Agricultural Economics* 78: 961–71.

Bellemare, M. F., and C. J. Wichman. 2020. "Elasticities and the Inverse Hyperbolic Sine Transformation." *Oxford Bulletin of Economics and Statistics* 82 (1): 50–61.

Bostian, M. B., and A. T. Herlihy. 2014. "Valuing Tradeoffs between Agricultural Production and Wetland Condition in the U.S. Mid-Atlantic Region." *Ecological Economics* 105: 284–91.

Boxall, P. C., O. Perger, K. Packman, and M. Weber. 2017. "An Experimental Examination of Target Based Conservation Auctions." *Land Use Policy* 63: 592–600.

Boyer, C. N., E. Park, and S. D. Yun. 2022. "Corn and Soybean Prevented Planting Acres Response to Weather." *Applied Economic Perspectives and Policy*. February.

Brown, L. K., E. Troutt, C. Edwards, B. Gray, and W. Hu. 2011. "A Uniform Price Auction for Conservation Easements in the Canadian Prairies." *Environmental and Resource Economics* 50 (1): 49–60.

Brown, Ralph J. 1976. "A study of the impact of the wetlands easement program on agricultural land values." *Land Economics* 52 (4): 509–517.

Burke, M., and K. Emerick. 2016. "Adaptation to Climate Change: Evidence from US Agriculture." *American Economic Journal: Economic Policy* 8 (3): 106–40.

Callaway, Brantly, Andrew Goodman-Bacon, and Pedro HC Sant'Anna. "Difference-in-differences with a continuous treatment." arXiv preprint arXiv:2107.02637 (2021).

Callaway, B., and P. H. Sant'Anna. 2021. Difference-in-Differences with multiple time periods. *Journal of Econometrics* 225 (2): 200–230.

Coble, K. H., T. O. Knight, R. D. Pope, and J. R. Williams. 1997. "An Expected-Indemnity Approach to the Measurement of Moral Hazard in Crop Insurance." *American Journal of Agricultural Economics* 79 (1): 216–26.

Congressional Budget Office (CBO). 2019. "CBO's May 2019 Baseline for Farm Programs." pp. 55.

Congressional Research Service. 2021. "Federal Crop Insurance: A Primer." Technical report.

Costello, C., and S. Polasky. 2004. "Dynamic Reserve Site Selection." *Resource and Energy Economics* 26 (2): 157–74.

De Chaisemartin, C., and X. D'haultfoeuille. 2020. "Two-Way Fixed Effects Estimators with Heterogeneous Treatment Effects." *American Economic Review* 110 (9): 2964–2996.

De Chaisemartin, C., X. D'haultfoeuille, and Y. Guyonvarch. 2019. "Fuzzy Differences-in-Differences with Stata." *The Stata Journal* 1–22.

Deschênes, O., and M. Greenstone. 2012. "The Economic Impacts of Climate Change: Evidence from Agricultural Output and Random Fluctuations in Weather: Reply." *American Economic Review* 102 (7): 3761–3773.

Deutsch, C. A., J. J. Tewksbury, M. Tigchelaar, D. S. Battisti, S. C. Merrill, R. B. Huey, and R. L. Naylor. 2018. "Increase in Crop Losses to Insect Pests in a Warming Climate." *Science* 361: 916–19.

Eck, M. A., A. R. Murray, A. R. Ward, and C. E. Konrad. 2020. "Influence of Growing Season Temperature and Precipitation Anomalies on Crop Yield in the Southeastern United States." *Agricultural and Forest Meteorology* 291: 108053.

English, B. C., A. S. Smith, J. R. Menard, D. W. Hughes, and M. Gunderson. 2021. "Estimated
Economic Impacts of the 2019 Midwest Floods." *Economics of Disasters and Climate Change* 5: 431–48.
Ferraro, P. J. 2008. "Asymmetric Information and Contract Design for Payments for Environmental Services." *Ecological Economics* 65 (4): 810–21.
Fleckenstein, M., A. Lythgoe, J. Lu, N. Thompson, O. Doering, S. Harden, J. M. Getson, and L. Prokopy. 2020. "Crop insurance: A Barrier to Conservation Adoption? *Journal of Environmental Management* 276: 111223.
Fleming, D. A. 2014. "Slippage Effects of Land-Based Policies: Evaluating the Conservation Reserve Program Using Satellite Imagery." *Papers in Regional Science* 93 (S1): S167–S178.
Fleming, P., E. Lichtenberg, and D. A. Newburn. 2018. "Evaluating Impacts of Agricultural Cost Sharing on Water Quality: Additionality, Crowding In, and Slippage." *Journal of Environmental Economics and Management* 92: 1–19.
Gelso, B. R., J. A. Fox, and J. M. Peterson. 2008. "Farmers' Perceived Costs of Wetlands: Effects of Wetland Size, Hydration, and Dispersion." *American Journal of Agricultural Economics* 90 (1): 172–85.
Glauber, J. W. 2004. "Crop Insurance Reconsidered Published." *American Journal of Agricultural Economics* 86 (5): 1179–195.
Glauber, J. W. 2013. "The Growth of the Federal Crop Insurance Program, 1990–2011." *American Journal of Agricultural Economics* 95 (2): 482–88.
Gleason, R. A., M. K. Laubhan, and N. H. Euliss. 2008. "Ecosystem Services Derived from Wetland Conservation Practices in the United States Prairie Pothole Region with an Emphasis on the U.S. Department of Agriculture Conservation Reserve and Wetlands Reserve Programs." U.S. Geological Professional Paper 1745, 58.
Goodman-Bacon, A. 2021. "Difference-in-Differences with Variation in Treatment Timing." *Journal of Econometrics* 225 (2): 254–77.
Goodwin, B. K., and N. E. Piggott. 2020. "Has Technology Increased Agricultural Yield Risk? Evidence from the Crop Insurance Biotech Endorsement." *American Journal of Agricultural Economics* 102 (5): 1578–1597.
Gourevitch, J. D., N. K. Singh, J. Minot, K. B. Raub, D. M. Rizzo, B. C. Wemple, and T. H. Ricketts. 2020. "Spatial Targeting of Floodplain Restoration to Equitably Mitigate Flood Risk." *Global Environmental Change* 61.
Hagerty, N. 2022. "Adaptation to Surface Water Scarcity in Irrigated Agriculture." Working Paper.
Hansen, L. 2007. "Conservation Reserve Program: Environmental Benefits Update." *Agricultural and Resource Economics Review* 36 (2): 267–80.
Hansen, L. R., D. Hellerstein, M. Ribaudo, J. Williamson, D. Nulph, C. Loesch, and W. Crumpton. 2015. "Targeting Investment to Cost Effectively Restore and Protect Wetland Ecosystems: Some Economic Insights." Technical report, U.S. Department of Agriculture, Economic Research Service.
Hatfield, Jerry L., Kenneth J. Boote, Bruce A. Kimball, L. H. Ziska, Roberto C. Izaurralde, Donald Ort, Allison M. Thomson, and D. Wolfe. 2011. "Climate impacts on agriculture: implications for crop production." *Agronomy Journal* 103 (2): 351–370.
Hatfield, J. L., and J. H. Prueger. 2015. "Temperature Extremes: Effect on Plant Growth and Development." *Weather and Climate Extremes* 10: 4–10.
Hebblethwaite, J. F., and C. N. Somody. 2008. "Progress in Best Management Practices." Chapter 32 in *The Triazine Herbicides. Amsterdam*: Elsevier.
Heimlich, R. E. 1994. "Costs of an Agricultural Wetland Reserve." *Land Economics* 70 (2): 234–46.

Hellerstein, D., N. Higgins, and M. Roberts. 2015. "Options for Improving Conservation Programs: Insights from Auction Theory and Economic Experiments." *The Conservation Reserve Program: Issues and Considerations* 181; 79–139.

Hornbeck, R., and P. Keskin. 2014. "The Historically Evolving Impact of the Ogallala Aquifer: Agricultural Adaptation to Groundwater and Drought." *American Economic Journal: Applied Economics* 6 (1): 190–219.

Horowitz, J. K., and E. Lichtenberg. 1993. "Insurance, Moral Hazard, and Chemical Use in Agriculture." *American Journal of Agricultural Economics* 75 (4): 926–35.

IPCC. 2012. "Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation: Special Report of the Intergovernmental Panel on Climate Change." Technical report. Cambridge: Cambridge University Press.

Jabran, K., S. Florentine, and B. S. Chauhan. (2020). "Impacts of Climate Change on Weeds, Insect Pests, Plant Diseases and Crop Yields: Synthesis." In: *Crop Protection Under Changing Climate*, edited by K. Jabran, S. Florentine, and B. Chauhan. New York: Springer. https://doi.org/10.1007/978-3-030-46111-9_8.

Johnson, K. A., B. J. Dalzell, M. Donahue, J. Gourevitch, D. L. Johnson, G. S. Karlovits, B. Keeler, and J. T. Smith. 2016. "Conservation Reserve Program (CRP) Lands Provide Ecosystem Service Benefits That Exceed Land Rental Payment Costs." *Ecosystem Services* 18: 175–85.

Kim, T., and M.-K. Kim. 2018. "Ex-post Moral Hazard in Prevented Planting." *Agricultural Economics* 49 (6): 671–80.

Kirwan, B., R. Lubowski, and M. Roberts. 2005. "How Cost-Effective Are Land Retirement Auctions? Estimating the Difference between Payments and Willingness to Accept in the Conservation Reserve Program." *American Journal of Agricultural Economics* 87 (5): 1239–1247.

Kousky, C., and M. Walls. 2014. "Floodplain Conservation as a Flood Mitigation Strategy: Examining Costs and Benefits." *Ecological Economics* 104: 119–28.

Kucharik, C. J. 2008. "Contribution of Planting Date Trends to Increased Maize Yields in the Central United States." *Agronomy Journal* 100 (2): 328–36.

Lawley, C., and C. Towe. 2014. "Capitalized Costs of Habitat Conservation Easements." *American Journal of Agricultural Economics* 96 (3): 657–72.

Lichtenberg, E., and R. Smith-Ramírez. 2011. "Slippage in Conservation Cost Sharing." *American Journal of Agricultural Economics* 93 (1): 113–29.

Mérel, P., and M. Gammans. 2021. "Climate Econometrics: Can the Panel Approach Account for Long-Run Adaptation?" *American Journal of Agricultural Economics* 103 (4): 1207–1238.

Miao, R., H. Feng, D. A. Hennessy, and X. Du. 2016. "Assessing Cost-Effectiveness of the Conservation Reserve Program (CRP) and Interactions between the CRP and Crop Insurance." *Land Economics* 92 (4): 593–617.

Miao, R., D. A. Hennessy, and H. Feng. 2016. "Grassland Easement Evaluation and Acquisition: an Integrated Framework." *Agricultural and Applied Economics Association Annual Meeting*, 51.

Mushet, D. M., and C. L. Roth. 2020. "Modeling the Supporting Ecosystem Services of Depressional Wetlands in Agricultural Landscapes." *Wetlands* 40 (5): 1061–1069.

Narloch, U., U. Pascual, and A. G. Drucker. 2013. "How to Achieve Fairness in Payments for Ecosystem Services? Insights from Agrobiodiversity Conservation Auctions." *Land Use Policy* 35: 107–18.

Newburn, D. A., P. Berck, and A. M. Merenlender. 2006. "Habitat and Open Space at Risk of Land-Use Conversion: Targeting Strategies for Land Conservation." *American Journal of Agricultural Economics* 88 (1): 28–42.

Nickerson, C. J., and L. Lynch. 2001. "The Effect of Farmland Preservation Programs on Farmland Prices." *American Journal of Agricultural Economics* 83 (2): 341–51.

NOAA. 2020. "NOAA National Centers for Environmental Information, State of the Climate: National Climate Report for Annual 2019." Technical report.

NOAA National Centers for Environmental Information (NCEI). 2023. "U.S. Billion-Dollar Weather and Climate Disasters." Technical report. https://www.ncei.noaa.gov/access/billions/, DOI: 10.25921/stkw-7w73.

NRCS. 2011. "Conservation of Wetlands in Agricultural Landscapes of the United States: Summary of the CEAP-Wetlands Literature Synthesis." Technical report.

NRCS 2012. "Restoring America's Wetlands: A Private Lands Conservation Success Story." Technical report. Washington, DC.

NRCS. 2021a. EWP Floodplain Easement Program-Floodplain Easement Option EWPP-FPE. www.nrcs.usda.gov/wps/portal/nrcs/detail/national/programs/landscape/ewpp/?cid=nrcsl43 008216.

NRCS. 2021b. Wetlands. www.nrcs.usda.gov/wps/portal/nrcs/main/national/water/wetlands/?cid=stelprdb1043554.

NRCS. 2021c. Wetlands Reserve Program. www.nrcs.usda.gov/wps/portal/nrcs/detail/null/?cid=nrcsl43 008419.

Ortiz-Bobea, Ariel. 2021. "The empirical analysis of climate change impacts and adaptation in agriculture." In *Handbook of Agricultural Economics*, volume 5, 3981–4073. Amsterdam: Elsevier.

Parker, D. P., and W. N. Thurman. 2018. "Tax Incentives and the Price of Conservation." *Journal of the Association of Environmental and Resource Economists* 5 (2): 331–69.

Perry, E. D., J. Yu, and J. Tack. 2020. "Using Insurance Data to Quantify the Multidimensional Impacts of Warming Temperatures on Yield Risk." *Nature Communications* 11 (1): 1–9.

Pfaff, A., and J. Robalino. 2017. "Spillovers from Conservation Programs." *Annual Review of Resource Economics* 9: 299–315.

Roberts, M. J., and S. Bucholtz. 2005. "Slippage Effects of the Conservation Reserve Program or Spurious Correlation? A Comment." *American Journal of Agricultural Economics* 87 (1): 244–50.

Roley, S. S., J. L. Tank, J. C. Tyndall, and J. D. Witter. 2016. "How Cost-Effective Are Cover Crops, Wetlands, and Two-Stage Ditches for Nitrogen Removal in the Mississippi River Basin? *Water Resources and Economics* 15:43–56.

Rosenzweig, C., J. Elliott, D. Deryng, A. C. Ruane, C. Müller, A. Arneth, K. J. Boote, C. Folberth, M. Glotter, N. Khabarov, K. Neumann, F. Piontek, T. A. M. Pugh, E. Schmid, E. Stehfest, H. Yang, and J. W. Jones. 2014. "Assessing Agricultural Risks of Climate Change in the 21st Century in a Global Gridded Crop Model Intercomparison." *Proceedings of the National Academy of Sciences* 111 (9): 3268–3273.

Rosenzweig, C., F. N. Tubiello, R. Goldberg, E. Mills, and J. Bloomfield. 2002. "Increased Crop Damage in the US from Excess Precipitation under Climate Change." *Global Environmental Change* 12: 197–202.

Savary, S., L. Willocquet, S. J. Pethybridge, P. Esker, N. McRoberts, and A. Nelson. 2019. "The Global Burden of Pathogens and Pests on Major Food Crops." *Nature Ecology & Evolution* 3: 430–39.

Schlenker, W., and M. J. Roberts. 2009. "Nonlinear Temperature Effects Indicate Severe Damages to U.S. Crop Yields under Climate Change." *Proceedings of the National Academy of Sciences* 106 (37): 15594–15598.

Schnapp, F., J. Driscoll, T. Zacharias, and R. Josephson. 2000. "Ratemaking Con-

sideration for Multiple Peril Crop Insurance." Report prepared for USDA/Risk Management Agency.
Schulte, L. A., J. Niemi, M. J. Helmers, M. Liebman, J. G. Arbuckle, D. E. James, R. K. Kolka, M. E. O'Neal, M. D. Tomer, J. C. Tyndall, H. Asbjornsen, P. Drobney, J. Neal, G. V. Ryswyk, and C. Witte. 2017. "Prairie Strips Improve Biodiversity and the Delivery of Multiple Ecosystem Services from Corn-Soybean Croplands." *Proceedings of the National Academy of Sciences* 114 (50): 11247–11252
Seifert, C. A., M. J. Roberts, and D. B. Lobell. 2017. "Continuous Corn and Soybean Yield Penalties across Hundreds of Thousands of Fields." *Agronomy Journal* 109 (2): 541–48.
Shirzaei, M., M. Khoshmanesh, C. Ojha, S. Werth, H. Kerner, G. Carlson, S. F. Sherpa, G. Zhai, and J. C. Lee. 2021. "Persistent Impact of Spring Floods on Crop Loss in U.S. Midwest." *Weather and Climate Extremes* 34: 100392.
Shoemaker, R. 1989. "Agricultural Land Values and Rents under the Conservation Reserve Program." *Land Economics* 65 (2): 131–37.
Shultz, S. D., and S. J. Taff. 2004. "Implicit Prices of Wetland Easements in Areas of Production Agriculture." *Land Economics* 80 (4): 501–12.
Sloat, L. L., S. J. Davis, J. S. Gerber, F. C. Moore, D. K. Ray, P. C. West, and N. D. Mueller. 2020. "Climate Adaptation by Crop Migration." *Nature Communications* 11 (1243): 1–9.
Smith, V. H., and B. K. Goodwin. 1996. "Crop Insurance, Moral Hazard, and Agricultural Chemical Use." *American Journal of Agricultural Economics* 78 (2): 428–38.
Sonnier, G., P. J. Bohlen, H. M. Swain, S. L. Orzell, E. L. Bridges, and E. H. Boughton. 2018. "Assessing the Success of Hydrological Restoration in Two Conservation Easements within Central Florida Ranchland." *PLoS ONE* 13 (7): e0199333.
Speir, S. L., J. L. Tank, and U. H. Mahl. 2020. "Quantifying Denitrification following Floodplain Restoration via the Two-Stage Ditch in an Agricultural Watershed." *Ecological Engineering* 155: 105945.
Tack, J., K. Coble, and B. Barnett. 2018. "Warming Temperatures Will Likely Induce Higher Premium Rates and Government Outlays for the U.S. Crop Insurance Program." *Agricultural Economics* 49 (5): 635–47.
Taylor, C. A., and H. Druckenmiller. 2022. "Wetlands, Flooding, and the Clean Water Act." *American Economic Review* 112 (4): 1334–1363.
Uchida, S. 2014. "Indirect Land Use Effects of Conservation: Disaggregate Slippage in the US Conservation Reserve Program." Working paper. University of Maryland.
Urban, D. W., M. J. Roberts, W. Schlenker, and D. B. Lobell. 2015. "The Effects of Extremely Wet Planting Conditions on Maize and Soybean Yields." *Climatic Change* 130 (2): 247–60.
USDA 2021. NRCS Conservation Programs. www.nrcs.usda.gov/Internet/NRCS RCA/reports/cp nat.html.
Watson, K. B., T. Ricketts, G. Galford, S. Polasky, and J. O'Niel-Dunne. 2016. "Quantifying Flood Mitigation Services: The Economic Value of Otter Creek Wetlands and Floodplains to Middlebury, VT." *Ecological Economics* 130: 16–24.
Wing, I. S., E. De Cian, and M. N. Mistry. 2021. "Global Vulnerability of Crop Yields to Climate Change." *Journal of Environmental Economics and Management* 109: 102462.
Woodard, J. D., B. J. Sherrick, and G. D. Schnitkey. 2011. "Actuarial Impacts of Loss Cost Ratio Ratemaking in U.S. Crop Insurance Programs." *Journal of Agricultural and Resource Economics* 36 (1): 211–28.

Wu, J. 2000. "Slippage Effects of the Conservation Reserve Program." *Journal of Environmental Economics and Management* 82 (November): 979–92.

Wu, J., D. Zilberman, and B. A. Babcock. 2001. "Environmental and Distributional Impacts of Conservation Targeting Strategies." *Journal of Environmental Economics and Management* 41 (3): 333–50.

Wu, S., B. K. Goodwin, and K. Coble. 2020. "Moral Hazard and Subsidized Crop Insurance." *Agricultural Economics* 51 (1): 131–42.

Yu, J., and N. P. Hendricks. 2020. "Input Use Decisions with Greater Information on Crop Conditions: Implications for Insurance Moral Hazard and the Environment." *American Journal of Agricultural Economics* 102 (3): 826–45.

Yu, J., and D. A. Sumner 2018. "Effects of Subsidized Crop Insurance on Crop Choices." *Agricultural Economics* 49 (4): 533–45.

Zipper, S. C., J. Qiu, and C. J. Kucharik. 2016. "Drought Effects on US Maize and Soybean Production: Spatiotemporal Patterns and Historical Changes." *Environmental Research Letters* 11: 094021.