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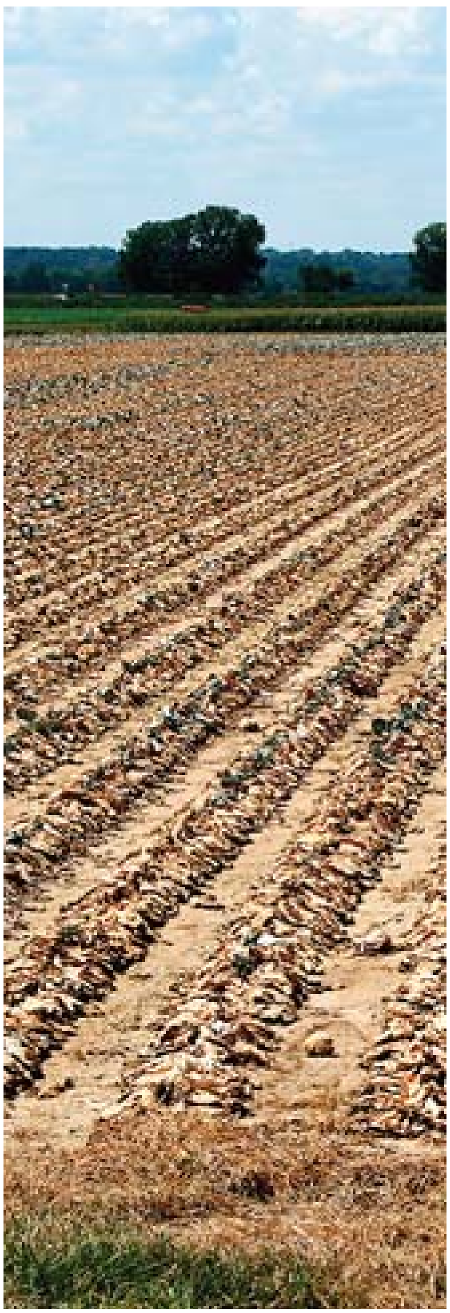

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The Role of Conservation Programs in Drought Risk Adaptation

Steven Wallander, swallander@ers.usda.gov
Marcel Aillery, maillery@ers.usda.gov
Daniel Hellerstein, danielh@ers.usda.gov
Michael Hand, mshand@fs.fed.us

Abstract

This report evaluates the extent to which farms facing higher levels of drought risk are more likely to participate in conservation programs, and finds a strong link between drought risk and program participation. Prior research has shown that climate-related risk exposure influences production decisions such as crop choice; our research shows that adaptation also includes program participation decisions. Programs like the Conservation Reserve Program and Environmental Quality Incentives Program play a role in drought preparedness and climate adaptation even if they do not directly target such behavior. Conservation program outcomes are influenced by regional differences in production risk, so participation choices due to drought risk can be an important consideration in designing such programs.

Keywords: Climate, conservation programs, drought, adaptation, irrigation efficiency, land retirement, risk, tillage

Acknowledgments

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Contents

Summary

During the summer of 2012, almost 80 percent of U.S. agricultural land suffered drought. In terms of severity and geographic extent, the 2012 drought approached the peak Dust Bowl year of 1934. However, agricultural production has grown more adaptive since the 1930s, aided by crop genetics, crop insurance, and conservation programs. This report examines the relationship between drought risk and patterns of conservation program participation, and whether regional differences in drought risk can be incorporated into conservation program design.

What Is the Issue?

A major drought is among the most serious production shocks a farm can experience. Over the past decade, total drought-related crop insurance indemnities and disaster relief payments averaged about $4 billion annually, after averaging less than $1.3 billion per year in the 1980s. The rise in total payments is due to a combination of expanded enrollment in crop insurance, increased liabilities due to higher yields and commodity prices, and a series of major droughts in recent decades. Farms in more drought-prone regions may adapt to higher levels of risk by adjusting their crop choices or investing in more efficient irrigation systems. But do existing farm programs encourage or discourage farmers from reacting to drought risk?

What Did the Study Find?

Most prior research on this question has examined the role of crop insurance. Here we hypothesize that participation in the Conservation Reserve Program (CRP) and the Environmental Quality Incentives Program (EQIP) is responsive to drought risk, as evidenced by the role of many funded practices—retirement of sensitive lands, investment in technology that improves irrigation efficiency, and adoption of tillage practices that conserve soil moisture—in improving drought preparedness. Therefore, program outcomes can vary widely between low-risk counties, which are expected to experience fewer than 6 severe or extreme droughts per century, and the highest-risk counties, which are expected to experience between 12 and 20.

We find that differences in climate influence conservation program participation. Farms in more drought-prone regions are more likely to offer eligible land for enrollment in CRP—a 1-percent increase in drought risk leads to a 2.4-percent increase in the offer rate. Irrigators facing higher drought risk are more likely to be enrolled in EQIP contracts with irrigation practices. And crop farms facing higher drought risk are more likely to be enrolled in EQIP contracts with conservation tillage practices.

CRP bid caps for retiring farmland are designed to set the maximum CRP rental rate equal to the expected cash rental rate for a given cropland parcel, so most landowners should be fairly indifferent between putting land into CRP and leaving land in crop production. However, idling cropland can be an important way to replenish soil moisture and recharge aquifers, and special grazing provisions under the CRP provide a means of drought response for livestock operations. To demonstrate how existing program designs constrain drought risk adaptation, we create a number of

policy scenarios, through which we model changes in factors such as contract rankings or county enrollment caps.

- Revising the Environmental Benefits Index (EBI) to assign points for land in counties facing higher drought risk would lead to a small increase in offer rates and a 1.4-percent increase in total acres offered. Raising the EBI in high-risk counties effectively reduces offer rates in other counties. This suggests that a moderate increase in EBI points, granted to medium- and high-drought-risk (HDR) counties, would have a limited impact nationally (increasing total acres offered by less than 2 percent) but a more pronounced impact within drought-prone counties.
- Since drought risk increases offer rates, HDR counties are more likely to hit the county enrollment caps. Increasing the county CRP enrollment cap from its current 25 percent of cropland acres to 70 percent would increase offered acres almost 28 percent compared to the baseline, over a third of which come from the HDR counties.

We observe a similar relationship between drought risk and program outcomes under EQIP. Irrigators who install improved technology are often able to reduce water lost to evaporation and infiltration, which allows them to provide more water for their crops, particularly during drought years. Similarly, crop producers who utilize conservation tillage are often able to improve the capture and storage of soil moisture, which provides their crops an important buffer against drought impacts. For livestock producers, prescribed grazing plans provide some private benefits in coping with drought risk: forage management, prescribed animal stocking rates or planned grazing, and water supply augmentation for livestock. EQIP program design may also limit the extent to which producers rely on financial assistance for drought risk adaptation, but the impacts of specific policy changes are not as readily modeled given differences in data on program participation.

If climate change increases drought risk, as many studies predict, this may lead to increased demand by farmers for participation in conservation programs. However, both CRP and EQIP have policy designs that may discourage or limit the extent to which farmers rely on the programs for drought risk adaptation, with unintended effects on the geographic pattern of participation. For example, factors that limit participation in CRP, particularly county enrollment caps and program eligibility requirements, are most often binding constraints in the highest drought-risk counties.

How Was the Study Conducted?

Drought risk is measured by the variance in the Palmer Modified Drought Index over the past 100 years. To assess the response of farmers to variation in drought risk, we develop econometric models to separate the effects of drought risk from other factors that influence program participation.

With CRP, we evaluate the effect of drought risk on the probability that eligible land is offered for enrollment. Based on newly constructed estimates of the amount of eligible land within each county, we econometrically estimate a likelihood-to-offer model. With EQIP, we evaluate the effect of drought risk on the share of farms in a county using EQIP contracts for financial assistance with practices—irrigation-related and conservation tillage—that have been demonstrated to have drought-mitigating benefits.

For the livestock sector, we discuss a number of features within conservation programs that may help producers respond to drought risk. CRP includes emergency haying and grazing provisions that are helpful to farms facing severe reductions in forage production. EQIP includes funding for a number of practices that help address water shortages for livestock and drought damages on pastureland. While we do not perform the same type of empirical analysis as for cropland, the available livestock sector data indicate that the connection between drought risk and conservation program participation is not limited to the crop sector.

Introduction

During the summer of 2012, almost 80 percent of U.S. agricultural land suffered drought. In terms of severity and geographic extent, the 2012 drought rivaled the 1988 and 1954 droughts and approached the peak Dust Bowl year of 1934. However, many aspects of agricultural production have changed since 1934, 1954, and even 1988. With respect to drought, three very significant changes are crop genetics, crop insurance, and conservation programs. In this report, we examine the relationship between conservation programs and drought.

While a number of reports examine the role of agricultural policy in encouraging drought preparedness (NDPC, 2000), very few empirical studies assess the factors that influence farmer preparedness efforts. This report examines drought risk adaptation, defined as the choices that farmers make in response to drought risk exposure. Many practices cited as potentially effective adaptation responses to drought—including land retirement, irrigation efficiency improvements, and conservation tillage—are already an important focus of USDA conservation programs.

To conduct our analyses, we gather data on farm-level eligibility for and participation in conservation programs. We then aggregate that data to the county level to measure variation in participation rates. We use econometric models to estimate the effect of drought risk on participation while controlling for other factors that also influence program participation.

Conservation Programs and Drought Risk

A new era for U.S. resource conservation emerged from the Dust Bowl years of the 1930s. With the establishment of the Soil Conservation Service—precursor to the Natural Resources Conservation Service (NRCS)—in 1935 and the formation of local soil conservation districts, the Federal Government joined with the farm community to promote agricultural resource conservation through information dissemination, technical assistance, and financial assistance.

Today, the majority of agricultural conservation funding is allocated within two broad program areas. *Working lands* programs provide financial and technical assistance for adoption of eligible conserving practices on working farms and ranchlands. *Land retirement* programs remove environmentally sensitive cropland from production under long-term contracts or permanent easements. Participating farms may receive annual rental payments, a one-time permanent easement purchase payment, and financial assistance to establish and maintain vegetative cover (see box, "USDA Conservation Programs").

Federal funding for agricultural conservation has expanded significantly under successive farm legislation since 1985. Land retirement programs dominated conservation funding from 1987 through 2002 (fig. 1). Since the 2002 Farm Act, Congress has increased the level of financial support for working lands programs.

In evaluating the role of Federal programs in promoting adaptation to drought risk, we focus on two major USDA conservation programs—the Environmental Quality

USDA Conservation Programs

There are many different USDA conservation programs, including a number of pilot programs. Here we present brief descriptions of the largest programs.

Working lands programs

Environmental Quality Incentives Program (EQIP)—Provides financial and technical assistance to encourage voluntary adoption of farming and ranching systems that conserve resources and enhance environmental performance.

Conservation Stewardship Program (CSP)—Provides financial and technical assistance for conserving systems; targets farmers and ranchers who have demonstrated high levels of conservation stewardship (formerly the Conservation Security Program).

Wildlife Habitat Incentives Program (WHIP)—Provides financial and technical assistance for habitat enhancement on farm and ranch operations.

Emergency Conservation Program (ECP)—Provides emergency funding and technical assistance to rehabilitate farmland damaged by natural disasters, including drought, and to provide drought-emergency water supplies for livestock.

Land retirement programs

Conservation Reserve Program (CRP)—Targets retirement of highly erodible lands and other environmentally sensitive lands from agricultural production under long-term lease agreements. Most land is enrolled through general signup, but other variations include:

CRP continuous signup—Administered under the CRP, provides additional financial incentives for primarily partial field enrollment in priority conservation practices.

Conservation Reserve Enhancement Program (CREP)—Administered under the CRP in collaboration with States, tribes, and other entities, provides additional financial incentives for retirement of environmentally sensitive lands targeted to local priorities.

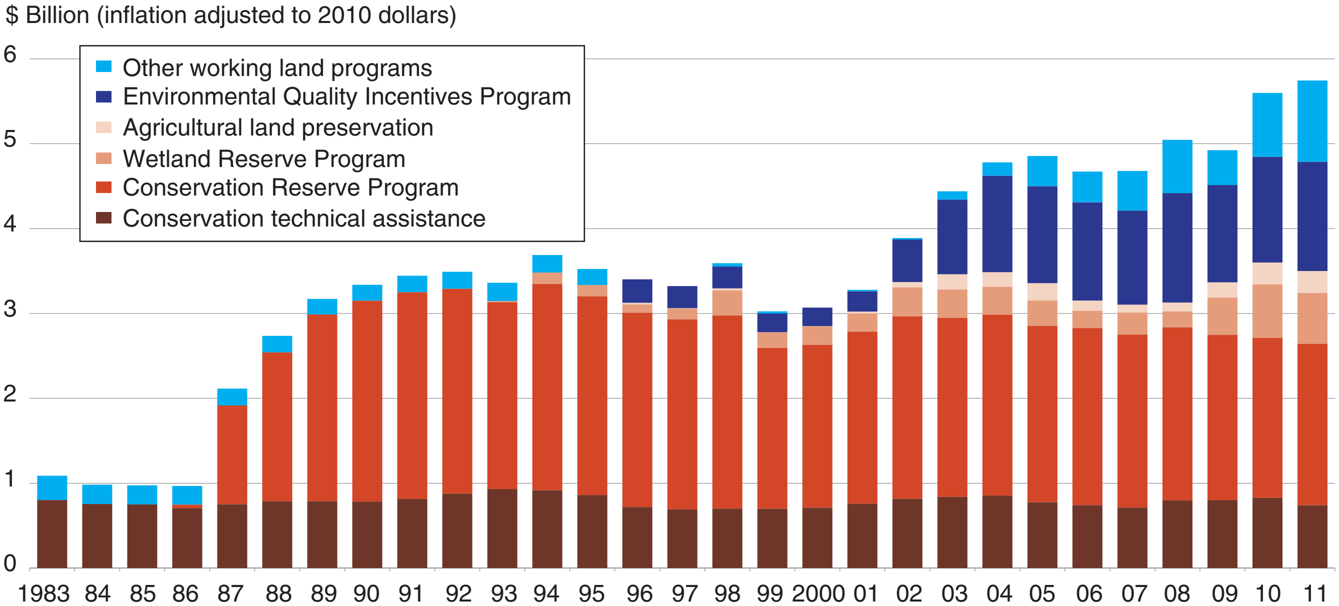
Wetlands Reserve Program (WRP)—Provides financial and technical support for restoration of wetlands under permanent easement or long-term agreements.

Farmland preservation

Farm and Ranch Lands Protection Program (FRPP)—Provides funds to States, tribes, and other entities to help purchase development rights that keep production farmland in agricultural uses.

Grassland Reserve Program (GRP)—Provides financial and technical assistance to preserve and improve native-grass grazing lands through long-term contracts and easements.

Figure 1
Trends in USDA conservation expenditures, 1983 to 2011



Notes: The 1985 Farm Act introduced the CRP. The 1996 Farm Act introduced the EQIP to replace and consolidate earlier working lands programs. EQIP expenditures include the Agricultural Water Enhancement Program (AWEP), the Ground and Surface Water Conservation Program (GSWC), and the Klamath Basin Program. "Other working land programs" include the Conservation Security Program, the Conservation Stewardship Program, and the Wildlife Habitat Incentives Program (WHIP). Expenditures are inflation-adjusted to 2010 dollars using the Bureau of Economic Analysis first quarter Gross Domestic Product deflator.

Source: ERS calculations based on Office of Budget and Policy Analysis reports. Data are for authorized outlays.

Incentives Program (EQIP), the largest of the working lands programs, and the Conservation Reserve Program (CRP), the largest of the land retirement programs. Since 2008, these two programs together have comprised more than 70 percent of direct conservation payments.[1] Neither program has drought response nor climate adaptation as a primary focus, but both may have added appeal to producers in more drought-prone regions.

Adaptation to Drought Risk and Climate Change

Since farms vary in their exposure to drought risk, we expect farmers to vary in their levels of drought preparedness. Drought risk adaptation is the variation in drought preparedness that is due to differences in drought risk and is a form of climate adaptation. Climate change is already affecting the agricultural sector (Hatfield et al., 2008), and drought risk is likely to increase in most areas of the United States (Hirabayashi et al., 2008; Strzepek et al., 2010).

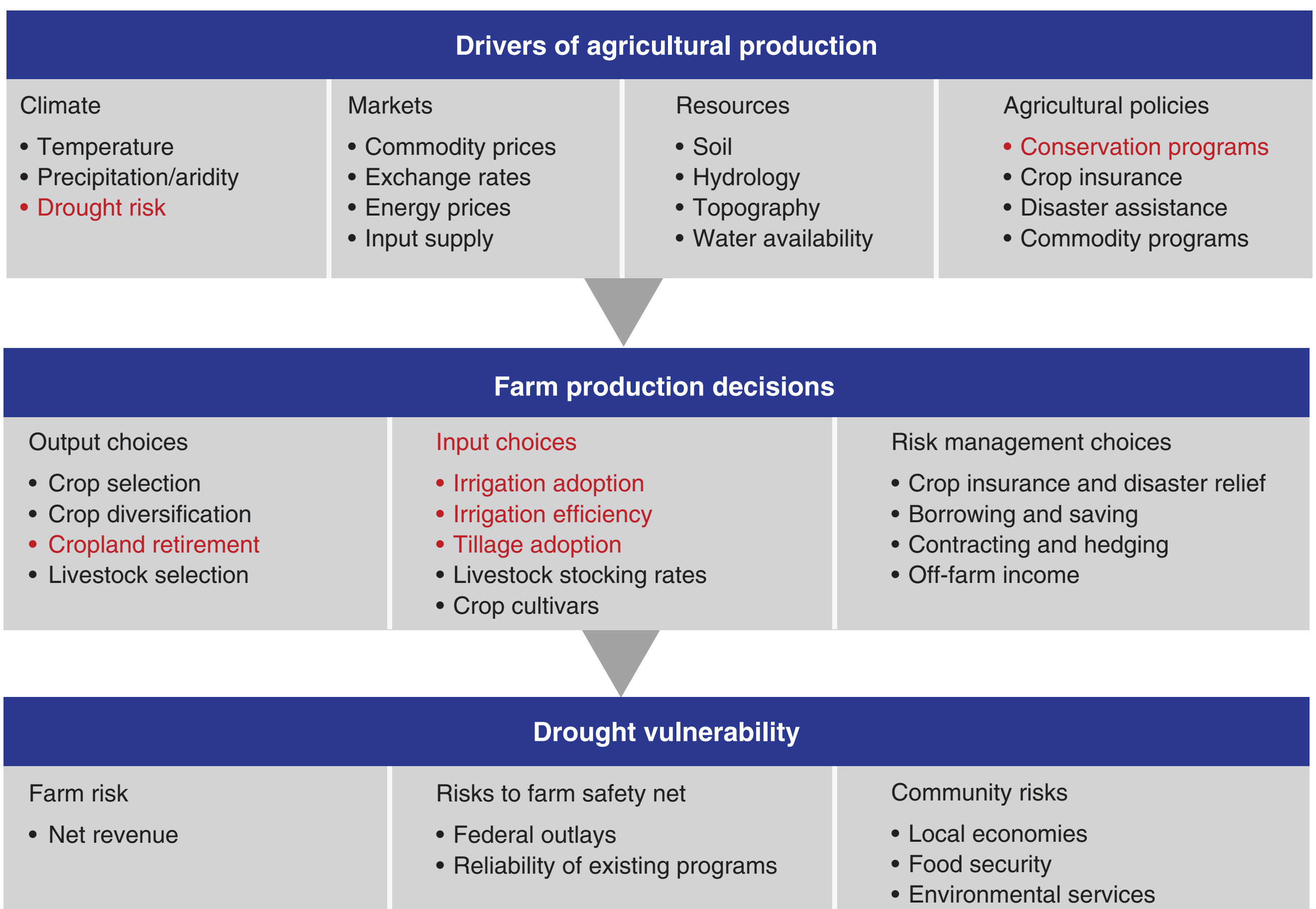
The climate change literature draws a distinction between "autonomous" adaptation to climate change, or adjustments by individuals, and "planned" adaptation, or adjustments by policymakers. Planned climate adaptation consists of changes in

[1] Direct conservation payments include rental payments and financial assistance payments. Indirect conservation payments include conservation technical assistance, which supports the development of conservation plans.

institutions, policies, and infrastructure, generally in advance of expected changes in climate. Agricultural policies often involve voluntary participation by farmers, so any effort at planned adaptation is contingent on farm-level production decisions (fig. 2).[2] Autonomous adaptation to risk, and particularly drought risk, may be costly (Just and Pope, 2002). This report assumes that producers understand the costs of alternative strategies for drought risk adaptation and that participation in a conservation program will make sense for some producers and not for others.

An empirical link between drought risk and conservation program participation would suggest that conservation program design may affect program participation in a changing climate. Such a link would also imply a potential tradeoff between crop

Figure 2
Research framework: farm production decisions, climate, and conservation programs

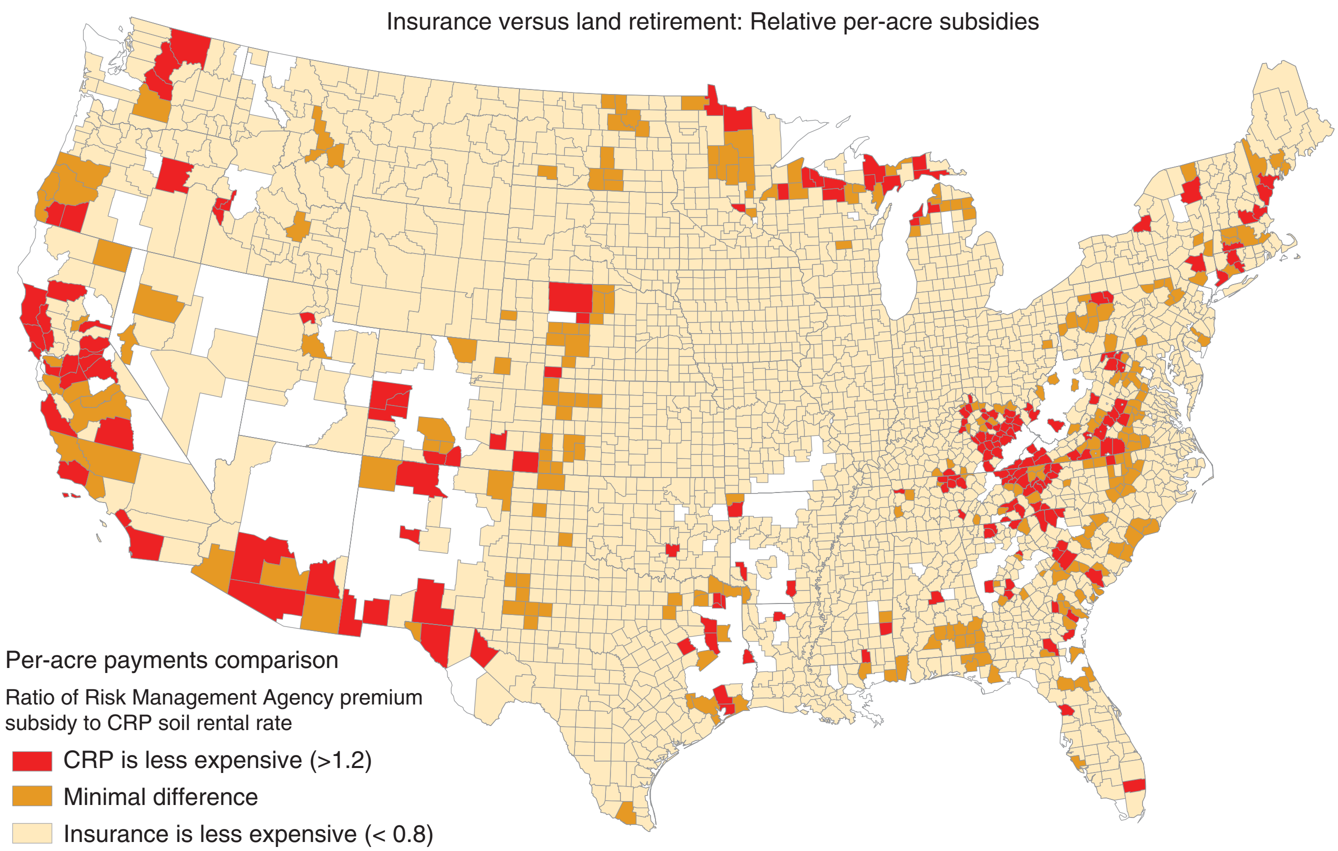


[2] One notable exception, a policy that is mandatory (conditional on other program participation), is conservation compliance.

insurance enrollment and conservation program participation, with budgetary implications for both programs. Enrollment in CRP illustrates such a tradeoff. Marginal lands that are more likely to be retired in CRP also tend to face above-average production risk (Lubowski et al., 2006). An implication of this tradeoff is that there may be high-risk, marginally productive land for which CRP rental payments are less than crop insurance premium subsidies, on a per-acre basis. In such areas, expanding CRP enrollment and reducing crop insurance enrollment could lead to greater environmental benefits and lower Federal outlays. However, such opportunities are likely rare. In the majority of counties, the average insurance premium subsidy is less than 80 percent of the CRP rental rate (fig. 3). There are some counties, though, where the reverse is true and the average premium subsidy is at least 20 percent higher than the average CRP rental rate. The extent to which costs could actually be reduced by encouraging CRP enrollment in some areas depends upon farm-level decisions—including CRP contract offers and crop insurance enroll-

Figure 3

Conservation Reserve Program rental rates and crop insurance subsidies by county, 2008



Source: ERS calculations. Data on CRP rental rates are calculated from USDA/Farm Service Agency CRP contract data. These rental rates are the average payment per acre that farms currently enrolled in CRP receive in exchange for agreeing to retire their land from crop production and instead maintain cover crops and other practices to provide environmental benefits. Data on per-acre crop insurance subsidies are calculated from USDA/Risk Management Agency summary-of-business files. These subsidies are the average cost per acre per year to pay the federally financed portion of crop insurance premium subsidies. These payments are not made directly to the farms, so the comparison between programs is a partial look at Federal costs per acre and does not reflect differences in payments to farms.

ment (e.g., buy-up) decisions. We do not attempt to model those decisions in our analysis since that would require joining micro data in a way not currently possible with acceptable accuracy.

Amid heightened drought risk, U.S. agricultural policymakers could focus on increasing the extent to which existing programs and policies facilitate adaptation (Council on Environmental Quality, 2010; Antle, 2009) or they could consider new adaptation policies (Easterling et al., 2004). Under either planned adaptation strategy, the role of conservation programs depends, in part, on how climate influences farmer participation in such programs. This report addresses that policy uncertainty by examining the role of drought risk within agricultural conservation programs and considering potential changes in conservation program design, such as adjustments in contract ranking criteria or changes in eligibility requirements.

Defining Drought Risk Adaptation

This report focuses on two concepts that require careful definition for empirical research: drought risk and drought risk adaptation. To introduce these concepts, we begin with a history of Federal drought assistance over the past 40 years. Then we present a brief primer on meteorological measures of drought severity and look at the past century of U.S. droughts in terms of these measures. From the Palmer Modified Drought Index (PMDI), we construct an empirical measure of drought risk. Last, we define drought risk adaptation. There are two key findings in this chapter:

- Over the past decade, total drought-related crop insurance indemnities and disaster relief payments, which capture a portion of the cost of drought damages to agriculture, averaged about $4 billion annually.
- Measures of drought risk reflect geographic differences in precipitation and temperature probability distributions.

How Harmful Is Drought?

Local precipitation is an essential input for agricultural production in most regions of the country. Droughts result from below-normal precipitation over a sustained period, often in conjunction with above-normal temperatures, and can severely reduce agricultural productivity. In the context of agriculture, there are three types of drought impacts:

- ***Farm-level impacts*** can include declines in farm income resulting from reduced crop yields or forage production, though these impacts may be offset by increases in income from higher commodity prices and Federal drought assistance.
- ***Market-level impacts*** include higher commodity prices, which can greatly reduce the income of livestock producers who depend on purchased feed and can erode the purchasing power of consumers.
- ***Environmental impacts*** include stresses on land and water resources and the provision of ecosystem services such as wildlife habitat and water quality. In some cases, as with soil erosion during the Dust Bowl, environmental impacts may exacerbate farm-level and market-level impacts.

The significance of drought to the Federal budget depends upon the extent to which USDA and other Federal agencies are tasked with alleviating the farm-level, market-level, and environmental impacts of drought. The farm safety net in the United States—a combination of Federal crop insurance and ad hoc disaster assistance payments as well as several other farm programs—provides a partial buffer against the farm-level impacts of price shocks or production impacts such as drought. Drought-related payments are discussed here only as a proxy for farm-level drought impacts. In many cases, farm productivity losses may not be sufficient to trigger payments, or may not be fully compensated under drought payment programs. Market-level impacts, including shocks to food prices and secondary impacts on farm communities that are heavily dependent on farm income and production, are not directly addressed by the farm safety net. In addition, drought impacts outside of the agricultural sector are not included at all. Payments made through the farm safety net rarely reflect total economic impacts.

Over the past four decades, drought has been the largest individual cause of U.S. farm production losses. Drought is responsible for 40 percent of total crop insurance indemnity payments made through the Federal crop insurance program. The crop insurance program, administered by USDA's Risk Management Agency (RMA), provides enrolled farms with indemnity payments when yields and/or prices fall below specified levels. Since the earliest years of the crop insurance program, RMA has tracked indemnity payments by cause of loss. Between 1948 and 2010, crop insurance provided $86.5 billion in indemnities for farm production losses (adjusted for inflation to 2010 dollars), of which $32.5 billion resulted from drought. The next largest causes of loss were excess moisture ($20.5 billion), hail ($7.7 billion), freezes ($3.3 billion), heat ($3.2 billion), and commodity price declines ($3.2 billion).[3] The 2011 and 2012 droughts are likely to significantly increase the relative importance of drought, but data on indemnities from these droughts are still preliminary.

Disaster assistance payments are an equally important part of the farm safety net. During the 1976-77 drought, a standing disaster relief program generated billions of dollars in payments and considerable controversy (GAO, 1979) that led to the creation of the modern crop insurance program in 1980 (Dismukes and Glauber, 2005). Since the expansion of the crop insurance program did not entirely replace ad hoc disaster assistance, it is helpful to examine indemnity payments and disaster assistance together (fig. 4).[4]

Examining indemnity and disaster payments together reveals several facts about the farm-level impacts of drought. First, focusing only on indemnity payments would dramatically understate the significance of drought. Second, drought impacts vary widely from year to year. Last, average annual payments for drought impacts

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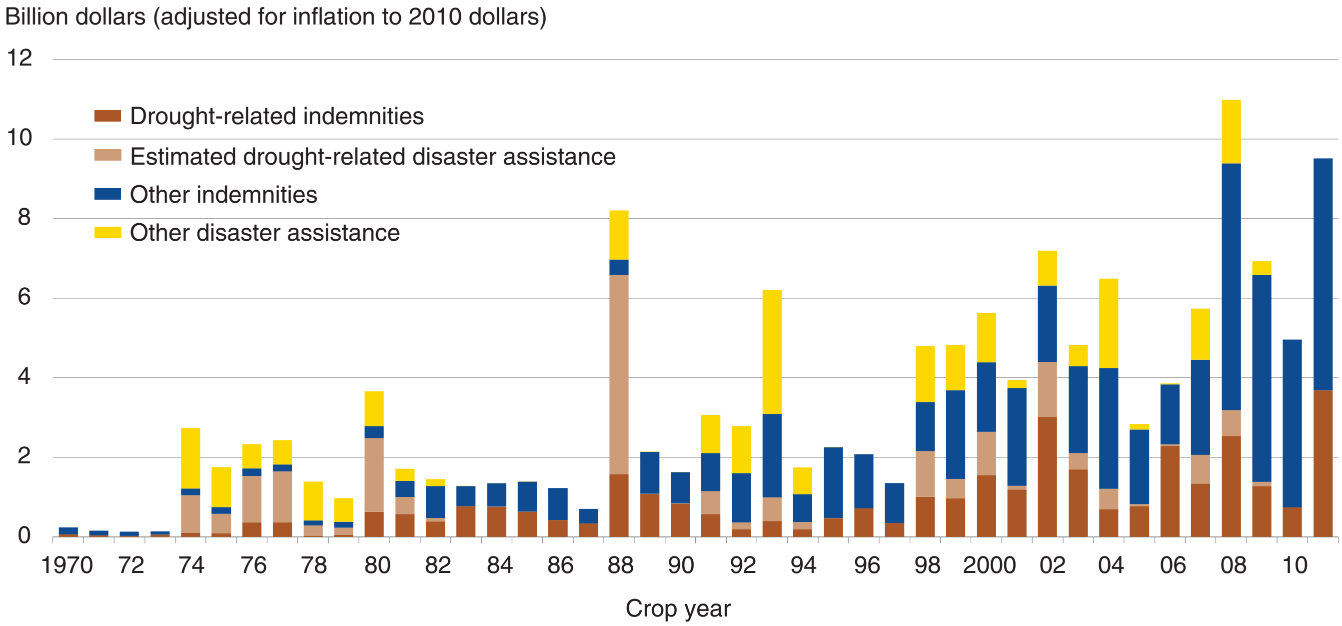
[3] Total indemnities are reported in the RMA summary of business file (www.rma.usda.gov/data/sob.html), which was converted to 2010 dollars using the annual Consumer Price Index (CPI-U) and then aggregated by cause of loss. Total assistance for price declines represents a small portion of crop insurance indemnity payments, in part because most price risk was historically addressed through other programs such as emergency loans, loan deficiency payments, and countercyclical payments. With the recent shift of many farms from yield-based insurance to revenue insurance, price risk is gaining in significance as a source of indemnity payments.

[4] Because the RMA tracks the cause of loss for every indemnity payment, the exact portion of indemnity payments due to drought is reported in each crop year. In contrast, disaster payments are not tracked by cause of loss and so the exact portion of disaster payments due to drought is not known. We assume that the portion of disaster assistance due to drought in each year is the same as the proportion of indemnity payments due to drought, an assumption supported by the fact that crop insurance participation is a prerequisite for most disaster assistance programs. A review of the legislative actions authorizing disaster assistance qualitatively confirms the relative significance of drought within ad hoc assistance (Chite, 2006). Drought has likely played a similar role in current disaster assistance programs, most notably the Supplemental Revenue Assistance Payments (SURE) program. However, since payments through SURE lag the actual disasters, current data on these payments are preliminary and understate total impacts.

Figure 4

Drought-related indemnity and disaster assistance payments, 1970-2011



Notes: Following Glauber (2004), Commodity Credit Corporation (CCC) disaster assistance payments are lagged by 1 year (i.e., FY95 payments appear above in 1994 since losses for those payments occurred in 1994). Beyond drought, major disaster assistance payments reflect a variety of disasters: floods (1993), freezing (1994), low prices (1998-2000), and hurricanes (2006). While some of the indemnities shown here include coverage for drops in commodity prices, this figure does not include major ad hoc payments that are recorded in CCC tables as "market loss assistance," including $6.6 billion in 1998, $14.8 billion in 1999, and $11.3 billion in 2000 (all nominal dollars), or other standing assistance programs such as marketing loans because these programs are not related primarily to yield risk.

Sources: USDA Risk Management Agency provides "cause-of-loss" files that categorize indemnity payments by cause of loss for the (crop) year in which they occur. USDA provides annual (FY) reports of CCC expenditures, including a category for disaster assistance. Disaster assistance is categorized as either drought-related or other (non-drought-related) based on descriptions of appropriations given in Congressional Research Service Report RL31095. Disaster relief payments for 1981-85 are from Glauber (2004). More recent disaster assistance payments are obtained from annual CCC reports (http://www.fsa.usda.gov/FSA/webapp?area=about&subject=landing&topic=bap-bu-cc).

are clearly trending upward. The rise in total payments is due to a combination of expanded enrollment in crop insurance, increased liabilities due to higher yields and commodity prices, and a series of major droughts in recent decades.

How Is Drought Measured?

The details underlying standard measures for drought are crucial to understanding the drought risk measure that we construct for this study. Droughts vary by timing, duration, severity, and geographic extent. Since each of these factors influences drought impacts, meteorologists and statisticians have developed drought indices to make comparisons across years within a given region and across regions within a given year. Every drought index includes some measure of precipitation. Many drought indices reflect other environmental factors such as temperature, wind, and soil characteristics. Drought indices often differ based on differing definitions of drought and in their statistical derivations (see box, "Drought Indices").

Meteorologists, hydrologists, and other researchers have not reached a scientific consensus on the "best" technical definition of drought. By common usage, drought

Drought Indices

Index	Overview	Comments
Standardized Precipitation Index (SPI)	Measures the divergence of total precipitation (totaled over a given time scale) from the historical median precipitation. Negative values indicate below-average cumulative precipitation.	Only measures precipitation; rescales deviation to reflect drought rarity (frequency) rather than drought severity. Available on various time scales indicated by the number of months over which precipitation is totaled (SPI-1 to SPI-60). Has been found to be better, in a statistical sense, than the PDSI at making comparisons across months and across regions (Guttman 1998).
Palmer Drought Severity Index (PDSI) and Palmer Modified Drought Index (PMDI)	Tracks the stock of soil moisture over time based on a hydrologic model of recharge from precipitation and losses to evapotranspiration, infiltration, and runoff. Negative values indicate below-average soil moisture.	Incorporates key variables beyond precipitation that influence drought severity. Usually calculated at a monthly time scale. Has long "memory," which requires significant dry periods to "start" a drought and significant rainy periods to "end" a drought. Introduced the idea of moderate (PDSI from -2 to -2.99), severe (-3 to -3.99), and extreme (-4 and below) drought.
Palmer derivatives (PHDI, Palmer-Z, CMI)	These indices extend the PDSI to different time periods.	The Palmer Hydrologic Drought Index (PHDI) has longer memory than the PDSI, which makes it a better measure of long-term drought. The Crop Moisture Index (CMI) is calculated on a shorter time scale (often weekly) and has a shorter memory than the PDSI, which makes it better at forecasting impacts on crops.
Surface Water Supply Index	Tracks storage in reservoirs, rivers, and snowpack.	Useful to measure the severity of drought in the Western U.S. where surface-water supplies are a key focus.
Drought Monitor	A compilation of PDSI, CMI, SPI, and other measures	A low-resolution drought index intended for national or regional analysis. A collaborative effort between USDA and the National Oceanic and Atmospheric Administration.

Sources: Hayes (2006) and Heim (2002).

is a prolonged shortage of water, usually of precipitation. Definitions of drought differ in the type of water shortage emphasized and in how shortage is defined. For example, "meteorological drought" emphasizes shortages in precipitation, "hydrological drought" emphasizes shortages in surface-water flows, and "agricultural drought" emphasizes shortages in soil moisture.[5]

[5] Sometimes these definitions of drought are distinguished by the relevant time horizon for which they are designed. "Agricultural drought" is often more of a short-term measure since short-term droughts (on a weekly or monthly scale) can have large agricultural impacts; "meteorological drought" is a medium-term measure (on a multi-monthly or annual scale) since most ecological systems can "store" water locally over several months; and "hydrological drought" is a long-term measure (both intra- and inter-annual) since reservoirs, aquifers, lakes, and rivers often contain water that fell as precipitation in previous years.

A drought index can perform several different functions, and the choice of an appropriate index depends upon the context in which it is being used:

- In an agricultural production context, a drought index can identify the onset of drought, which can facilitate adoption of adaptation or mitigation practices at the farm level and resource-management-agency level.
- In an administrative context, a drought index can be used as a trigger for some action, such as distribution of disaster or indemnity payments.
- In a statistical context, a drought index can be used to compare drought outcomes at different points in time or across different geographic areas. Much of the scientific debate over choice of drought index is related to statistical properties of the different indices.

Average precipitation and the resulting water shortages can vary dramatically by region, so most drought indices measure departures from a local, longrun average. Negative values reflect water shortages relative to average conditions, while positive values reflect water surpluses. To allow for comparisons on a national level, drought indices are usually rescaled to reflect some standardized measure of drought severity or drought frequency.[6] Figure 5 shows how drought severity, as measured by the Palmer Modified Drought Index (PMDI), varies over time and across regions. The continuous PMDI measures are mapped into four categories (minimal or no drought, moderate drought, severe drought, and extreme or exceptional drought), and the share of cropland in each category is mapped over the past century for two States—South Dakota and Indiana—with very different histories of exposure to drought.

The location and geographic extent of a drought are key determinants of its impact on agricultural markets. During the Dust Bowl in 1934, about 55 percent of U.S. agricultural land was affected by severe or extreme drought (as measured by the Palmer Drought Severity Index). The 1954 and 2012 droughts were almost as severe and extensive as the 1934 drought. In contrast, at the height of two other major droughts in the past 50 years (1988 and 2002), about 20 percent of agricultural land was under severe to extreme drought (Gollehon and Buckholtz, 2007). The market-level effects of drought depend on the severity and the spatial extent of the drought, as well as the coincidence of drought area with major commodity production areas.

The duration and timing of drought are often key determinants of drought impacts. Major droughts are typically both widespread and prolonged (often spanning 1 to 10 years).[7] In agricultural production, though, even short-term droughts (ranging from

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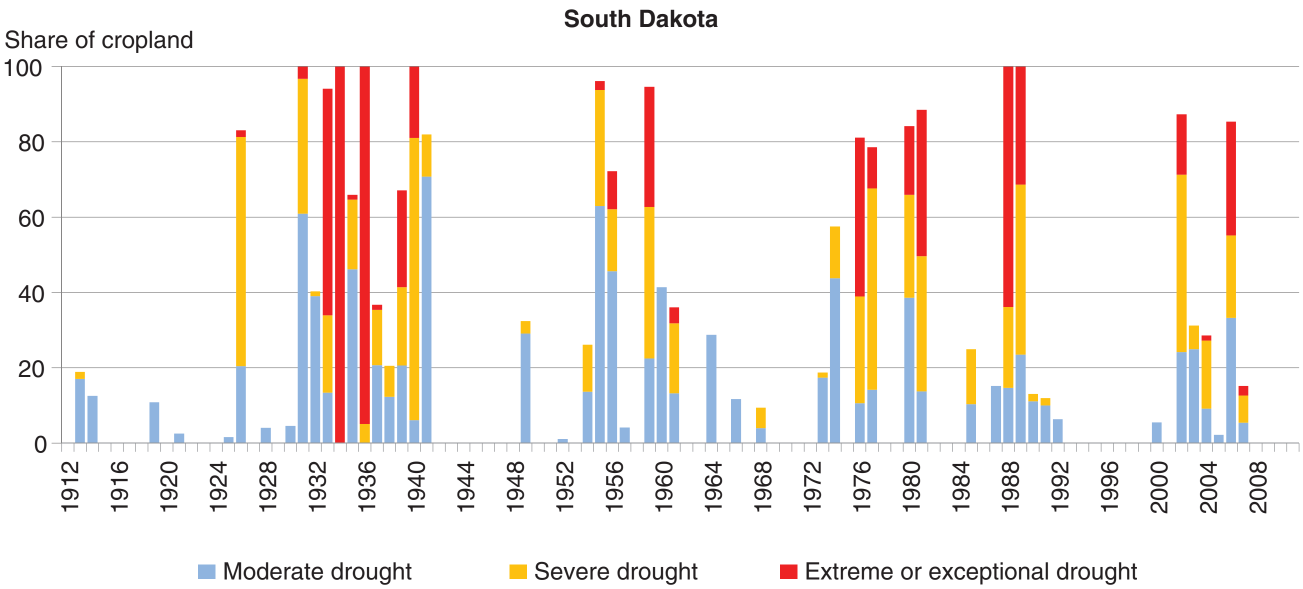
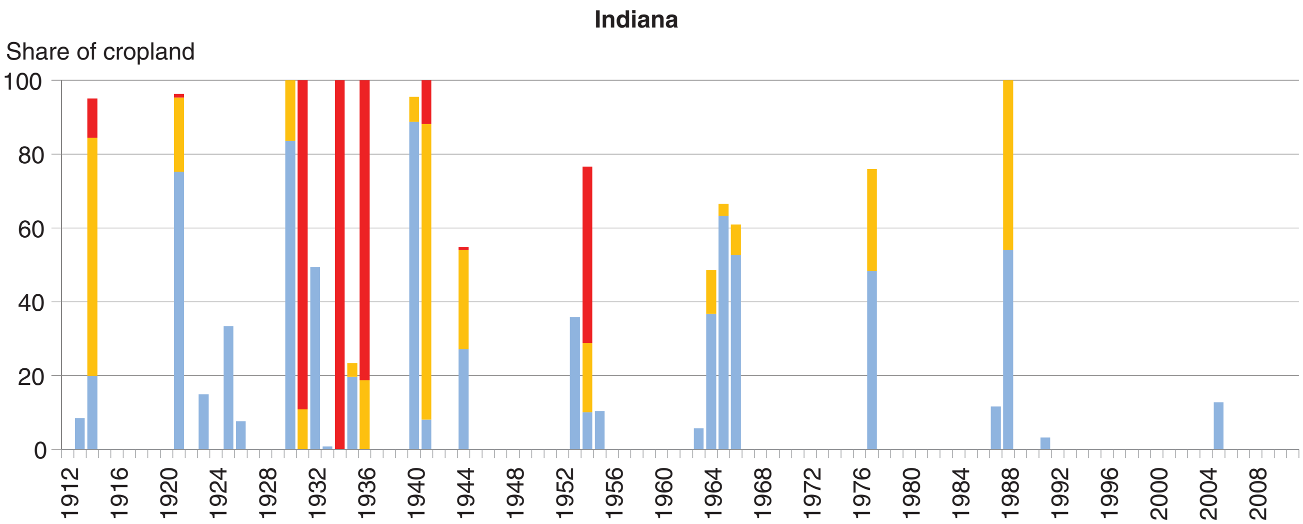
[6] Deviations in absolute levels of precipitation would not capture the significance of meteorological drought. For example, a shortfall of a few inches in annual precipitation is probably not significant in Birmingham, Alabama, which has an average annual precipitation of 54 inches, while such a shortfall could have major impacts in Casper, Wyoming, which has an average annual precipitation of about 13 inches.

[7] The major droughts of the past century may not represent the worst that can occur. Drought measures for the past 2,000 years, reconstructed from tree ring observations, suggest that some historical droughts far exceeded the Dust Bowl drought in duration and severity (Wodehouse and Overpeck, 1998).

Figure 5

Drought severity in South Dakota and Indiana, 1912-2008





Sources: ERS calculations based on county-level cropland acreage from the 2007 Agricultural Census and weather-station-level Palmer Modified Drought Index (PMDI) data from the National Oceanic and Atmospheric Administration. The weather station-level data were interpolated to county centroid for the July PMDI. (http://www.ncdc.noaa.gov/temp-and-precip/drought/nadm/indices.php?mdf=data&divstn=stn&indicator=palmer).

a few weeks to a few months) can have major impacts because soil moisture during key stages of plant development is a critical determinant of crop yield.

What Is Drought Risk?

Drought severity, as captured by drought indices, is a measure taken at a given point in time. Climatologists refer to such measurements as weather and distinguish weather from climate. Measures of climate (such as average temperature in June) reflect longrun patterns at a given location. In contrast to drought severity and duration, which reflect prevailing weather conditions at a point in time, drought ***risk*** is a measure of climate. Drought risk captures differences across regions in the likelihood of periodic water shortages. The semi-arid Western regions of the United States generally face greater drought risk because their average soil moisture content is lower than in more humid regions, causing extreme droughts to occur more frequently.[8] When farmers make long-term decisions about how to prepare for potential drought—including decisions about retiring cropland or investing in major conservation practices—they are adapting to drought risk, not current weather conditions.

Efforts to measure drought risk, or the related concepts of drought proneness and drought vulnerability, are less common than efforts to develop drought indices. Wilhelmi and Wilhite (2002) and Banik et al. (2002) both attempt to develop localized measures of drought risk for agricultural land in Nebraska and Maharashtra (India), respectively. In general, drought experts recognize that drought risk reflects several climate-related factors, including variance in precipitation, the correlation between high temperatures and precipitation shortages, and soil's capacity to store water. Measures of drought risk can either be constructed directly from these variables or from drought indices.

Since severe droughts are rare events, good measures of drought risk require decades of weather data. Instrumental weather data are available in most U.S. locations for about 100 years, although data on some weather variables (such as humidity, evapotranspiration, and wind) are only available for the past few decades. While some meteorological studies suggest that drought risk can change over decades in response to changing sea-surface temperatures, detecting changes in drought risk as they occur is exceptionally difficult (Cook et al., 2007).[9] Under several major climate change scenarios, drought risk is projected to increase for most of North America, in part because increases in average temperatures will lead to lower soil moisture levels, even in those regions of the country where annual precipitation is projected to increase (Hirabayashi et al., 2008; Strzebek et al., 2010).

This study relies on a measure of drought risk constructed from the PMDI. For our drought-risk measure, we estimate the variance in the June PMDI, calculated at the

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[8] See Appendix A for a discussion of spatial differences in factors that contribute to drought risk.

[9] Given that we are examining regional difference in drought risk and participation in conservation programs, we assume that drought risk is fixed over our timeframe within regions.

weather-station level from over 100 years of data and interpolated to the county level. We selected the June-based measure because early to midsummer is a critical period for crop development for most major crops (Prasad et al., 2008; USDA/NASS, 2010). In addition, within a given area (a county or a weather station), drought risk measures are very similar across growing season months.[10] Variance of PMDI is roughly equivalent to measures of drought risk based on the frequency of a severe or extreme drought per decade or per century, but the variance-based measure is better at capturing minor variations in drought risk.[11] Figure 6 maps this measure of drought risk. Appendix A discusses these calculations in greater detail.

What Is Drought Risk Adaptation?

Drought ***vulnerability*** is closely related to and often confused with drought ***risk***, but drought vulnerability invokes choices. Drought risk is a climatic characteristic that is static and does not vary with the choices made by individuals and governments. In contrast, drought vulnerability is the probability of experiencing drought-related damage, which depends upon a variety of production decisions, policy choices, and site-specific resources. For example, two irrigators in the same county would face the same drought risk, but the farm with access to a more reliable source of water would be less likely to experience negative impacts from a drought and so would have lower drought vulnerability. Economic modeling can help us understand how farmers make choices that may either reduce or exacerbate their drought vulnerability.

Drought ***preparedness*** is the state of having planned and taken actions in advance that reduce drought vulnerability. Agricultural drought preparedness is not a very precise policy goal because farmers and resource managers are rarely willing or able to totally eliminate drought vulnerability.[12] Proposals to increase drought preparedness often operate on two assumptions: (1) farmers can take certain actions to be more prepared for drought and to reduce drought vulnerability; and (2) farmers are not taking these actions to a sufficient degree, with implications for regional economic costs and Federal budgetary liabilities. The degree and sufficiency of drought preparedness is determined by particular actions, including production decisions (crop choices, irrigation, and conservation practices) and revenue risk management strategies (insurance, contracting, savings, off-farm

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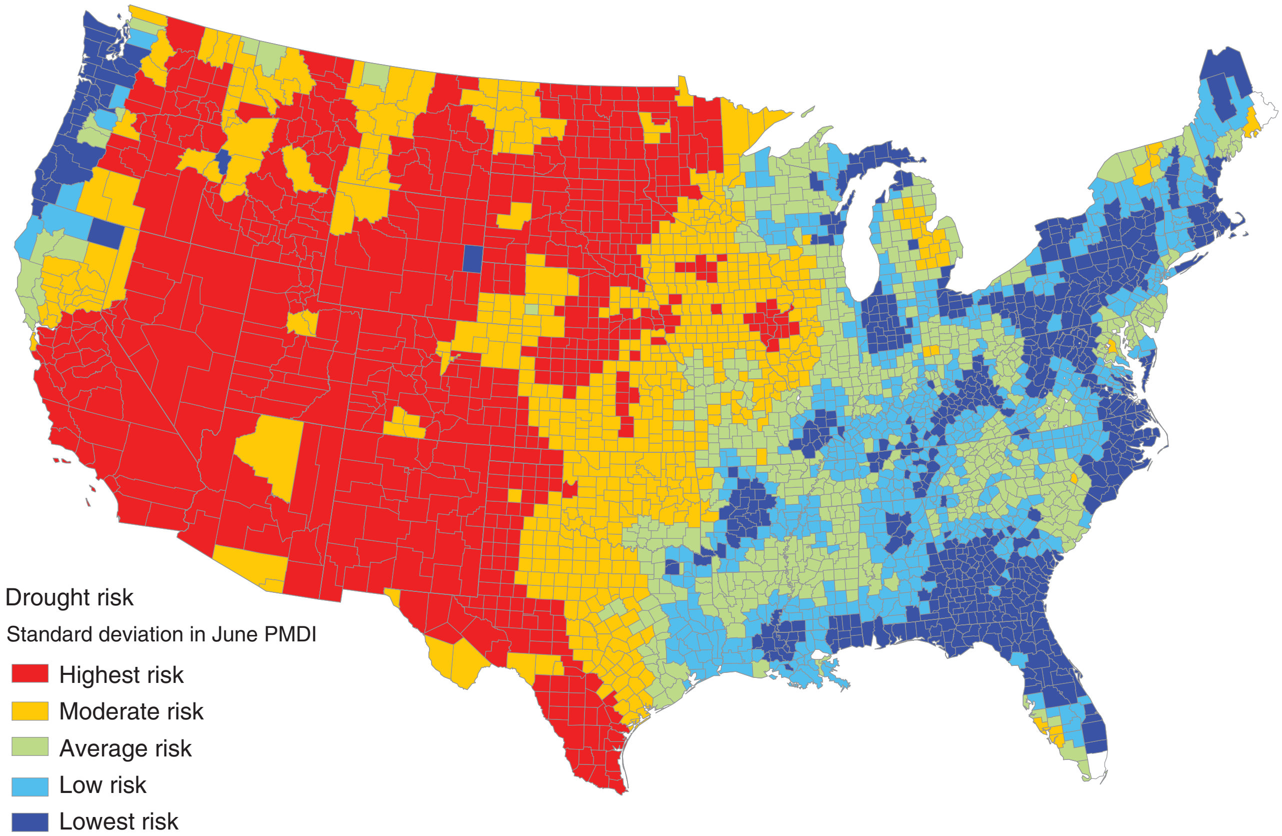
[10] At the weather-station level, the correlation coefficient for June and July PMDI variances is 0.95, for July and August it is 0.96, and for June and August it is 0.90. In other words, regions that are more prone to experience June drought are almost equally prone to experience July drought and so on. Not surprisingly, the lowest correlation is between January- and July-based drought risk measures, but even those two variances have a correlation coefficient of 0.51.

[11] For example, 2 counties with 10 severe or extreme droughts over the past century would have the same drought risk measure under a frequency-based calculation but would probably have different drought risk measures under a variance-based calculation since the PMDI values are not likely to be identical for both boundaries. In this sense, frequency-based measures of drought risk are “throwing away information” by categorizing droughts into discrete (but overly broad) categories of severity.

[12] In contrast, many drinking water-supply systems maintain sufficient capacity to nearly eliminate the risk of drought restrictions.

Figure 6
Variation in drought risk as measured by the Palmer Modified Drought Index (PMDI)



Notes: Drought risk is calculated as the standard deviation in natural soil moisture over the past century as captured in the PMDI in June of each year. Drought risk is calculated at weather stations and then interpolated to county centroids using the seven nearest weather stations to each centroid (http://www.ncdc.noaa.gov/temp-and-precip/drought/nadm/indices.php). The variance categories can be converted into ranges of the expected number of severe or extreme droughts per century as follows:

- Highest risk: 12.2-19.3 per century
- Moderate risk: 9.0-12.1
- Average risk: 7.4-8.9
- Low risk: 6.6-7.3
- Lowest risk: 1.8 -6.5

Source: ERS calculations based on National Oceanic and Atmospheric Administration station-level data. Spatial patterns are reflective of the underlying spatial patterns in temperature and precipitation. Corrections were not made for the few outliers that result from outliers within the original weather station data.

income). It is also important to consider why relative inaction by some farmers might occur.[13]

Drought risk ***adaptation*** is the process of selecting the appropriate level of drought preparedness conditional on drought risk. Farmers facing high levels of drought risk

[13] There are a number of reasons why farmers might not exhibit maximum drought preparedness in their production decisions: (1) farmer preferences (i.e., risk aversion); (2) costs (i.e., even for highly risk-averse farmers the opportunity costs of drought preparedness may be too high); (3) perverse incentives or moral hazard (i.e., farmers may assume riskier choices if risk-mitigating policies are in place); or (4) market failure (e.g., a failure to properly price risk-reducing or risk-increasing inputs/practices).

have a higher incentive to invest in drought preparedness. However, these same farmers may also face higher costs of investing in drought preparedness. Drought risk is one of several drivers of farmers' production decisions, and conservation choices are among the many production decisions that farmers must make. While this report focuses on conservation program decisions, many production decisions are a part of drought adaptation.

The Conservation Reserve Program and Drought Risk Adaptation

The Conservation Reserve Program (CRP), introduced in 1985 and reauthorized under subsequent farm acts, is the primary USDA program for retiring environmentally sensitive land from crop production. Landowners participating in CRP agree to remove farmland from agricultural production and maintain specified cover crops and conservation practices on that land under long-term (10-15 year) contracts. In return, participants receive an annual rental payment plus additional financial assistance to establish and maintain vegetative cover that enhances environmental benefits. Eligible land includes highly erodible cropland and other environmentally sensitive land with an established cropping history. An estimated 212 million acres, or 23 percent of U.S. farmland, are eligible to participate in CRP; as of June 2012, about 29.6 million acres were enrolled.

Enrolling Land in CRP

Farmers and farmland owners have two options for enrolling land in the CRP. Under the ***general signup***, parcels are offered for enrollment during designated signup periods that typically last only a few weeks.[14] Under the ***continuous signup***, which tends to involve more intensive conservation practices on smaller parcels of land, parcels within special project areas may be offered for enrollment at any time during a year. This report focuses on farmer participation in the general signup, which accounts for 24.3 million of the 29.6 million acres in CRP.

In the general signup, owners of eligible land submit an offer to enroll a specific parcel. To meet eligibility requirements, a land parcel must have an established cropping history (i.e., have been in crop production for 4 of the 6 years prior to the most recent authorizing (2008) Farm Act) or be currently enrolled in CRP under a contract that is expiring. In addition, a land parcel must either be highly erodible land (as determined by an erodibility index calculated by NRCS) or located within conservation priority areas designated by USDA's Farm Service Agency (FSA) in cooperation with each State or subject to an expiring contract.

For each parcel, an offer to enroll in CRP consists of a bid with a proposed annual rental payment (the "bid rate"), a proposed set of conserving practices, and a decision whether to accept financial assistance that offsets the installation costs for conservation practices (fig. 7). Annual rental payments are subject to bid caps (maximum bid rates), which vary by county and by soil type. Offers are ranked nationally by FSA using an Environmental Benefits Index (EBI) that assigns points based on field characteristics (such as erodibility), proposed conservation practices, and the bid rate. Prior to 2010, offers were also awarded points based on the acceptance or rejection of financial assistance.

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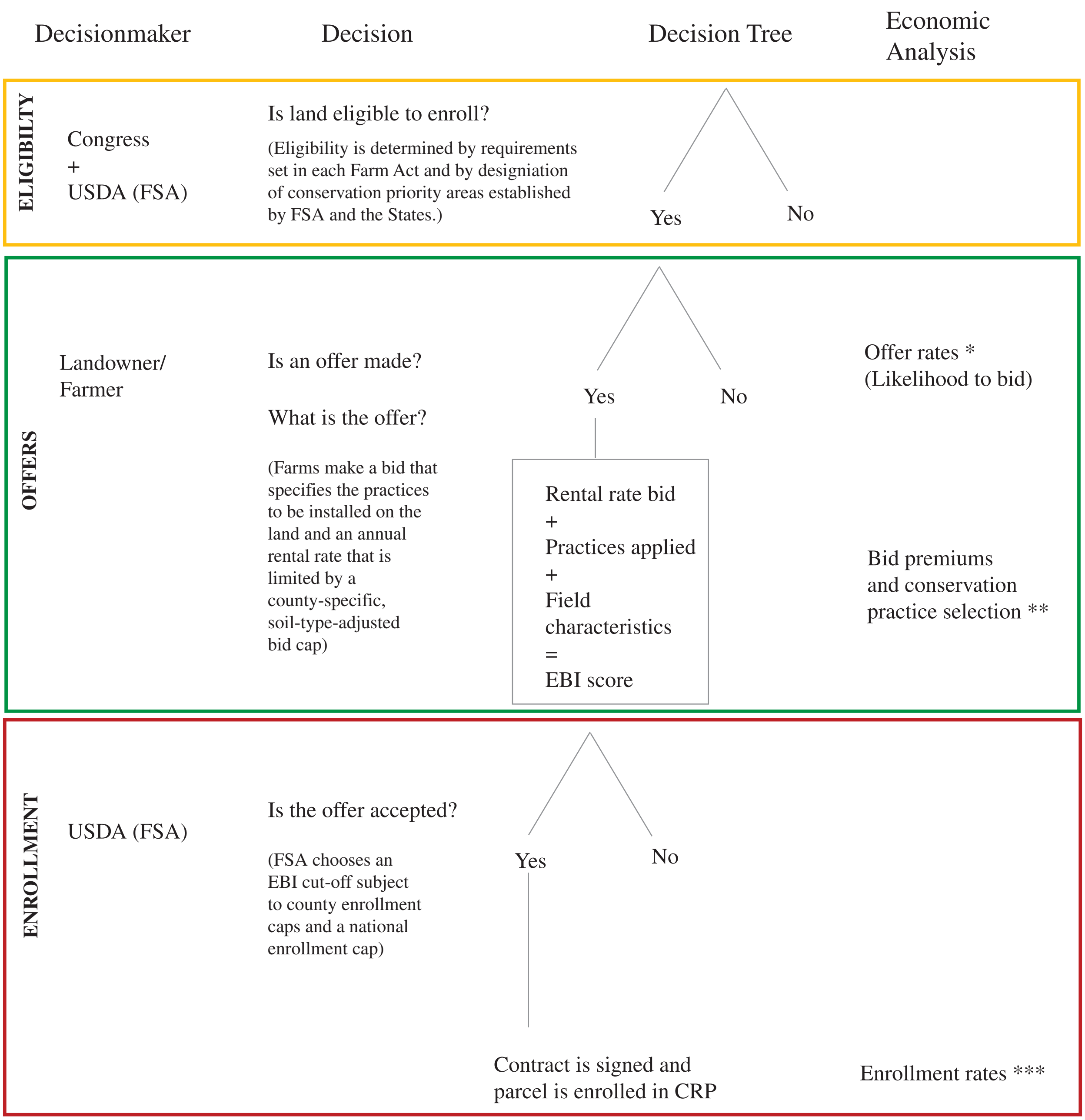
[14] In most cases, there is one general signup period per year, but not all years have had general signups due to regulatory review requirements and an extended re-enrollment and extension (REX) process that occurred during 2006.

Figure 7
Enrollment process for general signup Conservation Reserve Program

USDA's Farm Service Agency (FSA) begins the process by announcing the date for a general signup and establishing the formula for calculating the Environmental Benefits Index (EBI), which is used to rank offers.



* This report is the first study to econometrically examine offer rates.
** A handful of studies examine bid premiums and practice selection (Kirwan et al., 2005; Roberts and Lubowski, 2007; Vukina et al., 2008).
*** Many CRP participation studies look at enrollment outcomes at either the field level or the county level (Wu, 2000; Sullivan et al., 2006; Wu and Lin, 2010).

Environmental benefits considered under the EBI have evolved from an initial focus in the early 1990s on soil erosion control on highly erodible land. At the time of preparing this report, the EBI is based on six factor scores, including five environmental factors: wildlife habitat, onfarm soil erosion, water quality, air quality, and enduring benefits beyond the contract period. Wildlife habitat, soil erosion, and water quality benefits receive the greatest weight, followed by enduring benefits and air quality benefits.[15]

At the end of a general signup, FSA selects a cutoff EBI score and enrolls those parcels with an EBI score at or above the cutoff. When submitting an offer, landowners know their own EBI score but not the final EBI cutoff. Landowners can increase their EBI score and thus the probability that their offer will be accepted by either lowering their bid rate or selecting conservation practices with higher EBI points. Several studies confirm that landowners choose bid rates and practices strategically (Kirwan et al., 2005; Roberts and Lubowski, 2007; Vukina et al., 2008).

Enrollment in CRP is potentially constrained by national and county acreage enrollment caps, although the significance of enrollment caps varies among counties and over signups. A national cap on CRP acreage enrollment has been modified under successive farm acts; the 2008 Farm Act set the current national enrollment cap at 32 million acres.[16] The county enrollment cap stipulates that no more than 25 percent of a county's cropland may be enrolled in the program.[17] Many U.S. counties are at or near this cap, while other counties (with less than 25 percent of cropland eligible for CRP) are not impacted at all. Landowners in counties that are at or near the cap are likely to be more reluctant to offer their land in the general signup since the likelihood of acceptance is diminished.

Modeling Drought Risk Adaptation and the CRP

This report illustrates the challenge of using existing conservation programs to facilitate climate adaptation, specifically to drought risk. If landowners consider drought risk when deciding whether to offer eligible land for CRP contracts, then CRP is already facilitating climate adaptation, albeit indirectly. Changes to the design of CRP, even if those changes are designed to address the conservation goals of the program, could therefore either facilitate or hinder participation in CRP by landowners who are purposely adapting to drought risk.

How might an offer to enroll land in CRP be a response to higher levels of drought risk? The bid caps are designed to set the maximum CRP rental rate equal to the expected cash rental rate for cropland given a parcel's county and soil type, so most

[15] Additional points are assigned to offers that accept below-average rental payments, a feature of the EBI that is designed to improve the cost-effectiveness of the CRP.

[16] See the ERS topic page on Conservation Programs for more information on enrollment caps and other program details (www.ers.usda.gov/topics/natural-resources-environment/conservation-programs.aspx).

[17] The 2008 Farm Act only applies the county enrollment cap to acres enrolled through the general signup, so acres enrolled through the continuous signup no longer count against the cap. In some instances, counties have applied for and received waivers for (small adjustments to) the enrollment cap.

landowners should be fairly indifferent between putting land into CRP and leaving land in crop production. However, a number of considerations, such as risk aversion or dynamic production decisions in water-scarce environments, provide plausible reasons for why landowners facing greater drought risk might prefer CRP.

Over the life of a CRP contract, a farmer receives a fixed annual rental payment for enrolled acreage, thereby lessening farm income variability attributable to price and yield variation. Since CRP payments are fixed, retiring land through CRP may enable farmers to diversify their income stream and reduce their exposure to revenue risk. Several studies find that risk is an important factor in CRP participation. Lubowski et al. (2006) find that environmentally sensitive land enrolled in CRP also tends to be higher risk land, where risk is measured as an acre-weighted average of returns to crop insurance premiums. Chang et al. (2008) find that farmers accept reduced levels of income with CRP enrollment, which supports the idea that risk aversion drives participation decisions. Williams et al. (2010) demonstrate that risk-averse farmers are likely to prefer CRP enrollment to standard cropping rotations in western Kansas.

Even if farmers are not risk averse, CRP may have added benefits in more drought-prone regions. Idling cropland can be an important way to replenish soil moisture and recharge aquifers, which could provide benefits to cropland adjacent to parcels enrolled in CRP (Rao and Yang, 2010). Also, special grazing provisions under the CRP may be attractive to livestock producers with eligible cropland enrolled in the program, and livestock production is generally more prevalent in regions of the country facing higher drought risk.

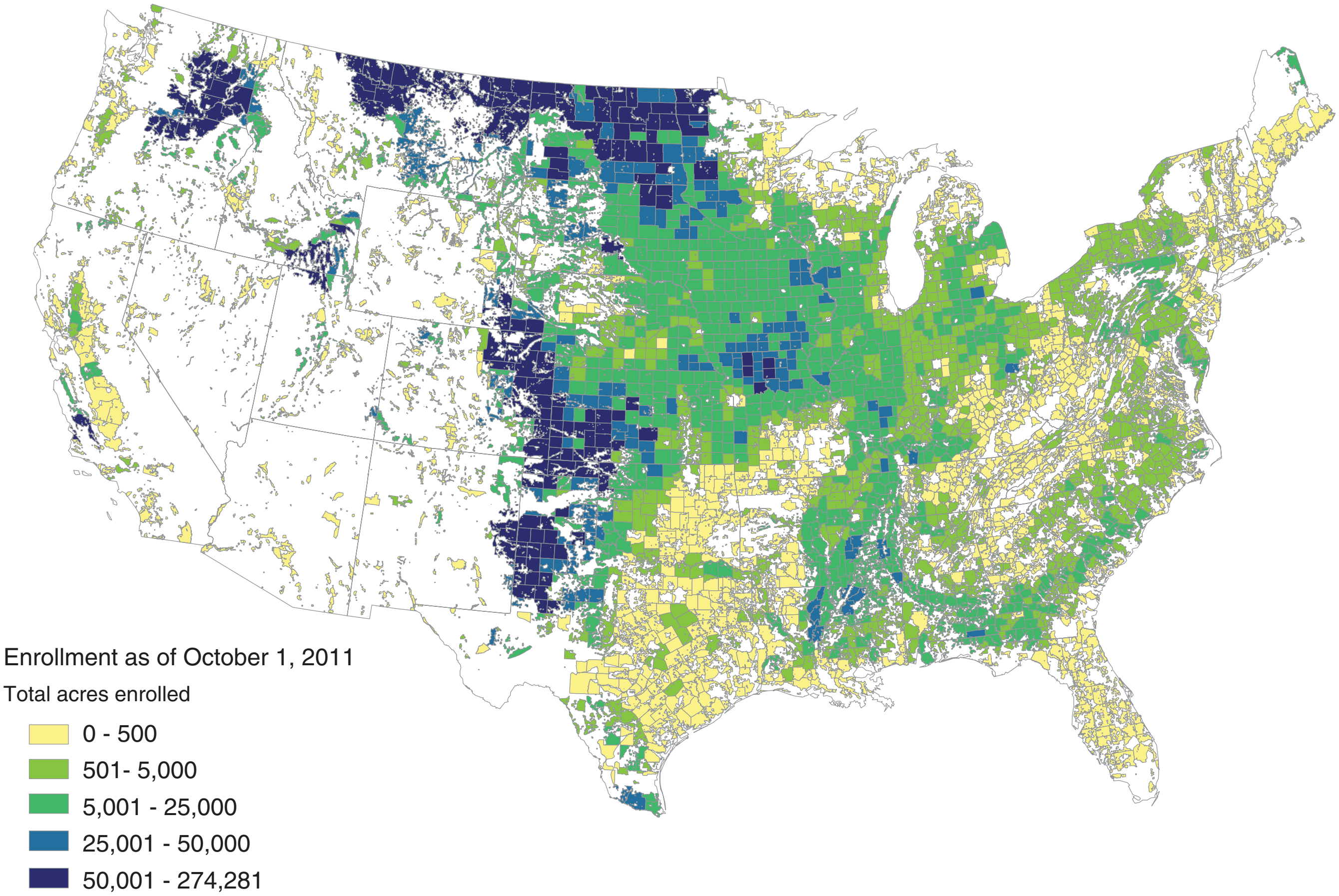
Much of the CRP enrolled acreage is concentrated in the Plains States, reflecting the program's historical emphasis on erosion control on highly erodible soils (fig. 8). The biggest challenge in evaluating the effect of drought risk on farmer behavior is that the EBI may favor enrollment of marginal soils in transitional agricultural zones (corn/wheat, wheat/grasslands), which are also apt to be more vulnerable to drought. Since enrollment rates are likely to be higher in high-risk counties, county caps are more likely to be binding in those counties. Failing to control for county caps likely understates the impact of drought risk on CRP offer rates because offers are less likely when county caps are binding.[18]

Some facets of the CRP may actually discourage farmers from using the program for drought risk adaptation. Bid caps reflect local rents for dryland production, so limits on rental payment rates may drive down enrollment in irrigated areas of the West where higher returns to irrigated production are capitalized into the value of the land. However, increased financial assistance for irrigated enrollment may be available through Federal/State partnerships under the Conservation Reserve Enhancement Program (CREP). In several CREP project areas where financial assistance is available, retirement of irrigated lands improves water supply reliability—a de facto response to drought risk—for remaining irrigators and for

[18] A similar issue arises for irrigation adoption rates. Since irrigation adoption is likely greater in areas with higher drought risk and since irrigated land is much less likely to accept dryland rental rates for crop retirement, failing to control for irrigation would likely understate the impact of drought risk on CRP offer rates.

Figure 8

Conservation Reserve Program enrollment by county, 2011



Source: USDA Farm Service Agency data on county-level CRP enrollment.

environmental flows.[19] County-level enrollment ceilings that restrict enrollment to not more than 25 percent of cropland may also be limiting in drought-affected areas. Since binding county caps and extensive irrigation adoption are (potentially) positively correlated with drought risk and negatively correlated with CRP enrollment decisions, failing to control for the effects of these factors could lead to a downwardly biased estimate of the effect of drought risk on offer rates.

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[19] Today, four CREP projects in Western river basins target irrigated land retirement to achieve reductions in consumptive water use and restoration of hydrologic flows and groundwater systems. The projects are intended to lessen the effect of water-supply shortfalls on agricultural producers and natural systems during periods of drought. Through these projects, FSA offers higher payments tied to irrigated rental rates for projects that create water savings, while State, tribal, and private partners may provide funding for additional expenses, including permanent easements and retirement of water rights. The partnership also acknowledges the primacy of State law in water-supply management, helping ensure that water withdrawals are restricted in project areas and that resulting water savings are allocated to desired uses.

Data and Methods

This study is the first to econometrically estimate the likelihood that cropland is ***offered*** for enrollment in CRP. Conceptually, we build on earlier efforts that evaluated the probability that farmland is ***enrolled*** in CRP (e.g., Wu, 2000; Sullivan et al., 2004; Lubowski et al., 2006; Wu and Lin, 2010).[20] While assessing CRP participation in terms of the probability of being enrolled rather than making an offer may be necessary given traditional data sources, there is a downside: enrollment reflects both the landowner's decision and FSA's ranking of offers using the EBI. Moreover, when working with observations of enrollment rather than offers, it is difficult to correctly control for the influence of county enrollment caps.

For this report, our analysis uses a combination of data on CRP offers and data on land eligibility and availability. The offer data are traditionally used to evaluate how landowners formulate their offers to enroll land in CRP (Kirwan et al., 2005; Roberts and Lubowski, 2007; Vukina et al., 2008). The offer data do not include any information on landowners who did not make a bid, so the data are insufficient for analyzing factors that influence landowner decisions to bid or not. Our analysis was made possible by the construction of a careful measure of land eligible for CRP enrollment within each county. To compute, for every county, the number of acres "eligible" for the program, we use data on soil erodibility, cropping history, and conservation priority area delineations. To compute the number of eligible acres that are "available" to be offered in a signup, we subtract enrolled acres from eligible acres.[21]

Our strategy is thus to model the farm-level decision of whether to make an offer in a CRP signup. We incorporate nonparticipants into the model by aggregating offered acreage and eligible acreage at the county level. We model offer rates as the share of eligible acres (not already in the program) that are offered. For our offer data, we use the offer rates that occurred during the eight most recent general signups: 1997, 1998, 1999, 2000, 2003, 2004, 2006, and 2010. Participation probabilities are estimated using a grouped logit model, the results of which are detailed in Appendix B.

To determine how the CRP may be used for drought risk adaptation, we estimate the effect of drought risk on the probability of eligible land being offered to the program. Spatial variation in drought risk is captured by calculating, at the county level, the long run variance in the Palmer Modified Drought Index (PMDI). Other variables, also measured as county averages, are included to control for attributes that may be correlated with drought risk.

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[20] Those studies that model the participation decision usually compare participants to non-participants by either sampling parcels of land or aggregating contract data to the county level. Samples of parcels identifying CRP enrollment status can be obtained from either the Natural Resources Inventory (NRI) data or from the Agricultural Resource Management Survey (ARMS) data. Data on contracts (acres enrolled) at the county level can be obtained from FSA and combined with Agricultural Census data to generate an estimate of the share of cropland enrolled in CRP.

[21] Acres enrolled in an expiring CRP contract are not subtracted from eligible acres since they are eligible to re-enroll.

Results: Base Case and Policy Scenarios

The model results indicate that drought risk is a strong predictor of the likelihood that eligible land is offered for enrollment into CRP.[22] Our analysis of offer rates therefore suggests that landowners use the CRP as a tool for drought risk adaptation. We also find that nearly binding county enrollment caps reduce the probability that eligible land is offered for enrollment. A higher average EBI score—looking only at the (environmental) portion of the EBI score that is not directly affected by the bids—leads to a higher probability that eligible land is offered. We also find that higher average soil rental rates lead to a lower probability of eligible land being offered. Details on the magnitude of these effects and on the likely reasons for such farmer behavior are discussed in Appendix B.

Given the potential for increased drought risk under projected climate change scenarios, CRP design options, such as eligibility and enrollment rules, may be able to enhance the program's usefulness for drought adaptation. We evaluate three program design provisions—the EBI, county enrollment caps, and eligibility criteria—in that regard. To implement these drought adaptation scenarios, we categorize counties as having either low, medium, or high drought risk.[23] The specific scenarios are as follows:

1. An ***EBI adjustment*** that adds a "drought risk factor" (DRF). The *EBI-DRF* scenario creates a factor that assigns an additional 10 or 20 EBI points to counties with medium or high drought risk, respectively. Thus, if having a higher EBI score increases the attractiveness of offering a parcel to the CRP, incorporating drought risk will increase offers in drought-prone counties and reduce offers in less drought-prone counties.

2. A ***county cap adjustment*** (CC) that increases the share of total cropland that can be enrolled in a county. The *CC-35* variant of this scenario models an increase in the cap from the current level of 25 percent of county cropland to 35 percent. The *CC-70* variant models an increase to 70 percent of county cropland. The *CC-70-HDR* variant models an increase in the county cap for only those counties with the highest levels of drought risk.

3. ***An eligibility adjustment*** (EA) that increases land eligible for enrollment in high-drought-risk counties. As with conservation priority areas, the *EA* scenario assumes that all land in high-drought-risk regions with an appropriate cropping history would be eligible for enrollment. In other words, to be eligible for CRP enrollment, farmland would either have to be highly erodible, within a conservation priority area, or located in a county with a high level of drought risk.

The first scenario we consider is the revision of the EBI to assign points for land in counties facing higher drought risk. Changing the EBI to reflect drought risk in the

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[22] See tables B3 and B4 in Appendix B for details on model estimation.

[23] Based on the PMDI drought risk measure defined in Appendix A, the low-, medium-, and high-drought-risk counties represent 85 percent, 7.5 percent, and 7.5 percent of counties, respectively. Since drought-prone counties in the West tend to be larger, the 85 percent of counties that are low drought risk represent only 75 percent of CRP-eligible acreage.

EBI-DRF scenario leads to a small increase in offer rates and a 1.4-percent increase in total acres offered (table 1).[24] Raising the EBI in high-risk counties effectively lowers the normalized (relative) EBI in other counties. In other words, the increase in offer rates in high-drought-risk (HDR) counties is offset by the decrease in offer rates in other counties. This suggests that a moderate increase in EBI points, granted to medium- and high-drought-risk counties, would have a limited impact nationally (increasing total acres offered by less than 2 percent) but a more pronounced impact within drought-prone counties (fig. 9).

The *CC* scenarios, in which the county cap is increased, show more substantive changes in expected offer rates (fig. 10). For example, the *CC-70* scenario yields an almost 28-percent increase in offered acres (when compared to the baseline), over a third of which come from the high-drought-risk counties. (Of an average increase of 588 acres per county, 207 come from the 13 percent of counties that are medium or high drought risk. In general, HDR counties have higher offer rates and larger percentage point changes in offer rates in all scenarios (table 1). This large increase in rates, combined with the larger size of HDR counties, explains why HDR counties comprise such a disproportionate share of the increase in offered acres.

Table 1

Offer rates under alternative program design scenarios

	Percent of eligible acres that are offered	Percentage change in total acres offered compared to baseline	Percent of eligible acres that are offered	Percentage change in total acres offered compared to baseline
	All counties		*Drought-prone counties*[1]	
Observed	7.08		9.66	
Baseline prediction	7.08		10.04	
Program design scenarios				
Changing the EBI				
1) EBI-DRF[2]	7.12	1.4	10.29	4.1
Changing county caps				
2a) CC-35[3]	7.26	7.2	10.39	6.9
2b) CC-70[4]	7.59	27.6	11.08	27.7
2c) CC-70-HDR[5]	7.23	9.9	11.08	27.7
Changing eligibility				
3) EA[6]	7.08	38.0	10.04	106.4

[1]Drought-prone counties are those in the top 15th percentile of drought risk (those with a drought risk score above 2.65).

[2]Increases the Environmental Benefits Index score (drought risk factor) for land in medium- and high-drought-risk counties.

[3]Increases the county enrollment cap to 35 percent of cropland acres for all counties.

[4]Increases the county cap to 70 percent for all counties.

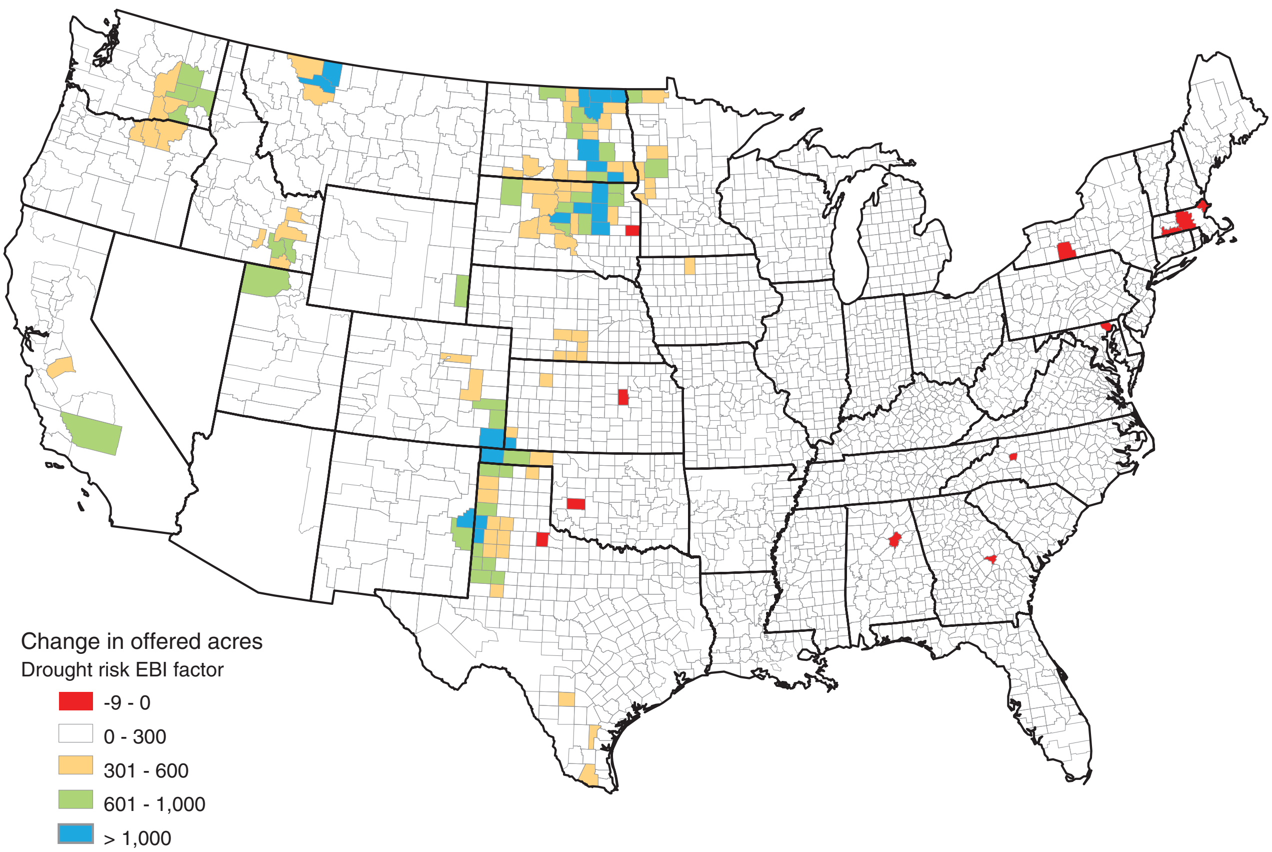
[5]Increases the county cap to 70 percent for high-drought-risk counties only. In the CC-70-HDR scenario, counties that are not highly drought prone have no change in county caps and therefore are not affected by the program design change. Thus, changes in the “all counties” column for the CC-70-HDR scenario are entirely due to changes in the 13 percent of counties that are HDR.

[6]Eligibility adjustment; eliminates the crop history requirement for eligibility within high-drought-risk counties.

[24] Due to aggregation of data and uncertainty regarding unobserved characteristics on nonparticipating eligible lands, scenario results should be taken as indicative of the type of possible responses to changes in CRP policies.

Figure 9

Scenario map for changes in Environmental Benefits Index (EBI)



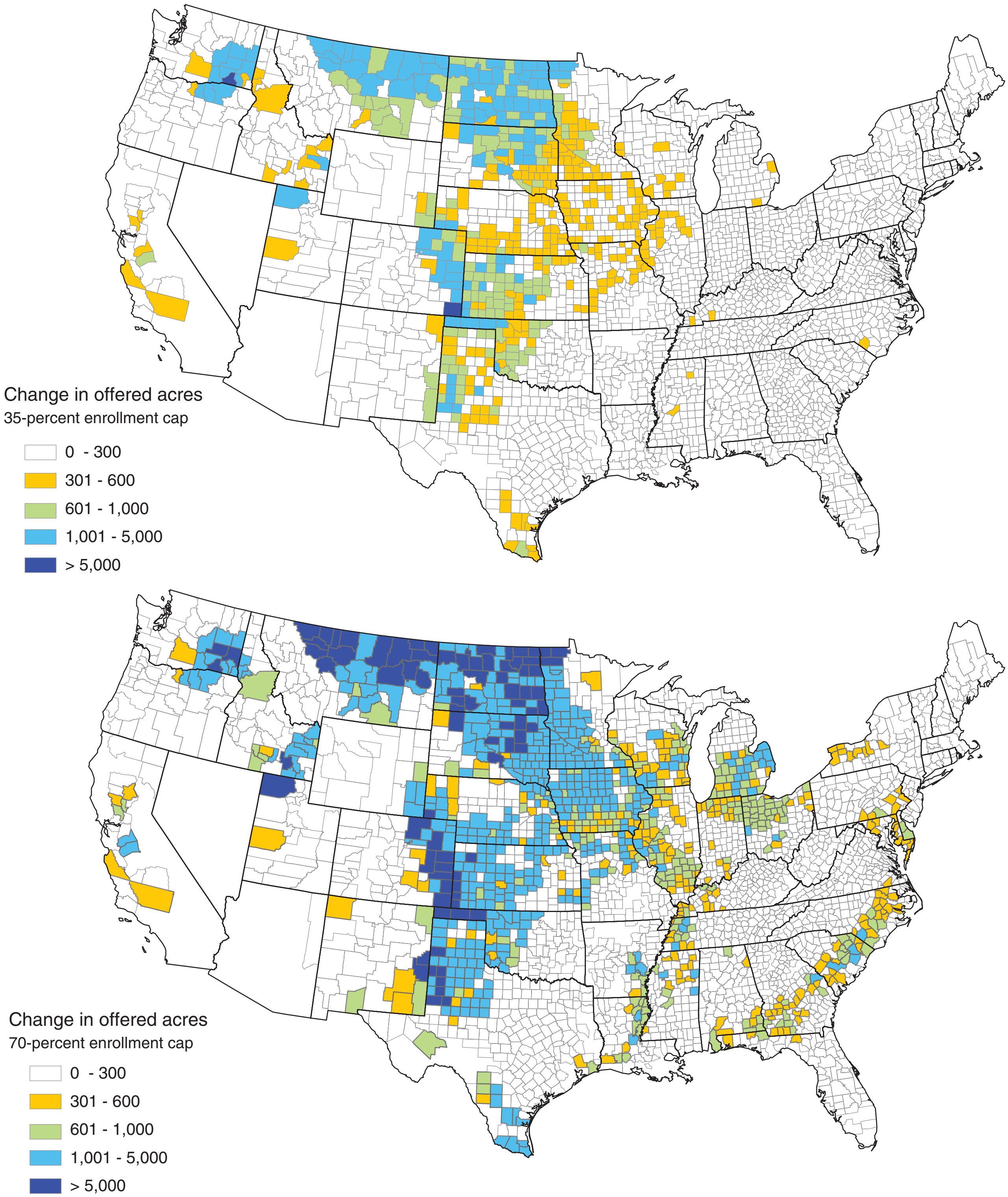
Source: USDA Economic Research Service simulations based on model of Conservation Reserve Program offer rate.

In the *EA* scenario a dramatic expansion in CRP eligibility in drought-prone counties has a large impact on total acres offered into CRP (fig. 11). Offer rates remain essentially identical to the baseline as both acres offered and eligible acres increase proportionately. However, total acres offered increase by almost 40 percent for all counties, and over 100 percent for HDR counties (table 1). These calculations assume that landowners with currently ineligible acres in HDR counties will have the same propensity to offer land to the CRP as landowners with currently eligible acres, which may lead to an overestimation.

One caveat to these results is that it is not possible to model the corresponding impact of increased offers leading to increasingly binding county caps. We cannot model this because we do not model which offers will be accepted. The geographic distribution of enrollment, as well as the net environmental impacts, depends not only on offer rates, which we model, but upon the structure of the offers (i.e., the portion of EBI score determined by conservation practice decisions), which we do not model. Future research is needed, along with parcel-specific data, to accurately predict the enrollment and environmental outcomes of these program design options.

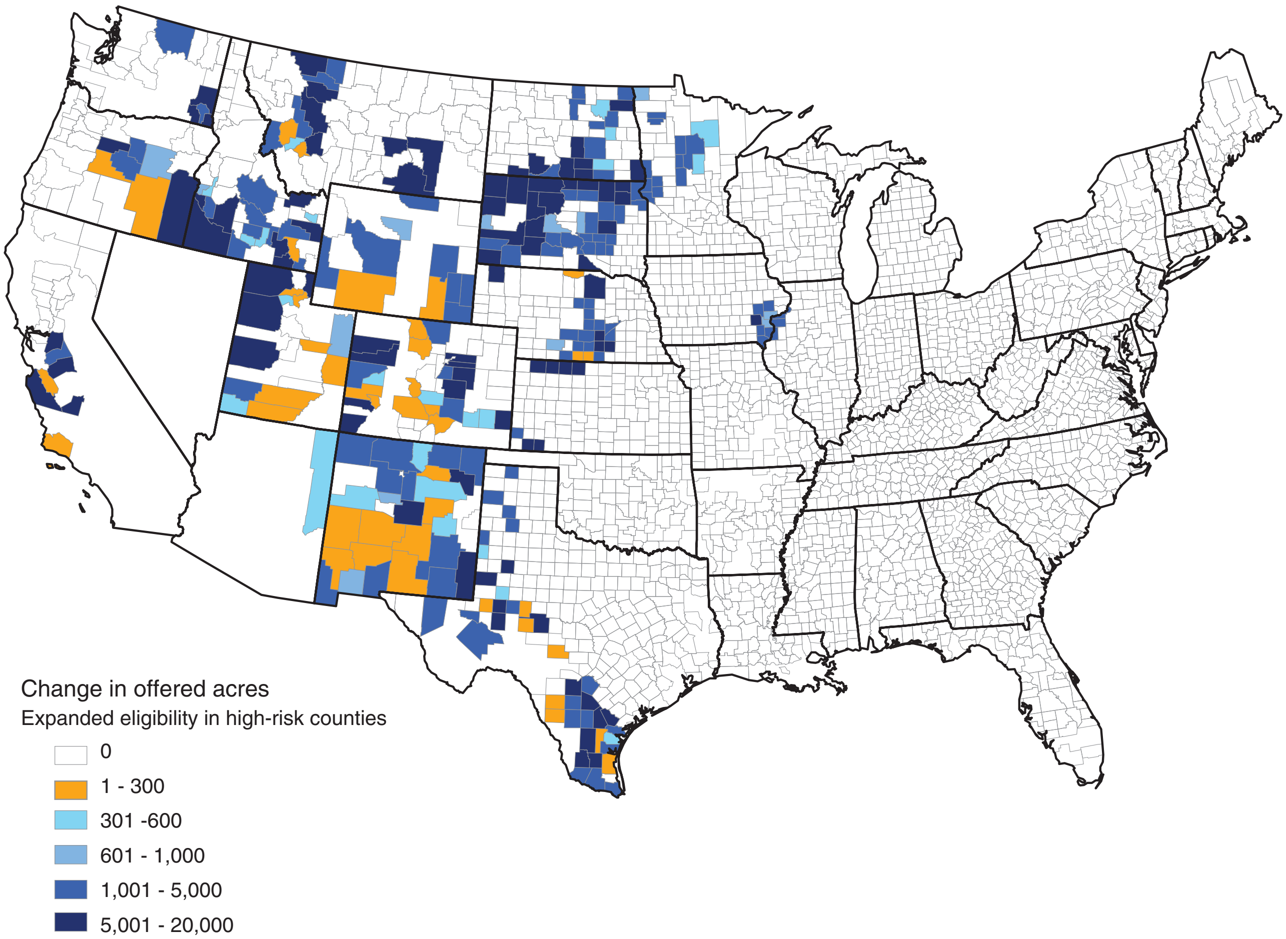
Figure 10

Scenario map for increases in county caps



Source: USDA Economic Research Service simulations based on model of Conservation Reserve Program offer rate.

Figure 11
Scenario map for changes in CRP eligibility



Source: USDA Economic Research Service simulations based on model of Conservation Reserve Program offer rate.

Conclusion

We find that drought risk currently influences CRP offer rates, which likely occurs because the revenue certainty associated with CRP payments is more important to landowners in higher risk regions. This finding implies that the CRP is already implicitly serving as a tool for drought risk adaptation. Landowners in higher drought-risk (HDR) regions are more likely to offer eligible land for enrollment in CRP, which increases competition for enrollment in these regions and makes county enrollment caps more likely to be binding.

Changes in CRP provisions could influence how producers rely on the CRP for drought risk adaptation. These program design provisions include changes that explicitly focus on drought-prone counties, such as adding points to the EBI or relaxing eligibility requirements in HDR counties, as well as changes that may be applied nationally, such as relaxing county enrollment caps. However, changes in

CRP enrollment to address drought risk may affect regional enrollment patterns, with implications for environmental benefits, rural economies, and program cost-effectiveness.

The Environmental Quality Incentives Program and Drought Risk Adaptation

The Environmental Quality Incentives Program (EQIP), introduced in 1996 and extended under the 2002 and 2008 Farm Acts, is the Nation's primary conservation program for working farms and ranches. Administered by USDA's Natural Resources Conservation Service (NRCS), EQIP provides technical and financial assistance for the adoption of conservation practices under contracts ranging from 1 to 10 years.

EQIP is a complex program that addresses many different resource concerns. In the enabling regulations for EQIP, NRCS identified five national environmental priorities for the program: (1) reduction of nonpoint-source pollution in impaired watersheds, (2) conservation of ground and surface water, (3) reduction of emissions that contribute to air quality impairment, (4) reduction in soil erosion and sedimentation, and (5) conservation of wildlife habitat for at-risk species (USDA/NRCS and CCC, 2009). NRCS developed a list of 80 resource concerns that fall within these 5 categories. EQIP provides payments for over 150 different types of practices, each of which addresses one or more of these resource concerns. State and county NRCS offices, given their knowledge of local conditions, have considerable flexibility in identifying which combinations of resource concerns and practices represent the most appropriate use of EQIP funds. However, EQIP is a voluntary program, so the willingness of farmers to enter into contracts for the desired practices is also key to program outcomes.

Enrolling in EQIP

As with CRP, farmers voluntarily apply for EQIP. Farmers must submit an EQIP application, with an associated conservation plan, to their local NRCS field office.[25] The conservation plan specifies a set of practices, the fields or parcels on which those practices will be implemented, the schedule of implementation, and the resource concerns that will be addressed by those practices. Enrollment is open to all crop and livestock producers.

Many of the conservation practices covered by EQIP result in both offsite environmental benefits and onfarm production benefits. For example, conservation tillage may reduce soil loss and associated off-farm pollution while also helping farmers conserve soil moisture for improved productivity. Other conservation practices are implemented primarily for their environmental benefits. For example, stream buffer strips provide both water quality and wildlife benefits but do not generally enhance returns to crop or livestock production. EQIP is intended primarily to encourage, through financial assistance, the adoption of conserving practices that provide environmental benefits. Financial assistance for installation of structural and vegetative practices ranges from 50 to 75 percent of typical installation costs as established at the county level. Annual payments for up to 3 contract years are also offered for

[25] While conservation plans are a prerequisite for EQIP enrollment, a number of other programs and policies within USDA also encourage or require conservation plans.

implementation of management practices relating to nutrient and pesticide use, irrigation water application, and wildlife habitat.

The process for selecting which contracts to fund is an important determinant of enrollment rates. Within this process, any practices that farmers favor for drought risk adaptation must compete with other practices that may more effectively address local environmental resource concerns. The contract selection process for EQIP can be divided into two major components: funding allocation and contract ranking. Funding allocations influence both the spatial distribution of EQIP contracts and the types of farms that receive contracts. Contract ranking influences which practices are funded within a given region.

Funding Allocation

At the national level, EQIP must meet certain congressional mandates for funding allocations across agricultural sectors and States. At least 60 percent of funding must go toward livestock-related practices. In addition, the EQIP budget is apportioned across States by the NRCS national office. Roughly two-thirds of the national EQIP budget appropriation is allocated based on a "general financial assistance" formula, which considers indicators of natural resource endowments and priority environmental concerns by State (GAO, 2006). A total of 31 individual factors are included in the formula, with corresponding weights that determine how much of the total national EQIP budget is allocated by factor. This amount is then apportioned across States based on the relative importance of individual factors (i.e., measured by number of farms in various categories, highly erodible acres, animal units, and miles of impaired streams) in each State.

The remaining portion of national EQIP funds is allocated across States for conservation technical assistance, performance bonus funds, conservation grants, and other special programs. These special programs often target specific resource concerns and regions. Other funding appropriations made for a number of regional programs administered under EQIP rules have included the Colorado Salinity Program, the Agricultural Water Enhancement Program (formerly the Ground and Surface Water Conservation Program) and the Klamath River Basin Program, (GAO, 2006).[26] In contrast to CRP acreage enrollment, EQIP funding has been fairly evenly distributed across producing areas, reflecting the wide array of eligible practices, the broadly defined targeting provisions based on national resource priorities (particularly after 2002), and regional equity considerations (SWCS and EDF, 2008).

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[26] Klamath River Basin funds were divided evenly between California and Oregon. Funding for the Colorado Salinity Program was divided among Colorado, Utah, and Arizona, based on acreage requiring salinity-control treatment. Funding criteria varied by State groupings under the Ground and Surface Water Conservation (GSWC) Program. For eight Plains States, GSWC funds were tied to acreage overlying the High Plains aquifer. For nine Western "drought" States, funding reflected extent of irrigated acreage. For other States with agricultural water needs, distributions were based on proportion of total water diversions used for agriculture.

Contract Ranking

While funding allocations under the general financial assistance formula and the special programs effectively determine each State's EQIP budget, States have considerable leeway in allocating funds across resource concerns and locations within the State. Unlike the CRP, States are given wide discretion in setting resource priorities, defining priority practices and payment rates within legislated limits, and establishing State enrollment procedures. In approximately half of the States, all funding and enrollment decisions are made at the State level. In the remaining States, one or more of these responsibilities is handled at a county or subwatershed level (Nickerson and Ribaudo, 2008). A number of newer national and regional EQIP initiatives provide States with greater guidance on choosing which contracts to fund, reflecting the complex partnership between the national and local offices in administering the program.

Contracts are ranked similarly to the CRP's EBI, with practices rated according to the degree to which they address key resource concerns. Most conservation practices address multiple resource concerns. NRCS captures the relationship between practices and resource concerns using a set of metrics known as the Conservation Practice Physical Effects (CPPE). The CPPE metrics give each practice a "score" for each of the 80 resource concerns. While there is a national CPPE table, the effects of each practice depend upon the regional context in which it is implemented, and so State CPPE tables play a more prominent role in contract ranking. Other factors beyond the CPPE also enter into contract ranking.

"Drought vulnerability" is not explicitly identified as a priority resource concern under EQIP, but funding provisions focus on resource concerns that are often exacerbated by droughtand therefore likely to receive more funding in higher drought-risk regions. Generally, the drought-related resource concerns are ancillary to other resource concerns such as water quantity, soil quality, soil erosion, and water quality.

Modeling Drought Risk Adaptation and EQIP: Irrigation and Tillage Practices

When deciding what practices to include on their EQIP application, farmers are likely to consider two key factors: the net onfarm benefits of practice adoption and the likelihood that NRCS will agree to fund those practices. Drought risk is potentially an important consideration in projecting net onfarm benefits of some EQIP-eligible practices, particularly those related to water and soil conservation. We focus on practices likely to have significant private benefits in drought-prone regions—irrigation and tillage-related practices—by helping crop farmers manage soil moisture levels.[27]

[27] Other soil-moisture retention practices supported by EQIP may also mitigate drought. Windbreaks composed of planted or manufactured materials help slow surface velocity of winds that dry the soil. Snow fences capture snowfall that increases moisture infiltration on portions of the field. Terraces and other land forming measures can help capture and route storm runoff to maximize soil-moisture infiltration. Rotation-fallowing with crop stubble or cover crops may help replenish subsoil moisture.

Despite the variation in priority resource concerns across regions and the large number of practices available for producers to include in their conservation plans, most EQIP funding goes to a small number of practices. The 10 most prevalent practices account for more than half of total funding, while 20 practices account for three-quarters of funding (table 2). Irrigation and tillage practices represent a substantial portion of EQIP financial assistance expenditures.[28] Since the program's inception in 1996, EQIP has contributed more than $250 million toward the adoption of conservation tillage practices. More than $1 billion has been allocated to irrigation-related practices under the program, with the most prevalent system upgrades involving low-pressure sprinkler systems, conveyance pipelines, and micro-irrigation systems.

The responsiveness of EQIP enrollment to drought risk depends upon how producers respond to drought risk. We expect that farmers facing greater drought risk will be more likely to adopt practices that lessen soil-moisture variability and

Table 2

Obligated Environmental Quality Incentives Program funds for the 20 most prevalent practices, 1997-2010

Rank in funding	NRCS practice code	Practice name	Total funding *($ million, nominal)*	Share of funding *(Percent)*	Cumulative share *(Percent)*
1	313	[Animal] Waste Storage Facility	610.84	10.1	
2	382	Fence	455.31	7.6	17.7
3	442	Irrigation System, Sprinkler	433.30	7.2	24.9
4	430	Irrigation Water Conveyance Pipeline	333.41	5.5	30.4
5	314	Brush Management	304.53	5.1	35.5
6	*	[Reduced] Tillage (*329, 345, 346)	258.88	4.3	39.8
7	516	Pipeline	246.19	4.1	43.9
8	590	Nutrient Management	233.72	3.9	47.8
9	441	Irrigation System, Microirrigation	201.86	3.4	51.1
10	512	Pasture and Hay Planting	189.96	3.2	54.3
11	561	Heavy Use Area Protection	177.57	2.9	57.2
12	595	Pest Management	174.77	2.9	60.1
13	614	Watering Facility	154.75	2.6	62.7
14	528	Prescribed Grazing	153.46	2.5	65.2
15	410	Grade Stabilization Structure	116.15	1.9	67.2
16	378	Pond	99.39	1.7	68.8
17	642	Water Well	99.10	1.6	70.5
18	464	Irrigation Land Leveling	98.69	1.6	72.1
19	600	Terrace	97.88	1.6	73.7
20	533	Pumping Plant	92.15	1.5	75.2

Source: Data from 1997 to 2001 were compiled from the Farm Service Agency EQIP data, which preceded the USDA Natural Resources Conservation Service (NRCS) ProTracts database. Data from 2002 to 2010 were compiled from ProTracts. Only active or completed contracts were used to compile funding totals. EQIP expenditures (or contract counts or other appropriate variables) are ERS estimates using NRCS data and are not official NRCS values.

[28] Prior to the 2008 Farm Act, financial assistance was referred to as cost-share.

to seek EQIP funding for such practices.[29] However, the extent to which conservation practice adoption decreases drought vulnerability is complex and depends on many factors. The ability of a particular practice to alleviate moisture deficits during drought may differ across enterprises, climatic conditions, and resource settings. Practice adoption and related input adjustments typically involve costs and may also involve changes in average yield.

The responsiveness of EQIP to drought risk also depends on program funding criteria. While drought is not an explicit resource concern used in funding allocations, EQIP enrollment decisions at the State or sub-State level are potentially more responsive to the incidence of drought than national weighting criteria might suggest. NRCS State offices, State technical committees, and local conservation districts provide input in defining priority resource concerns and practices, setting payment rates by eligible practice, and establishing program enrollment criteria. Producers, in turn, influence payment distributions through contract proposals that identify resource concerns and practices to be adopted. Consequently, local funding for drought adaptation may diverge from Federal allocations. According to an analysis of EQIP practice expenditures, funding rates for water conservation practices exceeded the weighting assigned to water conservation at the national level for purposes of State budget apportionment; the effect was largest where State ranking and enrollment decisions were made at a sub-State level (Nickerson and Ribaudo, 2008).

Irrigation-Related Practices

Irrigation has been widely used to ensure adequate soil moisture for crop growth. Irrigation is often required in arid regions with limited growing-season precipitation, and may be used in humid regions to enhance crop yield and minimize yield variability. While Western irrigated acreage has expanded since the mid-1980s, a decline in aggregate regional water use reflects continued improvements in water-use efficiency as well as changes in cropping patterns (Schaible and Aillery, 2012).

Drought risk is likely an important factor in irrigation investment decisions. Research on technology adoption rates among irrigators has generally shown that drought risk is associated with greater adoption of irrigation (Negri et al., 2005) and irrigation efficiency improvements (Peterson and Ding, 2005), although there may be exceptions or limits to this relationship (Green and Sunding, 1997; Schoengold and Sunding, 2011). In very high-risk regions, concerns over water supply reliability may inhibit investment in efficiency improvement, making the relationship between drought risk and investment decisions nonlinear. A number of studies suggest that it

[29] There are two alternatives to this behavioral hypothesis. First, farms may be able to purchase crop insurance, which, if providing high enough coverage, would mean that farms would not have any additional net benefits from reducing soil moisture variability. This is compatible with our null statistical hypothesis that there is no relationship between drought risk and EQIP participation for these practices. A second hypothesis is that these practices are used primarily because they are yield increasing, and therefore revenue increasing, thus making any relationship to risk spurious. However, irrigation efficiency and conservation tillage often increase average yields precisely by increasing yields in the lower tail of the yield distribution, which is a form of risk reduction. Ultimately distinguishing between the yield and yield-risk benefits/costs of particular production practices is very difficult in most contexts and requires data that permit stochastic dominance tests.

may be drought occurrence and the associated water-supply shortfalls, rather than simply drought risk, that have spurred increased adoption of more efficient irrigation practices (Carey and Zilberman, 2002; Schuck et al., 2005). Over time, this observation would still imply that higher drought-risk regions have greater investment in irrigation efficiency.[30]

Conservation Tillage Practices

Conservation tillage refers to various methods of soil cultivation—including no-till, ridge-till, and mulch-till—intended to reduce soil erosion and runoff. Under conservation tillage systems, 30 percent or more of the prior year's crop residue (eg., corn stalks or wheat stubble) is maintained on the field after planting. Adoption of conservation tillage systems involves specialized equipment and management adaptations, and yield effects may vary with local soils and climate or weather factors. Potential benefits include both public gains for water and air quality, as well as farm-level benefits involving soil moisture retention, labor and energy savings, and long-term soil productivity.

Conservation tillage may be an important drought adaptation response in many areas.[31] Reduced soil disturbance limits moisture loss from the soil profile, as less soil surface is exposed to drying. Soil compaction and crusting are also reduced, enhancing water infiltration. Increased residue cover that lowers soil temperatures further lessens moisture loss while contributing organic material that enhances water infiltration and soil moisture-holding capacity (Bruce and Steiner, 1995). However, conservation tillage may delay planting and seed germination under cool and wet spring conditions, particularly on heavier soils with limited drainage.

The use of conservation tillage has expanded over time, with notable variation in adoption rates observed across crops. Nationally, the estimated 2009 acreage share in no-till was highest for soybeans (45.3 percent), with lesser shares for corn (23.5 percent), wheat (21.9 percent), and rice (11.8 percent) (Horowitz et al., 2010).[32] Ding et al. (2009) find that adoption of conservation tillage is positively correlated with the incidence of abnormally dry conditions in preceding crop years, while wet conditions at planting time generally restrict the use of conservation tillage.

[30] While irrigation investments may reduce drought vulnerability at the farm level, the potential expansion of regional consumptive water use with widespread irrigation adoption may decrease water supply reliability at a basin level, particularly in surface-water systems since drought is more likely to lead to withdrawal restrictions in those systems.

[31] Conservation tillage may be especially beneficial as a drought response in rainfed production areas. Cropping systems that rely on natural precipitation may be particularly susceptible to yield loss due to soil-moisture deficits. While moderate drought of short duration may have relatively little impact on crop growth, sustained moisture stress during critical phases of the growing season can result in significant declines in crop yield and quality.

[32] Based on acreage in no-till observed in the most recent ARMS crop survey years (2003-07), with an estimated annual acreage expansion rate of 1.5 percent through 2009.

Data and Methods

Data on EQIP contracts are obtained from the NRCS ProTracts database. The database includes all EQIP contracts for which funds were obligated between fiscal years 2002 and 2010. For this analysis, we developed county-level counts of all contracts with obligated funds for the relevant practices. We identify irrigation-related contracts and tillage-related contracts based on the practice codes that appear in the contract data (see Appendix C).

We are interested in modeling the likelihood of EQIP participation conditional on drought risk and other variables. However, unlike the CRP case, the EQIP dataset does not include data on offers that were not accepted by NRCS. Instead, we model enrollment by looking at participation in terms of the number of active (i.e., funded) contracts in a county. Since we are interested in establishing longrun relationships between climate and program participation, we use the average number of contracts per year over 2002-10.

To express the number of contracts as a participation rate, we rely on agricultural census data to determine potentially eligible farms in each county. For irrigation-related practices, this is represented by operations with harvested irrigated cropland in a county. For tillage-related practices, this is the number of operations with crop sales in a county. To allow for fluctuation in the number of crop farms and the number of irrigators, both of which may vary from year to year due to price and weather shocks, we take the maximum number of operations over the past three censuses (1997, 2002, and 2007).

Using these two variables (the number of contracts and the number of eligible operations in each county), we use a conditional grouped logit model to estimate the likelihood of program participation. Our primary concern is in identifying the effect of drought risk on EQIP enrollment. The data reflect enrollment, and not offers, so there is a greater risk in this analysis of confounding farmer decisions with the NRCS offer selection process. To control for the NRCS selection process, we rely upon two types of variables: the Erodibility Index (EI), which was also used in the CRP analysis, and State-level dummy variables, which capture differences in State-level ranking criteria such as the Conservation Practice Physical Effects (CPPE). We also run versions of the model that incorporate measures of CPPE directly (Appendix C).

For irrigators, a number of other variables could influence the likelihood that farms rely on EQIP for irrigation-related capital improvements. The value of the land, for example, may affect the ability of farmers to borrow for capital improvements. If that value increases the likelihood of making irrigation investments, counties with higher land values may also be more likely to rely on EQIP. Alternatively, if NRCS is able to identify farms that are less likely to invest in irrigation improvements in the absence of financial assistance, then land values may be negatively correlated with enrollment rates. The type of water source used for irrigation may also influence investment and participation decisions. As a measure of land values, we use the soil rental rate variable from the CRP analysis. These rental rates are for dryland crop production, which is more likely than irrigated cropland rents to be correlated with drought risk. As a measure of water source, we use the share of irrigated acreage that is supplied by groundwater, a statistic available at the county level from the U.S. Geological Survey.

For crop producers, a similar set of control variables (soil rental rates, State fixed effects, EI values, and CPPE values) potentially influences the likelihood of enrolling in EQIP tillage-related contracts. Since conservation tillage is directly related to crop choice, we also use the share of cropland in soybeans as a control variable. The share of cropland in soybeans is calculated as the maximum share of planted soybean acres to total cropland over the 2002 and 2007 agricultural censuses. For counties that grow no soybeans in any year, this variable is zero. Since conservation tillage is applied to soybeans much more than to other crops such as corn, wheat, and cotton (Horowitz et al., 2010), the share of crop farms with tillage-related EQIP contracts will likely be higher in counties with a greater share of soybeans.

Potential EQIP Design Responses to Drought Risk

For both irrigation-related practices and tillage-related practices, counties with higher drought risk tend to have higher EQIP participation rates (Appendix C, table C1). For irrigation-related practices, this effect diminishes as drought risk increases, likely because the benefit of capital investments in irrigation is attenuated when there is increased risk that water supplies will be interrupted during droughts, a concern in many high-risk counties where surface water is the primary water source. Counties with higher erodibility and greater groundwater dependence also have higher EQIP participation rates among irrigators.

For tillage practices, counties with higher concentrations of soybeans have higher participation rates, which is consistent with higher conservation tillage adoption rates for soybeans relative to other crops. In contrast, counties with higher erodibility have lower participation rates in conservation tillage contracts. One of the only other studies to examine tillage contract participation found that the relationship between highly erodible land (HEL) and EQIP participation is small and not statistically significant (Cooper, 1997). One reason that we might find a negative relationship is that farmers may have been more likely to have adopted conservation tillage on HEL fields prior to our study period due to both conservation compliance provisions, which were initiated by the 1985 Farm Act, and the larger private benefits of conservation tillage on erodible land. Having already adopted conservation tillage, these fields would not have been eligible for EQIP payments on tillage practices during the years over which we observe program participation.

The view that EQIP is currently facilitating drought risk adaptation by farmers is consistent with these results. We are only able to examine EQIP enrollment data (not offer data), so we structured our analysis in an effort to control for administrative decisions. Without any control variables, it could be that irrigation and tillage practices are more common in more drought-prone counties because these practices receive higher contract ranking scores where drought risk is higher. For example, we know that contract ranking scores vary considerably across States.[33] We are able

[33] See, for example, the contract ranking scores within Nebraska (www.ne.nrcs.usda.gov/programs/EQIP/eqip_NRD.html) and Illinois (www.il.nrcs.usda.gov/programs/eqip/index.html).

to control for administrative decisions made at the State level through either State fixed effects or our CPPE variables. However, if there are more local decisions, such as at the county level, we are not able to control for those given currently available data.

The program design implications of farm-level drought risk adaptation are less apparent for EQIP than for CRP. Unlike CRP, EQIP does not include county caps or strict eligibility requirements that can steer participation toward higher risk areas. In addition, while the CPPE scores are incorporated into contract rankings, the decentralized nature of EQIP means that States and counties have flexibility in how those CPPE scores are set. In addition, our simple models do not find a strong positive relationship between CPPE scores and participation rates. Setting the CPPE matrix at a national level could influence the local planning process but would not necessarily target certain practices.

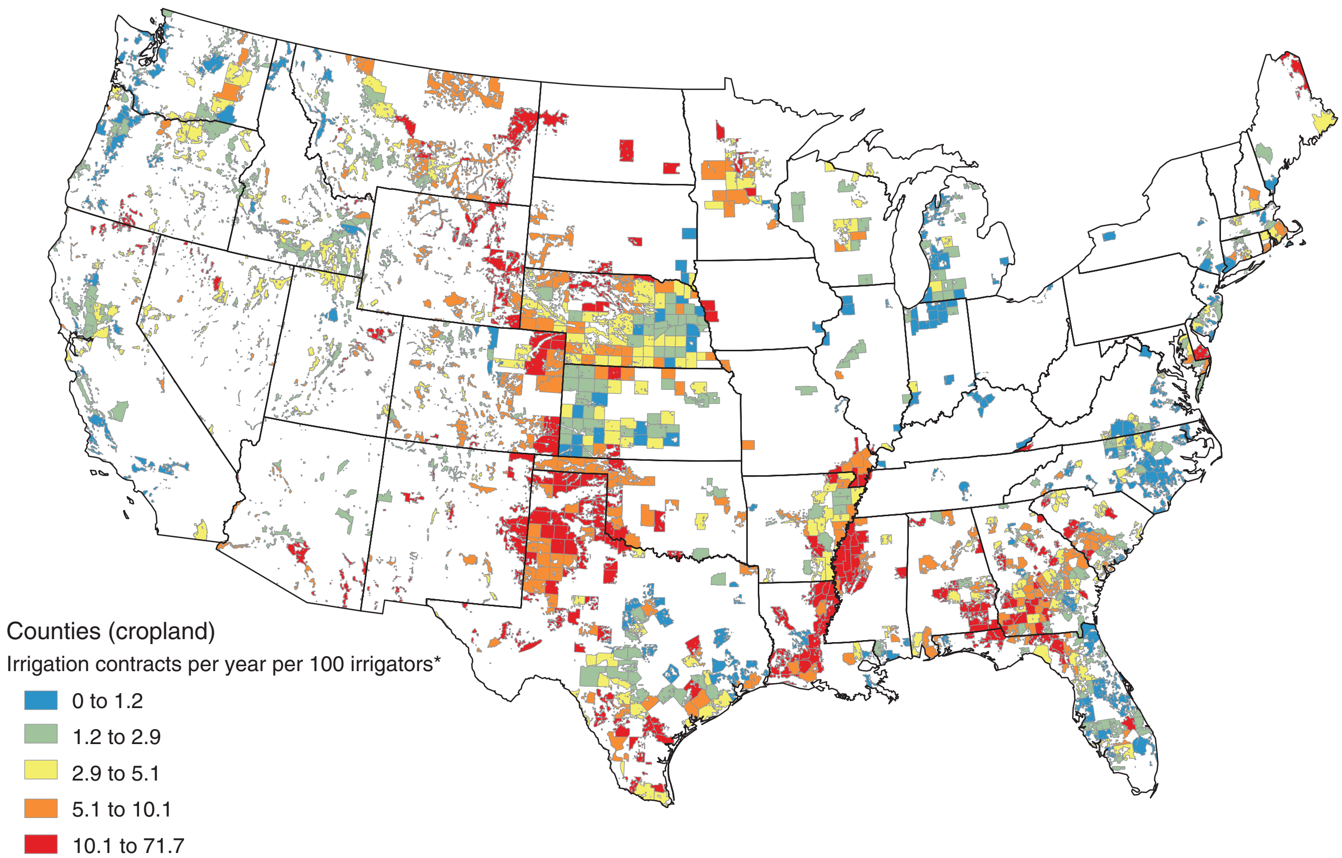
The importance of State-level influence is particularly pronounced in the EQIP data and can be seen in maps of participation rates. The number of irrigation-related contracts, shown for counties with at least 5 percent of harvested cropland irrigated, shows that participation rates vary significantly by State (fig. 12). Often there are noticeable differences in participation across jurisdictional boundaries in locations where the climatological and hydrological conditions are very similar. For example, in the Central Plains, where there is a great deal of irrigation based on withdrawals from the High Plains Aquifer (mostly coincident with the Ogallala Aquifer) and relatively high drought risk, both western Nebraska and northern Texas have relatively high EQIP participation rates while western Oklahoma and western Kansas have lower participation rates. Similarly, participation rates vary by State within the Mississippi Alluvial Aquifer region (where drought risk is relatively low); Alabama and Louisiana have high participation rates while southeastern Arkansas has much lower participation rates. The cross-jurisdiction differences within regions of similar drought risk indicate that local planning is a critical determinant of participation rates. In general, though, drought risk does seem to influence EQIP participation.

The number of tillage-related EQIP contracts similarly shows that participation rates vary by State (fig. 13). The contrast is most notable in the Northern Plains. Participation in conservation tillage contracts is relatively high in North Dakota and Minnesota but nearly zero in neighboring counties in South Dakota.

Given the great deal of local flexibility in ranking and selecting EQIP contracts, it may be that national concerns about drought adaptation can be addressed through EQIP using special project designations. Similar to previous efforts in the Klamath River Basin or the Colorado Salinity Project, drought adaptation could be targeted using set-aside funding for areas identified as being at high risk of drought or projected to have increased drought risk in the future. The tradeoff of this approach, however, is that it implies a de facto reduction in local flexibility to determine the optimal mix of practice funding. If we assume flat budgets for national EQIP funding, adding set-aside funding for a special project would reduce the share of funding going to practices that are unrelated to drought, and to geographic areas that are unlikely to face high drought risk.

Figure 12

Irrigation-related Environmental Quality Incentives Program participation rates by county, 2002-10



*Contract data are obtained from the USDA's Natural Resources Conservation Service (NRCS) ProTracts database and totaled within the county in which the practices are located. The number of irrigators in the county is maximum value within each county of the number of operations with harvested irrigated cropland in each Agricultural Census (1997, 2002, and 2007).

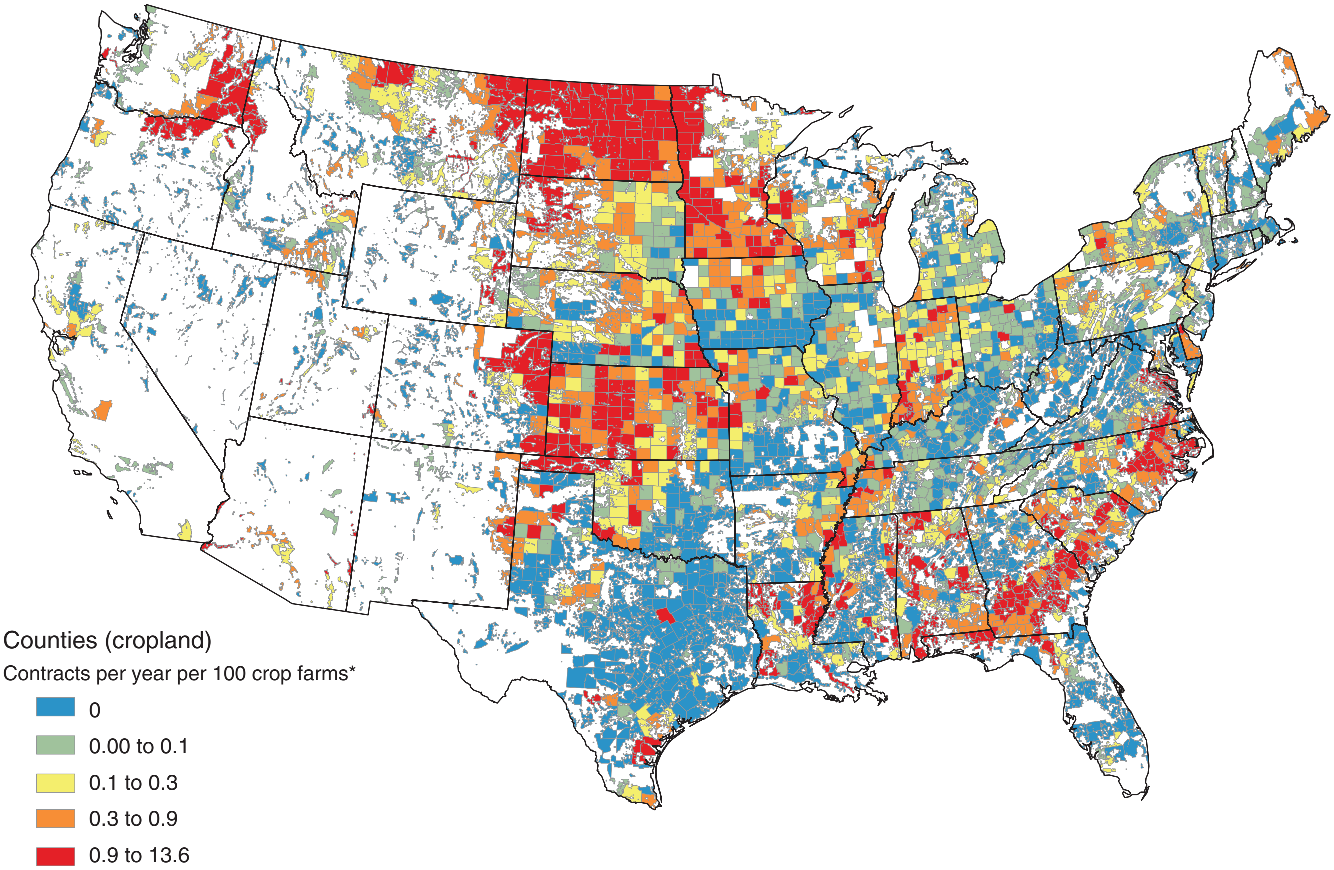
Source: Data on irrigation-related contracts were compiled from the NRCS ProTracts database. Data on the number of farms with irrigated cropland were compiled from the 1997, 2002, and 2007 Agricultural Censuses. Note that the set of practices used by ERS to identify irrigation-related contracts differs with respect to a handful of practices when compared to NRCS designations of irrigation practices. EQIP expenditures (or contract counts or other appropriate variable) are Economic Research Service estimates using NRCS data and are not official NRCS values.

Conclusion

Counties with higher drought risk have higher EQIP participation rates for irrigation and tillage practices. As with CRP, this result suggests that climate adaptation is likely to include changes in conservation program participation. The tools for USDA to encourage or enhance such adaptation are more limited in the case of EQIP, in part because of the extent to which contract ranking is determined at local levels. Since EQIP involves practices on working lands, the role of drought risk in program participation may also have important implications for how drought risk affects the farm safety net. Investment in drought-mitigating practices, for example, may lessen reliance on crop insurance. It is also conceivable that such investments may favor expansion of cultivated land in areas more prone to drought. Improving our understanding of the connections between EQIP participation and farmers'

Figure 13

Conservation tillage-related Environmental Quality Incentives Program participation rates by county, 2002-10



*Contract data are obtained from the USDA's Natural Resources Conservation Service (NRCS) ProTracts database and totaled within the county in which the practices are located. The number of farms in the county is maximum value within each county of the number of operations with crop sales in each Agricultural Census (1997, 2002, and 2007).

Source: Data on tillage-related contracts were compiled from the NRCS ProTracts database. Data on the number of farms with crop sales was compiled from the 1997, 2002, and 2007 Agricultural Censuses. EQIP expenditures (or contract counts or other appropriate variable) are Economic Research Service estimates using NRCS data and are not official NRCS values.

exposure to production risks, however, will require better EQIP data, most notably improved data on EQIP offers and not just EQIP contracts.

Drought Risk Adaptation in the Animal Sector

While this report focuses primarily on drought adaptation in the U.S. crop sector, drought is also an important concern for livestock producers, especially those who use grazing land for forage needs. Prolonged drought can have significant effects on regional economies where livestock grazing is an important land use. Resulting degradation of land and water resources can reduce returns to livestock grazing systems, both through declining animal productivity and greater reliance on purchased feed and emergency water supplies. Local market effects—such as higher costs for supplemental hay and silage and reduced prices of animals sold at lower weights—may exacerbate income losses for both confined and non-confined production. In this section, we describe how USDA conservation programs, historically focused on the crop sector, have broadened in scope to provide livestock production with tools for adapting to drought risk.[34]

Grazing Land Resources and Drought Prevalence

Land resources available for livestock grazing covered roughly 779 million acres in 2007, or roughly two-thirds of the U.S. agricultural land base. Grassland pasture and rangeland accounted for 614 million acres, with an additional 36 million acres in cropland pasture and 129 million acres in forested rangeland (Nickerson et al., 2011). While private grazing lands are located in all States, grazing lands are concentrated in the Mountain and Plains regions of the West. Much of the Nation's grazing land is in areas prone to drought, according to the Palmer Modified Drought Index (PMDI) (see fig. 6. p. 15). Moreover, a large share of the Nation's rangeland is characterized by poorer soils with low moisture-holding capacity, making the land particularly vulnerable to drought (Wilhelmi and Wilhite, 2002).

A related concern for livestock grazing systems is the compounding effect of rising temperatures during drought. The coincidence of low precipitation and higher temperatures is evident across the Mountain States, Plains, and Southeast regions—an expanse encompassing much of the Nation's private grazing land resources (see Appendix A, fig. A3). Lack of precipitation during drought, in combination with higher temperatures, can weaken grazing animals and deplete the land and water resources upon which they depend.

Drought Impacts and Adaptation

Drought management is an important element of livestock grazing systems. Various farm practices—augmenting water supply and shade, maintaining forage by land grading or brush removal, and regulating animal stocking rates—may be implemented prior to, during, and after drought to mitigate drought-related losses.

[34] Unlike for CRP and EQIP, we do not empirically evaluate the role of drought risk in program participation rates.

Livestock Water Supply

Livestock production depends on an adequate and reliable supply of high-quality water. Water-supply shortages and poor water quality due to sustained drought are especially important concerns for livestock grazing operations. Ponds, streams, and shallow wells that normally serve as water sources may dry up or become undrinkable. Higher temperatures often associated with drought generally increase livestock water requirements for animal growth and thermal control, further exacerbating water-supply concerns. Limited water supplies may affect animal health and productivity via reduced feed intake and efficiency, reduced weight gain, and increased susceptibility to disease.

Small-scale water-supply augmentation, through a variety of off-stream livestock watering systems and catchments, can provide critical supplies during drought. Constructed ponds, or “dugouts,” may be developed from springs, seeps, and high groundwater tables. Water obtained from wells or rural water sources, or hauled from elsewhere, may be stored in tanks and piped to livestock troughs. Ensuring shade for livestock is also important; constructed shade structures and planted shelterbelts can reduce heat exposure while helping to disperse herds.

Forage Productivity and Quality

While rangeland vegetation and perennial forage and hay crops may be relatively resistant to moderate drought stress over short periods, more severe drought—often in combination with higher temperatures—may result in declining productivity. This is particularly true for the more marginal soils characteristic of many grazing lands. Drought may also reduce the nutritional quality of forage production; dormant pasture and native range forage during drought is often lower in protein, vitamins, and minerals. Dry forage crops may be harder to digest, while concentrations of salts, nitrates, and acid levels can increase to harmful levels. The risk of weed poisoning may also increase as some rangeland plants accumulate toxins when subject to drought stress. Livestock are more apt to graze on toxic weeds in drought years when desirable forage is limited, and drought-stressed animals may be more susceptible to toxins.

Land treatments for pasture and rangeland may help to maintain forage productivity under drought conditions. Brush removal to reduce non-crop water use, mechanical treatments to enhance soil permeability, and land grading to create runoff catchments can all increase soil moisture for forage production. Planting of perennial and self-sustaining vegetation may improve the drought tolerance of forage cover. Weed infestations that can be especially hazardous during drought may be treated through herbicides or mechanical means.

Stocking Rates

Balancing animal stocking rates with the forage capacity of land is a critical element of managed grazing systems.[35] Sustainable stocking rates contribute to healthy

[35] Stocking rate is defined as the number of animals on a given amount of land over a certain period of time. Stocking rate is generally expressed as animal units per unit of land area. Carrying capacity is the stocking rate that is sustainable over time per unit of land area.

grazing systems that are better able to withstand the onset of drought. Reduced stocking levels during prolonged drought can help alleviate grazing pressure on pasture and rangeland, lessening plant stress while providing additional forage for remaining animals.

To minimize reductions in herd size and productivity, supplemental feeding is often necessary to offset the loss of forage and fodder supplies. Alternative onfarm feed sources may include forage harvested and stored in advance; drought-damaged crops that are grazed or harvested for silage; crop residues such as small grain straw and corn stover; or short-season forage crops such as buckwheat or millet planted to offset early crop losses. Alternative commercial feeds—such as corn gluten, soybean meal, and distillers' grains—may also help to stretch limited forage supplies. Renting additional pastureland can increase access to forage and water, although drought may restrict the local supply and quality of available grazing land. Temporary feeding in off-farm feedlots may be an option for some animal types. In many instances, however, sustained drought will require producers to reduce herd size through selective culling.

Conservation Programs and Livestock Grazing

USDA has provided technical assistance for grazing systems since the 1930s. However, the stewardship of private grazing land resources has emerged as an important conservation priority in recent years, with expanded policy emphasis and program funding. Support for improved management of private grazing land comes from both working lands programs such as EQIP and from land retirement programs such as CRP.

Under the 2008 Farm Act, 60 percent of EQIP conservation expenditures are targeted to livestock production. Grazing land practices generally address multiple resource concerns, with adaptation to drought often secondary to grazing land productivity and water-quality control. Prescribed grazing plans, for example, typically include a drought contingency plan that identifies mitigation actions to minimize drought-related damages. For this report, we identified a select group of practices that clearly provide some private benefits in coping with drought risk: forage management, prescribed or planned grazing, and livestock water supply augmentation. Since 1997, these practices have accounted for more than 13 percent of total EQIP funding (table 3). Contracts containing one or more of these practices are heavily concentrated in the more drought-prone regions of the country (fig. 14).

Other USDA programs also provide funding for grazing land conservation practices that support drought preparedness and recovery. Under the Conservation Stewardship Program (CSP), administered by NRCS, pasture and rangeland have accounted for a significant share of acres approved for contracts. The Grassland Reserve Program (GRP), administered jointly by NRCS and FSA, is designed to preserve grasslands for livestock grazing and other uses under long-term easements and rental agreements; an approved grassland resource management plan is required for enrollment, with financial support available for approved practices. The Emergency Conservation Program (ECP), administered by FSA, provides funding and technical assistance for farm and ranchland damaged by drought, as well as emergency livestock water supplies. NRCS technical assistance is funded primarily

Table 3

Drought-related livestock practices in Environmental Quality Incentives Program, 1997-2010

NRCS practice code	Practice name	Total funding *($ million, nominal)*	Percent of total EQIP funding *(Percent)*
512	Pasture and hay planting	189.96	2.96
516	Pipeline	246.19	3.83
528	Prescribed grazing	153.46	2.39
550	Range planting	2.35	0.04
574	Spring development	15.11	0.24
614	Watering facility	154.75	2.41
642	Water well	99.10	1.54
708	Cistern	0.08	< 0.01
762	Planned grazing system	0.61	0.01

Note: Detailed practice descriptions are available on the USDA, Natural Resources Conservation Service (NRCS) website: http://www.nrcs.usda.gov/technical/Standards/nhcp.html

Practice 642 (water well) also appears under irrigation practices because it can be used for both livestock and irrigation. Practice 516 (pipeline) appears only as a livestock-related practice because it may not be used for irrigation purposes. EQIP expenditures (or contract counts or other appropriate variables) are ERS estimates using NRCS data and are not official NRCS values.

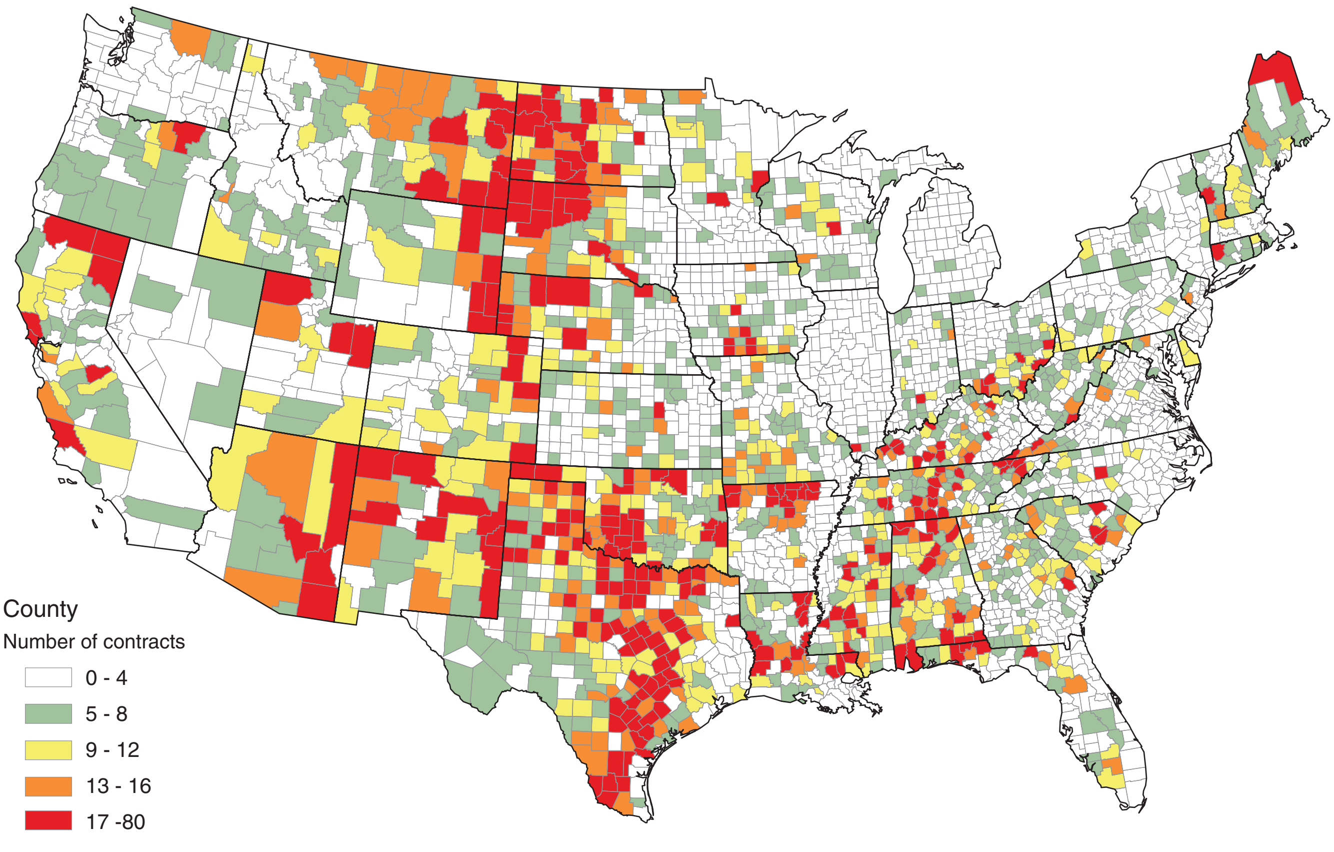
through the Conservation Technical Assistance program. Non-Federal grazing lands constitute about half of the total land for which NRCS provides technical assistance (USDA/NRCS, 2003).

CRP enrollment can be a potential drought risk-management strategy for crop producers with environmentally sensitive cropland. Enrollment may also lessen drought-related income risk for livestock producers with eligible cropland. Much of the CRP enrolled acreage is concentrated in the Plains States, where marginal soils in transitional cropland/grassland agricultural zones—favored under CRP contract ranking criteria—coincide with concentrations of livestock production. For CRP participants who maintain livestock operations, haying and grazing access on enrolled acreage in exchange for a reduction in CRP rental payments can provide additional flexibility in managing livestock feed requirements. In the Texas High Plains, the presence of a livestock enterprise on a CRP participant's farm operation significantly increased the probability of re-enrollment (Johnson et al., 1997), underscoring the importance of CRP land as a forage source for many livestock producers.

Two separate provisions for haying and grazing are authorized under the CRP. *Managed haying and grazing* may be permitted during specific time intervals (eg., in accordance with the nesting season for grassland birds) for no more than 1 out of every 3 years after the CRP cover is fully established, depending on site conditions and conservation objectives. While managed haying and grazing allows for diversification of returns from CRP enrolled acreage, the primary purpose of acreage enrollment is to maintain or enhance wildlife habitat, minimize soil erosion, and protect water quality. However, CRP lands may provide an important source of livestock forage, especially during dry years.

Emergency haying or grazing may be authorized to provide emergency relief to livestock producers in designated areas affected by severe drought or other natural

Figure 14
Environmental Quality Incentives Program contracts with drought-related livestock practices, 2008-10



*Contract data are obtained from the USDA's Natural Resources Conservation Service (NRCS) ProTracts database and totaled within the county in which the practices are located.

Source: NRCS ProTracts database, active and completed contracts only. EQIP expenditures (or contract counts or other appropriate variable) are Economic Research Service estimates using NRCS data and are not official NRCS values.

disaster.[36] During periods of prolonged drought when local hay supplies are often limited and hay prices are high, CRP acreage in grasses and other vegetative cover can provide an important reserve for livestock grazing and haying. Managed and emergency haying and grazing are subject to conservation plan provisions that protect environmental benefits achieved under the program. CRP participants are assessed a reduction in rental payments under managed haying and grazing and a reduction under emergency conditions, a loss in payments that is presumably offset by revenues from livestock production since activation of these provisions is voluntary.[37] The size of the payment reductions has varied over time. In addition, in some

[36] To be approved for drought-related emergency haying or grazing on CRP land, a county must be suffering from either extreme drought conditions (D3 on the Palmer Drought Index or worse) or 40 percent less precipitation than average over a 4-month period.

[37] Producer participation incentives reflect the quantity and quality of available CRP hay and forage, the reduction in annual rental payments, and the costs of harvest and hauling as well as the costs of alternative feed sources.

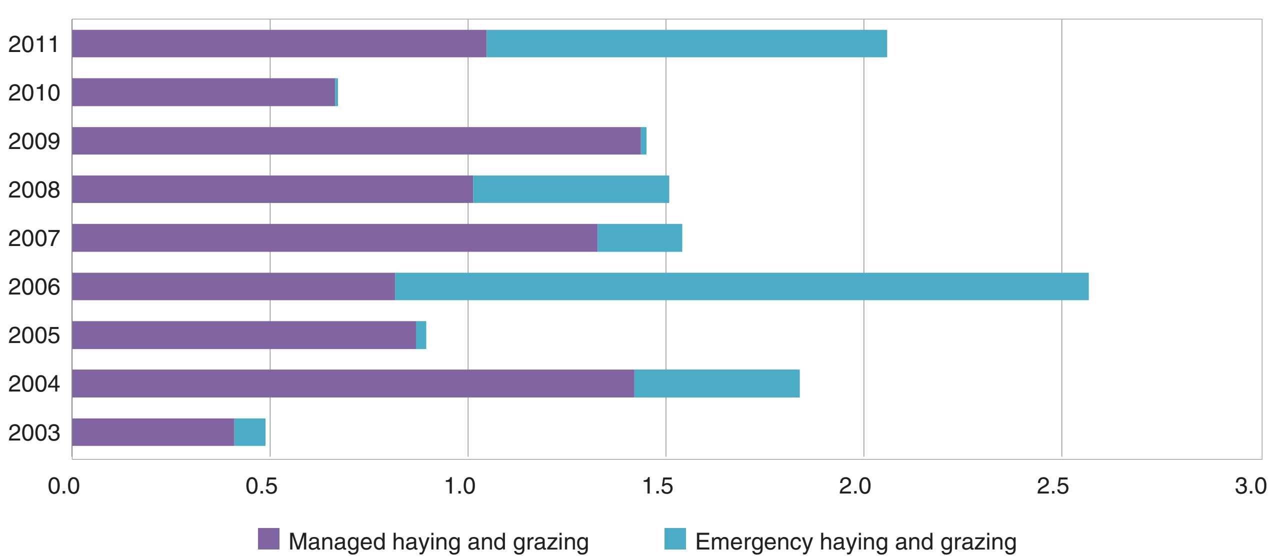
regions farmers may not invoke hay and grazing provisions on CRP land until after the completion of primary nesting season, which is in the summer for most bird species.

Over the 2003-11 period, U.S. acreage approved for managed haying ranged from less than 500,000 acres to more than 1 million acres annually, representing roughly 2 to 3 percent of all CRP contracts nationwide (fig. 15). Smaller CRP acreages have been used for managed grazing than for emergency grazing, generally representing less than 1 percent of CRP contracts (USDA/FSA, 2012). Managed haying on CRP-enrolled land occurs throughout the United States, particularly in the drought-prone Northern Plains and northern Mountain regions. Managed grazing on CRP land occurs predominantly in the West, with the largest acreages concentrated in the Southern and Northern Plains and northern Mountain regions.

While participation in managed haying and grazing has held fairly constant, the use of CRP emergency haying and grazing provisions has been more variable across years and regions, reflecting the uncertain nature of extreme weather events. National participation peaked in the summer of 2006, when moderate, severe, or extreme drought conditions extended across much of the Mountain West, Plains States, and Central-Southeastern United States. Emergency haying was authorized on an estimated 875,000 acres nationwide in 2006, including more than 15 percent of active CRP contracts in North and South Dakota; emergency grazing was authorized on an estimated 877,000 acres, including more than 8 percent of CRP contracts in Wyoming, Colorado, and Texas (USDA-FSA, 2012). Under prolonged drought conditions in 2011, 845,000 acres were enrolled in CRP emergency grazing across Texas, Oklahoma, Kansas, New Mexico, and Colorado. The large increase in

Figure 15

Conservation Reserve Program managed/emergency haying and grazing allotments, 2003-11



Source: USDA Farm Service Agency data on CRP contract utilization of haying and grazing provisions.

national CRP acreage in managed haying and grazing in 2007 and 2009, following years with higher enrollment in CRP emergency provisions, suggests its use by some CRP participants as a hedge against multi-year drought effects on livestock forage supply.

Conclusion

Multiple conservation programs encourage practices that help livestock producers adapt to drought risk. In some cases, program provisions for livestock producers may be explicitly designed to address drought impacts—as in the case of emergency grazing provisions on CRP land. Conservation programs, therefore, already serve a role in facilitating drought risk adaptation for livestock producers. To the extent that climate change increases drought risk in some regions, producer demand for these programs is likely to increase.

Conclusion

Drought risk, a key measure of climate, is shown to influence conservation program participation. For both EQIP and CRP, this implies that these programs are currently serving as de facto drought risk adaptation tools. Crop producers in higher drought-risk regions are more likely to offer land for retirement in CRP or to enroll in EQIP contracts that fund irrigation and conservation tillage practices. For livestock producers using emergency haying and grazing provisions, the link between drought and program design is generally more explicit.

Climate change, to the extent that it alters drought risk, is likely to affect the ability of conservation programs to achieve USDA goals. It may be possible to adjust program provisions to encourage drought-risk adaptation, although this may involve tradeoffs with the conservation goals of the programs.

The extent to which conservation programs can actually reduce drought vulnerability is an important area for future research. Given that producers in areas with higher production risk due to drought are more likely to participate in USDA conservation programs, there may be important interactions between conservation programs and the farm safety net. As the science of climate change improves to provide more precise predictions about regional changes in drought risk, USDA programs would benefit from greater consideration of how voluntary adaptation by farmers is likely to affect participation.

References

Antle, J.M. 2009. *Agriculture and the Food System: Adaptation to Climate Change.* Washington, DC, Resources for the Future. June.

Banik, Pabitra, Abhyudy Mandal, and M. Sayedur Rahman. 2002. "Markov Chain Analysis of Weekly Rainfall Data in Determining Drought-Proneness," *Discrete Dynamics in Nature and Society* 7: 231-239.

Bruce, R.R., and J.L. Steiner. 1995. "Influence of Tillage on Soil Water," *Farming for a Better Environment.* Soil and Water Conservation Society.

Carey, J., and D. Zilberman, 2002. "A Model of Investment Under Uncertainty: Modern Irrigation Technology and Emerging Markets in Water," *American Journal of Agricultural Economics* 84(1): 171-183.

Chang, Hung-Hao, Dayton M. Lambert, and Ashok K. Mishra. 2008. "Does Participation in the Conservation Reserve Program Impact the Economic Well-Being of Households?" *Agricultural Economics* 38: 201-212.

Chite, Ralph M. 2006. *Emergency Funding for Agriculture: A Brief History of Supplemental Appropriations: FY1989-FY2006.* Congressional Research Service Report Number RL31095. July 3.

Cooper, Joseph C. 1997. "Combining Actual and Contingent Behavior Data to Model Farmer Adoption of Water Quality Protection Practices." *Journal of Agricultural and Resource Economics.* 22(1): 30-43.

Council on Environmental Quality. 2010. *Progress Report of the Interagency Climate Change Adaptation Task Force: Recommended Actions in Support of a National Climate Change Adaptation Strategy.* October 5. www.whitehouse.gov/sites/default/files/microsites/ceq/Interagency-Climate-Change-Adaptation-Progress-Report.pdf)

Cook, Edward R., Richard Seager, Mark A. Cane, and David W. Stahle. 2007. "North American Drought: Reconstructions, Causes, and Consequences," *Earth-Science Reviews* 81: 93-134.

Ding, Ya, Karina Schoengold, and Tsegaye Tadesse. 2009. "The Impact of Weather Extremes on Agricultural Production Methods: Does Drought Increase Adoption of Conservation Tillage Practices?" *Journal of Agricultural and Resource Economics* 34(3): 395-411.

Dismukes, Robert, and Joseph Glauber. 2005. "Why Hasn't Crop Insurance Eliminated Disaster Assistance?" *Amber Waves*. U.S. Department of Agriculture, Economic Research Service. June.

Easterling, William E., Brian H. Hurd, and Joel B. Smith. 2004. *Coping with Global Climate Change: The Role of Adaptation in the United States.* Pew Center on Global Climate Change, Washington, DC.

Glauber, Joseph W. 2004. “Crop Insurance Reconsidered,” *American Journal of Agricultural Economics* 86 (5): 1179-1195.

Gollehon, Noel, and Shawn Bucholtz. 2007. “In the Long Run: Drought Is a Recurring Risk Faced by Agricultural Producers,” *Amber Waves*. U.S. Department of Agriculture, Economic Research Service. May.

Green, G.P., and D.L. Sunding. 1997. “Land Allocation, Soil Quality, and the Demand for Irrigation Technology,” *Journal of Agricultural and Resource Economics* 22(2): 367-375.

Guttman, Nathaniel B. 1998. “Comparing the Palmer Drought Index and the Standardized Precipitation Index,” *Journal of the American Water Resources Association* 34 (1): 113-121.

Hatfield, J., K. Boote, P. Fay, L. Hahn, C. Izaurralde, B.A. Kimball, T. Mader, J. Morgan, D. Ort, W. Polley, A. Thomson, and D. Wolfe. 2008. “Agriculture.” *The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States.* U.S. Climate Change Science Program and the Subcommittee on Global Change Research. Washington, DC.

Hayes, M.J. 2006. “Comparison of Major Drought Indices: Introduction.” National Drought Mitigation Center. http://drought.unl.edu/Planning/Monitoring/ComparisonofIndicesIntro.aspx

Hirabayashi, Y., S. Kanae, S. Emori, T. Oki, and M. Kimoto. 2008. “Global Projections of Changing Risks of Floods and Droughts in a Changing Climate,” *Hydrologic Sciences* 53 (4): 754-772.

Horowitz, John, Robert Ebel, and Kohei Ueda. 2010. *“No-Till” Farming Is a Growing Practice.* USDA Economic Research Service, EIB-70. November.

Heim, Richard R., Jr. 2002. “A Review of Twentieth-Century Drought Indices Used in the United States,” *Bulletin of the American Meteorological Society*. Aug.: 1149-1165.

Johnson, Phillip N., Sukant K. Misra, and R. Terry Ervin. 1997. “A Qualitative Choice Analysis of Factors Influencing Post-CRP Land Use Decisions,” *Journal of Agricultural and Applied Economics* 29(1): 163-173. July.

Just, Richard E., and Rulon D. Pope. 2002. *A Comprehensive Assessment of the Role of Risk in U.S. Agriculture.* Boston: Kluwer Academic Publishers.

Kellogg, R.L. 2002. *Profile of Farms with Livestock in the United States: A Statistical Summary*. U.S. Department of Agriculture, Natural Resources Conservation Service. www.nrcs.usda.gov/technical/NRI/pubs/livestockfarm.html

Kirwan, B., R.N. Lubowski, and M.J. 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.

Lubowski, R.N., S. Bucholtz, R. Claassen, M.J. Roberts, J.C. Cooper, A. Gueorguieva, and R. Johansson. 2006. *Environmental Effects of Agricultural Land-Use Change: The Role of Economics and Policy.* ERR-25. U.S. Department of Agriculture, Economic Research Service.

Mika, J., S. Horvath, L. Makra, and Z. Dunkel. 2005. "The Palmer Drought Severity Index (PDSI) as an Indicator of Soil Moisture," *Physics and the Chemistry of the Earth.* 30: 223-230.

National Drought Mitigation Center (NDMC). 2010. "Drought in the Dust Bowl Years." University of Nebraska, Lincoln. http://drought.unl.edu/whatis/dustbowl.htm

National Drought Policy Commission (NDPC). 2000. *Preparing for Drought in the 21st Century.* http://govinfo.library.unt.edu/drought/finalreport/fullreport/pdf/reportfull.pdf

Negri, D., N. Gollehon, and M. Aillery. 2005. "The Effects of Climatic Variability on U.S. Irrigation Adoption," *Climatic Change* 69: 299-323.

Nickerson, Cynthia, Robert Ebel, Allison Borchers, and Fernando Carriazo. 2011. *Major Uses of Land in the United States, 2007*. U.S. Department of Agriculture, Economic Research Service, EIB-89. Dec.

Nickerson, C., and M. Ribaudo. 2008. "Achieving National Priorities in Decentralized Conservation Programs." U.S. Department of Agriculture, Economic Research Service, Selected poster at AAEA meetings, Orlando, FL. July.

National Oceanic and Atmospheric Administration (NOAA). 2006. "Tracking and Evaluating U.S. Billion Dollar Weather Disasters, 1980-2005." Neal Lott and Tom Ross. www1.ncdc.noaa.gov/pub/data/papers/200686ams1.2nlfree.pdf

Parry, M.L., O.F. Canziani, J.P. Palutikof, P.J. van der Linden, and C.E. Hanson. 2007. *Climate Change 2007: Impacts, Adaptation and Vulnerability.* Cambridge, U.K: Intergovernmental Panel on Climate Change.

Peterson, Jeffrey, and Ya Ding. 2005. "Economic adjustments to groundwater depletion in the High Plains: Do water-saving irrigation systems save water?" *American Journal of Agricultural Economics* 87: 148-160.

Prasad. P.V.V., S.A. Staggenborg, and Z. Ristic. 2008. "Impacts of Drought and/or Heat Stress on Physiological, Developmental, Growth, and Yield Processes of Crop Plants," *Response of Crops to Limited Water: Understanding and Modeling Water Stress Effects on Plant Growth Processes.* ASA: Madison, WI.

Rao, M.N., and R. Yang. 2010. "Groundwater impacts due to the Conservation Reserve Program in Texas County, Oklahoma," *Applied Geography* 30: 317-328.

Roberts, M.J., and R.N. Lubowski. 2007. "Enduring Impacts of Land Retirement Policies: Evidence from the Conservation Reserve Program," *Land Economics* 83(4): 516-538.

Schaible, G., and M. Aillery. 2012. *Water Conservation in Irrigated Agriculture: Trends and Challenges in the Face of Emerging Demands*. EIB-99, U.S. Department of Agriculture, Economic Research Service, Sept.

Schimmelpfennig, D., J. Lewandrowski, J. Reilly, M. Tsigas, and I. Parry. 1996. *Agricultural Adaptation to Climate Change: Issues of Longrun Sustainability*. AER-740. U.S. Department of Agriculture, Economic Research Service.

Schoengold, K., and D.L. Sunding. 2011. "Input Price Risk and the Adoption of Conservation Technology." White Paper, University of Nebraska, Lincoln, http://digitalcommons.unl.edu/ageconfacpub/107/.

Schuck, E.C., W.M. Frasier, R.S. Webb, L.J. Ellingson, and W.J. Umberger. 2005. "Adoption of More Technically Efficient Irrigation Systems as a Drought Response," *International Journal of Water Resources Development* 21(4): 651-662.

Soil and Water Conservation Society and Environmental Defense Fund. 2008. *Conservation Reserve Program (CRP): Program Assessment*. April. www.swcs.org/documents/filelibrary/CRPassessmentreport_3BEFE868DA166.pdf

Soil and Water Conservation Society and Environmental Defense Fund. 2007. *Environmental Quality Incentives Program (EQIP): Program Assessment*. March. www.swcs.org/documents/filelibrary/EQIP_assessment.pdf

Strzepek, Kenneth, Gary Yohe, James Neumann, and Brent Boehlert. 2010. "Characterizing Changes in Drought Risk for the United States from Climate Change," *Environmental Research Letters* 5: 1-9.

Sullivan, Patrick, Daniel Hellerstein, LeRoy Hansen, Robert Johansson, Steven Koening, Ruben Lubowski, William McBride, David McGranahan, Michael Roberts, Stephen Vogel, and Shawn Bucholtz. 2004. *The Conservation Reserve Program: Economic Implications for Rural America.* AER-834. U.S. Department of Agriculture, Economic Research Service.

U.S. Department of Agriculture, Farm Service Agency. 2012. Annual State Summary Report – CRP Managed Haying and Grazing (unpublished data, 2003-11).

U.S. Department of Agriculture, National Agricultural Statistics Service. 2007. *Agricultural Census*. Volume 1, Part 51. Dec. www.agcensus.usda.gov/Publications/2007/Full_Report/Volume_1,_Chapter_1_US/index.asp

U.S. Department of Agriculture, National Agricultural Statistics Service. 2010. Crop Progress Timetables. www.nass.usda.gov/Publications/National_Crop_Progress/index.asp.

U.S. Department of Agriculture, Natural Resources Conservation Service. 2005. "Environmental Quality Incentives Program (EQIP)—Livestock Emphasis Action Plan." Aug. www.nrcs.usda.gov/Programs/eqip/leap.html

U.S. Department of Agriculture, Natural Resources Conservation Service. 2009. “EQIP payment data.” www.nrcs.usda.gov/programs/eqip/index.html#2009

U.S. Department of Agriculture, Natural Resources Conservation Service. 2005a. CPPE data.

U.S. Department of Agriculture, Natural Resources Conservation Service. 2005c. National Resources Inventory.

U.S. Department of Agriculture, Natural Resources Conservation Service. “Prepare Your Farm or Ranch Before Drought Strikes.” www.nrcs.usda.gov/feature/highlights/droughtprepare.html

U.S. Department of Agriculture, Natural Resources Conservation Service. National Conservation Practice Standards. www.nrcs.usda.gov/Technical/Standards/nhcp.html

U.S. Department of Agriculture, Natural Resources Conservation Service. 2008a. *Fact Sheet: Environmental Quality Incentives Program.* May.

U.S. Department of Agriculture, Natural Resources Conservation Service. 2008b. *National Program Priorities for Fiscal Year 2008.* April.

U.S. Department of Agriculture, Natural Resources Conservation Service. 2003. *National Range and Pasture Handbook.* www.glti.nrcs.usda.gov/technical/publications/nrph.html

U.S. Department of Agriculture, National Resources Conservation Service and Commodity Credit Corporation. 2009. “Environmental Quality Incentives Program,” *Federal Register*. 74(10) 7 CFR Part 1466. Jan. 15. www.gpo.gov/fdsys/pkg/FR-2009-01-15/pdf/E9-530.pdf

U.S. Government Accountability Office. 2006. *Agricultural Conservation: USDA Should Improve Its Process for Allocating Funds to States for the Environmental Quality Incentives Program*. GAO-06-969. Sept.

U.S. General Accounting Office. 1979. *Federal Response to the 1976-77 Drought: What Should Be Done Next?* CED-79-26. Jan. 31.

Vukina, T., X. Zheng, M. Marra, and A. Levy. 2008. “Do Farmers Value the Environment? Evidence from a Conservation Reserve Program Auction,” *International Journal of Industrial Organization* 26: 1323-1332.

Wilhelmi, Olga V., and Donald A. Wilhite. 2002. “Assessing Vulnerability to Agricultural Drought: A Nebraska Case Study,” *Natural Hazards*. 25: 37-58.

Williams, Jeffery R., Richard V. Llewelyn, Dustin L. Pendell, Alan Schlegel, and Troy Dumler. 2010. “A Risk Analysis of Converting Conservation Reserve Program Acres to a Wheat-Sorghum-Fallow Rotation,” *Agronomy Journal* 102: 612-622.

Wodehouse, Connie A., and Johathan T. Overpeck. 1998. "2000 Years of Drought Variability in the Central United States," *Bulletin of the American Meteorological Society* 79(12): 2693-2714.

Wu, J. 2000. "Slippage Effects of the Conservation Reserve Program," *American Journal of Agricultural Economics* 82: 979-992.

Wu, J., and H. Lin. 2010. "The Effect of the Conservation Reserve Program on Land Values," *Land Economics* 86: 1-21.

APPENDIX A: Constructing a Measure of Drought Risk

Our drought risk measure is a variant of the Palmer Modified Drought Index (PMDI) for the month of June, calculated at the weather-station level from over 100 years of data and interpolated to the county level (see fig. 6). In this appendix, we explain our choice of this measure for drought risk and compare it with a number of biophysical characteristics that are thought to be associated with drought risk, such as available soil water storage, the variance of precipitation, and the covariance between precipitation and temperature.

From previous literature, there is no standard measure of drought risk. Some studies measure drought risk as the frequency of severe and extreme droughts over the previous century. Other studies generate an index based on Geographic Information Systems (GIS) data of variables that influence drought vulnerability, such as soil moisture holding capacity, but none of these indices are available at the national level. Due to the national scope of our study, we needed to develop a unique measure of drought risk that varied at the county level and captured fine-grained differences in risk. Five factors influenced our choice of a drought risk measure:

1. PMDI measures variance in soil moisture, which is more relevant for most agricultural production than simple measures of precipitation.
2. PMDI is not normalized with respect to variance (unlike the Standardized Precipitation Index, SPI), which allows a measure of variance to indicate the relative frequency of severe and extreme droughts.
3. Measures of variance provide a more refined (i.e., continuous) measure of drought risk than counts of severe and extreme droughts.
4. June PMDI is a reasonable measure of drought risk since most spring crops are most sensitive to drought during the month of June.
5. Our measure of drought risk is roughly compatible with biophysical measures of drought vulnerability such as soil moisture availability, precipitation variance, and precipitation and maximum temperature covariance.

Some measures of drought intensity focus only on precipitation, and many others focus on measures of water availability, either in hydrological systems or as soil moisture. The widely used Palmer Drought Severity Index (PDSI) translates measures of precipitation and temperature into an index of estimated soil moisture availability. Despite some criticisms of the PDSI on statistical grounds (Guttman, 1998), the PDSI has been found to be a good estimator of actual soil moisture (Mika et al., 2005). Since we are focused primarily on national conservation programs designed for crop and livestock producers, the focus on soil moisture makes the PDSI (and the related PMDI) a natural starting point for our measure of drought risk.

The PMDI is structured to provide a measure of soil moisture variability that allows for spatial comparisons. Like the popular standardized precipitation index (SPI), the PDSI and PMDI are locally standardized (demeaned) so that a value of zero represents the average conditions at a given location. However, unlike the SPI, the PDSI and PMDI are not normalized with respect to variance, which means that both the PDSI and PMDI measure drought severity according to a common scale.[38] Tellingly, when mapping variance in the SPI, there is little spatial pattern.

In contrast to some other drought indices, such as the crop moisture index (CMI), the PDSI and PMDI are available for a long period of time at the weather-station level. That availability of data (more than 100 years) reduces the noise when estimating the local variability of drought severity. We chose June PMDI because for many crops the sensitivity to drought is greatest in the early portion of the growing season. We calculated the variance of June PMDI at individual weather stations and then interpolated that measure to county centroids based on the nearest seven stations to each centroid.

Drought risk, when defined as the variability of soil moisture availability, is actually a complex characteristic of climate that reflects both more basic climatic variables and local environmental characteristics, most notably soil characteristics. To ensure that our measure of drought risk conforms to key biophysical characteristics that influence drought risk, we also examined a number of other “factors” of drought risk. Three of those factors are presented here graphically: available soil water storage (fig. A1), the variance of precipitation (fig. A2), and the covariance between precipitation and temperature (fig. A3).

Since the PMDI models deviations in soil moisture, any measure of drought risk should reflect spatial variation in soil moisture holding capacity. There is some east-to-west variation in soil water storage (fig. A1) that corresponds to our measure of drought risk. However, soil moisture capacity is more reflective of underlying geology that accounts for the extremely deep soils in the Corn Belt (with large soil moisture capacity) and the extremely shallow soils along the Appalachians (with very little soil moisture capacity). Future research on drought risk would likely benefit from a more detailed examination of the extent to which PMDI calculations adequately capture local biophysical characteristics.

The variance of precipitation is a major driver of our measure of drought risk, as evidenced by the close correspondence between our measure of drought risk (fig. 6) and the coefficient of variation (CV) of June precipitation (fig. A2). Mapping the CV of precipitation normalizes variance with respect to mean precipitation, not unlike the local normalization of PMDI, although the two are not mathematically equivalent.

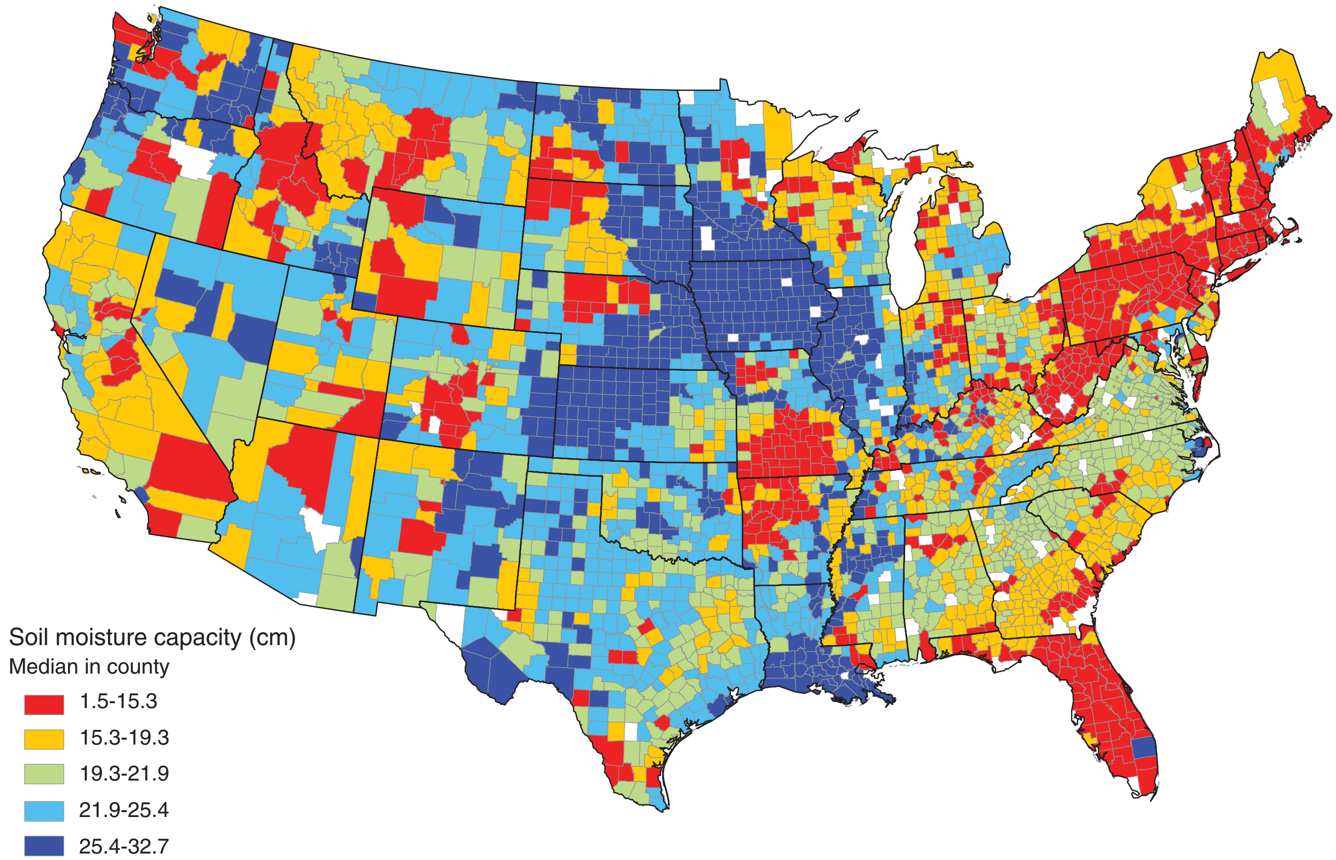
Since PMDI incorporates both precipitation and temperature, drought risk is also a function of temperature patterns. The interaction of precipitation and temperature is particularly important because extremely hot weather increases crop evapotranspiration, thus exacerbating precipitation shortfalls that occur simultaneously with high temperature. From the perspective of drought risk, then, the important climatic variable is the extent to which high temperatures and low rainfall are likely to occur in the same season. The spatial pattern of this covariance reveals that the Southern Plains, the Intermountain West, and the Lower Mississippi Valley are the most vulnerable regions in this regard (fig. A3). However, precipitation levels in the

[38] In contrast, since the SPI is normalized in both mean and variance, the SPI measures drought rarity or frequency rather than drought severity.

Lower Mississippi Valley (fig. A2) are seemingly high enough to offset the impact of this covariance on drought risk.

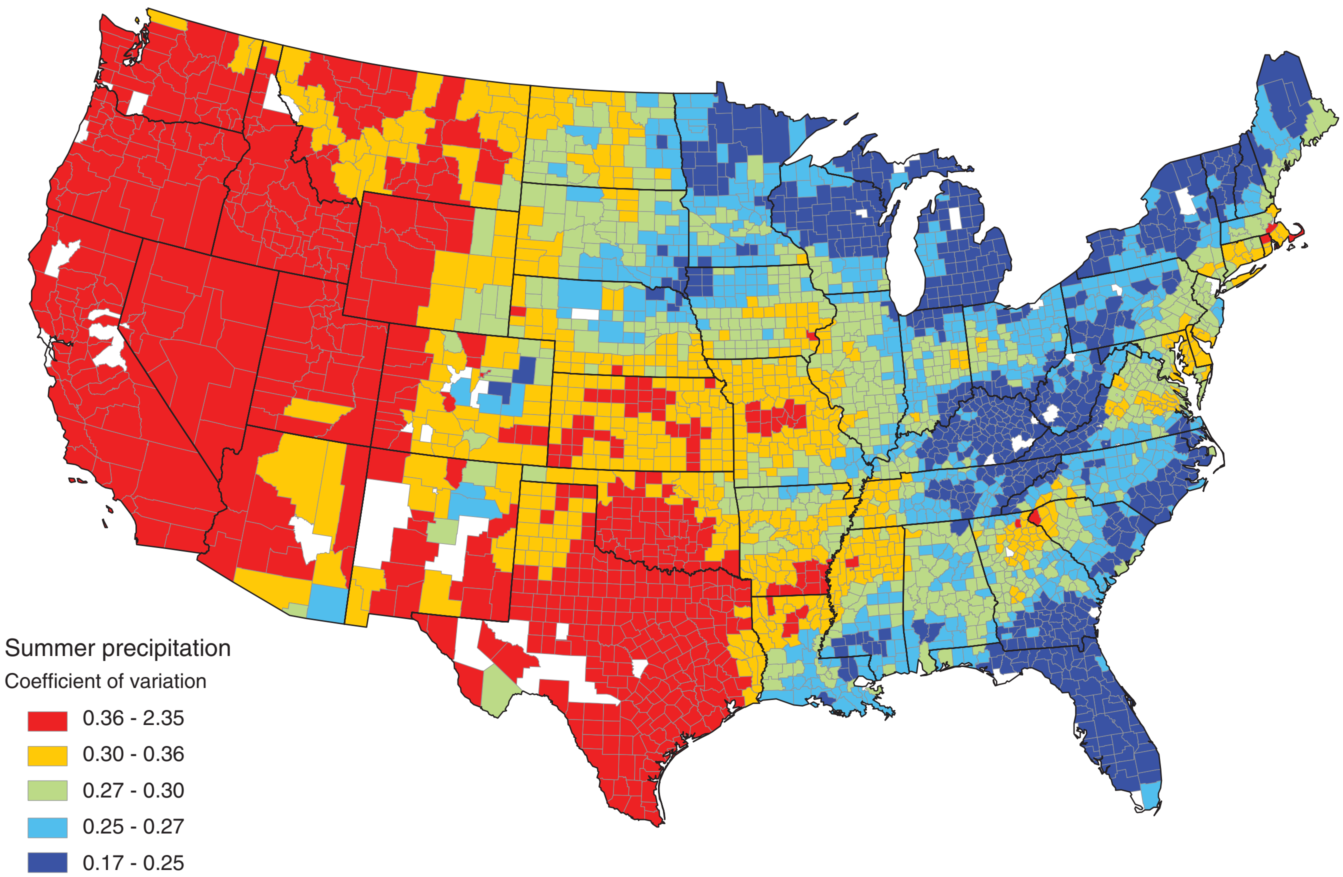
Figure A-1

Median water storage capacity in the top 150 centimeters of the soil profile, by county



Source: ERS calculations based on USDA Natural Resources Conservation Service Soil Survey Geographic (SSURGO) database.

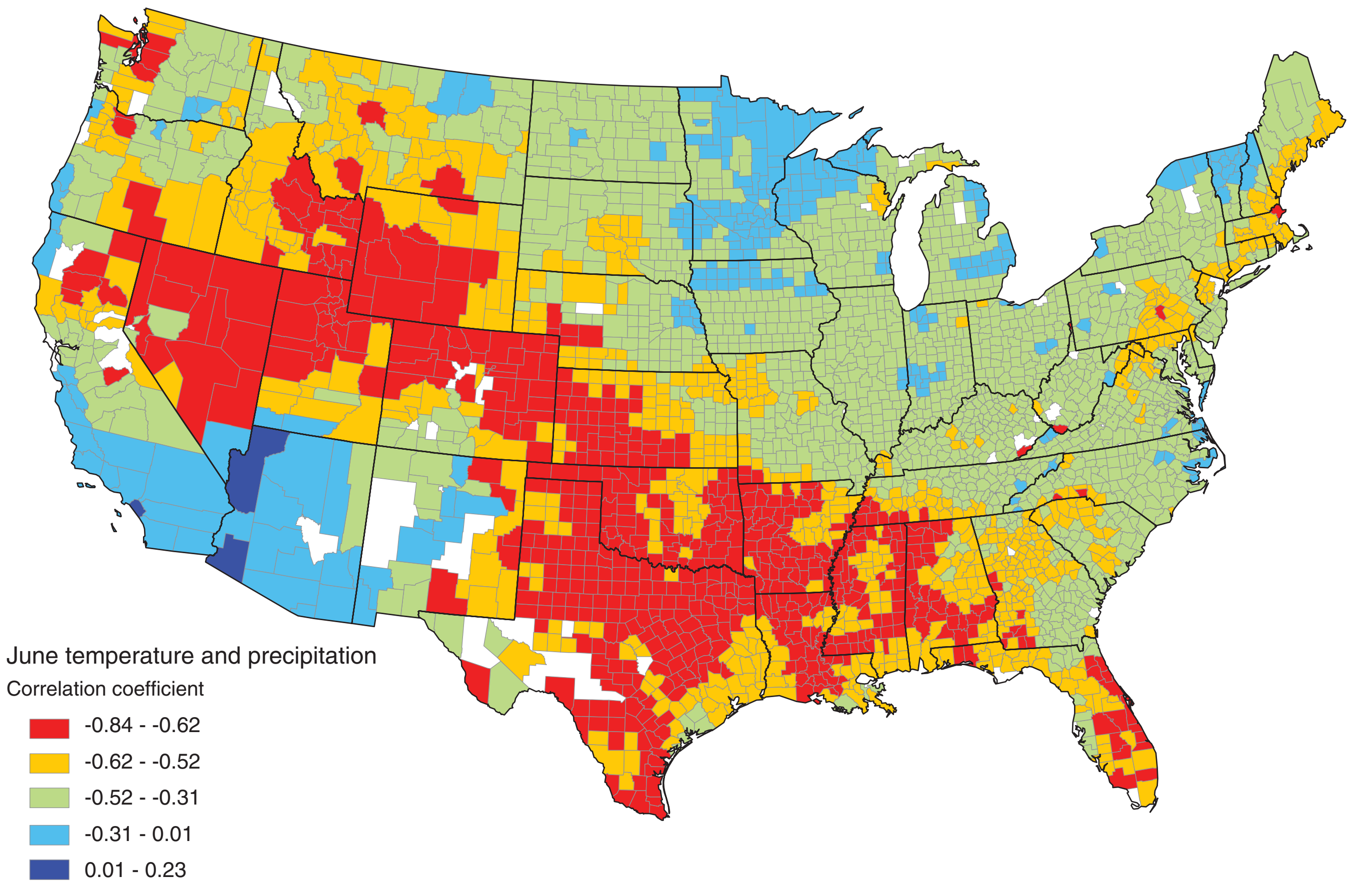
Figure A-2
Variability of precipitation by county, 1950-2009



Source: ERS calculations based on 1950-2009 PRISM data. Coefficient of variation calculations are based on annual values of total June-to-August precipitation from 1950 to 2009. Monthly county-level precipitation totals are the averages within counties masked to cropland based on the latest National Land Cover Dataset (NLCD) coverage.

Figure A-3

Correlation between June precipitation and average maximum temperature by county, 1950-2009



Source: ERS calculations based on 1950-2009 PRISM data. Correlation coefficient calculations are based on June average daily maximum temperature and total precipitation values from 1950 to 2009. County-level values are the averages within counties masked to cropland based on the latest National Land Cover Dataset (NLCD) coverage.

APPENDIX B: Modeling CRP Participation

This appendix presents additional detail on the econometric model of farmer participation in the CRP, the variables used in that analysis, and the results of that analysis.

Variable Discussion

Table B1 presents the variables used in the econometric analysis, as well as a number of variables used to construct the measures of cropland acres eligible for enrollment and share of eligible acres that are acceptable, based on the county acreage cap.

The dependent variable, a measure of CRP participation, is modeled as the offer rate, *pctOffer*, or the share of eligible acres in a county that are offered in a general signup. The variable *Offered* is the numerator in that share and is calculated from data on individual offers. Data are aggregated to the county in which the property being offered for enrollment is located, which in most cases is the same as the administrative county in which the offer is submitted. The denominator is based on ERS estimates of the number of acres available for enrollment in each county; the variable *availableAcres* is the estimate of total eligible acres in a county minus total acres that are enrolled (and not expiring) prior to each general signup. As a proxy for parcel-level data on cropping history, we identified cropped lands based on the National Land Cover Dataset (NLCD) classifications. Erodibility index calculations for eligible land were developed by ERS from the SSURGO (Soil Survey Geographic) soil characteristics database. Conservation Priority Area (CPA) boundaries and erodibility index estimates were overlaid on the NLCD cropland surface to estimate the total acres in each county that met enrollment criteria. The variable *dRisk* is the drought risk variable developed by ERS and described in Appendix A. Table B2 highlights the expected impacts of *dRisk* and the other regressors in the model.

County caps are reflected in the variable *%Acceptable*, which is the ratio of acres that can be accepted (*canAccept*: the county cap (0.25 * total cropland) minus total currently enrolled acres) to the variable *availableAcres*. When this ratio is zero, there is no room within the cap to accept additional acres. When this ratio is greater than 1, the variable *%Acceptable* is set to 1.

The variables on soil rental rates (*SRR*) and EBI scores (*eEBInorm*) are developed from CRP offer data. The *eEBInorm* variable is based on USDA's Environmental Benefits Index (EBI), which is used to rank parcels offered for CRP enrollment. To address the endogeneity of portions of the EBI that are jointly determined with the decision to make an offer, we rely only on the environmental components of the EBI, or those portions of the score that are exogenous (i.e., determined entirely by land characteristics and therefore unaltered by the details of the offer). The EBI has five factors (N1-N5) that measure various environmental and conservation services provided by retired land. Since the factor values change over time, we normalize the EBI score such that the variables we use (*avgN1* to *avgN5*) represent the "fraction of the maximum score achievable" (averaged over all offers from a county in a

Appendix table B-1

Variables used in CRP analysis

Variable	Description	Level of measurement	Mean	Standard deviation
Offered	Acres offered, including re-enrollments	by county and year	2,563.22	9,581.34
Retained	Acres retained in the program: currently enrolled acres minus expiring acres	by county and year	9,000	22,580
canAccept	Maximum number of acres that can be accepted: county cap minus Retained acres	by county and year	27,870	28,960
availableAcres	Eligible acres minus retained acres. Note that availableAcres may be greater than, or less than, canAccept acres	by county and year	77,403.7	121,030
pctOffer	Percent of acres offered: offered/availableAcres	by county and year	0.0708734	0.193757
dRisk	Drought risk; larger values represent higher drought risk	by county	2.24798	0.302072
%Acceptable	Share of available acres that can be accepted, accounting for county cap: equal to canAccept/ availableAcres. Values >1.0 are set to 1.0	by county and year	0.663018	0.350890
SRR	The average dryland cropland rental rate.	average by county and year (FSA data)	55.1121	37.6734
eEBInorm	Normalized average “environmental EBI score”: sum of EBI factors that cannot be influenced by the structure of the bid (exact set of factors varies by signup), which is then divided by the maximum number of points that can be awarded for the N1-N5 factors.	by county and year	0.41	0.10
%Expire	Expiring acres divided by the number of acres that can be accepted (canAccept)	by county and year (FSA data)	0 .07	0.22
%Irrigated	Percent of cropland irrigated (max % of cropland irrigated in 1997, 2002, and 2007)	by county (Ag Census)	15.1950	26.3899

given year). Note that *eEBInorm* reflects the qualities of the acres actually offered to the program. This is likely an overstatement of environmental attributes of all land in the county, since higher EBI land is more likely to be offered to the program.

We also include in our model the variable *%Irrigated*, the maximum share of cropland in each county that is irrigated over the past 3 agricultural census survey years. Enrollments in general signups are limited by bid caps based on the average dryland soil rental rate, so CRP enrollment may be less attractive to producers in counties where irrigation is more prevalent. Table B2 includes a brief explanation of the predicted coefficient signs for model variables.

Appendix table B-2

Expected responsiveness of offer rates to key variables

Variable	Expected sign	Discussion
dRisk	+	We assume that landowners in more drought-prone counties (i.e., counties where the variance of returns is high) will be more interested in enrolling land in the CRP.
%Acceptable	+	This is a measure of competitiveness, ranging from 0 to 1, that captures the effects of county enrollment caps. A value of 1 indicates that if 100 percent of eligible land were offered, all of it could be accepted into the program. For these counties, the county cap is nonbinding and the only constraint on enrollment is the selection of the national EBI cutoff. A value of 0 indicates that a county is at its enrollment cap and cannot accept any additional acres. These values can vary from year to year within a county as new contracts are signed and other contracts expire without being re-enrolled. Since a higher value implies less competition, we expect %Acceptable to be positively correlated with offer rates. With less competition, any individual offer has a greater likelihood of being accepted, which will lead to greater interest in the program. One caveat to this prediction is that, since being close to the cap is a sign that a large share of a county's eligible land is already enrolled, small values of %Acceptable may also reflect some unobserved characteristic that leads to increased popularity of CRP within a given county. If there is a major factor affecting CRP enrollment incentives for which we are not controlling, a lack of local competition may simply reflect a lack of local interest in the program and the coefficient on this variable may be negative.
SRR	-	The SRR is a county average of dryland cropland rental rates. There are two considerations about how variation in SRR across counties may impact CRP participation: the role of SRR as a proxy for opportunity cost and the role of SRR in the EBI. First, as an average dryland rental rate, SRR approximates the opportunity cost of enrolling land in CRP under the assumption that the land could otherwise be rented out for crop production. Since FSA uses SRR to set the maximum bid rate, SRR is the expected value for the maximum annual rental payment that CRP contracts can specify in each county. We expect that, in this regard, since farms can bid up to their opportunity cost, the marginal effect of SRR on the probability of offering land is zero. This implies that SRR reflects both the expected value and variance of profit from the land. A second consideration is that the EBI includes a cost factor. Bids with a higher SRR will tend to have higher rental rates, and therefore will tend to receive a lower EBI score. Thus, counties with a higher SRR are slightly less competitive in the CRP ranking process and are therefore expected to be less likely to offer land to CRP. Outside of the impact on EBI, there are two other reasons to include SRR as a control variable. If SRR (and therefore maximum bids) are systematically mismeasured in higher risk counties, or if heterogeneity in risk aversion is greater in higher drought-risk counties, then estimation of the participation without SRR included would lead to biased estimates of the impact of drought risk. There is no clear reason to suspect that systematic errors occur since counties use soil productivity information to tailor parcel-specific maximum bid rates based on the county SRR. Any risk premia incorporated into local agricultural land rents will be an equilibrium phenomenon, so that prices clear for some marginal ("equilibrium") participants. For landowners with a more risk-averse profile, guaranteed long-term rental payments (from the CRP) will be more attractive than either growing crops or renting yearly to neighboring farmers.

Continued—

Appendix table B-2

Expected responsiveness of offer rates to key variables—Continued

Variable	Expected sign	Discussion
SRR —continued	-	The impacts of these influences are ambiguous, and may vary by county. For example, if a county's average rental rate is too high, this may encourage more participation in the CRP.
eEBInorm	+	Parcels with higher EBI scores are more likely to be selected and hence, have a competitive advantage. However, these measures may suffer from endogeneity, since they are based on offers rather than eligible acres.
%Expire	+	We expect that a large share of expiring acres will be reoffered to the program – which suggests that offer rates will be larger when the share of expiring acres is large.
%Irrigated	-	Since irrigation represents an alternative risk-mitigation strategy, high levels of irrigation are likely to reduce interest in the CRP.

Model Discussion

Table B3 shows the coefficient estimates from our primary model, while table B4 shows those estimates expressed as elasticities. We apply a grouped logit model using *pctOffer* as the dependent variable.[39] Thus, rather than use a 0/1 dependent variable, we use a proportion (ranging between 0.0 and 1.0).

The modeling results are mostly in line with expectations, especially for the variables of greatest interest. In particular, the coefficient on drought risk is positive and highly significant – counties more prone to drought are likely to have greater interest in the CRP. Acres with lower potential competition, as measured by values of *%Acceptable* close to 1.0, also have greater offer rates; we consider this more closely in our policy scenario simulations. A greater number of just-expired acres increases the offer rate. Increasing soil rental rates decrease offer rates, as does higher percentage of land in irrigation. Not surprisingly, the positive coefficient on *eEBInorm* indicates that counties with relatively high, increasing environmental scores have higher offer rates.[40] Model fit is reasonable, with a 75-percent correlation between predicted acres offered and actual acres offered (by county).

Given the nonlinearity of the logit model, it may be more informative to consider elasticity estimates rather than coefficient values. Interestingly, drought risk (*dRisk*) has the largest, most highly significant (different from zero) elasticity of all the independent variables. *SRR*, *%Acceptable*, and *eEBInorm* also have moderately sized, and statistically significant, elasticities.

[39] We also estimated a Tobit model and several Poisson models. The Tobit performed less well, in terms of goodness of fit and coefficient significance. The Poisson models yielded results that were similar to the logit (i.e., 93 percent correlation in predicted offer rates between the grouped logit and the Poisson), with slightly worse goodness of fit. Therefore, in this analysis we focus on the grouped logit results.

[40] We also ran other variants, using a fuller set of variables (such as individual EBI factor scores). Results were similar for the more important variables, such as drought risk. Since the coefficients on these other factors were less than robust (for example, sign switches occur as variables are dropped and added), in this analysis we focus on this "sparse" model.

Appendix table B-3

Grouped logit model results: coefficients

	coefficient	*t-stat*	*coeff. var. (*100)*
Constant	-6.576	-16.7	-35.5
dRisk	1.16	8.6	16.6
%Acceptable	0.533	4.4	12.2
SRR	-0.00617	-5.33	-14/2
eEBInorm	1.18	3 1	6.3
%Expire	4.78	48.7	74.3
%Irrigated	-0.00656	-4.4	-8.4
Log likelihood	-34,785		

Notes:

- Dependent variable: *pctOffer*
- In all models, N=21,466 (up to 8 years for 2,783 counties).
- The *coeff_var* values (sd/mean of coefficient estimates) are generated from 100 bootstrap estimates; each estimate uses a randomly chosen 60% sample of observations.

Appendix table B-4

Logit model results: elasticities

	Estimates		Bootstrap results	
	Average	stdDev	10% of CI *(% of median)*	90% of CI *(% of median)*
dRisk	2.44	0.531	7.5	7.9
%Acceptable	0.322	0.182	10.2	9.8
SRR	-0.320	0.232	9.9	8.6
eEBInorm	0.449	0.134	21.6	21.5
%Expire	0.147	0.337	1.98	1.94
%Irrigated	-0.0918	0.163	15.6	17.2

Notes:

- Elasticities are based on the average across all observations, computed for each variable using a 1% change in own values.
- The bootstrap results are based on 100 coefficient estimates, where each estimate comes from a separate model run that uses a randomly drawn 60% sample for each observation.
  - 100 elasticity measures are computed.
  - A median value, and 10% and 90% quantile measures, are drawn from these 100 estimates.
  - The 10% column (90% column) uses the observation-specific difference between the median and this 10% (90%) quantile, as a fraction of the median. Thus, small values of these measures indicate more precise measures of that observation's elasticity.

The reported values are the averages, across 21,466 observations.

Policy Simulation Discussion

Given the nonlinearities of our models, both in terms of functional form and in the use of aggregate data, we run policy scenarios based on a more disaggregated prediction. Using actual offers from the most recent CRP signups (2004, 2006, and 2010), we predict a probability of making an offer for each of these signups, using the offer-specific variables commensurate with the variables used in the county/year grouped logit model. Some of these measures (such as *SRR* and EBI factor scores) are offer-specific, while others (such as *dRisk* and *%Acceptable*) are county-specific.

The goal is to predict changes in overall offer rates as policy changes. Offer data are used to capture within-county variation in land attributes—variations that may be washed out when county-level measures are used. However, the use of offers means that we have no implicit information on parcels *not* offered to the program.

Thus, we use weightings that treat offers as representative of a large pool of parcels. We treat changes in probabilities as indicative of what other parcels that were not offered might do. In particular, a baseline probability of participating (PPb) is computed for each offer.

For example, a PPb value of 8 percent may be computed for a given parcel. This implies that "8 percent of parcels that look like this were offered to the program."

Then, we predict a new probability of participation, under a policy scenario (PPs). This is then normalized by the baseline probability (PPb) to provide a parcel-specific weight. This weight is used to scale up (or down) the offer's actual acreage. This scaled "offered acres" is used to predict total acres offered in the scenario.

For example, if the given parcel's PPs=10 percent and PPb=8 percent, the weight would be 1.25. This implies that, under this scenario, 25 percent more acres would be offered (relative to the baseline) – or that this parcel's acreage contribution to the CRP is increased by 25 percent.

In addition to scenario-specific weights for each offer, a county-specific "correction" weight (CCW) is computed. The CCW is used to scale up the 6.5 million acres of accepted offers (in the 3 years of data used) with a goal of generating a program size of 25.8 million "general signup" acres. Applying these CCW weights to all offered acres yields a prediction of 36.4 million acres of offered land, which implies a 70-percent (25.8/36.4) acceptance rate on offered acres.

To develop policy scenarios based on these variables, we create a categorical variable to differentiate counties with higher drought risk from those with lower drought risk. Within the EBI scenarios, this categorization provides a basis for awarding EBI points based on a drought risk factor (DRF), which is scored as follows:

- All counties with a *dRisk* value < 2.65 are assigned 0 DRF points: this represents 76 percent of eligible acres and 85 percent of all counties.

- For 2.65 < *dRisk* < 2.78, DRF = 10 (representing 7.5 percent of counties and 13 percent of acreage). In addition, the county is identified as a medium-drought-risk county.

- For *dRisk* > 2.78, DRF = 20 (representing 7.5 percent of counties and 11 percent of acreage). In addition, the county is identified as a high-drought-risk county.

There are 2,859 observations (out of 21,466) that classify as high-drought-risk (HDR) counties (for example, of the 2,732 counties with observations in the 2010 signup, 374 are high-drought-risk counties). Not surprisingly, the *dRisk* elasticity in these counties is higher than average, as is the percent irrigated elasticity.

To model these scenarios, several variables are modified:

- The first policy scenario requires some means of simulating the impacts of modifications to the EBI. The *eEBInorm* variable is used to simulate the impacts of DRF points.

- The second scenario uses the *%Acceptable* variable—increasing eligibility will increase the share of eligible acres that can be accepted. This has two impacts: the acreage that can be accepted in a county is increased, and more landowners are encouraged to submit offers.

- The third scenario involves no changes in the model's independent variable, but does increase the number of eligible acres. Thus, while the predicted offer rate is constant, the number of acres that may be offered may vary.

Modeling these scenarios requires several assumptions:

- Scenario one: the "normalized" EBI is recomputed, adding the DRF points to the numerator and adjusting the denominator. This assumes that DRF points will have the same impacts as all other points (that may appear in the EBI measure).

- Scenario two: the use of *%Acceptable* assumes that relaxing county caps will encourage participation in newly "uncapped counties" as it would in counties currently below the cap.

- Scenario three assumes that ineligible acres are similar to eligible acres, in terms of their owners' interest in participating in the CRP.

APPENDIX C: Modeling EQIP Participation

In this appendix, we present several aspects of our model of EQIP participation: the dependent variable of participation levels; the measure of CPPE ranking scores; and the results of the regression.

Participation Levels

Our modeling strategy was to focus primarily on only those EQIP practices likely to be related to drought risk. To do this, we needed to determine reasonable categories of practices for which we could identify both participation levels and some population of eligible participants. We grouped practices into the two fairly broad categories—tillage-related practices and irrigation-related practices.

The practices (and NRCS practice codes) that we use to identify tillage-related contracts are residue and tillage management (329 (A,B, and C)), seasonal residue management (344), mulch tillage (345), ridge tillage (346), mulching (484), residue management by direct seeding (777), and long-term no-till (778).

The practices (and practice codes) that we use to identify irrigation-related contracts are irrigation canal or lateral (320), irrigation field ditch (388), diversion dams (348), multipurpose dams (349), well decommissioning (351), well water testing (355), diversion (362), dam (402), irrigation water conveyance ditch (428 (A, B, and C)), irrigation water conveyance pipeline (430 (AA, CC, DD, EE, FF, GG, and HH)), above-ground multi-outlet pipeline (431), irrigation storage reservoir (436), microirrigation (441), irrigation sprinklers (442), surface and subsurface irrigation systems (443), tailwater recovery (447), irrigation water management (449), irrigation land leveling (464), pond sealing or lining (521), pumping plant (533), irrigation regulating reservoir (552 (A and B)), structure for water control (587), surface drainage field ditch (607), surface drainage main or lateral (608), toxic salt reduction (610), water harvesting catchment (636), water spreading (640), water well (642), soil salinity control (738), pond sealing and lining with soil cement (740), and improved water application (743). Most of the funding and contracts within this category are focused on a few practices consisting primarily of sprinklers, micro irrigation, and land leveling.

CPPE Ranking Scores

Applications for EQIP funding are ranked at the State or county level. Several factors influence ranking, including CPPE scores. The precise formula for incorporating CPPE scores into ranking involves calculations that are often performed at the county level and rely on data that are not available at the national level. To overcome this limitation, we developed a method for collapsing CPPE scores based on the practice categories described above.

The CPPE scores are assembled in tables with the 80 conservation resource concerns listed by column and the practice codes listed by row. Every practice receives a score between -5 and 5 for each resource concern. Negative values indicate that a practice exacerbates a particular resource concern and positive values indicate that a practice alleviates a particular concern. While there is a national CPPE table that serves as a template, contract ranking is based on the State CPPE tables.

NRCS provided ERS with State-level matrices of CPPE scores for 2008 and 2009. For each practice we calculated a simple total of CPPE scores across all resource concerns. We then calculated the maximum total score for all practices in a State and the maximum and average total scores for the two practice categories described above. This provided us with a normalized measure of how tillage and irrigation practices rank within each State according to the CPPE.

Results

Table C1 presents the regression results of our grouped logit model. The first two columns present the irrigation-related participation rates and the last two columns present the tillage-related participation rates.

For the model of participation in irrigation-related practices, we are only interested in measuring participation within counties for which irrigation is a viable production practice. We estimate our model on counties for which at least 5 percent of cropland is irrigated in at least one census year (1997, 2002, and 2007). The preferred model for irrigation participation is the first column of coefficients, which includes State-level fixed effects and should therefore be interpreted as a model of the average difference in participation rates across the drought risk gradient within a State. As expected, drought risk is positively correlated with EQIP participation by irrigators. Irrigators in areas with higher erodibility and higher use of groundwater are also slightly more likely to have an EQIP contract containing irrigation-related practices. Irrigators in counties with higher land values are less likely to rely on EQIP contracts for irrigation-related practices, perhaps reflecting that our measure of land values captures dryland rental rates or that EQIP is most attractive to farms that face credit constraints due to lower land values.

The second column presents a similar model with qualitatively similar results that are obtained by replacing the State-level fixed effects with our CPPE metric. This model results in a surprising negative correlation between our CPPE metric and participation rates, suggesting that participation rates are lower in States where irrigation practices are ranked higher. This could reflect measurement error in our CPPE index or could reflect the greater prevalence of negative CPPE values for some resource concerns in areas where irrigation is more widespread and therefore more associated with both positive and negative physical effects.

Appendix table C-1

Coefficient estimates for Environmental Quality Incentives Program participation

Variables	(1) Irrigation contracts per year per irrigator	(2) Irrigation contracts per year per irrigator	(3) Tillage contracts per year per crop farm	(4) Tillage contracts per year per crop farm
risk	4.420***	2.715**	0.526***	0.563***
	(1.490)	(1.263)	(0.200)	(0.118)
risk2	-0.843***	-0.567**		
	(0.289)	(0.257)		
eimax	0.00754*	0.0200***	-0.0196***	-0.0281***
	(0.00406)	(0.00423)	(0.00510)	(0.00542)
ShareGW	0.00655***	0.00631***		
	(0.000853)	(0.000791)		
SRR2008	-0.00854***	-0.0116***	-0.00340**	-0.00723***
	(0.00138)	(0.00121)	(0.00134)	(0.00123)
CPPE_IRR		-0.0106**		
		(0.00435)		
SHARE_SOY			0.874***	0.638**
			(0.305)	(0.301)
CPPE_TILL				-0.00180
				(0.00386)
Constant	-7.751***	-6.273***	-5.979***	-6.548***
	(1.835)	(1.551)	(0.439)	(0.344)
State fixed effects	Y	N	Y	N
Observations	1,155	1,155	1,695	1,695
R-squared	0.439	0.152	0.341	0.059

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Note: statistical models using EQIP expenditures (or contract counts or other appropriate variable) are ERS estimates using USDA Natural Resources Conservation Service data and are not official NRCS values.