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BUILDING THE RESILIENCE OF THE UNITED STATES' AGRICULTURAL SECTOR TO EXTREME FLOODS

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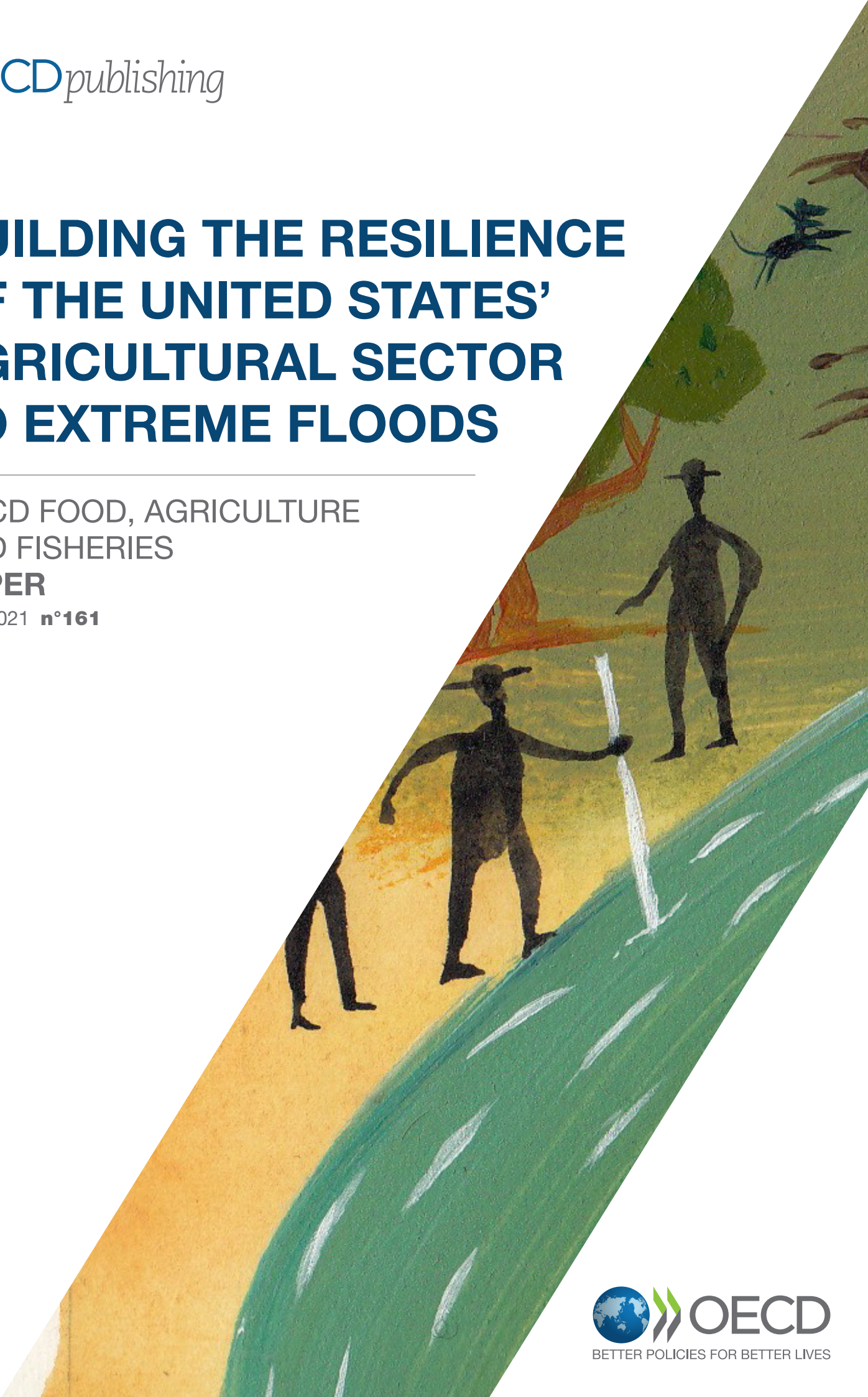

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Building the Resilience of the United States' Agricultural Sector to Extreme Floods

Emily Gray and Katherine Baldwin

Agricultural producers in the United States have significant experience in managing the risk of natural hazard-induced disasters (NHID), but the 2019 Midwestern Floods and Hurricane Florence in 2018 highlighted the importance of increasing resilience to extreme floods. A number of current practices already build resilience. Producers can access science-based information on adaptation to climate and weather-related risks, preparedness and recovery, including through the USDA Climate Hubs. Formal networks build relationships and capabilities before a disaster, improving the effectiveness of disaster preparedness and response. USDA conservation programmes and various soil health initiatives help farmers to mitigate the impacts of floods on production. However, most farm support is directed to agricultural risk management policies and disaster assistance that help producers cope with the impacts of NHID. Integrating resilience objectives into these programmes would send a clearer signal to producers about the need to adapt and increase resilience. Policy makers should also engage with trusted stakeholders – including farm organisations and extension agents – to promote the benefits of practices that build resilience to NHID ID.

Keywords: Resilience; floods; agricultural risk management, disaster risk

JEL codes: Q54, Q18, Q15, Q16, Q25

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Key messages

What is the issue and why is it important?

- The United States' agricultural sector is exposed to a range of natural hazards. In particular, heavy losses and damage caused by the 2019 Midwestern Floods and Hurricane Florence in 2018 have highlighted the importance of increasing resilience to extreme floods.
- US producers have experience in managing natural disaster risk, but more frequent and intense floods because of climate change will challenge even experienced farm managers. Adaption – and where necessary, transformation – will require policies and on-farm strategies that emphasise flood preparedness, mitigate impacts on production, and ensure a more resilient recovery.

What did we learn?

- Comprehensive agricultural risk management and disaster assistance policies compensate producers for losses caused by natural hazards. However, ad hoc disaster assistance risks undermining the *ex ante* framework established by these policies and is a potentially significant barrier to adaptation on farm.
- Producers and other stakeholders can access extensive, science-based information on adaptation to climate and natural hazard risks, preparedness and recovery. Information – such as the decision-support tools and resources developed by the USDA Climate Hubs – is tailored to the needs of the sector, and by region and natural hazard.
- Nature-based solutions to mitigate flood risks and impacts receive technical and financial support through USDA's conservation programmes. In addition, various soil health initiatives promote experimentation and address constraints to the adoption of soil health practices, which can help to mitigate the impacts of natural hazards on production.
- Formal networks such as the Critical Infrastructure Sectors, the Extension Disaster Education Network (EDEN) and the Multi-State Partnership for Security in Agriculture build relationships and response capabilities before a disaster, improving the effectiveness of disaster preparedness and response.

Key recommendations

- Policies should provide clear signals for producers to manage risks and develop their capacity to plan for, absorb, recover from, and more successfully adapt to natural hazard risk. Risk management programmes could be reviewed for their effects on farm-level incentives to mitigate and prevent risk in the long term, and for opportunities to integrate resilience considerations. USDA conservation programmes could also be leveraged to improve *ex ante* natural hazard risk management and support a more resilient recovery.
- Tools and programmes that support adaptation to climate and natural hazard risks receive relatively less support than risk coping tools, with many subject to funding limitations and other constraints that limit use, despite high demand for these resources. Raising the profile of these programmes and strengthening the links with risk coping tools could improve outcomes.
- Policy makers should engage closely with trusted stakeholders – including farm organisations and local extension agents – to promote the benefits of prevention and mitigation to reduce exposure to natural hazard risk, as well as to better understand farm-level constraints to adopting practices that improve farm resilience.

1. Introduction

The United States' diverse climate and geography exposes it to a wide variety of natural hazard risks. Hurricanes, tornadoes, flooding, drought and wildfires are common, and can have severe economic impacts on affected areas – in 2019 alone, there were 14 separate weather and climate disaster events that each caused losses to the US economy exceeding USD 1 billion (NOAA National Centers for Environmental Information, 2020[1]). The US agricultural sector is similarly vulnerable to natural hazards and has experienced significant losses in recent years because of hurricanes, floods, tornadoes, typhoons, volcanic activity, snowstorms and wildfires. These natural disasters also resulted in significant costs to the United States in terms of farm disaster assistance, as well as substantial indirect losses from supply chain disruptions and impacts on social wellbeing.

This case study examines how governance arrangements and policy measures help to build the resilience of US farmers and the agricultural sector to natural hazard-induced disasters (NHID). It is one of seven case studies[1] prepared for the joint OECD-FAO project on *Building Agricultural Resilience to Natural Hazard-Induced Disasters: Insights from Country Case Studies* (OECD-FAO, 2021[2]). This project examines Disaster Risk Management[2] (DRM) frameworks in selected OECD and developing countries to identify what governments and agricultural sector stakeholders can do to build resilience to NHID – defined here as the ability of farmers to prepare and plan for, absorb, respond, recover from, and more successfully adapt and transform in response to natural hazards (OECD, 2020[3]). The project identifies good practices for building resilience at each stage of the DRM cycle – risk identification, assessment and awareness; prevention and mitigation; preparedness; response and crisis management; and recovery and reconstruction – where good practices are identified according to four principles for effective disaster risk management for resilience (Box 1).

Box 1. Principles for effective disaster risk management for resilience

In 2017, G7 Agriculture Ministers in Bergamo recognised the effects of natural hazards on farmers' lives, agro-food systems, agricultural production and productivity in regions all over the world, and that climate change is projected to amplify many of these impacts. Ministers also noted the importance of strengthening the resilience of farmers to natural hazard (G7 Agriculture Ministers, 2017[4]).

Responding to this imperative, the joint OECD-FAO project on *Building Agricultural Resilience to Natural Hazard-Induced Disasters: Insights from Country Case Studies* identifies good practices for building agricultural resilience at each stage of the DRM cycle. Good practices in the case study countries are identified according to principles and recommendations from key international frameworks for managing the risks posed by disasters and other critical shocks, including OECD recommendations and the Sendai Framework.[1] Based on these frameworks, each case study assesses their country-specific situation according to the following four *Principles for Effective DRM for Resilience*:

- An inclusive, holistic and all-hazards approach to natural disaster risk governance for resilience.
- A shared understanding of natural disaster risk based on the identification, assessment and communication of risk, vulnerability and resilience capacities.
- An *ex ante* approach to natural disaster risk management.

[1] The seven case study countries are Chile, Italy, Japan, Namibia, New Zealand, Turkey and the United States.

[2] UNISDR (2015[10]) defines disaster risk management as the application of disaster risk reduction policies and strategies to prevent new disaster risk, reduce existing disaster risk and manage residual risk, contributing to the strengthening of resilience and reduction of disaster losses.

- An approach emphasising preparedness and planning for effective crisis management, disaster response, and to "build back better"[2] to increase resilience to future natural hazards.

Good practices encompass policy measures and governance arrangements that encourage public and private stakeholders to address gaps in their resilience levels. This can be done by helping stakeholders understand the risks that they face from natural hazards and their responsibilities for managing the risks they pose to their assets. For example, while rarer catastrophic risks such as NHID may require public intervention, on-farm strategies and the individual farmer's overall capacity to manage risk also play a critical role in reducing risk exposure to catastrophic events, particularly over the long term (OECD, 2009[5]; OECD, 2020[3]). Specifically, good practices that build agricultural resilience to natural hazards are policies and governance arrangements that:

- Encourage public and private actors to consider the risk landscape over the long term, including to take into account the potential future effects of climate change on the agricultural sector, and to place a greater emphasis on what can be done *ex ante* to reduce risk exposure and increase preparedness.
- Provide incentives and support the capacity of farmers to prevent, mitigate, prepare and plan for, absorb, respond, recover from, and more successfully adapt and transform in response to natural hazards.
- Consider a wide range of future scenarios, including expected environmental, economic and social structural change, and contribute to agricultural productivity and sustainability, even in the absence of a shock or stress.
- Take into account the trade-offs inherent in natural disaster risk management, including between measures to build the capacities of the sector to absorb, adapt, or transform in response to natural disaster risk, and between investing in risk prevention and mitigation *ex ante* and providing *ex post* disaster assistance.
- Are developed with the participation of a wide range of actors, to ensure that all relevant stakeholders are equally involved in the design, planning, implementation, monitoring and evaluation of interventions; and share a common understanding of the risk landscape and their respective responsibilities for managing natural disaster risk.

Notes:
1. OECD's Approach to Risk Management for Resilience (OECD, 2009[5]; OECD, 2011[6]; OECD, 2020[3]); the Sendai Framework for Disaster Risk Reduction (UNISDR, 2015[7]); the OECD Recommendation on the Governance of Critical Risks (OECD, 2014[8]); and the Joint Framework for Strengthening resilience for food security and nutrition of the Rome-based Agencies (FAO, IFAD and WFP, 2019[9]).
2. Building back better is defined as using the recovery, rehabilitation and reconstruction phases after a disaster to increase the resilience of nations and communities through integrating disaster risk reduction measures into the restoration of physical infrastructure and societal systems, and into the revitalization of livelihoods, economies and the environment (UNISDR, 2015[10]).

Each of the country case studies in this project focuses on a particular type of natural hazard in order to explore how different policy measures, governance arrangements, on-farm strategies and other initiatives contribute to building resilience. The US case study focuses on extreme floods – in particular, experience from Hurricane Florence in 2018 and the 2019 Midwestern Floods,[3] both of which caused significant agricultural damage and losses.[4] Climate change is expected to increase the frequency and intensity of heavy rainfall events and the risk of floods in the United States, with attendant impacts on agriculture (USGCRP, 2018[11]). Given this, increasing the resilience of US agriculture to floods is important for farmers facing recurrent extreme floods that can threaten the viability of their businesses. Achieving this will require the holistic use of government resources, in order to position the sector to better prepare for, mitigate and manage flood risk.

[3] The decision to focus on extreme floods, and Hurricane Florence in 2018 and the 2019 Midwestern Floods in particular, was made in consultation with the United States Department of Agriculture's Office of the Chief Economist.

[4] "Damage" refers to the total or partial destruction of physical assets and infrastructure in disaster-affected areas, expressed as replacement or repair costs. "Losses" refer to the changes in economic flows or revenues arising from the disaster (FAO, 2016[101]).

2. Country context

The United States is significant globally as a producer and exporter of agricultural commodities. Abundant pasture and arable land, along with diverse climatic conditions, allow the production of a wide range of crop and livestock products. While primary agriculture accounts for a small share of the US economy – around 0.9% of GDP and 1.6% of employment in 2018 – agro-food exports account for over 10% of total exports (OECD, 2020[12]), and agriculture and its related industries[5] accounted for 5.4% of the US economy and 11% of total employment in 2018 (USDA ERS, 2020[13]). Moreover, in some states, the sector accounts for a larger share of employment and economic activity, such that disruptions to agricultural activities caused by natural hazards can have significant spill-over effects. For example, a recent study estimated that in districts affected by major natural disasters in 2018 and 2019, the total economic contribution of agriculture was around USD 83.8 billion, with the sector providing 419 000 direct jobs (AFBF, 2019[14]).

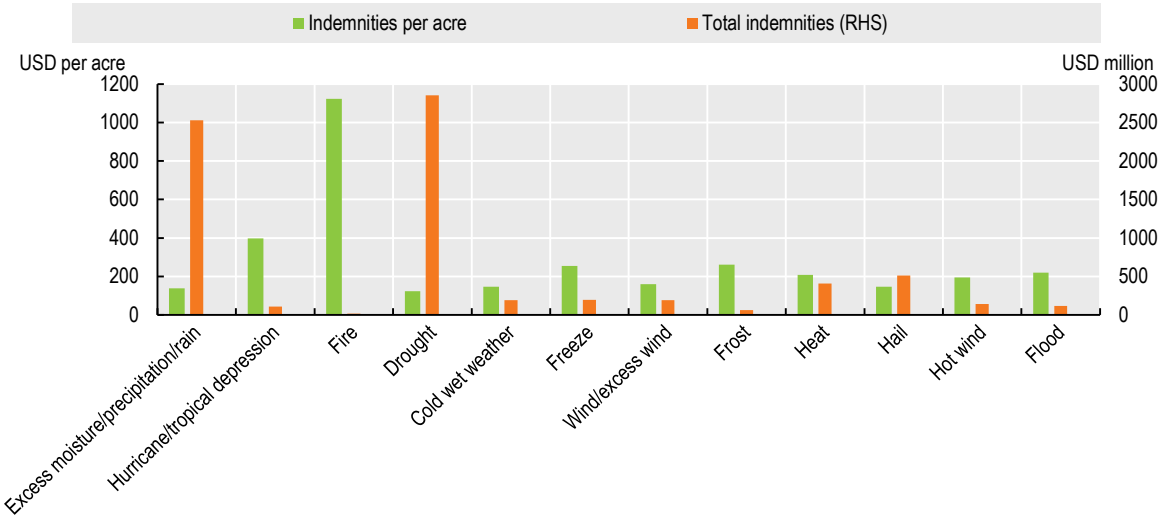
Reflecting the natural hazard exposure of the country overall, the US agricultural sector is exposed to a range of natural hazards, with drought, floods, hurricanes, storms and wildfires causing large losses (Smith, 2019[15]). While drought is the main driver of indemnity payments under the Federal Crop Insurance Program and accounts for a large share of disaster assistance over time (Wallander, Marshall and Aillery, 2017[16]), data for 2010-20 indicate that the indemnities per acre can be higher for fires, tropical cyclones/hurricanes and floods (Figure 1). Moreover, floods can cause extensive damage to farm equipment and infrastructure, in addition to crop and livestock losses. Floods can also degrade farmland and soil through erosion, contamination, and sediment deposits from upstream sources, reducing future farm productivity. In addition, although the impacts of individual flood events on farm business operations can be significant and long-lasting, they can also be exacerbated by subsequent events. For example, when Hurricane Florence made landfall in 2018, many South Carolina producers were still recovering from severe flooding in 2015. Finally, floods can have significant indirect impacts, by delaying or preventing farmers from planting crops and disrupting rural infrastructure and transport.

The US Atlantic and Gulf states have long been accustomed to occasional hurricane damage. However, recent storms have seen increased inland rainfall, compounding wind damage and causing much larger losses over a wider area. For example, in 2018, Hurricane Florence disrupted agricultural production in North Carolina, South Carolina, Georgia, Virginia and Maryland. In North Carolina alone, direct agricultural impacts were estimated at USD 1.3 billion, including USD 1.1 billion in crop and livestock losses, USD 118 million in damage to farm buildings, equipment and infrastructure, and USD 20 million in emergency livestock disposal[6] (NC Office of the Governor, 2018[17]). Similarly, while the Midwest, Great Plains and Northeast states have long experience with floods, in 2019, the Midwest Floods across the Missouri, Arkansas, and Mississippi River Basins caused extensive damage, including an estimated USD 1 billion in agricultural damage in Nebraska and USD 2 billion in Iowa (Reuters, 2019[18]; AGU, 2019[19]). Climate change is expected to increase the frequency and intensity of heavy rainfall and flood events. The Fourth US National Climate Assessment reports that heavy precipitation is becoming more intense and frequent across most of the United States, particularly in the Midwest and Northeast, and that these trends are projected to continue. Hurricane rainfall and intensity in the Atlantic are also projected to increase (USGCRP, 2018[11]).

[5] Agriculture and related industries includes forestry, fishing, and related activities; food, beverages, and tobacco products; textiles, apparel, and leather products; food and beverage stores; and food service, eating and drinking places (USDA ERS, 2020[13]).

[6] The methodology for estimating costs can be found in Hurricane Florence Recovery Recommendations: Building Communities Stronger and Smarter – Based on Preliminary Damage and Needs Assessment (NC Office of the Governor, 2018[17]), https://files.nc.gov/ncosbm/documents/files/Florence_Report_Full.pdf.

Figure 1. Crop insurance indemnities and indemnities per acre, averages for 2010-2020



Source: USDA RMA (2021[20]), *Cause of Loss Historical Data Files*, https://www.rma.usda.gov/SummaryOfBusiness/CauseOfLoss.

Frequent exposure to flooding caused by heavy rainfall events and hurricanes means that US producers have significant experience with managing natural disaster risk – and indeed, the range of risks faced by farm operations. Farm-level capacity for managing that risk is also generally high. US producers are innovative, adopting new developments in crop and livestock breeding, nutrient use and pest management, farm practices and farm equipment, including precision agriculture technologies (Lowenberg-DeBoer and Erickson, 2019[21]; Schimmelpfennig, 2016[22]), conservation tillage practices (Claassen et al., 2018[23]), genetically-engineered crops (including drought-tolerant corn) (McFadden et al., 2019[24]), and weather and climate service tools (Haigh et al., 2018[25]). Farms frequently employ a portfolio of measures to manage risk, such as agricultural derivatives and marketing contracts to protect against price fluctuations, production diversification, and off-farm sources of income (Prager et al., 2020[26]). The agricultural workforce is also relatively well-educated, with around 45% of farm operators having some level of college education (Castillo and Simnitt, 2020[27]).

Nevertheless, more frequent and intense floods may present a challenge to even experienced farm managers due to the magnitude of the impacts and the cascading effects of multiple events. Applying a resilience approach to the risk of extreme floods requires stakeholders – both public and private – to consider the risk floods pose to the sector over the long term, and place a greater emphasis on what can be done *ex ante* to reduce risk exposure, increase preparedness for floods, and ensure a more resilient recovery. At present, the US Department of Agriculture (USDA) has a suite of programmes that compensate producers when a natural disaster causes severe production losses. There is also increasing recognition that there are actions that producers can take proactively to reduce their farm's exposure to flood risks – and climate-related hazards more broadly – and mitigate their impacts. Reflecting this, there is a range of public, and joint public-private efforts that aim to improve agricultural resilience and natural hazard preparedness, such as initiatives to improve soil health, and to develop science-based tools, forecasts and extension services to support risk-based decision-making on farms. Given this policy landscape, an important question is whether current agricultural risk management and disaster assistance policies place sufficient weight on, and provide sufficient incentives for, measures to prevent and mitigate flood risks in the long run, and support a recovery that reduces the risks from extreme floods in the future.

The following section considers the main frameworks and policy measures in place in the United States for managing natural disaster risk in agriculture, focusing on those that influence flood risk. It explores how they influence efforts by agricultural sector stakeholders to build resilience, and highlights examples of practices that build agricultural resilience to floods, as well as areas that may contribute to gaps in resilience levels (Box 1).

3. Natural disaster risk management in the United States

Resilience to natural hazards is an outcome of measures put in place before, during and after an extreme event, such as a flood. Measures undertaken by governments, farmers and other stakeholders at each stage of the DRM cycle play a role in helping the agricultural sector to absorb and recover from the impacts of natural hazards, and to adapt and transform in order to increase resilience to future disaster risks. This includes efforts to identify, assess and raise awareness of natural disaster risks; to prevent or mitigate those risks; to prepare for likely or imminent natural disasters; to manage crises and disaster response efforts; and to support recovery and reconstruction.

The following section outlines the main governance frameworks and actors with responsibilities for natural disaster risk management in the United States. Then, the key policies and strategies for natural disaster risk management – and how they contribute to building agricultural resilience – are discussed for each stage of the risk management cycle: risk identification, assessment and awareness; prevention and mitigation; preparedness; response and crisis management; and recovery and reconstruction.

3.1. Governance frameworks affecting disaster risk management in agriculture

Strong and effective governance arrangements are crucial for building agricultural resilience to natural hazard-induced disasters. Institutions and policy frameworks influence decisions by farmers, government agencies and other stakeholders on whether or not to invest in building resilience, by defining stakeholders' roles and responsibilities for managing natural disaster risk, and by providing incentives to invest in disaster risk prevention and mitigation, including after a disaster (OECD, 2014[28]; UNISDR, 2015[7]). Governance arrangements can also support – or indeed, be a barrier to – a more resilient recovery after a disaster through the relative emphasis they place on the different stages of the DRM cycle, and on the capacities to absorb the impacts of natural hazards versus adapt and transform in response to future disaster risks in the agricultural sector (OECD, 2020[3]).

Four general governance framework areas, involving a variety of stakeholders and policy documents, influence the US agricultural sector's approach to managing natural disaster risk. These are the US frameworks for all-sector emergency management; governance arrangements for flood risk management; agricultural risk management policies; and other agricultural policies that can affect the sector's capacity to manage floods.

Generally speaking, disaster risk management in the United States is based on the principle of preparedness for all hazards. The system for disaster preparedness and response is outlined in the *National Preparedness System* (NPS) and its component policies, which guide how the whole community – including all levels of government, the private and non-profit sectors, and the wider public – build and sustain the capabilities that are needed to prevent, protect against, mitigate, respond to, and recover from all hazards, as identified in the *National Preparedness Goal*.[7] The NPS includes a series of strategic *National Planning Frameworks* across the five preparedness mission areas: Prevention, Protection, Mitigation, Response, and Recovery. These frameworks outline the roles and responsibilities of public and private stakeholders, co-ordinating structures and practices for managing incidents that range from those managed locally to larger-scale incidents, including catastrophic natural disasters such as floods. At the federal level, the Federal Emergency Management Agency (FEMA) – an agency of the US Department of Homeland Security (DHS) – is the lead agency responsible for disaster preparedness, response and recovery, with support provided by other federal agencies and departments. While FEMA is the lead agency for disaster management at the federal level, the US disaster management system assumes that local, state and tribal governments affected by an incident will take a leadership role. The federal government provides co-ordinated supplemental resources and disaster assistance only if requested and

[7] The National Preparedness Goal identifies the 32 core capabilities necessary to achieve preparedness across the five mission areas: prevention, protection, mitigation, response and recovery. The National Preparedness Goal is: "A secure and resilient nation with the capabilities required across the whole community to prevent, protect against, mitigate, respond to and recover from the threats and hazards that pose the greatest risk."

approved. In the event that a disaster overwhelms local or state resources, the President can declare a major disaster (via a Stafford Act Declaration) in response to a request for federal government and FEMA assistance from the state governor.[8]

The approach for managing natural hazard risks to critical infrastructure[9] – including in the food and agriculture sector – is outlined in the *National Infrastructure Protection Plan* (NIPP), which guides how government and private sector owners and operators of critical infrastructure work together to manage risks and achieve security and resilience outcomes. Each of the 16 critical infrastructure sectors has a sector-specific plan that outlines how the NIPP framework is applied to the unique characteristics of the sector. These are developed and implemented as a collaboration between public and private sector partners.[10] In the case of the Food and Agriculture Critical Infrastructure Sector, the sector-specific plan emphasises the importance of public-private partnerships, given that food and agriculture critical infrastructure is almost entirely under private ownership (FDA, USDA and DHS, 2015[29]). USDA and the Food and Drug Administration (FDA) are the co-Sector-Specific Agencies for the Food and Agriculture Sector.

Responsibility for flood risk management is shared across multiple federal, state, and local government agencies. States and local governments are responsible for land use and development decisions in floodplains, including building codes and zoning (Carter et al., 2018[30]). At the national level, the US Army Corps of Engineers (USACE), FEMA and USDA (discussed below) have a range of programmes to assist states and communities to implement measures to reduce flood damages and improve flood risk management. The USACE is the principal federal agency engaged in construction projects for flood control and damage reduction, such as dams, levees and flood walls, and their rehabilitation when damaged by flood events. The USACE also has a significant role in flood response and recovery. FEMA is responsible for the National Flood Insurance Program (NFIP), which makes flood insurance available to homeowners, renters, and business owners if their community participates in the NFIP and adopts FEMA's minimum floodplain building and land use requirements. FEMA also provides funding to states, territories, tribes, and local communities for flood hazard mitigation projects, including through the NFIP.

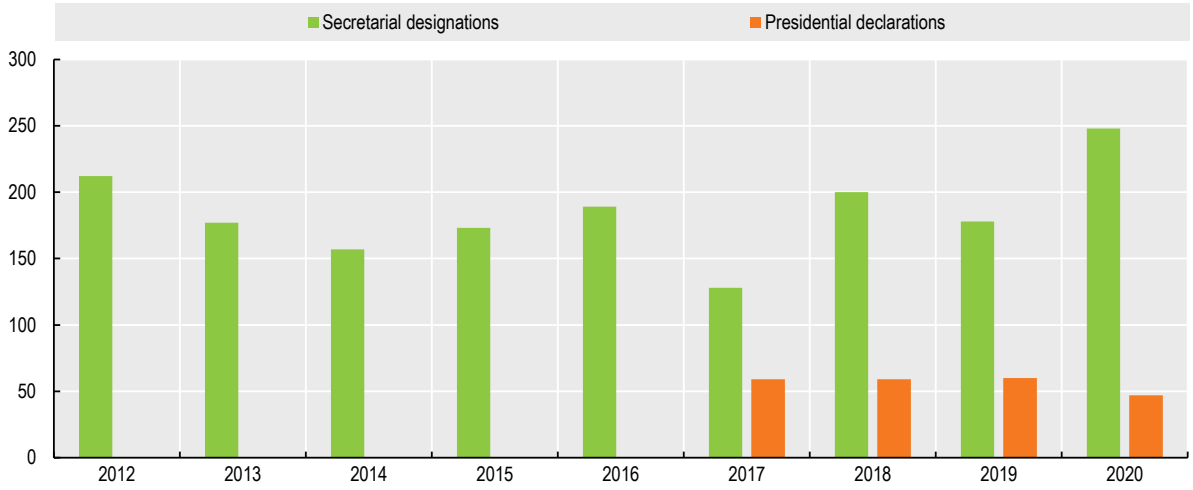
In the area of agricultural risk management, USDA offers a variety of programmes to help producers cope with and recover from natural disasters, including hurricanes, floods, drought, wildfires and earthquakes. The Secretary of Agriculture has the authority to issue agricultural disaster designations independent of presidential Stafford Act declarations. These secretarial designations are common (Figure 2), and trigger a range of disaster assistance programmes (USDA FSA, 2020[31]), which are administered by USDA's Farm Service Agency (FSA) and Natural Resources Conservation Service (NRCS). For these types of events (as well as smaller-scale disasters that do not result in a Presidential disaster declaration), USDA agencies have the statutory authority to assist local and state governments. Within USDA, the Office of Homeland Security and Emergency Coordination (OHSEC) is the focal point for incidents affecting agriculture, and co-ordinates the USDA response.

[8] The *Robert T. Stafford Disaster Relief and Emergency Assistance Act* is the statutory authority for most federal disaster response activities, including FEMA operations. In 2018, a number of reforms were made to FEMA's disaster assistance programmes by the *Disaster Recovery Reform Act* of 2018.

[9] Critical infrastructure is defined as the assets, systems, and networks that underpin American Society.

[10] The 16 critical infrastructure sectors are the Chemical; Commercial Facilities; Communications; Critical Manufacturing; Dams; Defense Industrial Base; Emergency Services; Energy; Financial Services; Food and Agriculture; Government Facilities; Healthcare and Public Health; Information Technology; Nuclear Reactors, Materials and Waste; Transportation Systems; and Water and Wastewater Systems Sectors.

Figure 2. Disaster designations, 2012-2020



Note: Disaster designations made by the US Secretary of Agriculture, and Presidential Major Disaster and Presidential Emergency Declarations. Data on Presidential Declarations for 2012-2016 not available.
Source: USDA FSA (2021[32]), *Disaster Designation Information*, https://www.fsa.usda.gov/programs-and-services/disaster-assistance-program/disaster-designation-information/index.

The suite of agricultural risk management and disaster assistance programmes in the 2018 Farm Bill were established to minimise the use of *ad hoc* measures,[11] and provide financial assistance to help producers cope with production, financial and physical losses (e.g. production infrastructure) related to or caused by a disaster (Stubbs, 2020[33]). The largest of these is the Federal Crop Insurance Program, which is administered by USDA's Risk Management Agency (RMA),[12] and offers subsidised insurance policies for both yield and revenue losses, including losses caused by natural disasters, and Whole-Farm Revenue Protection, which covers all commodities on the farm under one insurance policy. For producers of crops that are not covered by federal crop insurance, FSA administers the Noninsured Crop Disaster Assistance Program (NAP), which provides financial assistance when low yields, loss of inventory, or prevented planting occur due to natural disasters. FSA administers the Emergency Disaster Loans programme, which provides low-interest loans to help producers recover from production and physical losses caused by drought, flooding, quarantine, or other natural disasters. FSA also administers four standing disaster programmes for livestock and trees, bushes, and vineyards (the Supplemental Agricultural Disaster Assistance Programs), which are:

- The Livestock Forage Program (LFP), which provides compensation to eligible livestock producers who have suffered grazing losses due to drought or fire.
- The Livestock Indemnity Program (LIP), which provides benefits to livestock producers for livestock deaths in excess of normal mortality caused by adverse weather or by attacks by animals reintroduced into the wild by the federal government. LIP also provides compensation in the event that livestock are injured by an eligible loss condition but not killed, and are consequently sold for a reduced price.

[11] The Federal Crop Insurance Program in its current form was authorised by the Federal Crop Insurance Act of 1980, and modified by subsequent farm bills and other legislation. In particular, the Agricultural Risk Protection Act of 2000 (ARPA) expanded the geographic availability of insurance, increased premium subsidy levels, and removed restrictions on livestock insurance products. Most of the remaining disaster assistance programmes were established in the 2008 and 2014 Farm Bills.

[12] RMA administers the federal crop insurance programme in partnership with private insurance companies, which share a percentage of the risk of loss or the opportunity for gain associated with each policy. The delivery costs of private insurance companies are also subsidised.

- The Emergency Assistance for Livestock, Honeybees, and Farm-Raised Fish (ELAP) programme provides emergency assistance to eligible producers of livestock, honeybees and farm-raised fish for losses due to disease and costs incurred for some disease prevention, adverse weather, or other conditions, such as blizzards and wildfires, not covered by LFP and LIP.

- The Tree Assistance Program (TAP), which provides financial assistance to qualifying orchardists and nursery tree growers to replant or rehabilitate eligible trees, bushes, and vines damaged by natural disasters.

USDA also has several permanent disaster assistance programmes that help producers to restore damaged farmland following natural disasters. These programmes offer financial and technical assistance to producers to repair and restore damage on private land on a cost-shared basis. FSA's Emergency Conservation Program (ECP) assists landowners to restore agricultural land, including removing debris, restoring fences and conservation structures, and providing water for livestock in drought situations. NRCS's Emergency Watershed Protection (EWP) programme assists communities to implement emergency recovery measures when a natural disaster causes serious damage to land and infrastructure, including removing debris from stream channels, road culverts, and bridges; reshaping and protecting eroded banks; correcting damaged drainage facilities; establishing cover on critically eroded lands; removing carcasses; and repairing levees and structures. In addition to the permanently authorised programmes outlined above, at various times the United States has provided ad hoc disaster assistance payments to farmers and ranchers.

Although not considered part of the agricultural risk management policy portfolio, several USDA programmes influence producer capacity to prevent or mitigate flood risk. NRCS administers three conservation programmes that directly target improved disaster prevention and mitigation. These three programmes – the Emergency Watershed Protection Program – Floodplain Easements Option (EWPP-FPE), the Agricultural Conservation Easement Program – Agricultural Land Easements (ACEP-ALE), and the Watershed and Flood Prevention Operations (WFPO) programme – provide support for preventative structural and non-structural measures to reduce flood damage. Under EWPP-FPE, NRCS purchases permanent easements[13] in floodplains with the goals of restoring the land, to the maximum extent possible, to its natural condition[14] and restoring floodplain functions, which can help to reduce exposure to future floods. Under ACEP-ALE, NRCS provides financial assistance to protect working agricultural land; floodplain easements are allowed if they do not interfere with agricultural viability. The WFPO programme provides technical and financial (cost-shared) assistance to state and local organisations to plan and install structures to prevent erosion, sedimentation and flood damage, such as small levees and dams (Carter et al., 2018[30]).

FSA and NRCS also administer various agricultural conservation programmes that can indirectly improve producers' capacity to manage natural hazard risks. NRCS provides technical and financial assistance to individual producers to implement conservation measures, including land retirement programmes and programmes to encourage crop and livestock producers to adopt practices that reduce environmental pressures on working land. These measures can also play a role in mitigating flood risk and impacts, such as by improving soil health. For example, the Environmental Quality Incentives Program (EQIP) can be used to proactively mitigate potential damage from natural disasters through the use of conservation practices (e.g. vegetative buffer strips along waterways to reduce erosion and crop damage in the event of a flood) (Stubbs, 2020[34]). The Conservation Reserve Program (CRP) provides annual payments to agricultural producers to take highly erodible and environmentally sensitive land out of production, and install resource-conserving practices for ten or more years. Under CRP, many producers have been able to restore floodplains and rehabilitate wetlands. Similarly, the state-based Conservation Reserve Easements Program (CREP), which is part of CRP, also provides support for conservation practices that can mitigate flood risks such as riparian buffers and wetland restoration.

[13] A floodplain or flowage easement is a right granted by a landowner to allow the land to be temporarily inundated.

[14] This includes structural and non-structural practices to restore the flow and storage of floodwaters, control erosion, and to improve management of the easement.

3.2. Risk identification, assessment and awareness

A shared understanding of natural disaster risks is important to encourage investments in natural disaster risk prevention, mitigation and preparedness by all stakeholders (OECD, 2020[3]). Gaps in agricultural resilience – for example, due to deficiencies in protective or other critical infrastructure, or other preparedness capacities – and gaps in DRM frameworks may be due to stakeholders in government bodies, industry organisations or individual farmers lacking awareness of disaster risks, and how risks may evolve over the medium- and long-term. More broadly, information gaps can constrain decision-making on how to manage natural disaster risks.

In the United States, exercises and initiatives at the national and state levels – for example, risk assessments, climate and natural hazard modelling, and foresighting exercises – play an important role in increasing risk awareness across the whole community. In addition, agricultural stakeholders have access to tailored and accessible information on climate and natural hazard risks.

All levels of government undertake all-hazard risk assessments strategically as part of the processes of the NPS. To assist jurisdictions, FEMA has developed the National Risk and Capability Assessment (NRCA), which is a suite of assessment tools that can be used by all levels of government to measure risk and capabilities for managing risk (FEMA, 2020[35]). The NRCA includes the Threat and Hazard Identification and Risk Assessment (THIRA), a standardised risk assessment process that communities and governments at all levels can use to identify hazards, their consequences, and the capabilities needed to manage them. USDA is engaged in the national THIRA process, and state departments of agriculture typically contribute to state-level THIRAs. Recently, the THIRA process was customised to develop a toolkit for enhancing preparedness for drought, in order to better reflect the challenges drought poses for traditional risk management.

A number of agencies assess natural hazard- and climate-related risks. The US Global Change Research Program's (USGCRP) National Climate Assessment analyses the effects of climate change on regions, sectors, and the natural and built environment, including the effects on agriculture and rural communities across the United States. The Fourth National Climate Assessment provides information on future climate scenarios and their associated risks and impacts, and provides examples of actions communities are taking to reduce the risks associated with climate change, increase resilience, and improve livelihoods (USGCRP, 2018[11]).

While the national climate assessment focuses on the current and long-term effects of climate change, the US Geological Survey's (USGS) Natural Hazards Mission Area is responsible for long-term planning across a range of natural hazards. The USGS conducts research to understand the risks posed by natural hazards, so that policymakers and the public have the information that they need to make decisions about preparedness, response, and resilience. On floods, the USGS collects flood data and conducts targeted flood science that is used to improve situational awareness, drive predictive models, inform infrastructure design and operation, support floodplain mapping, and facilitate flood impact assessments (USGS, 2020[36]). While USGS historically focused on the science of natural hazards, it increasingly aims to improve risk communication, including on the societal impacts of natural hazards, and to build partnerships to enhance the availability and use of natural hazard information. For example, USGS's Science Application for Risk Reduction (SAFRR) Project undertakes large-scale, long-term scenario building exercises that model catastrophic hazard events, including floods. The scenarios bring together experts and stakeholders to increase visibility of the impacts of catastrophic events, identify points of failure that can be addressed in advance, build coalitions, and identify policy priorities for disaster risk management.[15]

In addition to USGCRP and USGS, other federal agencies are also involved in modelling and mapping flood hazards, including FEMA, USACE and the National Oceanic and Atmospheric Administration (NOAA). For example, FEMA identifies and maps flood hazards and disseminates flood risk information through floodplain maps as part of the NFIP. The maps depict the areas at risk of experiencing a 1 in 100 year flood (a 1% annual chance flood event) and a 1 in 500 year flood (a 0.2% annual chance flood event),

[15] For example, the ARkStorm Scenario, which was released in 2011, analysed a once in 500 to 1 000 years winter storm impacting the US West Coast. The scenario included consideration of agricultural damages and losses, and options and challenges for mitigating agricultural damages. USGS Science Application for Risk Reduction, https://www.usgs.gov/natural-hazards/science-application-risk-reduction.

providing mapped communities with information about their flood vulnerability. However, a recent review found that almost 58% of FEMA flood maps are considered inaccurate or out-of-date (DHS OIG, 2017[37]). Moreover, FEMA's flood maps do not currently depict future conditions or account for the impacts of climate change. Instead, they identify 100-year and 500-year floodplains based on past events (Scata, 2017[38]).

More targeted information for the agricultural sector on climate and extreme weather events is available through a range of public and private initiatives. USDA is developing tools that summarise climate information and communicate research findings to farmers in more accessible formats. USDA's Regional Climate Hubs develop and deliver region-specific and science-based information and resources to help USDA programme agencies (FSA, NRCS and RMA) and other stakeholders account for climate information in their planning processes (USDA, 2020[39]) (Box 2). The Climate Hubs programme incorporates data, tools and forecasts from USDA agencies and partners, including NOAA, to develop integrated services on climate and natural hazard adaptation that are targeted towards the agricultural sector and rural communities, with local NRCS staff providing the technical link between Climate Hubs research and its application in the field. This includes regional vulnerability assessments to provide stakeholders with a baseline "snapshot" of current climate vulnerabilities, along with specific adaptive management strategies to increase the resilience of working lands in each region – for example, see Hatfield et al. (2015[40]). Within USDA, the Office of the Chief Meteorologist briefs USDA officials on the impacts of weather and climate on agriculture.

Box 2. USDA Regional Climate Hubs

Established in 2014, the 10 regional Climate Hubs link USDA research and programme agencies in order to develop and deliver science-based, region-specific information and technologies to agricultural producers and other stakeholders to enable climate-informed decision-making and adaptation. The Climate Hubs facilitate the co-production of research outputs by working collaboratively with USDA agencies, other federal agencies (for example, NOAA), universities and co-operative extension, state and local governments, and producer interest groups such as the Farm Bureau, thereby ensuring that climate information and tools for building climate resilience are demand-driven, more accessible, and easier for producers to understand and apply to their operations. The Climate Hubs also provide access to a wide range of decision-support tools for the climate, agriculture and forestry sectors developed by other consortia and the private sector – such as *AgroClimate* tools and tools developed by the *Useful to Usable* project – via its *Climate Hubs Tool Shed*.

Specifically, the Climate Hubs:

- *Synthesise research and science information*, for example, to provide periodic regional assessments of risk and vulnerability to production sectors.
- *Develop science-based tools and strategies* for responding to impacts of a changing climate such as drought, extreme weather events, and changing growing seasons, and provide implementation assistance. For example, the Climate Hubs provide usable regional data and climate change projections and forecasts in support of risk management and climate adaptation planning.
- *Engage in stakeholder education and outreach* with farmers, ranchers, and other land managers on science-based risk management, and engage with stakeholders and partners in innovative and interactive ways to help lower the barriers to adaptation, manage risk and enhance rural productivity.

Source: USDA Climate Hubs, https://www.climatehubs.usda.gov/.

Climate and weather information and tools for agriculture is also provided by other consortia, agencies and the private sector. The Southeast Climate Consortium's *AgroClimate* provides interactive tools and climate information to improve crop management decisions and reduce production risks associated with climate change and variability for south-eastern states (SECC, 2020[41]). This includes a range of forecasts (short-term precipitation, seasonal forecasts, drought outlooks and hurricane forecasts) and extension resources. The *Useful to Usable* project brought together expertise in applied climatology, crop modelling, extension and other disciplines to improve the use and uptake of climate information for agricultural decision making (MRCC, 2017[42]).[16] NOAA's Climate Research Program offers regional climate information and products to improve decision makers' ability to prepare for and respond to short and long-term climate variability and change. The programme tailors its information on climate impacts based on regional stakeholder input, in order to help stakeholders and communities expand their capacity to prepare for and respond to floods, storms and other extreme events (GAO, 2018[43]). NOAA also developed the *US Climate Resilience Toolkit*, a website designed to help decision-makers – from farmers to policymakers – find and use scientific tools, information, and subject matter expertise to manage their climate-related risks and improve their resilience to extreme events. The Toolkit includes the Climate Explorer visualisation tool, which offers maps of climate projections at the county scale, and 'topic narratives' that explain how climate variability and change can impact particular regions and sectors of society, such as food and agriculture (NOAA, 2014[44]). Climate information is also available through private services, including as a bundled product with other agricultural inputs. Research suggests that private subscription services and free tools may be as important for farmers as services provided by universities, extension and government agencies (Haigh et al., 2018[25]).

Disaster impact data is a valuable risk management tool, as knowledge of past events can help identify vulnerabilities, and inform risk management policies and investments in risk prevention and mitigation. Moreover, timely provision of credible estimates of the agricultural losses associated with natural disasters is a critical component in the processes of official disaster declaration and disaster relief and recovery (Court, Hodges and Lollar, 2020[45]).

The United States does not report data on the agricultural impacts of natural disasters centrally; however, some information on natural disaster impacts is available from a range of USDA sources. USDA RMA's crop insurance database offers an insight into production losses related to natural disasters, publishing data on US crop insurance pay-outs at the US state and county levels by crop and for more than 20 types of disasters. However, this data provides an incomplete picture of disaster losses, as it covers losses incurred only by insured production.[17] For data on total disaster losses, the USDA Farm Production and Conservation Business Center is responsible for reporting on Sendai indicator 2c on direct agricultural losses due to hazardous events. Estimates are extrapolated from payments made to farmers under existing government programmes, specifically Federal Crop Insurance Program data for crop losses, and Livestock Indemnity Program (LIP) and the Emergency Livestock Assistance Program (ELAP) payments for livestock losses. Estimates only include farm production losses – for example, farmland rehabilitation after flooding or other natural disasters, damage to farm infrastructure and equipment, or input losses are not included, as no data are available to measure these. At the national level, NOAA tracks and evaluates weather and climate-related disasters with the greatest economic impact, namely those with losses exceeding USD 1 billion[18] (NOAA National Centers for Environmental Information, 2020[1]). The North American Alliance of Hazards and Disaster Research Institutes (NAAHDR), an alliance of hazards and disaster research centres and institutes throughout North America, also includes an array of research institutions involved in assessing disaster damages.

Agricultural impact data is also available to varying extents for some states, usually following an extreme event. In particular, the University of Florida's Institute of Food and Agricultural Sciences (UF/IFAS) Economic Impact Analysis Program regularly reports estimates of the agricultural losses associated with natural disasters. UF/IFAS has developed an online survey tool to harmonise and facilitate the collection of data on disaster impacts (Box 3) (FRED, 2018[46]). Other states also report agricultural losses for specific

[16] The *Useful to Usable* project is a collaboration between USDA's National Institute for Food and Agriculture (NIFA), nine Midwestern universities, NOAA's Regional Climate Centres, and the National Drought Mitigation Center.

[17] Since 2015, RMA data indicate that more than 80% of insured acres are covered at the 70% or higher level (NCIS, 2020[102]).

[18] The methodology and loss data used by NOAA are described in Smith and Katz (2013[100]).

extreme events. For example, North Carolina's preliminary impact assessment for Hurricane Florence provided estimates of direct and indirect impacts on the state's agricultural sector, including crop, livestock and commodity losses, as well as farm buildings, equipment, and infrastructure losses (NC Office of the Governor, 2018[17]).

Box 3. University of Florida's Economic Impact Analysis Program

The University of Florida's Economic Impact Analysis Program developed an online survey instrument to assist UF/IFAS Extension in collecting disaster impact information. The online survey addresses challenges UF/IFAS extension agents faced in collecting information in the field, as well as those faced by UF/IFAS faculty in using these data to determine the overall economic impacts associated with natural disasters, including:

- Redundant and sometimes uncoordinated efforts in response to requests by university administration and county- and state-level agencies.
- Confusion about the distinction between agricultural "losses" and "damages",[1] and the need to collect and evaluate information on those impacts separately.
- Issues related to the timing of losses, particularly for perennial crops.
- Difficulties in comprehensively evaluating the economic impacts of disasters given the complexity of Florida's agricultural sector.[2]

The survey instrument can be used to collect information on impacts caused by a range of extreme weather events, including crop and livestock losses and damage to farm infrastructure and equipment. All data for individual farm businesses and survey respondents remain confidential, and only group totals or averages are disclosed.

The online survey instrument harmonises and improves the timeliness and accuracy of reporting on observed damages caused by natural disasters. The survey will replace all previous reports filled out by UF/IFAS extension, thanks to its comprehensive nature and the ability to use it to generate multiple types of reports for different agencies. For example, the survey collects impact information in a format that is compatible with the requirements of USDA FSA disaster reporting and official disaster declarations, as well as the requirements of the Florida Department of Agriculture and Consumer Services. In 2020, UF/IFAS also used the online survey tool to assess the financial impact of COVID-19 on Florida's agricultural and marine industries.

Notes:
1. Losses generally represent a decrease in annual revenue flows for agricultural products and services due to reduced production levels, farm gate sales, or increased production costs. Damages, on the other hand, represent destruction of capital assets that must be replaced or repaired, or that have reduced capacity (Court, Hodges and Lollar, 2020[45]).
2. Florida produces nearly 300 different agricultural commodities, and the mix of these commodities varies widely across the state and by season.
Source: FRED (2018[46]); Court, Hodges and Lollar (2020[45]).

Given the wide availability of resources to support risk identification and assessment, and the frequent occurrence of various natural hazards in the United States, US producers have a good understanding of the current risk exposure of their operations. However, the extent of their awareness of how this risk environment is changing – and the implications for their operations – is less certain. Stakeholder feedback and literature on US producers' views on climate change suggest that on balance, producers believe that the climate is changing, and have noticed an increase in extreme weather events, although views vary by region. However, it is less clear whether producers consider that more frequent extreme events pose a risk to their operations, for example, see (Chatrchyan et al., 2017[47]; Niles et al., 2019[48]; Prokopy et al., 2015[49]). In this respect, commentators have noted that producers consider short-run factors such as market and weather conditions to be more important for farm management and planning.

3.3. Risk prevention and mitigation

Ex ante investments in measures to prevent or mitigate natural disaster risk can reduce the cost of disaster response and recovery, by addressing underlying vulnerabilities and reducing natural hazard exposure. Government policies and programmes can also encourage stakeholders to identify disaster risks to their own assets, address gaps in their resilience levels, and take steps to mitigate the impacts of natural hazards, including on agricultural production.

In the United States, a range of policies and programmes at the federal level aim to prevent and mitigate flood risks with structural measures such as levies, as well as the opportunities for nature-based solutions to mitigate floods. There is also growing recognition among government agencies, producers and other stakeholders of the role of soil health in mitigating the impacts of floods on farm.

A range of federal agencies have programmes for investing in structural measures to prevent and mitigate flood risks in rural areas, including the USACE, USDA NRCS and FEMA. The USACE is the principal federal agency engaged in constructing flood control infrastructure, and manages around 2 000 levee systems (approximately 23 000 km of levees). At a smaller scale, NRCS provides technical and financial assistance to support the construction of small levees and dams in rural areas through the WFPO programme.[19] The federal government pays all costs related to construction when they are for flood control purposes (Carter et al., 2018[30]). NRCS also provides technical and financial assistance to rehabilitate ageing watershed dam projects (including upgrading or removing dams) originally constructed under WFPO. FEMA administers several mitigation grant programmes that make funding available to states, tribes, territories, and local communities to reduce or eliminate the risk of repetitive flood damage. However, these grants rarely go to rural areas as local communities – and rural ones in particular – can lack the expertise and administrative capabilities to apply for and administer grants for mitigation activities. Moreover, FEMA's mitigation programmes are generally oversubscribed, and areas with critical facilities such as power plants and hospitals are prioritised (GAO, 2014[50]).

Non-federal entities also invest in flood control infrastructure, and most of the 160 000 km of levees across the United States are privately owned (USACE, 2020[51]). Public policies also provide communities and individuals with incentives to invest in flood risk prevention and mitigation. For example, the Stafford Act requires state, local, tribal, and territorial governments to develop and adopt FEMA-approved hazard mitigation plans as a condition for receiving certain types of non-emergency disaster assistance. Moreover, non-federal entities (including municipalities, irrigation districts and county flood control entities and private actors) may be required to share the cost of flood control projects.[20]

While flood prevention structures play a role in protecting assets in floodplains, levees and other flood control structures can encourage development – including agricultural development – in flood-prone areas and increase residual risks behind levees and downriver (Carter et al., 2018[30]). Moreover, levees do not prevent floods completely and most privately-owned levees are not designed to withstand severe floods – for example, levee failures featured prominently in the 2019 Midwestern Floods (Askew-Merwin, 2020[52]). Levees under the authority of the USACE are subject to inspections and assessed for their level of protection; however, only half have been assessed since the requirement was introduced in 2014. Of those that have been assessed, 5% are associated with a high to very high flood risk, and 15% with a moderate risk (ASCE, 2017[53]). The condition of the majority of privately-owned levees is unknown (USACE, 2020[51]).

Non-structural measures also provide producers with an incentive to mitigate flood risks to their assets. New agricultural structures (or substantial improvements to existing agricultural structures) built on 100-year floodplains in NFIP participating communities are required to meet FEMA's building requirements, which include elevating or flood proofing to or above the base flood elevation. However, producers in some areas – specifically, those located in vast and deep floodplains – can face challenges in meeting the requirements. A 2014 evaluation by the Government Accountability Office (GAO) found that FEMA's guidance on mitigating the risk of flood damage to agricultural structures was outdated and did not reflect developments in the size and scale of farm operations or the challenges of deep and vast floodplains

[19] Under the WFPO programme, a project cannot exceed 250 000 acres and no structure can exceed 12 500 acre-feet of floodwater detention capacity or 25 000 acre-feet of total capacity (Carter et al., 2018[30]).

[20] The Federal share of FEMA Hazard Mitigation Grants is usually 75%.

(GAO, 2014[50]). For example, it can be costly and complex to elevate large structures sufficiently in deep floodplains, and producers may lack suitable land outside of the 100-year floodplain to build structures. While FEMA has recently updated its guidance on agricultural structures (FEMA, 2020[54]), GAO had earlier found that these challenges resulted in some farmers 'working around' building requirements – for example, by making incremental additions that were below the NFIP threshold for substantial improvements – or forgoing insurance for their structures (GAO, 2014[50]). Moreover, this requirement only applies to new structures, such that existing structures remain exposed and vulnerable.

Nature-based solutions can also be a physically effective and cost-efficient option to mitigate and prevent flood risks (OECD, 2020[55]). At the farm level, various conservation practices can play a role in mitigating the risk of floods or their impacts, by improving floodplain functions and water infiltration, and preventing erosion. USDA conservation programmes provide nearly USD 6 billion annually for financial and technical assistance to farms to support the adoption of conservation practices on working land and for land retirement (USDA ERS, 2019[56]). NRCS also funds efforts to restrict land use in floodplains and to restore and enhance floodplain function and values through the EWPP-FPE programme. Since the mid-1990s, NRCS has enrolled 1 600 floodplain easements on over 75 000 hectares of land under the EWPP-FPE. In 2019, NRCS designated USD 217.5 million for the enrolment of floodplain easements in Arkansas, Illinois, Iowa, Kentucky, Louisiana, Minnesota, Mississippi, Missouri, Nebraska, North Carolina, Oklahoma, South Dakota, and Wisconsin (Stubbs, 2020[34]). In addition, eligibility for most federal commodity programme payments, including crop insurance premium subsidies, is subject to the recipients having established an individual farm-based conservation plan to protect highly erodible cropland and wetlands.

Stakeholder feedback and surveys have found that US producers recognise a need to adapt their operations in response to extreme weather events,[21] and many are already doing so (Arbuckle, 2020[57]; Chatrchyan et al., 2017[47]). In particular, there is increasing recognition of the role that healthy soil can play in mitigating floods on-farm, by improving water storage, infiltration and flow, and giving rain that could become floodwater "a place to go".

However, some producers are reluctant to adopt some soil health practices, in part because of a lack of evidence on the economic benefits. Stakeholders have also noted that financial constraints – specifically the cost of changing practices and the time and labour required – and the perceived riskiness of changing established farming methods may prevent farmers from adopting some practices such as cover crops (Bitterman, Bennett and Secchi, 2019[58]; Fleckenstein et al., 2020[59]), because they require an initial investment and/or reduce yields in the short term.[22] Farmland tenure arrangements can also shape farm decisions related to conservation, as producers may be reluctant or unable to implement soil health practices on rented farmland. Approximately 39% of farmland in the contiguous 48 states is rented, with that share rising to 60% or more throughout large portions of the Midwest and the Mississippi River Delta (Bigelow, Borchers and Hubbs, 2016[60]). Land tenure may influence on-farm investments to improve resilience, as renters and owners may have conflicting incentives on conservation and production practices, reflecting their financial interests in short- or long-term economic returns from agricultural land. For example, a 2014 survey found that landlords were often involved in decisions to implement permanent conservation practices on rented acres (Bigelow, Borchers and Hubbs, 2016[60]). Tenants may also be reluctant to invest in conservation practices if they may not have access to the land in the long term.

In response to some of these constraints, various soil health initiatives have emerged that aim to demonstrate and quantify the economic and environmental benefits of soil health practices to farmers, and provide technical and financial support for their adoption. These include NRCS's Soil Health Initiative, the Soil Health Partnership, and the National Association of Conservation Districts (NACD) Soil Health Champions Network and research (Box 4).

[21] Stakeholder interview with USDA National Climate Hub, 13 December 2019.

[22] Stakeholder interview with the National Association of Conservation Districts, 9 December 2019.

Box 4. Initiatives to promote soil health

Various soil health initiatives led by NRCS, producers and the conservation districts aim to promote and support soil health practices – such as cover crops and conservation tillage – by addressing constraints to on-farm adoption, including a lack of evidence on the economic and environmental benefits of those practices and the risks associated with changing farming methods.

NRCS's Soil Health Initiative offers technical and financial assistance to producers to adopt soil health practices and systems through various conservation programmes, including EQIP and the Conservation Stewardship Program (CSP). As part of the Initiative, NRCS is investing up to USD 25 million a year over five years to support on-farm trials and evaluation of innovative conservation practices on agricultural land as part of USDA's Conservation Innovation Grants programme, including a component focused on practices and systems that improve soil health (USDA NRCS, 2019[61]). NRCS has also released a series of farmer case studies on the economic benefits of applying soil health practices (USDA NRCS, 2020[62]).

The Soil Health Partnership (SHP) – a farmer-led research network that measures the impacts of implementing soil health practices on working farms – partners with state governments, commodity associations, non-profits, foundations and private companies to promote the adoption of soil health practices (SHP, 2020[63]). The SHP conducts on-farm field trials to compare soil health practices to historical field management, with findings communicated online, through farmer peer networks, and via field days. Other organisations also advocate for the benefits of soil health to improve farm performance. For example, the National Corn Growers Association promotes the SHP as its flagship sustainability programme.

The country's nearly 3 000 conservation districts – local units of government established under state law to carry out natural resource management programmes at the local level – work directly with landowners to conserve and promote healthy soils. The National Association of Conservation Districts (NACD) carried out four farm case studies in in the Mississippi River Basin in 2019, which offered year-to-year budget data and farmers' insights on why and how to use certain practices.[1] To promote soil health practices, NACD prioritises peer relationships, including through its Soil Health Champions Network, comprised of early adopters who promote soil health practices in their communities through field days and demonstrations (NACD, 2020[64]). NACD and other stakeholders are also advocating for lower insurance premiums linked to the implementation of certain soil health practices. While this has been constrained by a lack of data on their risk-reducing effect, Iowa and Illinois have offered USD 5 per acre discounts on crop insurance premiums based on the use of cover crops (IDA, 2021[65]; IDALS, 2020[66]), and a similar programme is planned for Indiana.[2]

Notes:
1. A further 25 case studies were planned for 2020.
2. Stakeholder interview with the National Crop Insurance Services, 3 February 2021.

Producers can obtain insurance to mitigate the financial impacts of natural hazards, including floods. The FEMA-managed NFIP makes federally backed flood insurance available to homeowners and other property owners, including farmers. The maximum coverage is USD 500 000 per building and USD 500 000 for contents, which for farmers can include machinery and equipment, harvested grain and stock. However, it is not clear what proportion of producers purchase flood insurance, or any type of private insurance for agricultural buildings and their contents,[23] or the extent to which this is because of the difficulties producers face in meeting FEMA's building requirements (as discussed above). As a case in point, in the context of the 2019 Midwest Floods, the Secretary of Agriculture noted that a very small share of farmers insure grain stored on farms (Good, 2019[67]).

[23] The National Flood Insurance Program is essentially the sole provider of flood insurance, as private provision is rare.

The Federal Crop Insurance Program offers subsidised insurance policies for yield and revenue losses caused by natural hazards, and more than 100 crops are eligible. RMA sets premium rates so that the premiums equal the expected payments to producers for losses in each year (i.e. are actuarially fair). The premium subsidy depends on the coverage level chosen, with most producers of major commodities choosing coverage levels between 70% and 85%. The federal government pays around 60% of total premiums on average (CBO, 2018[68]; Motamed et al., 2018[69]). Eligible producers[24] can also receive catastrophic (CAT) coverage without paying a premium.[25] Under CAT coverage, producers can receive a payment equal to 55% of the estimated market price of the commodity on crop losses in excess of 50% of normal yield (Stubbs, 2020[33]).

Crop insurance is highly regarded by public and private stakeholders as the primary policy tool for mitigating natural hazard risk. The programme is the largest of the 2018 Farm Bill farm programmes,[26] and accounted for around 15% of producer support in 2017-19 (OECD, 2020[12]). The agricultural area covered by crop insurance has steadily grown, and was approximately 300 million acres (121 million hectares) in 2017 (Motamed et al., 2018[69]), although the share of livestock and some specialty crops covered is low (CRS, 2018[70]; Rosa and Johnson, 2019[71]). Agricultural producers obtain a sizable benefit from the programme. For example, the Congressional Budget Office estimated that producers received about USD 65 billion more in claim payments than they paid in premiums between 2000 and 2016. Considered as a whole, producers' gross indemnities from claims exceeded their premium payments in all but one year during that period (CBO, 2017[72]).

For producers of crops that are not covered by federal crop insurance, NAP provides a basic level of coverage for losses exceeding 50% of expected production or prevented planting of 35% of intended acres, as well as options to purchase additional coverage. NAP applicants must also pay an administrative fee at the time of application, and producers who elect additional coverage pay a premium in addition to the administrative fee (Stubbs, 2020[33]). Producers can also obtain private insurance for some risks that cause spot losses via named-peril policies, such as for hail and fire. However, coverage for geographically correlated risks such as floods, drought and other natural hazards is generally limited to the Federal Crop Insurance Program.

3.4. Risk preparedness

Ex ante disaster preparedness and planning are crucial for effective crisis management – by public and private stakeholders with a role in disaster response, and on farms. Preparedness activities are an important and necessary complement to risk prevention and mitigation efforts, such that when natural hazards inevitably occur and disrupt agricultural activities, stakeholders have the networks, capacities and resources in place to manage a crisis effectively, minimise the disruptions to agricultural activities, and ensure a quicker and more resilient recovery (UNISDR, 2015[7]).

As noted in Section 3.1, disaster risk management in the United States is based on the principle of preparedness for all hazards. Rather than plan for every possible hazard, the NPS is based on capabilities-based planning, namely identifying and building the required capabilities that will help the whole community to prevent, protect against, mitigate, respond to, and recover from multiple hazards. Reflecting this, the NRCA includes tools to measure preparedness capabilities at the national and community levels – including a tool for jurisdictions to identify their preparedness gap called the Stakeholder Preparedness Review – which, together with the National THIRA, identify the national preparedness gap (FEMA, 2019[73]).

[24] Eligibility for most federal commodity programme payments, including crop insurance premium subsidies, is subject to the recipients having established an individual farm-based conservation plan to protect highly erodible cropland and wetlands.

[25] Although eligible producers do not pay a premium for CAT coverage, on enrolment, they are required to pay a USD 655 administrative fee per covered crop for each county where they grow the crop.

[26] Crop insurance is projected to account for 9% of total expenditures under the 2018 Farm Bill.

Disaster preparedness is also supported by "table top" or scenario exercises at the national and state levels involving a variety of actors. These help to build preparedness by identifying gaps in resilience levels and building ongoing networks and relationships for effective disaster response. FEMA leads national-level exercises every two years, with engagement by the whole community – including individuals, critical infrastructure sectors and the private sector (FEMA, 2020[74]). The Food and Agriculture critical infrastructure sector also participates in exercises to test the effectiveness of resilience procedures, with the outcome of each scenario providing feedback on how to enhance the protection of critical infrastructure (FDA, USDA and DHS, 2015[29]). State departments of agriculture also conduct disaster preparedness exercises, with recent exercises largely focusing on animal diseases such as Foot and Mouth Disease.

Stakeholders value developing relationships and networks for disaster risk management and capacity building before disasters occur, noting the importance of networks for effective disaster response.[27] For example, FEMA conducts emergency response exercises with states, including in the lead up to hurricanes. Such preparedness activities helped to strengthen the disaster response in states affected by the 2017 hurricanes and wildfires by building relationships among federal, state, and local partners (GAO, 2018[75]). At the national level, the Food and Agriculture critical infrastructure sector enhances collaboration and communication between USDA, FDA, and owners and operators of food and agriculture critical infrastructure, and with stakeholders in other critical infrastructure sectors.

Natural hazards – and other critical risks to agriculture and food systems – often have regional impacts, affecting agriculture in several states. Recognising this, various multi-state consortia are in place to build capabilities at the state level, maximise resource sharing, and minimise duplication of effort. The Multi-State Partnership for Security in Agriculture is a collaboration of state departments of agriculture, state veterinarians, animal health departments, Homeland Security advisors, and emergency management divisions of 15 Midwestern states.[28] The Multi-State Partnership has undertaken a range of projects to support emergency preparedness and response, including risk and crisis communication materials, emergency planning templates (for crops, livestock, and food processing), business continuity strategies, just-in-time training, and exercises to ensure the viability of agricultural systems during emergencies. For example, the *Prep4AgThreats* project developed a booklet and website that compiled educational material and information available from federal agencies such as FEMA, NOAA, USDA and USGS, to help agricultural communities prepare for a range of hazards, including floods (Multi-State Partnership, 2016[76]).

Overall, industry reporting[29] and surveys of USDA programme agency staff and co-operative extension agents suggest that farmers undertake a range of activities to prepare in advance of a potential hurricane or flood event (Wiener, Álvarez-Berríos and Lindsey, 2020[77]). Farmers can access information and resources on flood and hurricane preparedness from a range of sources, including USDA and its programme agencies. At the national level, USDA provides information on disaster assistance programmes, particularly in the lead up to a natural hazard event. USDA APHIS also provides information on protecting livestock during a disaster and links to other emergency resources. Region-specific information is available through a range of sources, including the USDA Climate Hubs (Box 2), state departments of agriculture, and the Cooperative Extension System (CES). All employers with 10 or more employees, including farm businesses, are also required to make a printed copy of an emergency action plan available to all employees.

Despite the wide availability of resources, some commentators have noted that a lack of scientific evidence on commodity-specific practices has been a barrier to effective hurricane preparedness (Wiener, Álvarez-Berríos and Lindsey, 2020[77]). To address this gap, the USDA Climate Hubs have recently produced a series of state-specific commodity manuals containing best practices and steps that producers in south-eastern states can take to prepare for and recover from hurricanes. For example, the manuals include information on drafting a farm emergency plan, guidance on essential documentation to have prepared in case of evacuation, and links to local, state and federal resources and sources of information (USDA,

[27] Stakeholder interview with the National Milk Producers Federation, 9 December 2019.

[28] Other regional alliances are the Southern Animal and Agriculture Disaster Response Alliance (SAADRA), the Mid-Atlantic Agriculture and Animal Emergency Management Alliance (MAAEMA), and the New England States Animal Agriculture Security Alliance (NESAASA).

[29] For example, https://www.agweb.com/article/how-north-carolina-farmers-prepared-for-hurricane-florence; https://www.floridamilk.com/in-the-news/blog/farming/how-do-dairy-farmers-prepare-for-hurricanes.stml.

2020[78]). More broadly, region- and hazard-specific resources on disaster preparedness – including various tools and information on good practices – are also available on the USDA Climate Hubs website and via the *Climate Hubs Tool Shed*, an online searchable database of tools and good practices.

Locally-based organisations, such as co-operative extension agents, Farm Bureaus and local USDA staff are also trusted sources of information due, to a significant extent, to having local knowledge of issues and established relationships with community members (Chatrchyan et al., 2017[47]; Niles et al., 2019[48]). In particular, the CES is an important source of non-formal education and information on natural hazard preparedness, providing research-based information to stakeholders through its connection to the US land-grant colleges and universities. More broadly, the CES also provides extension on overall farm risk management that can contribute to improved farm-level capacity to manage natural hazard risk (for example, farm financial benchmarking).

To ensure sufficient institutional capacity to help farmers prepare for and manage disasters, a number of initiatives aim to build the capacities of extension providers, industry organisations and local USDA staff. The USDA Climate Hubs build the capacities of USDA's programme agencies and industry organisations by connecting them with USDA's science agencies, and help to ensure that research outputs meet the needs of end users. USDA's National Institute for Food and Agriculture (NIFA) supports disaster education through the Extension Disaster Education Network (EDEN), a collaborative multi-state effort with NOAA, land-grant colleges and universities and CES across the country. EDEN supports local extension agents with research-based education and resources on disaster preparation and mitigation, and helps them to build relationships with their local and state emergency management (EDEN, 2018[79]). NIFA also supports risk management education more broadly through the Extension Risk Management Education (ERME) programme. The ERME programme provides risk management training to help producers learn and use tools and approaches that can reduce the adverse effects of different sources of agricultural risk. The four regional ERME centres conduct an annual competitive grant programme, which provides funding for educators to develop and deliver risk mitigation training (ERME, 2020[80]).

3.5. Disaster response and crisis management

Effective crisis management and disaster response hinge on all actors knowing their responsibilities in the event of an emergency and communicating effectively, with the public sector taking a leadership role when the private sector is unable to cope.

Alerts and real-time information on imminent hazards are provided by several agencies. NOAA develops and issues forecasts, watches and warnings for floods through the National Weather Service (NWS), and for hurricanes through the National Hurricane Center. The NOAA Weather Radio All Hazards is a nationwide network of radio stations that broadcast warning and post-event information for all types of hazards, as well as continuous weather information from the NWS. The USGS has responsibility for issuing alerts about earthquakes, landslides and volcanic eruptions. Information on drought is provided weekly through the US Drought Monitor, a map that shows which parts of the United States are in drought, and the severity of drought conditions.

For all disasters requiring federal co-ordination, the immediate response is generally guided by the *National Response Framework* (NRF), one of the five National Planning Frameworks, which defines the roles and responsibilities of different levels of government, as well as the private and non-profit sectors (OHS, 2019[81]). While FEMA has primary responsibility for co-ordinating disaster response, other federal agencies also assist. Specifically, the NRF defines 15 Emergency Support Functions (ESFs) for areas that most frequently need a co-ordinated federal response and resources, and assigns roles to different agencies. USDA is responsible for co-ordinating ESF #11 – Agriculture and Natural Resources, which organises and co-ordinates federal support to provide nutrition assistance; provide technical expertise in support of animal and agricultural emergency management; and ensure the safety and defence of food supply, among other functions. USDA also has supporting roles in the other ESFs.[30] For major disasters, such as those that result in a Stafford Act Declaration, FEMA activates the ESFs through "mission assignments", which direct co-ordinating federal agencies to undertake specific tasks. Within USDA, the

[30] With the exception of ESF #13 – Public Safety and Security. USDA's Fire Service is joint ESF Coordinator for ESF #4 – Firefighting, with the U.S. Fire Administration, an entity of FEMA.

Animal and Plant Health Inspection Service (APHIS) co-ordinates ESF #11, while for smaller-scale or agriculture-related disasters, OHSEC co-ordinates the response.

For all incidents, the approach to sharing resources, co-ordinating and managing incidents, and communicating information between jurisdictions and organisations is defined by the National Incident Management System (NIMS). The NIMS provides a consistent nationwide template to enable all government, private sector, and nongovernmental organisations to work together during domestic incidents. Key components include Multiagency Coordination groups (MAC), which co-ordinate the response and prioritise (potentially competing) demands for resources.

During a disaster, situational information – on potential impacts, evolving assistance needs and available resources – is an important input for a co-ordinated and effective response. Within USDA, several agencies provide situational information to support disaster response. For example, during hurricanes, OHSEC's Emergency Programs Division (EPD) co-ordinates information on which local USDA offices are open or closed during a hurricane, and the availability of USDA staff. The EPD also works with USDA meteorologists to track and forecast hurricane movements, and with APHIS to understand potential impacts on livestock. NASS contributes remotely sensed data and geospatial techniques to provide near-real time quantitative assessments of production impacts of disasters – for example, based on maps of flooded agricultural land, combined with knowledge of the potential impacts given the development stage of crops in affected areas (USDA NASS, 2020[82]).

US disaster frameworks also recognise that during disasters, the private sector can contribute resources, capabilities, and expertise in support of disaster response and recovery operations, and help ensure business continuity. Before, during and after disasters, FEMA co-ordinates with the private sector through the National Business Emergency Operations Center (NBEOC),[31] a virtual platform for two-way information sharing between public and private sector stakeholders. The NBEOC integrates private sector stakeholders into disaster operations and facilitates information sharing between public and private sector actors on existing needs and capabilities. Similarly, the 16 critical infrastructure sectors also facilitate information flows on where, and what kinds of assistance, are needed. For example, after Hurricane Irma made landfall in 2017, Food and Agriculture critical infrastructure sector stakeholders worked with Florida's State Agricultural Response Team and other public and private entities to prevent dairies in Okeechobee, Florida from running out of feed.

At the local level, the USDA programme agencies' role in disaster response is focused on providing information on disaster assistance programmes to affected producers. For major disasters, USDA deploys "jump teams" to help locally-based FSA and NRCS staff cope with increased demand for support. In this, USDA is also supported by other organisations, including the Farm Bureau and conservation districts, and local extension agents (including via EDEN). For example, conservation districts help landowners to navigate FEMA paperwork in order to apply for emergency assistance. Similarly, state Farm Bureaus supported the response to the Midwest Floods by organising fodder deliveries, and have worked with hog producers during hurricanes to reduce environmental impacts from overflowing waste lagoons.

3.6. Recovery and reconstruction

Following a natural disaster, recovery and reconstruction efforts offer an opportunity for public and private stakeholders to "build back better" by addressing underlying gaps in resilience, and building the capacities needed to manage natural hazards in the future (FAO, IFAD and WFP, 2019[9]). This requires all stakeholders – including producers – to learn from natural disasters in order to adjust DRM frameworks, policy measures and on-farm strategies with a view towards long-term resilience (OECD, 2014[8]; OECD, 2020[3]).

Recovery from disasters is guided by the *National Disaster Recovery Framework* (NDRF), one of the five National Planning Frameworks. The NRDF emphasises pre-disaster recovery planning and preparedness, and outlines co-ordinating structures and roles and responsibilities of different levels of government in short- and long-term recovery efforts following a disaster event (OHS, 2016[83]). Similar to the NRF, federal

[31] Participation in the NBEOC is voluntary and open to all organisations with significant and multistate geographical footprints in the private sector.

support for recovery is organised around Recovery Support Functions (RSFs). In the event that the President issues a major disaster declaration (pursuant to the Stafford Act), federal disaster assistance is made available to individuals, state and local governments, and non-government entities, primarily through programmes administered by FEMA. Since 2018, the Disaster Recovery Reform Act (DRRA)[32] has also authorised the President to set aside 6% of certain disaster assistance grants to use for pre-disaster hazard mitigation.

For many US producers, financial concerns are the most important barrier to – and priority for – recovery after a natural disaster (Wiener, Álvarez-Berríos and Lindsey, 2020[77]). Producers can access support from a range of federal disaster assistance programmes (Section 3.1). Only Emergency Disaster Loans require a disaster designation – for floods, this can take the form of a Presidential major disaster declaration or a USDA Secretarial disaster designation. To receive a disaster designation, a county must have experienced a 30% production loss of at least one crop, or a determination must be made by surveying producers that other lending institutions will not be able to provide emergency financing (USDA FSA, 2020[31]). While producers' assessments of their losses can be used to guide state and federal assistance, state departments of agriculture and CES staff also co-ordinate with FSA and NRCS offices to collect information on losses and ensure that producers properly document damage and losses within the required time frames.[33]

Assistance is received most quickly through the Federal Crop Insurance Program, which can provide payments two weeks to 30 days after loss adjustment (which usually takes place after harvest). These indemnities can be important for addressing cash flow constraints that impede the restoration of farm operations. In contrast, *ad hoc* disaster assistance is generally received at a considerable delay to the natural disaster that precipitates it. However, lower crop insurance participation for specialty crops – for example citrus, which was significantly impacted by recent hurricanes – can lead to calls for *ad hoc* assistance.

The authorisation of the Supplemental Agricultural Disaster Assistance Programs in the 2008 and 2014 Farm Bills, as well as expanded crop insurance over time – both in terms of commodity coverage and higher premium subsidies – and the availability of NAP policies, were intended to reduce the need for ad hoc disaster assistance (Stubbs, 2020[33]). However, this has not been the case. In recent years, ad hoc support has been provided in response to hurricanes and wildfires in 2017, and hurricanes, floods, tornadoes, typhoons, volcanic activity, snowstorms and wildfires in 2018 and 2019 (Figure 3 and Box 5).

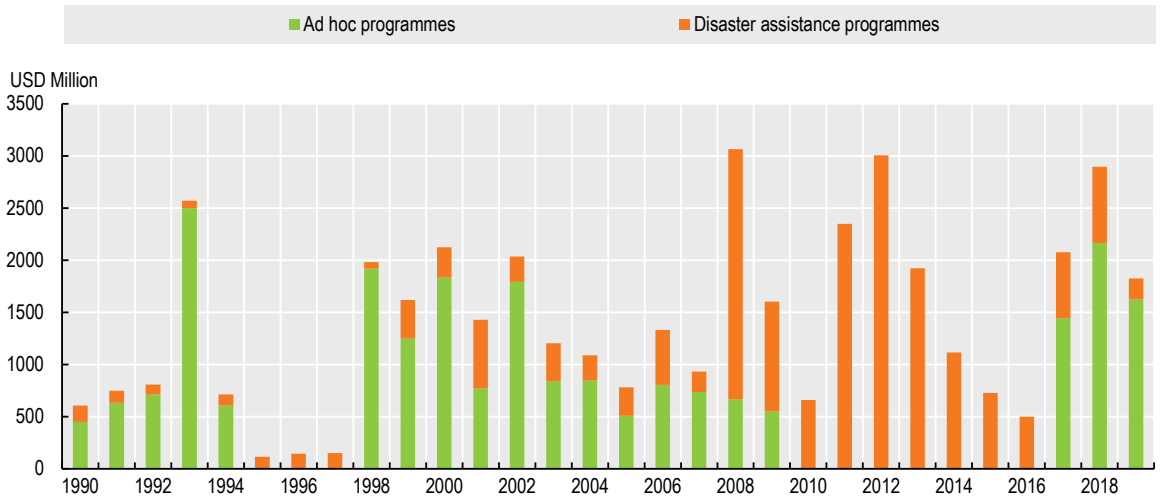
Following a flood, USDA also provides cost-shared assistance[34] for farmland rehabilitation through several programmes, including FSA's Emergency Conservation Program (ECP) and NRCS's Emergency Watershed Protection (EWP) programme (Section 3.1). Neither ECP nor EWP can be used to address problems that existed prior to the natural disaster, and there are limits to how frequently producers can receive funding. USDA also uses some existing conservation programmes to assist with rehabilitating land following natural disasters. For example, USDA has announced special EQIP sign-ups for producers in hurricane- or flood-affected areas (Stubbs, 2020[34]).

[32] Ibid footnote 7.

[33] For example, owners or contract growers who apply for the Livestock Indemnity Program (LIP) must file a notice of loss within 30 calendar days of when the loss of livestock is first apparent as well as file an application for payment within 60 calendar days after the end of the calendar year in which the eligible loss condition occurred.

[34] This can be up to 75% of the cost, or up to 90% of the cost if the producer or area is considered to be a limited-resources producer or area.

Figure 3. *Ex post* natural disaster assistance to US agriculture, 1990-2020



Notes: Ad hoc programmes includes: Cottonseed disaster payments; Dairy disaster payment; Sugar beet disaster payment; Crop disaster payments (ad hoc); WHIP Crop disaster payments (ad hoc); WHIP+ Crop disaster payments (ad hoc); and WHIP+ Milk Loss (ad hoc). Disaster assistance programmes includes: Supplemental Revenue Assistance Payments (SURE) Program; Noninsured Crop Disaster Assistance Program; Tree and vineyard disaster payments; Dairy Indemnity Payment Program; Livestock indemnity program (disaster relief); Emergency Assistance for Livestock, Honeybees and Farm-Raised Fish; Emergency assistance loans; Feed assistance.
Source: OECD (2020[84]), "Producer and Consumer Support Estimates", OECD Agriculture statistics (database), https://doi.org/10.1787/466c3b98-en.

Box 5. Wildfires and Hurricanes Indemnity Program (WHIP and WHIP+)

In response to hurricanes and wildfires in 2017, the *Bipartisan Budget Act of 2018* (BBA) provided USD 2.36 billion in disaster assistance to agricultural producers, which was implemented through the *Wildfires and Hurricanes Indemnity Program* (WHIP). USDA also provided a grant to the State of Florida to reimburse citrus producers for the cost of buying and planting replacement trees and repairing damage to irrigation systems, and for future losses sustained in the 2019, 2020 and 2021 crop years resulting from damage caused by the 2017 hurricanes.

In 2019, the *Additional Supplemental Appropriations for Disaster Relief Act of 2019* authorised just over USD 3 billion[1] in disaster assistance for crop losses related to hurricanes, floods, tornadoes, typhoons, volcanic activity, snowstorms and wildfires occurring in 2018 and 2019. The assistance was provided through three programmes:

- The *Wildfire and Hurricane Indemnity Program Plus* (WHIP+) for losses to eligible crops, trees, bushes, and vines.
- The *On-Farm Storage Loss Program* for eligible producers who suffered losses of harvested commodities (including hay) that were stored in on-farm structures.
- The *WHIP Milk Loss Program*, which provided payments to dairy operations for milk that was dumped or removed without compensation from the commercial milk market due to qualifying weather events in 2018 and 2019 that prevented the delivery of milk.

The *Disaster Relief Act* also provided USD 800 million – as part of the USD 3 billion package – in state block grants to agricultural producers in Alabama, Florida, and Georgia who were affected by hurricanes Michael and Florence.

In addition, a top-up payment was provided to producers who claimed prevent plant losses in 2019 through their federal crop insurance policy.[2]

A number of conditions associated with payments under WHIP and WHIP+ aimed to avoid creating a moral hazard for future participation in other risk management programmes, namely federal crop insurance and NAP. Producers with crop insurance or NAP coverage were eligible for higher loss compensation than those who were uninsured. In addition, producers receiving WHIP and WHIP+ payments were required to purchase crop insurance at the 60% coverage level or higher, or NAP if crop insurance is not available, for the next two crop years after payments were received. If producers failed to purchase crop insurance for the next two consecutive years, they were required to pay back their WHIP+ payment.

Notes:
1. Approximately 60% of 2017 WHIP went unobligated before funds expired on 31 December 2019. Those funds were repurposed to WHIP+ with expanded eligibility and additional programme requirements (Stubbs, 2020[33]). The same legislation also added excessive moisture, extreme drought and exceptional drought (d3 and d4 drought designations on the US Drought Monitor) to the list of qualifying events for WHIP+.
2. Under provisions of the Disaster Relief Act, the Federal Crop Insurance Corporation (FCIC) established prevented planting supplemental disaster payments for producers who were prevented from planting eligible 2019 crop year crops in the 2019 calendar year due to specified causes of loss.
Source: OECD (2019[85]; 2020[12]).

While these programmes can help producers to restore land to agricultural production, funding arrangements reduce how flexibly they can be used. In contrast to the Supplemental Agricultural Disaster Assistance Programs, which receive mandatory funding of "such sums as necessary" through the Commodity Credit Corporation, funding for ECP and EWP is variable, discretionary, and provided on an ad hoc basis (this is also the case for NRCS's flood mitigation programme, EWPP-FPE) (Stubbs, 2020[34]). Since most agriculture-related disasters do not trigger a standalone supplemental appropriations bill, funding for ECP and EWP depends on annual appropriation bills, which may not coincide with natural disasters and periods of high demand. Further, the Budget Control Act of 2011 requires that supplemental appropriations for disaster assistance be used for activities with a Stafford Act designation, meaning that funding for ECP and EWP received through supplemental appropriations can be used for fewer events. In the case of ECP, the 2018 Farm Bill required that 25% of all ECP funding made available in a fiscal year be set aside for repair and replacement of fencing, an activity that is not necessarily relevant for all disasters or farms (Stubbs, 2020[34]).

When incremental or adaptive changes are insufficient to reduce a farm or industry's exposure and vulnerability to natural disasters, more significant transformative changes may be required (OECD, 2020[3]). This need for transformation has been recognised in some areas of the country that are at high risk for flooding. In one example, following severe flooding in 1999, North Carolina created the voluntary Swine Floodplain Buyout Program, which provided support to pork producers to allow them to close down their hog operations and transition the land to conservation easements. Since 1999, the programme has bought out 43 swine operations in the 100-year floodplain at a cost of USD 18 million. A fifth phase, with around USD 5 million in funding, was approved following Hurricane Florence in 2018. An analysis by the state's Department of Agriculture indicated that, had the farms not been bought out, many would have flooded during subsequent hurricanes (National Pork Council, 2018[86]).

Post-incident evaluations provide an important opportunity to identify and address gaps in processes and co-ordinating mechanisms for disaster response and recovery, as well as gaps in resilience more broadly. After major disasters, FEMA's standard practice is to prepare an after-action report that identifies strengths, areas for improvement, and potential best practices identified during response and recovery efforts. While this process has identified areas for improvement and lessons learned following disasters, recent reviews have determined that FEMA has completed after-action reports for only 29% of disasters from 2017 through 2019 (GAO, 2019[87]). Agricultural sector stakeholders – including the Food and Agriculture critical infrastructure sector and APHIS as the co-ordinator of ESF #11 – also participate in multi-jurisdictional and cross-sector after-action report processes. Within USDA, FSA and RMA evaluate NAP and crop insurance payment data to identify counties and producers who frequently receive payments, as this may indicate the use of inefficient practices or crops that are poorly suited to the region. In addition, local offices of FSA and NRCS, as well as state Farm Bureaus, provide a pathway for producers to provide feedback on programmes and their implementation. However, these processes appear to focus on the performance of policies, rather than identifying key resilience gaps that could be addressed in advance of the next event.

In contrast, the Climate Hubs conduct inter-disciplinary post-disaster assessments that aim to understand the factors that contribute to vulnerability to natural disasters, and identify practices that built resilience ahead of the incident. For example, the 2018 *Strengthening Resilience After a Disaster* initiative aimed to develop recommendations to build resilience through technologies and practices, streamline response and recovery efforts, and enhance critical services in rural areas based on assessments of hurricanes and wildfires in previous years.

4. Analysis and assessment

4.1. Agricultural risk management and disaster assistance policies are comprehensive, but resilience objectives could be better integrated into farm programmes

As noted in Section 3.1, strong and effective governance arrangements are crucial for building agricultural resilience to natural hazard-induced disasters. The United States' emergency management frameworks establish an all-hazards approach to disaster risk management, in which the whole community is responsible for building the capabilities needed to prevent, protect against, mitigate, respond to, and recover from hazards. A nationally consistent approach to disaster risk management is supported by the NRCA and its tools for assessing risk and capabilities for managing risk, which all jurisdictions are encouraged to use. National frameworks also establish formal mechanisms for engaging with the private sector, as owners and operators of critical infrastructure and as an important source of information, resources, capabilities and expertise before, during and after an incident.

Agricultural risk management policies are comprehensive, although perceived gaps in the coverage of some programmes – for example, low participation for some specialty crops under the Federal Crop Insurance Program – have contributed to calls for ad hoc assistance in recent years. In the event of a disaster designation, producers have access to a range of programmes that provide compensation for losses caused by natural hazards, including crop insurance, Emergency Disaster Loans and the Supplemental Agricultural Disaster Assistance Programs. However, the recent return to providing ad hoc disaster assistance undermines the *ex ante* framework established by USDA's agricultural risk management and disaster assistance policies, and in turn, producers' incentives to adjust their operations in response to evolving natural hazard risk (Figure 3). Moreover, although WHIP and WHIP+ may have encouraged producers to implement additional risk coping strategies, by requiring producers to purchase either crop insurance or NAP (see Box 5), ad hoc disaster assistance is a potentially significant barrier to resilience-enhancing adaptation and transformation in the US agricultural sector. This is because the expectation of ad hoc disaster assistance can lead producers to take on more risk by reducing insurance coverage and their use of other on-farm strategies to self-insure against production shocks (Deryugina and Kirwan, 2018[88]).

There is also a need to better integrate resilience objectives into existing farm safety net programmes in the context of the sector's exposure to natural hazards, which is expected to intensify and increase in frequency with climate change. To some extent, the USDA Climate Hubs are progressing this through their work with USDA agencies, including to better integrate consideration of climate change impacts into farm programmes. However, these links could be strengthened, including by increasing the profile of the Climate Hubs among all stakeholders. At the same time, it is important that stakeholders acknowledge the need for programmes that complement risk coping policies. For example, while crop insurance is highly regarded by producers and other stakeholders as an important coping tool, there are limits to how programme design can encourage producers to take adaptive or transformative actions. For this reason, a greater emphasis on increasing the utility of programmes that promote adaptation or transformation is also needed.

There is also a need to evaluate farm programmes to identify how producers make trade-offs among risk management and disaster assistance programmes – and between those programmes and on-farm strategies for managing natural disaster risks – and the implications for natural hazards resilience. Policymakers and USDA could also explore opportunities to redirect resources and enhance incentives in farm programmes in order to encourage producers to adapt and transform in response to future natural hazard risks (Croft et al., 2020[89]).

4.2. Producers and other stakeholders can access extensive science-based and targeted information and tools for adapting to climate and natural hazard risks

A shared awareness and understanding of natural hazard risks is important to encourage public and private investments in natural disaster risk prevention, mitigation and preparedness, and reduce reliance on national governments for post-disaster assistance (OECD, 2014[28]; OECD, 2017[90]). The United States has extensive scientific capability for natural hazard risk identification and assessment, and organisations such as USGS and NOAA benefit from high levels of public trust. These agencies also prioritise communication about natural hazard impacts, and numerous initiatives, such as the US Climate Resilience Toolkit, aim to address gaps in stakeholders' awareness of their exposure and vulnerability to natural hazards, and offer solutions to address those gaps.

Within agriculture, producers and other agricultural stakeholders, such as county extension and local USDA staff, have access to science-based and targeted information and online tools on climate and extreme weather events, and strategies for reducing natural hazard risk. This includes information and tools developed by the USDA Climate Hubs, universities and government agencies, as well as tools and services offered by the private sector. An important feature of many of these initiatives is that they place significant emphasis on the co-production of information and tools by involving end-users in their development, to enhance their usability and relevance, and on tailoring climate information to meet the needs of producers in specific regions.

However, while there is no shortage of information, it is not clear whether it is acted upon and integrated into planning and decision-making. Commentators have noted that producers and agricultural advisors underutilise climate information and decision support tools due to factors such as low trust in their accuracy and a lack of local context, among other factors (Chatrchyan et al., 2017[47]; Haigh et al., 2018[25]). To this end, it is important that producers and other stakeholders continue to be included in the development of these tools, to ensure that they are useful and locally relevant. Commentators have also noted the relatively low awareness of the decision-support tools developed by the Climate Hubs, and indeed, of the Climate Hubs more broadly (Bottemiller Evich, 2019[91]). This suggests that more could be done to increase the profile of the Climate Hubs among all stakeholders. At the same time, given the importance of locally-based organisations as trusted sources of information for producers, it will be important to continue to develop the capacities of county extension agents and local USDA staff to communicate and integrate information on climate change and natural hazard risks into farm advisory services, including through initiatives such as EDEN. Other trusted non-government organisations, including commodity and producer interest groups such as the Farm Bureau, could also play a larger role in promoting natural hazard risk awareness to improve the preparedness of their stakeholders.

Finally, there are opportunities to increase awareness of the risks posed specifically by extreme floods in the long-term in several key areas. First, efforts to collect data on production losses and damage to farm infrastructure and equipment could be extended, and this information could be made publicly available, in order to help identify vulnerabilities, guide investments in risk prevention and mitigation, and inform revisions to disaster assistance programmes. This information could also be used to target voluntary NRCS programmes that support flood risk mitigation to areas with the highest potential for reducing overall flood impacts, including to non-farming activities and assets. For example, NRCS's easement programmes EWPP-FPE and ACEP-ALE could be targeted to producers on deep and vast floodplains. Second, revising FEMA's floodmaps, including by incorporating future flood risks projected under climate change, would ensure that producers clearly understand the nature of flood risks to their operations. Third, producers in areas protected by levees can be made aware of residual flood risks and the risk of levy failure, and the importance of flood preparedness given this risk.

4.3. Conservation programmes and soil health initiatives help to mitigate flood risks and impacts, but measures to prevent and mitigate natural hazard risks are under-emphasised

Applying a resilience approach to the risk of extreme floods requires stakeholders, both public and private, to shift their focus from coping with the impacts of floods and instead place a greater emphasis on what can be done *ex ante* to reduce risk exposure and increase preparedness.

A growing number of public and joint public-private initiatives aim to improve on-farm resilience by promoting strategies to mitigate the impacts of floods and other weather-related hazards on production – most notably, the various soil health initiatives led by producers (e.g. the SHP), conservation districts and NRCS. These initiatives share a number of strengths, in that they engage with, and benefit from the support of, a diverse range of stakeholders; support on-farm experimentation with adaptation; prioritise communication with producers, including via peer networks; and build the evidence base on the economic and environmental benefits of soil health practices, thereby addressing an important information constraint to their adoption on farm and lowering the risks to farmers from changing farming practices. The United States also has long-standing programmes that support nature-based solutions for flood risk mitigation, specifically NRCS conservation programmes for working land such as EQIP, and land retirement programmes such as EWPP-FPE and CRP.

But in general, agricultural stakeholders appear to under-emphasise measures for natural hazard risk prevention, mitigation and adaptation, including flood risk. First, the Climate Hubs face significant constraints in terms of funding and staffing levels,[35] despite their key role in delivering science-based services and tools on climate and natural hazard adaptation and demand for their programmes and products (Croft et al., 2020[89]; Elliot, 2020[92]). Second, disaster assistance programmes in the 2018 Farm Bill – the key policy framework for the sector – prioritise support that helps producers to cope with the impacts of natural disasters such as floods despite the importance of helping the sector adapt or transform in the wake of flood events. Indeed, most of these programmes lack guidance on – or any requirement to take – actions to reduce natural hazard exposure and vulnerability, including as a condition to receive future assistance (Croft et al., 2020[89]). This is a missed opportunity to send a clear signal about the need for adaptation, and to invest in and build the necessary capacities for mitigating the risks and impacts of natural hazards. This is further reinforced at the policy level by inflexible funding arrangements that constrain how NRCS can use available funding to support land retirement programmes for reducing flood risk, including through EWPP-FPE.

Agricultural risk management policies may also discourage producers from adapting their enterprises to prevent and mitigate the risks posed by floods and other natural hazards in the long term. In particular, attention has focused on crop insurance, which for many public and private stakeholders is the primary policy tool for mitigating natural hazard risk. The programme has important strengths: producers participate financially by purchasing insurance; payments are made quickly after a natural disaster, which helps to address cash flow constraints; and RMA can adjust premium rates and coverage to reflect production losses due to recent events, such that on average in a county, total premiums are expected to equal gross indemnities. Stakeholders also find that the financial security provided by crop insurance may be an important enabler for on-farm adaptation and the adoption of more resilient practices (Fleckenstein et al., 2020[59]), particularly those that require an initial investment and/or reduce yields in the short term. Moreover, although past reviews have argued that crop insurance requirements may constrain producers from adopting new practices that can increase resilience in the long-term (GAO, 2014[93]; 2019[94]), [36] the 2018 Farm Bill introduced additional flexibilities, including for cover crops.

However, while premiums fully reflect expected losses over the one-year term of the insurance contract, subsidies (around 60% of the premium on average) mean that producers do not bear the true cost of their risk of loss, which could affect farming decisions and induce maladaptive practices. Higher premium subsidies have been an important factor in increasing participation, and various programme features exist to deter moral hazard, including deductibles, experience rating and nonlinear pricing as coverage increases. This also makes the programme preferable to ad hoc disaster relief, which typically lacks these features (Deryugina and Kirwan, 2018[88]). Nevertheless, subsidised insurance (where premiums paid do not accurately reflect the underlying risk) has been found to discourage farm-level adaptation to a changing climate by blunting incentives to cultivate more resilient crops or by encouraging farming in riskier locations (Annan and Schlenker, 2015[95]; Chen and Dall'Erba, 2018[96]; Ignaciuk, 2015[97]).

[35] A 2017 Congressional Research Service report found that Climate Hubs funding was approximately USD 9 million (FY2016) to USD 13 million (FY2019) a year, contributed by several USDA agencies (Croft et al., 2020[89]).

[36] Producers are required to follow approved farming practices for their region in order to ensure yields that are consistent with historical production.

Going forward, it is important that stakeholders recognise the need to prevent and mitigate the risks and impacts of floods and other natural hazards to production and other assets on farm. This could be achieved by integrating resilience-enhancing practices into existing farm programmes, including disaster assistance programmes, and by placing a greater weight on the potential for natural hazard risk mitigation when valuing land in for enrolment in various conservation programmes. For example, the potential for flood risk mitigation – including for downstream areas – could be prioritised when considering farmland in flood prone areas for enrolment in CRP. These efforts could also be supported by increasing resources for the Climate Hubs, as an important source of science-based, region-specific information and technologies for climate-informed decision-making and adaptation.

4.4. Formal networks build disaster preparedness and response capacities, but more could be done to support a resilient recovery

Effective crisis management in the United States is supported by frameworks that clearly outline co-ordinating structures for disaster response, and the roles and responsibilities of different agencies and actors. “Table-top” exercises and well-established networks allow stakeholders to develop relationships and build capabilities for disaster preparedness before an incident occurs, strengthening disaster response and recovery. At the national level, the Critical Infrastructure Sectors framework and NBEOC are valued by agricultural stakeholders for connecting public and private actors before a hazard occurs, and for their role in improving the effectiveness of disaster response and supporting business continuity. At the state level, networks such as EDEN and the Multi-State Partnership for Security in Agriculture also build disaster preparedness and response capabilities, and minimise duplication of effort across states.

At the farm-level, locally-based organisations such as co-operative extension, Farm Bureaus and local USDA agencies are trusted sources of information on natural disaster preparedness, and provide support for disaster response. Producers can also access information to help them prepare for and recover from natural hazards, which is increasingly tailored to the specific needs of commodities and regions. However, much of this information lacks recommendations on longer-term preparedness (Wiener, Álvarez-Berríos and Lindsey, 2020[77]) or how to “build back better” by addressing underlying vulnerabilities and reducing future risk exposure. While short-term considerations are a priority for producers following a natural disaster, rebuilding offers an important opportunity to address underlying gaps in resilience and build the capacities needed to manage natural hazards in the future (Gruère, Ashley and Cadilhon, 2018[98]). Moreover, producers may be more receptive to information and technical advice after an extreme event, as a result of heightened risk perceptions (Widhalm, 2019[99]).

However, there is significant scope to further incorporate the principle of “building back better” after a natural disaster into disaster assistance programmes – and indeed, into US agricultural policies more broadly – in order to increase the sector’s resilience to future floods and other natural hazards. This could include providing guidance on on-farm options to reduce natural hazard exposure and vulnerability, including as a condition to receive future assistance; securing more balanced funding for conservation programmes that support farmland rehabilitation and future flood risk mitigation; and removing constraints that limit how flexibly funding can be used. In particular, EWPP-FPE provides a means to reduce future disaster assistance by taking farmland that is highly vulnerable to floods out of production. Moreover, by restoring and enhancing floodplain functions, the programme also serves to mitigate future flood risks to downstream producers and communities.

5. Conclusions

Natural disaster risk governance and policy measures in the United States offer many examples of good practices for building the agricultural sector’s resilience to natural hazards, and for floods in particular. Through the USDA Climate Hubs, other government agencies and the CES, producers and other stakeholders can access extensive, science-based information on climate and natural hazard risks, preparedness and recovery, which is tailored to the needs of the sector, and by region and natural hazard. This encourages producers and other stakeholders to consider the risk landscape over the long term by helping them to understand the risks that they face from natural hazards, and supports risk-informed

decision-making. Formal networks such as the NBEOC, Critical Infrastructure Sectors, the Multi-State Partnership for Security in Agriculture and EDEN engage key stakeholders at each stage of the natural disaster risk management cycle, and increase the effectiveness of disaster preparedness and response by helping stakeholders to identify and address gaps in their resilience levels. Technical and financial support provided through USDA conservation programmes and the various soil health initiatives increase the capacities of farmers to mitigate the impacts of natural hazards on production, and improve productivity and sustainability even in the absence of a shock. In the event of an extreme flood or other natural disaster, producers can quickly access and receive assistance, including through the highly regarded Federal Crop Insurance Program.

However, the recent return to ad hoc disaster assistance programmes – coupled with calls from stakeholders to make those programmes permanent – suggests that gaps remain. Most significantly, current policy settings reduce incentives to consider natural hazard risks over the long-term and place less emphasis on what can be done *ex ante* to reduce risk exposure and increase preparedness. Despite the availability of various programmes that aim to prevent or mitigate natural hazard impacts, the bulk of USDA farm support is still directed to programmes that help producers cope with the impacts of price and revenue risk, including that caused by natural hazards. This reduces incentives for producers to invest *ex ante* in preparedness capacities, risk prevention and mitigation measures, and limits the support available to help producers to "build back better" after a natural disaster. This disincentive is further reinforced by ad hoc disaster assistance.

Building the resilience of the US agricultural sector to floods and other natural hazards will require a holistic use of public resources. Specifically, policies could place a greater emphasis on *ex ante* measures for risk prevention and mitigation, and provide incentives for producers to make the necessary adjustments to enhance resilience to natural hazard risk over the long term, including in the suite of disaster assistance programmes. Importantly, existing USDA conservation programmes provide a policy framework to achieve this. For example, conservation programmes could place more weight on the potential for flood risk mitigation when valuing land for programme enrolment. More stable funding could also be secured for land retirement programmes such as EWPP-FPE that mitigate flood risks – particularly for areas with limited options for preventing and mitigating the impacts of floods, such as deep and vast floodplains – and for land rehabilitation programmes.

US producers display high rates of innovation and have a high capacity for managing risk, and they benefit from a wide availability of science-based information, tools, technologies and practices for enhancing on-farm resilience to climate and natural hazard risks. Nevertheless, it is important to provide clear policy signals for producers to manage risks to their assets, and develop their capacity to plan for, absorb, respond, recover from, and more successfully adapt to natural hazard risks. To this end, agricultural risk management programmes could also be reviewed for their effects on farm-level incentives to mitigate and prevent risk in the long term, and for opportunities to better integrate resilience considerations. Finally, OECD work on agricultural resilience has also emphasised the importance of the process countries follow in developing or revising risk management policies (OECD, 2020[3]). Industry organisations and locally-based stakeholders such as the Farm Bureau, county extension service and conservation districts are important and trusted sources of information for the US agricultural sector. It will be vital to engage closely with these organisations to promote the benefits of prevention and mitigation measures and ensure that producers, and indeed all stakeholders, understand the risks that natural hazards pose to US agriculture in the long term, and recognise the opportunities to build resilience to those risks.

References

AFBF (2019), *Farmers Need Disaster Assistance: Economic Contribution of Agriculture in Disaster-Impacted Regions*, American Farm Bureau Federation, Market Intel 8 April 2019, https://www.fb.org/market-intel/farmers-need-disaster-assistance. [14]

AGU (2019), *Surging Waters:Science empowering communities in the face of flooding*, https://scienceisessential.org/wp-content/uploads/sites/11/2019/09/Surging_Waters_credits_pages_web.pdf. [19]

Anderson, T. (ed.) (2015), *Midwest and Northern Forests Regional Climate Hub Assessment of Climate Change Vulnerability and Adaptation and Mitigation Strategies*, United States Department of Agriculture, https://www.climatehubs.usda.gov/sites/default/files/Midwest%20Region%20Vulnerability%20Assessment%203_20_2015_0.pdf. [40]

Annan, F. and W. Schlenker (2015), "Federal Crop Insurance and the Disincentive to Adapt to Extreme Heat", *American Economic Review*, Vol. 105/5, pp. 262-266, http://dx.doi.org/10.1257/aer.p20151031. [95]

Arbuckle, J. (2020), *Iowa Farm and Rural Life Poll - 2020 Summary Report*, Iowa State University Extension and Outreach and the Iowa Agriculture and Home Economics Experiment Station, https://store.extension.iastate.edu/product/16071 (accessed on 17 February 2021). [57]

ASCE (2017), *2017 Infrastructure Report Card*, American Society of Civil Engineers, https://www.infrastructurereportcard.org/. [53]

Askew-Merwin, C. (2020), *Natural Infrastructure's Role in Mitigating Flooding Along the Mississippi River*, Northeast-Midwest Institute Report, http://www.nemw.org/. [52]

Bigelow, D., A. Borchers and T. Hubbs (2016), "U.S. Farmland Ownership, Tenure, and Transfer", *EIB-161*, U.S. Department of Agriculture, Economic Research Service, https://www.ers.usda.gov/publications/pub-details/?pubid=74675. [60]

Bitterman, P., D. Bennett and S. Secchi (2019), "Constraints on farmer adaptability in the Iowa-Cedar River Basin", *Environmental Science & Policy*, Vol. 92, http://dx.doi.org/10.1016/j.envsci.2018.11.004. [58]

Bottemiller Evich, H. (2019), *'I'm standing right here in the middle of climate change': How USDA is failing farmers*, Politico Magazine, https://www.politico.com/news/2019/10/15/im-standing-here-in-the-middle-of-climate-change-how-usda-fails-farmers-043615 (accessed on 22 February 2021). [91]

Carter, N. et al. (2018), *Flood Resilience and Risk Reduction: Federal Assistance and Programs*, Report for Congress R45017, Congressional Research Service, https://crsreports.congress.gov/product/pdf/R/R45017. [30]

Castillo, M. and S. Simnitt (2020), *Farm Labor*, https://www.ers.usda.gov/topics/farm-economy/farm-labor/ (accessed on 19 February 2020). [27]

CBO (2018), *Options for Reducing the Deficit: 2019 to 2028*, Congressional Budget Office, Report no. 54667, https://www.cbo.gov/system/files/2019-06/54667-budgetoptions-2.pdf. [68]

CBO (2017), *Options to Reduce the Budgetary Costs of the Federal Crop Insurance Program*, Congressional Budget Office, Report No. 53375, https://www.cbo.gov/publication/53375. [72]

Chatrchyan, A. et al. (2017), "United States agricultural stakeholder views and decisions on climate change", *WIREs Climate Change*, Vol. 8/5, https://doi.org/10.1002/wcc.469. [47]

Chen, Z. and S. Dall'Erba (2018), *Do Crop Insurance Programs Preclude Their Recipients from Adapting to New Climate Conditions?*, https://ageconsearch.umn.edu/record/274398/files/Abstracts_18_05_22_16_05_10_02__98_228_48_129_0.pdf. [96]

Claassen, R. et al. (2018), "Tillage Intensity and Conservation Cropping in the United States", No. EIB-197, U.S. Department of Agriculture, Economic Research Service, https://www.ers.usda.gov/publications/pub-details/?pubid=90200. [23]

Court, C., A. Hodges and M. Lollar (2020), "Harmonizing the Assessment of the Impacts of Natural Disasters to Florida Agriculture", *EDIS*, Vol. 2 (March 2020), p. 15, http://dx.doi.org/DOI:https://doi.org/10.32473/edis-fe1075-2020. [45]

Croft, G. et al. (2020), *Climate Change Adaptation: U.S. Department of Agriculture*, CRS Report R46454, Congressional Research Service, https://crsreports.congress.gov/product/pdf/R/R46454 (accessed on 18 February 2021). [89]

CRS (2018), *Federal Crop Insurance: Program Overview for the 115th Congress*, CRS Report R45193, Congressional Research Service, https://crsreports.congress.gov/product/pdf/R/R45193/4. [70]

Deryugina, T. and B. Kirwan (2018), "Does the Samaritan's dilemma matter? Evidence from U.S. agriculture", *Economic Inquiry*, Vol. 56/2, http://dx.doi.org/10.1111/ecin.12527. [88]

DHS OIG (2017), *FEMA Needs to Improve Management of Its Flood Mapping Programs*, OIG-17-110, Department of Homeland Security, Office of the Inspector General, https://www.oig.dhs.gov/sites/default/files/assets/2017/OIG-17-110-Sep17.pdf. [37]

EDEN (2018), *Extension Disaster Education Network: Reducing the Impact of Disasters through Education*, Extension Disaster Education Network, https://eden.lsu.edu/ (accessed on 22 September 2019). [79]

Elliot, S. (2020), *Regional Hubs Put Climate Resilience Theory to Practice*, USDA, https://www.usda.gov/media/blog/2020/04/09/regional-hubs-put-climate-resilience-theory-practice (accessed on 23 February 2021). [92]

ERME (2020), *Extension Risk Management Education*, Extension Risk Management Education Network, http://extensionrme.org/. [80]

FAO (2016), *Damage and losses from climate-related disasters in agricultural sectors*, United Nations Food and Agriculture Organization, Rome, http://www.fao.org/3/a-i6486e.pdf (accessed on 9 February 2021). [101]

FAO, IFAD and WFP (2019), *Strengthening resilience for food security and nutrition: A Conceptual Framework for Collaboration and Partnership among the Rome-based Agencies*, Food and Agriculture Organization of the United Nations (FAO), the International Fund for Agricultural Development (IFAD) and the World Food Programme (WFP), https://docs.wfp.org/api/documents/WFP-0000062320/download/. [9]

FDA, USDA and DHS (2015), *Food and Agriculture Sector-Specific Plan*, Food and Drug Administration, United States Department of Agriculture and the Department of Homeland Security, https://www.cisa.gov/sites/default/files/publications/nipp-ssp-food-ag-2015-508.pdf. [29]

FEMA (2020), *FEMA Policy: Floodplain Management Requirements for Agricultural Structures and Accessory Structures*, FEMA Policy #104-008-03, February 2020, https://www.fema.gov/sites/default/files/2020-08/fema_floodplain-management_agriculture-accessory-structures_2020.pdf. [54]

FEMA (2020), *National Level Exercise*, https://www.fema.gov/emergency-managers/national-preparedness/exercises/national-level-exercise. [74]

FEMA (2020), *National Risk and Capability Assessment*, https://www.fema.gov/national-risk-and-capability-assessment. [35]

FEMA (2019), *2019 National Threat and Hazard Identification and Risk Assessment (THIRA): Overview and Methodology*, U.S. Department of Homeland Security, https://www.fema.gov/media-library/assets/documents/181470. [73]

Fleckenstein, M. et al. (2020), "Crop insurance: A barrier to conservation adoption?", *Journal of Environmental Management*, Vol. 276, http://dx.doi.org/10.1016/j.jenvman.2020.111223. [59]

FRED (2018), *Disaster Impact Analysis*, https://fred.ifas.ufl.edu/economicimpactanalysis/Disasterimpactanalysis/ (accessed on 20 September 2019). [46]

G7 Agriculture Ministers (2017), *G7 Bergamo Agriculture Ministers' Meeting Communiqué 14-15 October 2017 - Empowering Farmers, Developing Rural Areas and Enhancing Cooperation to Feed the Planet*, http://www.g7italy.it/en/documenti-ministeriali. [4]

GAO (2019), *Disaster Recovery: Recent Disasters Highlight Progress and Challenges*, GAO-20-183T, United States Government Accountability Office, https://www.gao.gov/products/GAO-20-183T. [87]

GAO (2019), *High Risk Report*, GAO-19-157SP report to Congressional Committees,U.S. Government Accountability Office, https://www.gao.gov/assets/700/697245.pdf. [94]

GAO (2018), *2017 Hurricanes and Wildfires: Initial Observations on the Federal Response and Key Recovery Challenges*, GAO-18-472, a report to Congressional Addressees, United States Government Accountability Office, https://www.gao.gov/assets/700/694231.pdf. [75]

GAO (2018), *Climate Change Funding*, GAO-18-223 report to the Chairman, Committee on Science, Space, and Technology, House of Representatives, United States Government Accountability Office, https://www.gao.gov/assets/700/691572.pdf. [43]

GAO (2014), *Climate Change: Better Management of Exposure to Potential Future Losses Is Needed for Federal Flood and Crop Insurance*, GAO-15-28 report to Congressional Requesters, United States Government Accountability Office, https://www.gao.gov/products/GAO-15-28. [93]

GAO (2014), *National Flood Insurance Program: Additional Guidance on Building Requirements to Mitigate Agricultural Structures' Damage in High-Risk Areas Is Needed*, GAO-14-583 report to Congressional Requesters, United States Government Accountability Office, https://www.gao.gov/products/GAO-14-583. [50]

Good, K. (2019), "Disaster Aid Issues", *Farm Policy News*, https://farmpolicynews.illinois.edu/2019/04/disaster-aid-issues/. [67]

Gruère, G., C. Ashley and J. Cadilhon (2018), "Reforming water policies in agriculture: Lessons from past reforms", *OECD Food, Agriculture and Fisheries Papers*, No. 113, OECD Publishing, Paris, https://dx.doi.org/10.1787/1826beee-en. [98]

Haigh, T. et al. (2018), "Provision of Climate Services for Agriculture: Public and Private Pathways to Farm Decision-Making", *Bulletin of the American Meteorological Society*, Vol. 99, pp. 1781–1790, https://doi.org/10.1175/BAMS-D-17-0253.1. [25]

IDA (2021), *"Fall Covers for Spring Savings" Cover Crop Premium Discount Program*, Illinois Department of Agriculture, https://www2.illinois.gov/sites/agr/Resources/LandWater/Pages/Cover-Crops-Premium-Discount-Program.aspx (accessed on 17 February 2021). [65]

IDALS (2020), *Crop Insurance Discounts Available for Farmers Who Plant Cover Crops*, Iowa Department of Agriculture and Land Stewardship, https://iowaagriculture.gov/news/crop-insurance-discounts-available-farmers-who-plant-cover-crops (accessed on 17 February 2021). [66]

Ignaciuk, A. (2015), "Adapting Agriculture to Climate Change: A Role for Public Policies", *OECD Food, Agriculture and Fisheries Papers*, No. 85, OECD Publishing, Paris, https://dx.doi.org/10.1787/5js08hwvfnr4-en. [97]

Lowenberg-DeBoer, J. and B. Erickson (2019), "Setting the Record Straight on Precision Agriculture Adoption", *Agronomy Journal*, Vol. 111/4, pp. 1552-1569, http://dx.doi.org/doi:10.2134/agronj2018.12.0779. [21]

McFadden, J. et al. (2019), "Development, Adoption, and Management of Drought-Tolerant Corn in the United States", No. EIB No. 204, U.S. Department of Agriculture, Economic Research Service. [24]

Motamed, M. et al. (2018), "Federal Risk Management Tools for Agricultural Producers: An Overview", No. ERR-250, USDA-ERS, Washington, DC, https://www.ers.usda.gov/webdocs/publications/89202/err-250.pdf?v=0 (accessed on 26 July 2019). [69]

MRCC (2017), *Useful to Usable*, Midwestern Regional Climate Center, https://mrcc.illinois.edu/U2U/. [42]

Multi-State Partnership (2016), *Multi-State Partnership for Security in Agriculture*, http://mjndvm96.magix.net/index.htm. [76]

NACD (2020), *NACD Soil Health Champions Network*, https://www.nacdnet.org/get-involved/soil-health-champions-network/. [64]

National Pork Council (2018), *N.C. Secures Funding to Close Hog Farms Located in 100-year Floodplain*, https://www.nationalhogfarmer.com/livestock-facilities/nc-secures-funding-close-hog-farms-located-100-year-floodplain. [86]

NC Office of the Governor (2018), *Hurricane Florence Recovery Recommendations: Building Communities Stronger and Smarter--Based on Preliminary Damage and Needs Assessment*, https://files.nc.gov/ncosbm/documents/files/Florence_Report_Full.pdf. [17]

NCIS (2020), "2019 Year in Review", *Crop Insurance Today*, Vol. 53/1, pp. 5-27, https://www.nxtbook.com/allen/cint/53-01/index.php?startid=14#/p/Cover1. [102]

Niles, M. et al. (2019), "Seeing is not always believing: crop loss and climate change perceptions among farm advisors", *Environmental Research Letters*, Vol. 14, https://doi.org/10.1088/1748-9326/aafbb6. [48]

NOAA (2014), *New Climate Resilience Toolkit helps communities prepare for a changing world*, https://www.noaa.gov/media-release/new-climate-resilience-toolkit-helps-communities-prepare-for-changing-world (accessed on 14 April 2020). [44]

NOAA National Centers for Environmental Information (2020), *U.S. Billion-Dollar Weather and Climate Disasters*, https://www.ncdc.noaa.gov/billions/ (accessed on 10 August 2019). [1]

OECD (2020), "Nature-based solutions for adapting to water-related climate risks", *OECD Environment Policy Papers*, No. 21, OECD Publishing, Paris, https://dx.doi.org/10.1787/2257873d-en. [55]

OECD (2020), *Producer and Consumer Support Estimates*, OECD Agriculture Statistics (database), https://doi.org/10.1787/466c3b98-en. [84]

OECD (2020), *Strengthening Agricultural Resilience in the Face of Multiple Risks*, OECD Publishing, Paris, https://dx.doi.org/10.1787/2250453e-en. [3]

OECD (2020), "United States", in *Agricultural Policy Monitoring and Evaluation 2020*, OECD Publishing, Paris, https://dx.doi.org/10.1787/6f8323d8-en. [12]

OECD (2019), "United States", in *Agricultural Policy Monitoring and Evaluation 2019*, OECD Publishing, Paris, https://dx.doi.org/10.1787/189dd9b6-en. [85]

OECD (2017), *Boosting Disaster Prevention through Innovative Risk Governance: Insights from Austria, France and Switzerland*, OECD Reviews of Risk Management Policies, OECD Publishing, Paris, https://dx.doi.org/10.1787/9789264281370-en. [90]

OECD (2014), *Boosting Resilience through Innovative Risk Governance*, OECD Reviews of Risk Management Policies, OECD Publishing, Paris, https://dx.doi.org/10.1787/9789264209114-en. [28]

OECD (2014), *Recommendation of the Council on the Governance of Critical Risks*, OECD Publishing, Paris, http://www.oecd.org/gov/risk/recommendation-on-governance-of-critical-risks.htm. [8]

OECD (2011), *Managing Risk in Agriculture: Policy Assessment and Design*, OECD Publishing, Paris, https://dx.doi.org/10.1787/9789264116146-en. [6]

OECD (2009), *Managing Risk in Agriculture: A Holistic Approach*, OECD Publishing, Paris, https://dx.doi.org/10.1787/9789264075313-en. [5]

OECD-FAO (2021), *Building Agricultural Resilience to Natural Hazard-induced Disasters: Insights from Country Case Studies*, OECD Publishing, Paris/FAO, Rome, https://doi.org/10.1787/49eefdd7-en. [2]

OHS (2019), *National Response Framework*, U.S. Department of Homeland Security, October 28, 2019, https://www.fema.gov/media-library/assets/documents/117791. [81]

OHS (2016), *National Disaster Recovery Framework*, Second Edition, U.S. Department of Homeland Security, https://www.fema.gov/media-library/assets/documents/117794. [83]

Prager, D. et al. (2020), "Farm Use of Futures, Options, and Marketing Contracts", No. EIB No. 219, U.S. Department of Agriculture, Economic Research Service, https://www.ers.usda.gov/webdocs/publications/99518/eib-219.pdf?v=8904.4 (accessed on 20 January 2021). [26]

Prokopy, L. et al. (2015), "Farmers and climate change: a cross-national comparison of beliefs and risk perceptions in high-income countries", *Environmental Management*, Vol. 56, pp. 492-504, https://doi.org/10.1007/s00267-015-0504-2. [49]

Reidmiller, D. et al. (eds.) (2018), *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II*, U.S. Global Change Research Program, Washington, D.C., http://dx.doi.org/10.7930/NCA4.2018. [11]

Reuters (2019), *US farmers face devastation following Midwest floods*, https://www.reuters.com/article/us-usa-weather-agriculture/us-farmers-face-devastation-following-midwest-floods-idUSKCN1R12J0 (accessed on 22 July 2019). [18]

Rosa, I. and R. Johnson (2019), *Federal Crop Insurance: Specialty Crops*, CRS Report No. R45459, Congressional Research Service, https://fas.org/sgp/crs/misc/R45459.pdf (accessed on 12 September 2020). [71]

Scata, J. (2017), *FEMA's Outdated and Backward-Looking Flood Maps*, NRDC Expert Blog, https://www.nrdc.org/experts/joel-scata/femas-outdated-and-backward-looking-flood-maps (accessed on 12 August 2020). [38]

Schimmelpfennig, D. (2016), "Farm Profits and Adoption of Precision Agriculture", No. ERR-217, October 2016, U.S. Department of Agriculture, Economic Research Service, https://www.ers.usda.gov/publications/pub-details/?pubid=80325. [22]

SECC (2020), *AgroClimate*, Southeast Climate Consortium (SECC), http://agroclimate.org/. [41]

SHP (2020), *Soil Health Partnership*, https://www.soilhealthpartnership.org/we-are-shp/. [63]

Smith, A. (2019), *2018's Billion Dollar Events in Context*, https://www.climate.gov/news-features/blogs/beyond-data/2018s-billion-dollar-disasters-context (accessed on 12 August 2019). [15]

Smith, A. and R. Katz (2013), "US billion-dollar weather and climate disasters: data sources, trends, accuracy and biases", *Natural Hazards*, Vol. 67/2, http://dx.doi.org/10.1007/s11069-013-0566-5. [100]

Stubbs, M. (2020), *Agricultural Disaster Assistance*, CRS Report No. RS21212, Congressional Research Service, https://crsreports.congress.gov/product/pdf/RS/RS21212 (accessed on 23 July 2019). [33]

Stubbs, M. (2020), *Emergency Assistance for Agricultural Land Rehabilitation*, CRS Report R42854, Congressional Research Service, https://fas.org/sgp/crs/misc/R42854.pdf. [34]

UNISDR (2015), *Reading the Sendai Framework for Disaster Risk Reduction 2015 - 2030*, United Nations Office for Disaster Risk Reduction, Geneva, https://www.preventionweb.net/files/46694_readingsendaiframeworkfordisasterri.pdf. [10]

UNISDR (2015), *Sendai Framework for Disaster Risk Reduction 2015 - 2030*, United Nations Office for Disaster Risk Reduction, https://www.unisdr.org/files/43291_sendaiframeworkfordrren.pdf (accessed on 22 August 2018). [7]

USACE (2020), *About Levees*, National Levee Safety, U.S. Army Corps of Engineers, https://www.usace.army.mil/National-Levee-Safety/About-Levees/. [51]

USDA (2020), *Hurricane Preparation and Recovery Commodity Guides*, https://www.climatehubs.usda.gov/hubs/southeast/topic/hurricane-preparation-and-recovery-southeast-us. [78]

USDA (2020), *USDA Climate Hubs*, https://www.climatehubs.usda.gov/ (accessed on 29 March 2020). [39]

USDA ERS (2020), *Ag and Food Sectors and the Economy*, Ag and Food Statistics: Charting the Essentials, https://www.ers.usda.gov/data-products/ag-and-food-statistics-charting-the-essentials/ag-and-food-sectors-and-the-economy/ (accessed on 26 June 2020). [13]

USDA ERS (2019), *Shifts in payments for the top five crop management practices in USDA's Environmental Quality Incentives Program*, https://www.ers.usda.gov/data-products/chart-gallery/gallery/chart-detail/?chartId=94846. [56]

USDA FSA (2021), *Disaster Designation Information*, https://www.fsa.usda.gov/programs-and-services/disaster-assistance-program/disaster-designation-information/index (accessed on 10 February 2021). [32]

USDA FSA (2020), *Disaster Assistance: Emergency Disaster Designation and Declaration Process*, Farm Service Agency Fact Sheet, https://www.fsa.usda.gov/Assets/USDA-FSA-Public/usdafiles/FactSheets/emergency_disaster_designation_declaration_process-factsheet.pdf. [31]

USDA NASS (2020), *NASS Research and Science: Disaster Analysis*, https://www.nass.usda.gov/Research_and_Science/Disaster-Analysis/. [82]

USDA NRCS (2020), *Case Studies: Economic Benefits of Applying Soil Health Practices*, https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/soils/health/?cid=nrcseprd1470394. [62]

USDA NRCS (2019), *USDA Opens Signup for New On-Farm Trials Effort*, https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/soils/health/?cid=nrcseprd1459619. [61]

USDA RMA (2021), *Cause of Loss Historical Data Files*, https://www.rma.usda.gov/SummaryOfBusiness/CauseOfLoss (accessed on 11 February 2021). [20]

USGS (2020), *USGS Flood Information*, https://www.usgs.gov/mission-areas/water-resources/science/usgs-flood-information?qt-science_center_objects=0#qt-science_center_objects. [36]

Wallander, S., E. Marshall and M. Aillery (2017), *Farmers Employ Strategies To Reduce Risk of Drought Damages*, https://www.ers.usda.gov/amber-waves/2017/june/farmers-employ-strategies-to-reduce-risk-of-drought-damages/. [16]

Widhalm, M. (2019), *Motivating the Agricultural Community to Build Climate Resilience*, U.S. Climate Resilience Toolkit, https://toolkit.climate.gov/case-studies/motivating-agricultural-community-build-climate-resilience (accessed on 16 June 2020). [99]

Wiener, S., N. Álvarez-Berríos and A. Lindsey (2020), "Opportunities and Challenges for Hurricane Resilience on Agricultural and Forest Land in the U.S. Southeast and Caribbean", *Sustainability*, Vol. 12/1364, https://doi.org/10.3390/su12041364. [77]

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Comments are welcome and can be sent to tad.contact@oecd.org.