Turning Soils into Sponges

How Farmers Can Fight Floods and Droughts

Union of Concerned Scientists

Floods and droughts are highly damaging and becoming more so each year. Combined, these extreme weather events have caused an estimated $340.4 billion in damages in the United States since 1980, and floods have killed more than 500 people during that period (NOAA 2017).[1]

Abundant evidence shows both heavy rains and extended dry periods are becoming more common as a result of climate change (IPCC 2013). For example, heavy rain events have increased 71 percent in the Northeast and 37 percent in the Midwest since the 1950s, compared with the earlier part of the 20th century (Walsh et al. 2014). Droughts have also intensified across the entire United States, particularly in the West (Walsh et al. 2014). Droughts are projected to increase across the entire United States in the decades ahead, becoming particularly intense in the central, southwestern, and western regions (Cook, Ault, and Smerdon 2015; Strzepek et al. 2010).

For US farmers and ranchers, droughts and floods pose a particular threat, devastating crops and livestock (Walthall et al. 2013), and damaging or washing away farmers' soil (Al-Kaisi et al. 2013; Pimentel et al. 1995). Much (though not all) of the financial loss is reflected in crop insurance payouts to farmers. Between 2011 and 2016, flood- and drought-related claims made to the taxpayer-subsidized federal crop insurance program resulted in $38.5 billion in payouts,[2] approximately two-thirds of the total paid for all types of claim by the program (RMA 2017). The federal Office of Management and Budget recently estimated that such claims could double as a result of climate change, costing taxpayers an additional $4 billion to $9 billion annually by 2080 (OMB 2016).

These disasters also have damaging effects in nonfarming regions, including cities and towns downstream from farm fields. Negative effects can be far reaching and include damage and destruction of homes and businesses due to inundation; damage to critical infrastructure, including roads, levees, and dams; and even malfunctions at wastewater treatment plants caused by soil and debris carried by floodwaters (see the table, p. 4). Moreover, floods and droughts can cause the greatest harm in vulnerable communities that have the least ability to cope with such damage. Flooding is known to affect lower-income populations disproportionately, partly because they are more likely to live in flood-prone areas and thus at increased risk of property damage, disease, and stress following floods (Adger 2006). And a report on the recent California drought found great inequities in the rates water consumers paid, with lower-income individuals paying more (Feinstein et al. 2017).

The causes of droughts and floods are complex—factors include weather (how much rain falls over what period of time) and land use (urban development, building, and zoning as well as agricultural practices). While rainfall patterns are

Don Becker/USGS

Soil quality can affect city dwellers as well as farmers. Excess runoff from farms with bare soil can contribute to flooding in towns and cities downstream, with resulting damage to homes, businesses, and critical infrastructure. Cedar Rapids, IA, was inundated by flooding in June 2008.

outside our control, people can make decisions about how they use land. And over the last several decades, farmers and policymakers have transformed agricultural landscapes by converting millions of acres from mixtures of crops and livestock to systems dominated by one or two plant species. In the Midwest today, more than 150 million acres feature monocrops of corn or other annual crops, such as soybeans. These crop systems leave fields bare between summer growing seasons, making soils vulnerable to erosion (EWG 2017; Mulik 2017). They also often rely on tillage (plowing) practices that degrade soil structure, reduce water infiltration and water storage capacity, and increase the flow of water (and any pollutants it carries) across the soil surface (Wheater and Evans 2009; Raymond et al. 2008; O'Connell et al. 2007). As a result, annual crop systems have contributed to significant shifts in regional water systems, such as increased stream flow and increased pollution of streams, lakes, coastal areas, and drinking water (Basche and Edelson 2017; David, Drinkwater, and McIsaac 2010; Hatfield, McMullen, and Jones 2009; Zhang and Schilling 2006).

When paired with extreme weather disasters, agricultural land use changes can have dramatic effects. This was demonstrated by the catastrophic dust storms that arose during the crippling droughts of the 1930s, which were in large part driven by soil degradation and the loss of vegetative plant cover on the landscape (Cook, Miller, and Seager 2009). Today, farmers and surrounding communities are again vulnerable to such events. Faced with increasing rainfall variability and the damage it can cause, US farmers and the farm management industry must take steps now to adapt.

In this report, we examine the potential of a set of farming practices known for their ability to build rich, porous, spongelike soils. Our analysis shows that these well-known practices could make a substantial difference if adopted widely across the Midwest. But taking on new practices is not easy for many farmers, and today's federal farm policies provide little support to ease the transition. Based on our analysis, we offer recommendations for the US Department of Agriculture (USDA) and for Congress as it reauthorizes federal farm legislation, indicating key policies and programs they can implement or change to bring about more resilient farming systems.

Building Climate Resilience by Creating Spongy Soils

A guiding principle for all efforts to adapt to shifting climate should be the use of science to understand and project likely effects. Decisionmakers in agriculture can learn from the adaptation successes of other sectors (Spanger-Siegfried et al. 2016). These successes include efforts that have reduced coastal flood damage by identifying flood-prone areas and curtailing development there; reduced wildfire risk achieved through proactive, science-based forest management; and alleviated risks associated with excess heat in urban areas by developing effective early warning systems and making available adequate cooling shelters (Cleetus and Mulik 2014; Spanger-Siegfried et al. 2014; Perera et al. 2012). In this report, we propose science-based approaches the agricultural sector can use to move proactively toward a climate-resilient future, including farming methods that demonstrate the potential to deliver benefits to farmers and communities during both floods and droughts.

Faced with increasing rainfall variability and the damage it can cause, US farmers must take steps now to adapt.

Many adaptation options have been proposed for agriculture. For example, some farmers may choose to invest in irrigation equipment as a response to drought, while others may look at expanding drainage solutions as a response to flooding rains. Although these approaches may offer short-term relief from water challenges, they may not be most helpful to farmers in the long term, and they can have unintended consequences. The irrigation of agricultural crops is depleting groundwater in arid and semiarid areas (Scanlon et al. 2012), and although the addition of drainage systems in wetter environments benefits crop productivity, it also increases polluting runoff from agricultural fields (David, Drinkwater, and McIsaac 2010). Another approach is to breed crop varieties that better withstand excessive heat, drought, or even flooding, but to date such varieties are not widely available and they do not increase the resilience of agricultural systems as a whole.

There is another approach to climate adaptation in agriculture that focuses on reducing water risks from both floods and droughts by creating more absorbent, spongelike soils. This approach, which manages rainfall as it moves through soil and crops, builds holistic resilience in both wet and dry periods (see text box and Figure 1, p. 7; Stewart and Peterson 2015; Sposito 2013). Global modeling studies have found that more effective management of water in soil has significant potential both to improve crop production and to reduce the overall amount of water runoff resulting from agricultural systems (Jagermeyr et al. 2016; Rost et al. 2009).

TABLE 1. Past Midwest Floods and Droughts Have Caused Major Damage But Modeled Farming Changes Could Reduce Future Harm

	Agricultural Damages	Drinking Water and Wastewater Effects	Infrastructure Effects	Total Economic Impact[a]	Estimated Water Improvements if Modeled Crop and Soil Changes Had Been in Place
1988 Drought	Corn yield declined 33%, soybean yield declined 20% (compared with 4-year average)[b] Average net farm income fell 24%[c] Crop losses ~$15 billion[d]	Municipal water supplies at critically low levels[e]	Low water levels reduced Mississippi River barge traffic by 50%[d]	$40.8 billion	Up to 9% more water available to crops Up to 21% less runoff, representing water savings in a drought year
1993 Flooding	2.4 million farm acres suffered severe erosion[f] Crop losses ~$2 billion[e]	Des Moines water treatment plant offline 19 days[g]	Mississippi River closed to barge traffic for 4 months[d] 1,000+ levees destroyed[d] Flood damage, delays, and other costs to railroads totaled $480 million[d] 60,000 homes lost and property damage ~$1.95 billion[d]	$35.1 billion	Up to 10% less runoff in eastern Iowa/Mississippi River region Up to 26% less runoff in other affected watersheds 20% reduction in flood frequency if crop changes implemented on highly erodible croplands
2008 Flooding	Nearly 10% of farm land in Iowa under water[h] 2.2 million acres suffered erosion up to 20 tons/acre[7] Crop losses ~$3 billion[7]	Widespread sewer backups[h] Serious damage to water and wastewater systems in Iowa City and Coralville[i]	Heavy losses to grain storage and handling facilities[i] University of Iowa damage ~$230 million[h] 5,390 residential properties damaged or destroyed[h] $2.4 billion total Cedar Rapids damage, including infrastructure[i]	$11.2 billion	Up to 7% less runoff in Cedar Rapids region 17% reduction in flood frequency if crop changes implemented on less-profitable croplands

TABLE 1. Past Midwest Floods and Droughts Have Caused Major Damage But Modeled Farming Changes Could Reduce Future Harm (CONTINUED)

	Agricultural Damages	Drinking Water and Wastewater Effects	Infrastructure Effects	Total Economic Impact[a]	Estimated Water Improvements if Modeled Crop and Soil Changes Had Been in Place
2011 Flooding	255,000 farm acres flooded[k] ~$1 billion in damages[k]	Untreated sewage runoff led to downstream E. coli and coliform 2,000 times the legal limit[l]	$1 billion damage to levees and dams[m] 64 miles of interstate highway, other primary roads closed[k]	$5.3 billion	Up to 19% less runoff in Cedar Rapids region 13% reduction in flood frequency if crop changes implemented on highly erodible croplands
2012 Drought	All Iowa counties in severe drought, ⅓ in "exceptional drought conditions"[n] Corn yields 22% below 20-year averages, soybeans down 15%[n] Record $16 billion in total federal crop insurance payout[o]	Two peak water alerts in Des Moines as demand reached a new high (96 million gallons)[p]	Low cooling pond levels forced power plants offline[q]	$31.5 billion	Up to 16% more water available to crops Up to 60% less runoff, representing water savings in a drought year

Notes: Cost estimates include damages recorded by insurance services, the Federal Emergency Management Agency, the National Flood Insurance program, and USDA crop insurance data. The National Oceanic and Atmospheric Administration characterizes the 2011 flood event as two concurrent events (April 1 through May 30: seven deaths and $3.2 billion in damages. May 1 through June 30: five deaths and $2.1 billion in damages). Estimates are based on revised crop patterns and improved soil as described in the analysis, and evaluation of key severe weather events in particular regions of the state (in the case of flooding) or statewide (in the case of drought).

SOURCES: (A) TOTAL ECONOMIC IMPACT DATA COMES FROM NOAA 2017; (B) HILLAKER 2012; (C) WHITTAKER 1990; (D) CHANGNON, KUNKEL, AND CHANGNON 2007; (E) KUNKEL AND ANGEL 1989; (F) GOVERNOR'S OFFICE, IOWA 1994; (G) PARRETT, MELCHER, AND JAMES 1993; (H) FEMA 2009; (I) AETF 2008; (J) MORELLI 2016; (K) IDHSEM 2011; (L) POTTER 2011; (M) BAILEY AND HENDEE 2011; (N) ISU 2012; (O) BABCOCK 2013; (P) YEE 2012; (Q)WALD AND SCHWARTZ 2012.

Analysis

Given the encouraging results of prior research on managing soils to reduce flood and drought damage, we wanted to understand in more detail how specific farming methods improve water storage on a field scale and then what effect these methods have on a landscape scale. We analyzed more than 150 field experiments from six continents—looking at methods including no-till, more diverse crop rotations, use of cover crops between cash crop seasons, improved livestock grazing, and incorporation of perennial crops—to understand these methods' ability to improve soil health and increase resilience to droughts and floods. Our analysis also quantifies the extent to which these methods reduce water runoff in flood events and increase water available during drought events on a landscape scale. We used a regional water balance model and focused on the state of Iowa, which typifies today's midwestern industrial production agriculture. Our findings are promising. Shifting to farming systems that keep the soil covered all year and rely more on perennials made the soil more spongelike in 70 percent of the experiments that

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An Iowa farming family surveys damage to their corn crop following a flood event in 2012.

we analyzed. And our model predicts that by shifting the most-erodible or least-profitable regions of Iowa to systems using perennial and cover crops, farmers could reduce rainfall runoff by up to 20 percent in flood events and make as much as 16 percent more water available to crops in droughts.

> ***Farmers could reduce rainfall runoff by up to 20 percent in flood events.***

EFFECTS OF FARMING PRACTICES ON SOIL WATER: A META-ANALYSIS OF FIELD-SCALE FINDINGS

To understand better how farming practices affect drought and flood events, we first asked: How does soil water change on a field scale if land is managed using conservation and ecological agriculture practices? To answer this question, we performed a rigorous quantitative summary of peer-reviewed experiments (Appendix A, online at *www.ucsusa.org/SoilsIntoSponges*; Basche and DeLonge n.d.a; DeLonge and Basche n.d.) that focused on infiltration rate, the rate at which water enters the soil—a critical element of soil water management.

We compiled experiments that evaluated techniques that used no-till (no plowing); cover crops (planting a crop to protect soil when it would otherwise be bare rather than for harvest); alternative grazing systems (reduced numbers of animals grazed, periods of grazing exclusion, or more intentional management such as rotational grazing); crop systems integrating livestock grazing (compared with crop systems only); and/or perennial crops (crops that have roots in the soil all year long compared with annual crops that require replanting every year).

We identified 126 experiments that fit the criteria for inclusion, representing 612 paired observations[3] on six different continents (Figure 2, p. 8).

Our examination of these studies revealed the following:

- **70 percent of experiments showed an increase in water infiltration when any of these practices were used.** This is the first step necessary for reducing flood and drought damage.
- **"Continuous living cover" of soil is the best strategy for improving water infiltration**. This cover, which keeps living roots in the soil all year, can be achieved by introducing perennials or cover crops, or by improving grazing practices (in grass-based systems) (Figure 3, p. 9). This improvement is likely related to the creation of continuous root systems in the soil, which contribute to topsoil retention, increased levels of soil carbon, enhanced biological activity, and reduced water loss from runoff. This is a novel scientific finding that can help prioritize the practices that help reduce climate risks.
- **Perennial crop systems are clear winners at managing heavy rains**. Agricultural management offered significant opportunities to buffer the damage caused by heavy rain events. In 28 percent of the studies analyzed, the experimental practices increased infiltration enough to absorb a heavy rain event of one inch per hour. This outcome occurred in more than half (53 percent) of the experiments involving perennial crops (Figure 4, p. 10).

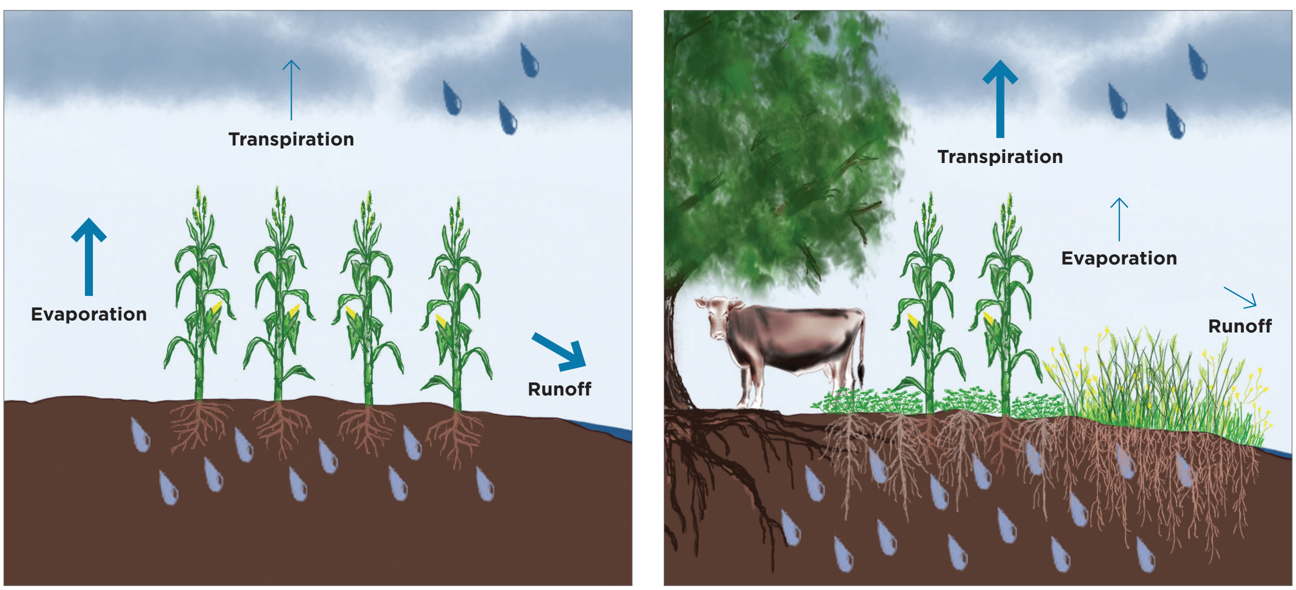
More Diverse Farm Systems Lead to Healthier Soils and Smarter Water Use

In agricultural systems, water moves through and interacts with soils and plants. Water enters farm fields and grazing lands via precipitation and, in some climates and systems, irrigation. It leaves fields via runoff (water not absorbed by soil that then runs downslope); transpiration (water emitted by plants as they cool); soil evaporation (water loss directly from the soil surface, especially bare surfaces); and, in some cases, via artificial drainage (removal of excess water through underground pipes or tiles). Between inflows and outflows, some water remains in the soil for periods of time; the amount and duration of soil water storage depends on soil properties such as pore space and size and on processes such as infiltration rate, the speed at which water filters into the soil.

Figure 1 illustrates how agricultural systems that are designed primarily around annual crops (Figure 1a) can experience greater water loss through increased runoff and soil evaporation. They may also depend on artificial drainage to remove excess water and/or irrigation to supply adequate water. By contrast, agricultural systems incorporating perennial crops, grasses, cover crops, and trees (Figure 1b) ensure permanent land cover; as a result, they can increase crop water use efficiency by simultaneously reducing evaporation and runoff and contributing to soil improvements that create more water storage. Rain-fed systems with multiple crops grown throughout the year require careful planning and crop sequencing to ensure that adequate water is available for all crops that need it, but such management pays off with multiple benefits, including increased resilience to both flooding and drought.

FIGURE 1. Sustainable Agriculture Practices Can Improve Soil Water Efficiency

a. Typical Corn Belt Annual Crop System **b. System Incorporating Perennials, Cover Crops, and Livestock**



Today's Midwest annual cropping system experiences significant water loss through runoff and evaporations from bare soil (a). Incorporating perennial crops or grasses, cover crops, trees, and grazing animals increases water retention in soil, improving efficiency (b).

Note: Arrows represent the relative extent of transpiration (crop water use), evaporation, and runoff in the two systems, and below-ground raindrops represent the relative capacity of soil in the two systems to store water.

SOURCES: HILLEL 1998; ROCKSTROM ET AL. 2009.

FIGURE 2. Global Distribution of Experiments Analyzed

Experiments conducted around the world show how diversifying agricultural practices—particularly a shift to using more continuous living cover—can greatly increase the amount of water that enters the soil and becomes available to farmers for their crops. Our meta-analysis of infiltration rates included 126 experiments on six continents.

> ***Converting approximately one-third of Iowa's cropped acres would result in significant water savings.***

A DEEPER DIVE INTO THE SOIL WATER IMPACTS OF CONTINUOUS LIVING COVER

This analysis also included a closer examination of the continuous living cover practices and some specific indicators of a healthy soil's ability to retain water. A healthy soil acts like a sponge in its ability to hold on to water. To act like a sponge, a soil requires adequate space between particles ("porosity") for water to move into and through the soil. Another indicator of a healthy soil's ability to retain water is the amount of water in it available for crops to use ("plant-available water").[4]

We performed an additional meta-analysis to search for experiments that measured how these two soil water properties responded to a subset of the alternative practices (cover crops, agroforestry, and perennial crops) compared with how they responded to more conventional methods that leave the soil bare for significant portions of the year (Appendix B, online at *www.ucsusa.org/SoilsIntoSponges*; Basche and DeLonge n.d.b). In this analysis, we identified 27 additional experiments.

We found that there were significant improvements to these two important soil properties that relate to soil water storage. The following are of particular note:

- **Cover crops and perennials actually change the structure of the soil**. These practices **increase porosity by an average of 8 percent** compared with practices that leave the soil bare for significant portions of the year.
- **Continuous cover systems make an average of 9 percent more water available to plants** than do annual crop systems.

MODELING PREDICTS SIGNIFICANT IMPROVEMENTS FROM PRACTICES ADOPTED ON A LANDSCAPE SCALE

Our analysis suggests that conservation and ecological practices can have a significant positive effect on field-scale outcomes, but we also wanted to understand how these soil improvements influence water outcomes on a landscape scale. Specifically, we wanted to learn how shifts in farming practices can reduce water runoff in flood events and increase water in the soil during drought events—and how these benefits might increase or decrease given likely future climate scenarios.

Answering these types of questions requires a tool that can integrate the physical processes of crop growth, the dynamics of water moving through soils, and the influence of rainfall and temperature. For this analysis, we worked with the Basin Characterization Model (BCM), a regional water balance model (Appendix C, online at *www.ucsusa.org/SoilsIntoSponges*).[5]

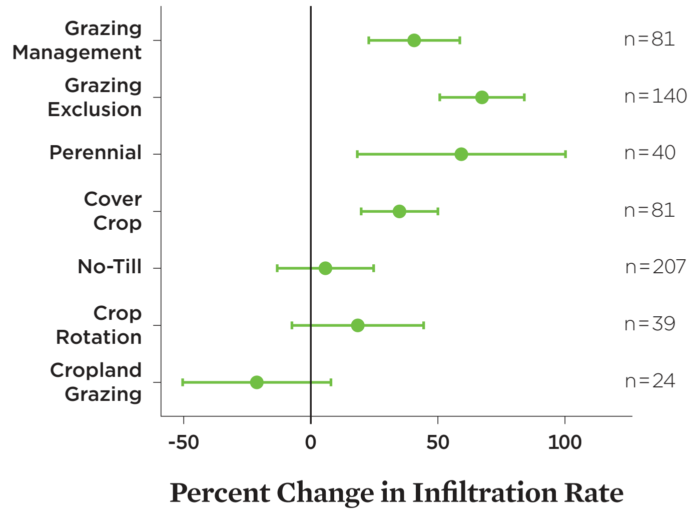
We focused on Iowa, an agriculturally intensive region typical of the larger Corn Belt that has experienced significant flood and drought events over the last several decades (see the table on p. 4; Basche and Edelson 2017).[6]

We wanted to understand how water outcomes might be improved if continuous living cover practices led to better soils in regions of the state currently more susceptible to erosion or less profitable than other regions. Improved agricultural resilience in these regions could have disproportionate economic and environmental benefits. To target these regions, we used the work of prior analyses that found large areas of the state losing soil at rates far greater than replacement (Mulik 2017; Montgomery 2007; Cruse et al. 2006) as well as regions where the combination of crop yields, soil characteristics, input costs, and commodity prices lead to decreased profitability (Brandes et al. 2016).

Selecting these less-profitable, more-erodible areas, and assuming based on our prior analysis (Basche and DeLonge n.d.b) that a shift to continuous cover practices in those regions would achieve an 8 to 9 percent improvement in the key soil properties represented in the BCM, we found the following:

- Converting **approximately one-third of Iowa's cropped acres**—today's least-profitable and most-erodible acres—**to perennial crops or to corn or soybeans grown with a winter cover crop** would result in significant water savings (Figure 5, p. 11).
- Such strategic adoption of cover crops and perennials could have lessened the impact of these past flood events:
  - Runoff, 1993: Our modeling predicts that shifting the most-erodible annual croplands to a perennial system would have resulted in 9 percent less storm water runoff in parts of Iowa affected by flooding during

FIGURE 3. Water Infiltration Improves with Alternative Crop and Soil Practices



Our analysis of experiments involving various soil management practices produced ranges of the rate of water entering and moving through soil. As this figure shows, the greatest increases resulted from continuous living cover practices and changes to grazing management. Estimated ranges show average changes from conventional practices. The "n" numbers show the number of experiments included in each category.

Sevie Kenyon/UW-Madison CALS

Cattle graze on kernza, a multipurpose perennial crop, in a research trial at the University of Wisconsin-Madison. A perennial cousin of wheat, kernza may be grazed by livestock in the spring, harvested for grain in the summer, and then grazed again in the fall. This deep-rooted plant grows year-round, protecting soil and increasing water infiltration.

1993 (see the table on p. 4). Less runoff means less potential for downstream flooding. That year, flooding caused an estimated $35.1 billion in damages.

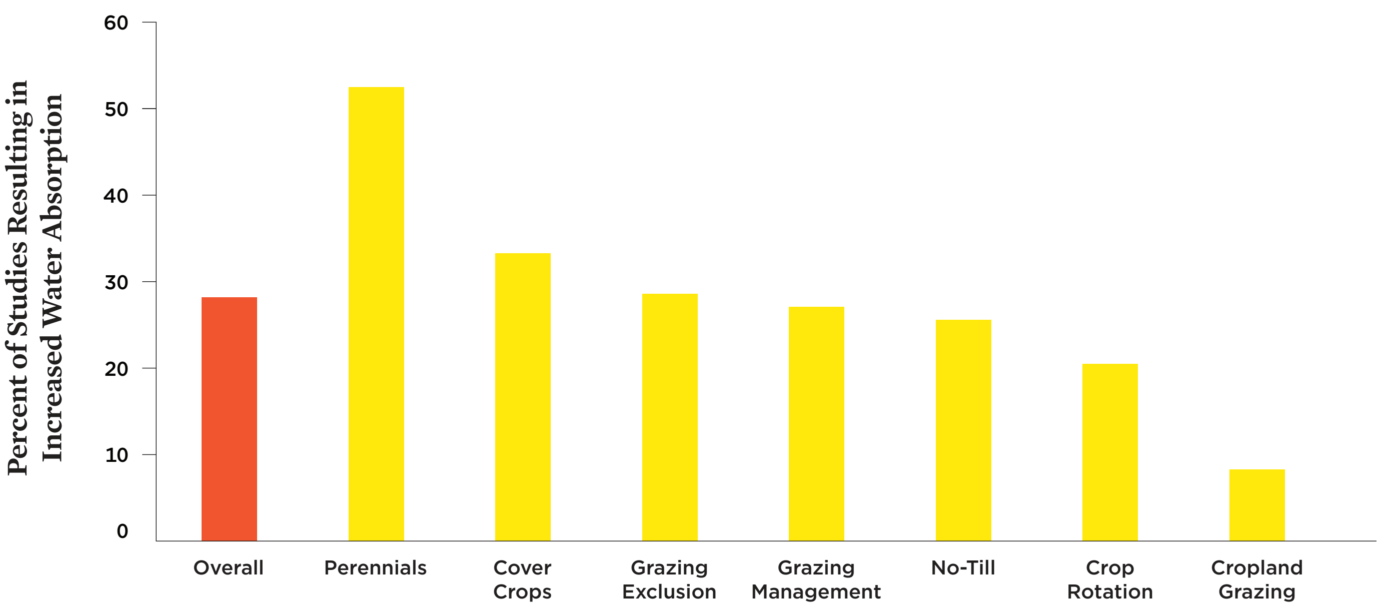
- Runoff, 2011: Our modeling shows that, during the floods of 2011, the conversion of the most-erodible croplands to either perennial crops or to corn or soy with a cover crop might have reduced runoff into the Missouri River by 20 percent. Conversion of the least-profitable croplands might have reduced runoff by 13 percent (see the table on p. 4; Figure 5). These floods primarily affected the western region of the state and caused an estimated $5.3 billion in damages.
- Flood frequency, 1993: Our modeling shows that flood frequency—defined as the number of months during which streams or rivers reach the critical flood inundation stage—could have been significantly reduced by a shift in farm practices. Flood frequency in 1993 in eastern Iowa could have been reduced by 20 percent if the most-erodible croplands had been converted to perennials and cover crops.
- Flood frequency, 2008: Our modeling shows that flood frequency in 2008 in the Cedar Rapids region could have been reduced by 17 percent if the least-profitable croplands had been converted to perennials and cover crops.[7]

[The model showed up to 16 percent more crop water use during drought years when compared with current crop and soil management.]

- Flood frequency, 2011: Our modeling shows that flood frequency in 2011 in the Council Bluffs and Omaha metro areas could have been reduced by 13 percent if the most-erodible croplands had been converted to perennials and cover crops.

In addition, perennially based agriculture demonstrated resiliency to drought conditions in our model. During the two most recent devastating droughts—in 1988 and 2012—each of which caused more than $30 billion in damages, more perennially based agriculture could have led to an average of 4 to 9 percent more water use by crops. In watersheds in which greater amounts of more-erodible or less-profitable land were converted to more perennially based agriculture, the model

FIGURE 4. Alternative Crop and Soil Practices Can Improve Water Absorption During Heavy Rainfall



The first bar shows the overall percentage of experimental alternatives that were able to increase the absorption of rainfall by more than one inch. The other bars show the percentage of experiments within each category that improved absorption of rainfall by the same amount.

FIGURE 5. Climate-Resilient Diversification of Highly Erodible or Less-Profitable Regions in Iowa Could Result in Significant Water and Soil Improvements

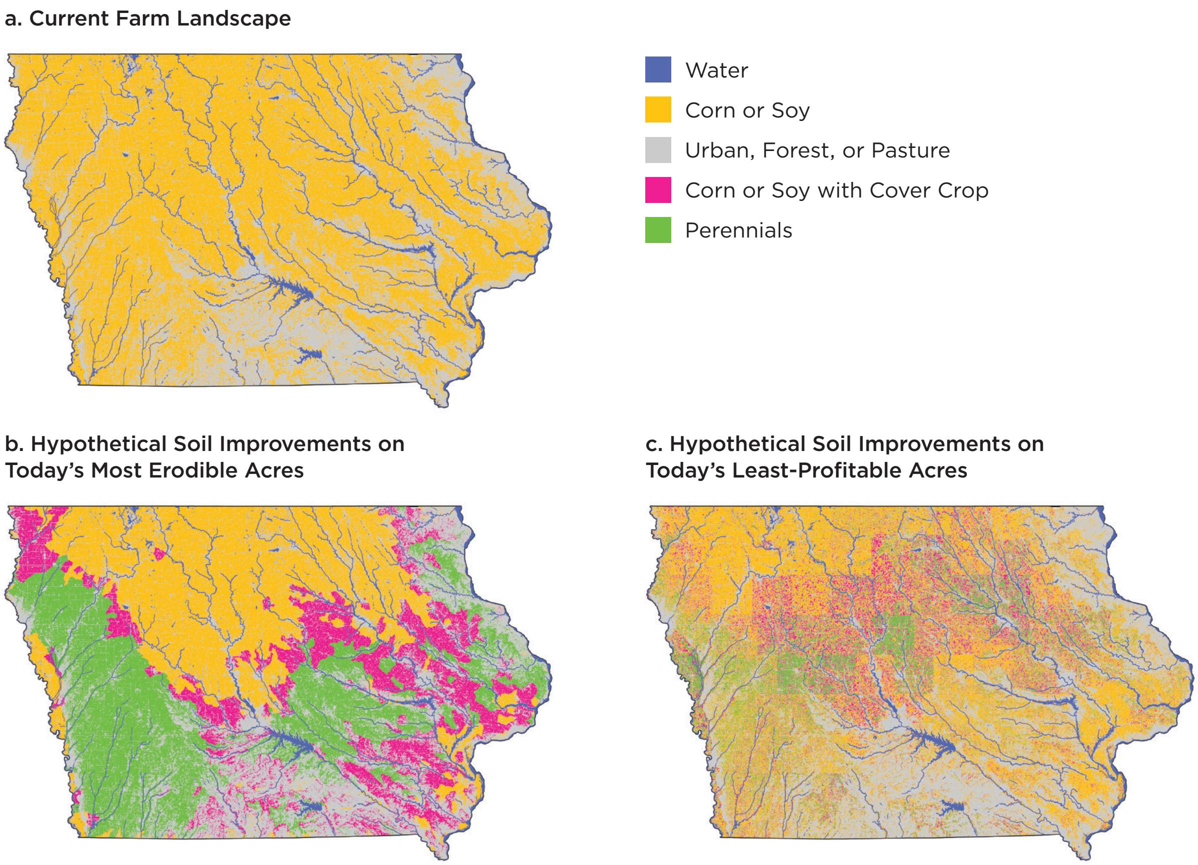


Figure 5a shows the current farm landscape in Iowa (USDA-NASS 2017), in which most cropland is planted with corn or soy. Figures 5b and 5c show what the state would look like if approximately one-third of corn and soy acres were shifted to improved soil-building systems: pink represents a shift to corn/soy rotation with a cover crop and green represents a shift to perennials. Figure 5b depicts such a hypothetical planting of soil-building systems on today's most-erodible acres, whereas Figure 5c depicts these systems on today's least-profitable acres. Perennial grass is shown planted on the most-erodible (>5 tons acre soil loss) and/or least-profitable (losses more than $29 per acre) corn and soybean acres. Cover crops are shown planted where erosion rates were from 2 to 5 tons/acre or acres where profits ranged from $20 gain to $29 loss.

showed up to 16 percent more crop water use during drought years when compared with current crop and soil management. Indeed, our analysis found that some of the largest values of runoff prevention occurred in drier years—up to 60 percent less runoff in 2012—suggesting that strategies that create healthier soils are effective at capturing every drop of rainfall when it matters most.

These perennially based crop systems can reduce damage from flood and drought events, which often cost taxpayers billions of dollars. More crop water use translates into greater crop productivity, a potential win–win protecting farmers from crop losses and taxpayers from higher insurance payouts. The amount of water that could be saved for crop use is astonishing. We estimate that over the last 35 years, the promotion of healthier soils in Iowa could have retained 400 trillion additional gallons of water. This is equal to nine years' worth of irrigation water withdrawn across the entire United States at current rates.[8]

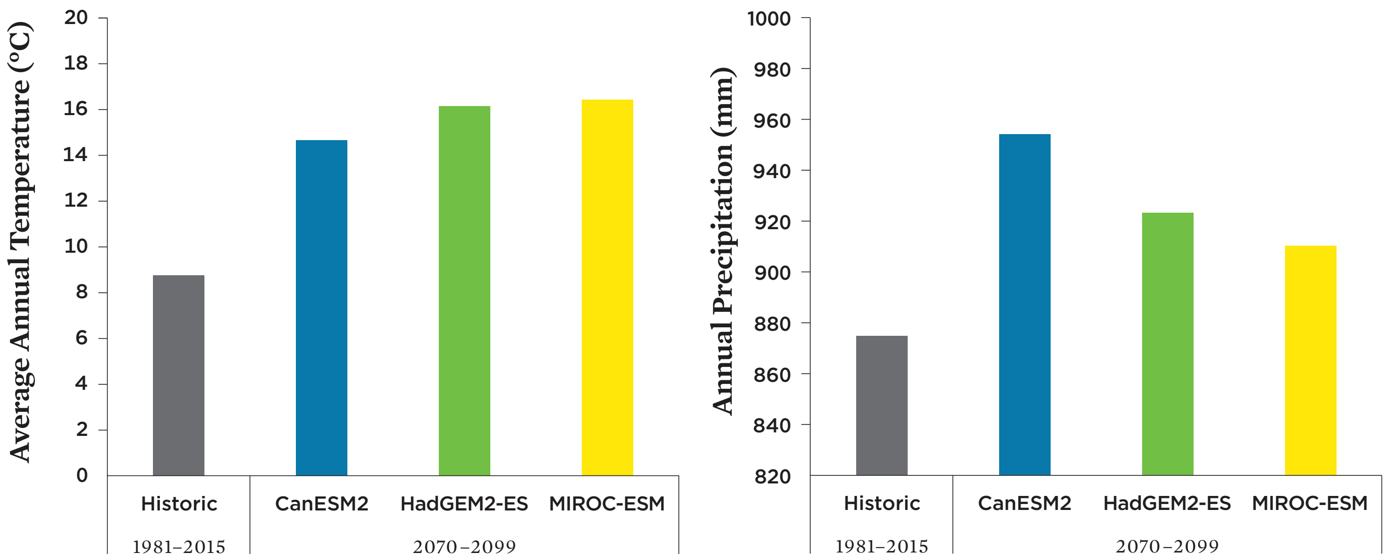
WHAT DOES THIS MEAN FOR FUTURE FLOODS AND DROUGHTS?

We used the BCM to predict the impact of projected climate change on this region and to evaluate the effectiveness of the crop and soil management options we are proposing as adaptation measures.[9]

FIGURE 6. Climate Change is Predicted to Significantly Affect Iowa by the End of the 21st Century

a. Iowa Will Become Hotter

b. Iowa Will Become Wetter



By the end of the 21st century (2070-2099), average temperature in Iowa is predicted to rise from 8.7°C (47.8°F) to as high as 16.4°C (61.6°F) under the representative carbon pathway 8.5 (greatest global warming emissions trajectory). Annual rainfall is predicted to increase by 35 to 80 mm (approximately one to three inches or 4 to 9 percent on average) in the future climate scenarios.

Notes: CanESM2 stands for Canadian Earth System Model. HadGEM2-ES is a coupled Earth System Model that was used by the Met Office Hadley Centre for the CMIP5 centennial simulations. MIROC-ESM is a model based on global climate model MIROC (Model for Interdisciplinary Research on Climate), cooperatively developed by the University of Tokyo, NIES (National Institute for Environmental Studies, Japan), and JAMSTEC (Japan Agency for Marine-Earth Science and Technology).

USDA

Proper soil management can lead to more water available for crop use, even during drought conditions.

The climate projections we used for Iowa predict much hotter and slightly wetter conditions by the end of the 21st century (Figure 6; Appendix C, online at *www.ucsusa.org/SoilsIntoSponges*). Significantly hotter conditions will cause additional stress to plants, resulting in less growth and associated water use overall (Walthall et al. 2013). Yet even under such conditions, we found significant opportunities for water use improvements if soils are made healthier and more spongelike through the planting of more perennially based crops. Resulting benefits in this expected future climate include the following:

- **7 to 11 percent more water available for crop use**, even with significantly hotter conditions, which could lead to better crop yields.
- **Runoff reductions ranging from 9 to 15 percent**. The largest runoff reductions occur in the wettest future scenario with the conversion of the most-erodible lands to perennial crops or corn and soybeans with a cover crop.

The projections for the Midwest's future climate underscore the importance of taking action now to ensure future resilience that would better protect farmers from crop losses and taxpayers from higher insurance payouts.

Public Policies Are Needed to Help Farmers

Our analysis suggests that intentionally designing agricultural regions to include more diversified agricultural practices could be a major opportunity to buffer rainfall extremes. Given the extensive negative effects of flood and drought events, policies that would lead to diversifying agricultural landscapes could bring broad benefit to both rural and urban constituencies.

Yet significant barriers exist for farmers who would implement these practices. These practices often involve significant up-front costs (such as for new equipment), and they require training, technical assistance, and research to optimize them for different crops, soils, and weather conditions. Too little such research and assistance is available. Although the federal crop insurance program offers short-term financial risk reduction to many farmers, it lacks any mechanism to incentivize or allow the long-term strategies most likely to help farmers and communities cope with a changing climate.

Federal farm policies—created and funded by Congress and implemented by the US Department of Agriculture (USDA)—have played a major role in creating and maintaining the dominant annual cropping system in the Midwest. This dominant system provides relatively little incentive or flexibility for producers seeking to diversify their land using ecologically driven practices. To facilitate the process of creating a more resilient landscape to mitigate flood and drought risks, policymakers should take the following actions:

- **Expand incentives and strengthen up-front financial support for farmers to encourage them to adopt soil management practices that deliver flood and drought resilience**. Changes to a variety of existing USDA programs can help farmers adopt these practices. Specific recommended changes include the following:
  - *Strengthen support in the Conservation Stewardship Program (CSP) for good soil management practices*. This federal program provides financial and technical assistance to farmers who implement practices that improve soil, water, and air; reduce energy use; and protect plant and animal life. The CSP program could dedicate additional funds, and/or over time shift existing funds, to agricultural management that promotes continuous living cover given its ability to mitigate flood and drought risk. This could be accomplished through the Resource-Conserving Crop Rotation initiative, which includes producer payments for using crop rotations that contain perennial grasses and/or cover crops.
  - *Facilitate state and regional solutions through the Regional Conservation Partnership Program (RCPP)*. The financial damage caused by floods and droughts can be crippling to both urban and rural communities. This common challenge provides a unique opportunity for urban–rural coalitions to combine resources and strategies to build resilience for extreme rainfall events. Established by the 2014 farm bill, the RCPP was designed to bring together states and nongovernmental organizations to provide financial and technical assistance to farmers interested in tackling natural resource concerns. It includes flood prevention as one of the criteria for new conservation projects, along with other priority concerns such as water quality and soil erosion. But demand for the program has been six times greater than the allocated funding, and just 25 percent of total program funds are available for state-level proposals. In order to foster state-driven solutions more successfully, the next farm bill should increase the state-level funding cap to 35 percent of total RCPP funds.
  - *Further encourage collaborative solutions through the Environmental Quality Incentives Program*. This farm bill program includes the Conservation Innovation Grants initiative, which supports collaborative initiatives to develop market systems for environmental services. Drought or flood mitigation could be specifically noted as a priority in this program to encourage innovative state-level partnerships and approaches to climate adaptation.

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Soil scientist Natalie Lounsbury and farmer Jack Gurley inspect a tillage radish cover crop as part of a project funded by the Sustainable Agriculture Research & Education Program. This plant's roots penetrate soil deeply, reducing compaction, and increasing water infiltration, making it an excellent cover crop to improve soil structure.

- **Provide incentives in the federal crop insurance program for risk reduction through soil management**. Taxpayer-funded crop insurance covers hundreds of millions of acres of US farmland, but the program—which makes payments to farmers based on losses in yield or revenue—does not currently take soil quality into consideration when determining premiums or payout rates. This can indirectly incentivize producers planting on areas of their fields that are less productive and possibly less profitable. An even more serious concern is that the program has focused the majority of funds on a small number of annual commodity crops such as corn, soy, cotton, and wheat. In 2016, 61 percent of all crop insurance payments went to these four crops (RMA 2017). When some producers have attempted to plant cover crops, crop insurance contracts, administered by the USDA's Risk Management Agency, have been negated because of uncertainty regarding cash crop yield impacts (NWF 2012). In order to create a federal crop insurance program that enhances our agricultural landscapes and promotes farmer viability, Congress and the USDA should enact the following improvements:

  – *Incorporate soil quality and management metrics into crop insurance*. Recent analysis indicates that high-resolution soil data—including soil properties relevant to crop productivity—not only exist but also could be incorporated into the crop insurance program (Woodard and Verteramo-Chiu 2017). This would be an incremental but important step toward ensuring that soils are incorporated into the formulation of actuarially sound crop insurance premium subsidies. It would also serve as a disincentive for planting in areas that are less productive and less profitable and create a framework allowing other soil properties that change with management to be included in crop insurance programs, thereby creating a mechanism to reward farmers who take care of their soil (for example, through practices that promote continuous living cover). These types of actions are equivalent to other climate adaptation measures that avoid incentivizing development in areas that are more vulnerable to climate risks such as wildfire or flooding. For example, the National Flood Insurance

Program (NFIP) includes the Community Rating System initiative, a voluntary incentive program that encourages community floodplain management activities that exceed the minimum NFIP requirements and in turn rewards the residents in these communities with 5 to 45 percent lower insurance premiums (FEMA 2016).

- *Improve enforcement of conservation compliance*. Since conservation requirements were relinked to the federal crop insurance program in the Agricultural Act of 2014, consistent enforcement of the new requirements has been called into question. According to a recent report from the USDA Office of Inspector General, conservation requirements to not plant on highly erodible land and to protect wetlands are inadequately reviewed at state and local levels; as a result, there is little national data on rates of enforcement (OIG 2016). Such irregularities point directly to the need not only for more stringent enforcement, but also for more individuals employed in enforcement.
- *Incorporate ecological principles into crop insurance*. The federal crop insurance program has become a barrier to good conservation practices, most notably to the adoption of cover crops. Because crop insurance consistently covers nearly 350 million acres of US farmland, removing barriers to healthy soil practices by incorporating National Resources Conservation Services conservation practices into the program would be an effective way to improve soil and water quality for the benefit of farmers and the environment. Creating space in the crop insurance program for farmers to implement diversified systems, such as alley cropping or cover crops, without being penalized by the loss of their insurance policies would be a major step forward.
- *Continue promotion of the Whole Farm Revenue Protection program (WFRP)*. The Agricultural Act of 2014 created the WFRP, which employs traditional insurance to cover an entire farm operation rather than just a single crop, thereby incentivizing on-farm diversification. In a relatively short time, the program has been successful in garnering participation. Yet in order for the program to continue to grow and consequently to advance on-farm diversification, it must become a promotional priority for the department. The USDA should enhance the WFRP by ensuring that all insurance agents have readily available resources that allow them to learn more about the program in order to assist farmers.

- **Invest in research to optimize the benefits of incorporating perennials and other soil management practices into agricultural landscapes**. Today, just 15 percent of USDA competitive research funding supports research that includes ecologically based agricultural practices, while less than 4 percent supports transformative agroecological research (DeLonge, Miles, and Carlisle 2016). Taxpayer-supported federal research programs, including the Agriculture and Food Research Initiative, the Sustainable Agriculture Research and Education Program, and the Organic Agriculture Research and Extension Initiative, could do much more to optimize the practices addressed in this report and help farmers adopt them in all regions of the country. These programs must therefore be protected, increased, and extended in future appropriations and authorizations. Furthermore, it makes good sense for the USDA to prioritize investing public funds into research that benefits not only farmers, but also the public good. Prioritizing research focused on ecological principles would yield resources useful to farmers as they seek to maintain their livelihoods in the face of a changing climate.

Conclusion

Our analysis indicates the tremendous opportunities that exist for more diversified agricultural landscapes—that feature healthier soils and more continuous living cover practices—to buffer the negative effects of flood and drought events. Farmers want to be part of the solution regarding the consequences of climate change; they can be if they are given support to make beneficial shifts in crop and soil management. Transformation at the farm, state, regional, and federal levels is required; and policymakers who desire greater financial stability for farmers, reduced flood damage and costs, and improved environmental conditions even as climate change presents new challenges can move the country toward more resilient agricultural systems that can achieve all these goals.

Andrea Basche *is a Kendall Science Fellow in the UCS Food and Environment Program.*

ACKNOWLEDGMENTS

This report was made possible in part through the generous support of New York Community Trust, the Grantham Foundation for the Protection of the Environment, the TomKat Foundation, the UCS Kendall Science Fellowship Program, and UCS members.

For their reviews of the report, the author would like to thank Elke Brandes PhD (scientist, Johann Heinrich von Thuenen Institute; and former postdoctoral researcher, Department of Agronomy, Iowa State University); Tom Driscoll (director of NFU Foundation and Conservation Policy, National Farmers Union); Lorraine Flint, PhD, and Alan Flint, PhD (research hydrologists with the US Geological Service), both of whom consulted with the author to build and run the hydrology model; Richard V. Pouyat, PhD (National Program Leader Air & Soil Research,

Research and Development, US Forest Service); and Keith Schilling, PhD (research engineer, IIHR-Hydroscience and Engineering, University of Iowa). The time they spent reviewing the report was considerable, and their comments and suggestions greatly improved it.

At UCS, the author thanks Astrid Caldas, Juan Declet-Barreto, Marcia DeLonge, Oliver Edelson, Jasmin Gonzalez, Mike Lavender, Glynis Lough, Jeremy Martin, Joy McNally, Kranti Mulik, Ricardo Salvador, Karen Perry Stillerman, and Shana Udvardy for their help in developing and refining this report.

Organizational affiliations are listed for identification purposes only. The opinions expressed herein do not necessarily reflect those of the organizations that funded the work or the individuals who reviewed it. UCS bears sole responsibility for the report's contents.

ENDNOTES

1 *This value represents approximately 28 percent of total estimated damages from severe weather events, including tropical cyclones, severe storms, wildfires, and winter storms. According to Smith and Katz (2013), these estimates represent "insured and uninsured direct losses includ[ing]: physical damage to residential, commercial and government/municipal buildings, material assets within a building, time element losses (i.e., time-cost for businesses and hotel costs for loss of living quarters), vehicles, public and private infrastructure, and agricultural assets (e.g., buildings, machinery, livestock). Our disaster loss assessments do not take into account losses to natural capital/assets, healthcare related losses, or values associated with loss of life."*

2 *This value was calculated as the sum from all US locations reporting indemnity data to the Risk Management Agency for one of three causes of loss: flood, drought, or excess moisture/precipitation/rain.*

3 Paired observations *refers to the comparison of an experimental treatment (alternative crop and soil management) to a control treatment (more conventional management). In many experiments, there was not just one comparison but many, depending on whether, for example, different species of cover crops were included or multiple tillage methods were evaluated. In most cases (95 percent), comparisons evaluated only the effect on infiltration rate of using the alternative practice (Appendix A, online at* www.ucsusa.org/SoilsIntoSponges*).*

4 *Not all water in soil is available to plants. Plant-available water is measured as the difference between the water content of saturated soil ("field capacity") and the water content of the soil drained of water that can be lost due to gravity or crop uptake. Management cannot change this lower bound; it can shift the upper bound. This analysis specifically evaluated field capacity.*

5 *The model represents the soil processes and features related to soil water storage, including plant-available water and porosity (Appendix C, online at* www.ucsusa.org/SoilsIntoSponges*; Flint et al. 2013; Flint and Flint 2008).*

6 *We first tested the model to ensure that its calculations matched the hydrology of watersheds in Iowa. Then we used the model to estimate how the water improvements at the field scale, discovered through the meta-analysis research, affected the water balance on a landscape scale (Appendix C, online at* www.ucsusa.org/SoilsIntoSponges*).*

7 *We evaluated the National Weather Service flood stage values for specific locations that corresponded to our modeled domain.* Flood stage *is defined as "the stage at which overflow of the natural banks of a stream begin to cause damage in the local area from inundation (flooding)." We equated flood stage values to a US Geological Survey stream flow value to estimate the number of months during which water would flow above a particular location's flood stage given baseline land use. We then calculated how many of those months had lower flow values in our models in which the most erodible or least profitable croplands had been converted to perennials and cover crops.*

8 *This value, 400 trillion gallons, represents the total water summed from reduced runoff that would result from conversion of approximately one-third of the most-erodible croplands in Iowa to perennially based agriculture (Figure 5, p. 11). Irrigation withdrawal is estimated at 120 billion gallons per day in 2010 (USGS 2016).*

9 *We used three different global climate models to project climate change: CanESM2 from the Canadian Centre for Climate Modeling and Analysis, MIROC-ESM from the Japan Agency for Marine-Earth Science and Technology, and HadGEM2-ES from the Met Office Hadley Center. These were selected based on global average temperature and precipitation changes predicting a range of wetter, drier, hotter, and cooler average changes by the end of the 21st century. For the locations selected in this analysis, the three global climate models predicted an average increase in rainfall of 4.9 percent and a maximum temperature increase of 7 to 9°C for the 2070 to 2099 period (Figure 6, p. 12).*

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Turning Soils into Sponges

How Farmers Can Fight Floods and Droughts

Spongy soils, created through a shift to soil-covering farming practices, can help to reduce the negative effects of floods and droughts, benefiting both farmers and downstream communities.

Floods and droughts have caused an estimated $340.4 billion in damages in the United States since 1980. On the nation's farms, these extreme weather events devastate crops and livestock, and damage or wash away soil. Taxpayers shoulder a heavy burden from these disasters, which also affect cities and towns downstream from farm fields.

Current agricultural policies incentivize farming practices that reduce soil's ability to absorb and hold water. A new Union of Concerned Scientists (UCS) analysis finds that a shift to soil-building practices that incorporate ground-covering crops year-round could help solve this problem. In 70 percent of field studies we analyzed, keeping soil unplowed and covered with living plants increased its sponge-like ability to absorb more water. Employing these farming practices on a large scale could reduce runoff in flood years by nearly one-fifth and cut flood frequency by the same amount, while also making as much as 16 percent more water available for crop use during droughts. Federal policy changes are needed to support adoption of such systems and reap significant benefits for farmers, downstream communities, and taxpayer-funded disaster relief and crop insurance programs.

Union of Concerned Scientists

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