THE ROLE OF CLIMATE RESEARCH IN SUPPORTING AGRICULTURAL RESILIENCY

HEARING

BEFORE THE

COMMITTEE ON AGRICULTURE
HOUSE OF REPRESENTATIVES

ONE HUNDRED SEVENTEENTH CONGRESS

SECOND SESSION

JUNE 15, 2022

Serial No. 117–35

Printed for the use of the Committee on Agriculture
agriculture.house.gov

U.S. GOVERNMENT PUBLISHING OFFICE
48–933 PDF WASHINGTON : 2022

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THE ROLE OF CLIMATE RESEARCH IN SUPPORTING AGRICULTURAL RESILIENCY

WEDNESDAY, JUNE 15, 2022

HOUSE OF REPRESENTATIVES,
COMMITTEE ON AGRICULTURE,
Washington, D.C.

The Committee met, pursuant to call, at 10:00 a.m., in Room 1300 of the Longworth House Office Building, Hon. David Scott of Georgia [Chairman of the Committee] presiding.

Members present: Representatives David Scott of Georgia, Costa, Adams, Hayes, Brown, Rush, Pingree, Kuster, Plaskett, O'Halleran, Carbajal, Khanna, Lawson, Craig, Harder, Axne, Schrier, Panetta, Kaptur, Ms. Davids of Kansas, Thompson, Austin Scott of Georgia, Crawford, DesJarlais, LaMalfa, Mr. Davis of Illinois, Allen, Bacon, Johnson, Baird, Cloud, Mann, Feenstra, and Cammack.

Staff present: Paul Babbitt, Lyron Blum-Evitts, Malikha Daniels, Ashley Smith, Michael Stein, Caleb Crosswhite, Ricki Schroeder, Erin Wilson, and Dana Sandman.

OPENING STATEMENT OF HON. DAVID SCOTT, A REPRESENTATIVE IN CONGRESS FROM GEORGIA

The CHAIRMAN. Good morning, everyone. The hearing will now come to order.

And first, I want to welcome and thank our outstanding panelists for joining us today at today's hearing, which is entitled, *The Role of Climate Research in Supporting Agricultural Resiliency.* Now, after brief opening remarks, Members will receive testimony from our distinguished witnesses today, and then the hearing will be open for questions. And let me start with my opening statement.

I really can't thank you all enough. Climate change was the very first hearing I opened up with as I became Chairman 18 months ago, and it is clearly one of the most significant and important issues facing our nation and the world today. So after brief opening remarks, we will have Members asking questions, and we will open it up for that at that time.

And let me just start out by saying climate change poses a threat to our ranchers, our foresters, and the production of our food, of our fuel, of our fiber. That means our food, our clothing, our shelter, and more and more, our fuel. Currently, many communities across the country are struggling with outstanding droughts, wildfires, and they are so pressing, as we have seen from various weather reports, the drastic changes in temperatures. And just leaving my home this morning and the news flashing historically all over this

country. This is the hottest time that we have ever had, at this time of the year.

That is why this particular hearing is not only timely, but it is sent to us with a sense of urgency to deal with it, real involvement, with research, with education and extension. These all play a critical role in both adaptation and our mitigation efforts.

And I am pleased that we have an exemplary researcher from our 1890 land-grant institutions here today to speak not only about our climate research but also about how our 1890s are leading the way with cutting-edge research. And as many of you may know, this was a great inspiration for me to move just a few years ago, to put together an historic scholarship program targeting our 1890s. And I am proud to say that with the help of my Republican friends, we were able to get this scholarship program going with $80 million for student scholarships. And now, not only that, with this upcoming farm bill, we are going to make an additional amount of $100 million and make our scholarship program at the 1890s permanent. So for generations to come, we will have a legacy that stands for the right for our outstanding institutions.

Our research institutions, which play an important role in developing our student leaders are advocates in supporting rigorous scientific analysis on issues related to community and agricultural resiliency, adaptation to climate change, and environmental and climate justice. This is so important because, ladies and gentlemen, recent EPA analysis found that harms from climate change disproportionately impact our underserved communities, which are least able to prepare for and recover from climate-related disasters. And also, today, we are all experiencing how these disruptions can impact the price and availability of products, given the global nature of our food and agriculture supply chains.

So make no mistake about it, changing weather patterns and increased natural disasters have and will continue to impact our food and agriculture system and particularly our supply chains. And that is why research is so important. And that is why I am so delighted that we have assembled this distinguished panel of researchers here today so we can understand the challenges, test theories, build resiliency, develop solutions, and take advantage of opportunities. We must ensure that climate research is innovative, cutting-edge, and revolutionary. But we must also ensure that it leads to practical and applicable solutions for our farmers, our ranchers, and our foresters. These are the ones that are on the front-lines of climate change. Our research institutions are already doing this important work, and we must support them.

Today's panel of witnesses has a wide range of experiences. Your backgrounds are absolutely remarkable. And the significant depth of knowledge that you all have, that you will share with us today is so important. And we are very thankful that you have brought your expertise to the House Agriculture Committee today.

[The prepared statement of Mr. David Scott follows:]

PREPARED STATEMENT OF HON. DAVID SCOTT, A REPRESENTATIVE IN CONGRESS FROM GEORGIA

As many of you will recall, our first hearing in my tenure as Chairman of this Committee discussed the role that farmers, ranchers, and foresters have in addressing climate change, as well as the impact climate change has on their communities.

Today's hearing will focus on the vital roles that research, education, and extension play in understanding and adapting to climate change and supporting agricultural resiliency.

Climate change poses a threat to our rural and urban communities; our farmers, ranchers, and foresters; and the production of our food, fuel, and fiber.

Currently, many communities across the country are struggling with droughts, wildfires, temperature extremes, and altered patterns of pest pressure exacerbated by climate change. Unfortunately, this has only increased as natural disasters and changing weather conditions continue to impact our country and our planet.

Research, education, and extension all play a key role in supporting both adaptation and mitigation efforts. I am pleased that we have an exemplary researcher from an 1890 Land-Grant Institution here today to speak not only about climate research but also about how 1890s are leading the way with cutting-edge research.

Our research institutions, including our Historically Black Colleges and Universities and other minority-serving institutions, play an important role in developing student leaders, advocates, and supporting rigorous scientific analysis on issues related to community and agricultural resiliency, adaptation to climate change, and environmental and climate justice.

This is so important because a recent EPA analysis found that harms from climate change disproportionally impact underserved and under-resourced communities who are least able to prepare for and recover from climate-related disasters.

Today we are all experiencing how disruptions can impact the price and availability of products given the global nature of our food and agricultural supply chains.

Make no mistake, changing weather patterns and increased natural disasters have, and will, continue to impact our food and agricultural systems and our supply chains. That is why research is so important—to understand the challenges, test theories, build resiliency, develop solutions, and take advantage of opportunities.

We must ensure that climate research is innovative, cutting-edge, and revolutionary. But we must also ensure that it leads to practical and applicable solutions for the farmers, ranchers, and foresters on the front-lines of climate change. Our research institutions are already doing this important work, and we must support them.

Today's panel of witnesses has a wide range of experiences and a significant depth of knowledge, and we are thankful that they have brought their expertise to the House Agriculture Committee today.

I now recognize my friend and the Ranking Member of the Full Committee, 'GT' Thompson, for any opening remarks he may have.

The CHAIRMAN. And with that, now, I would like to turn it over to my distinguished friend, the gentleman from Pennsylvania, our hardworking Ranking Member.

OPENING STATEMENT OF HON. GLENN THOMPSON, A REPRESENTATIVE IN CONGRESS FROM PENNSYLVANIA

Mr. THOMPSON. Mr. Chairman, thank you so much. Good morning, everybody, and thank you to all of our witnesses that are participating today in this important discussion.

Whenever I discuss—not just climate solutions, but what guides me when it comes to climate and agriculture, I try to follow a principle-based approach. And so I have four guiding principles that guide me in the work that I do when it comes to climate and agriculture, American agriculture.

First and foremost, first principle, climate policies need to benefit producers. Our farmers, our ranchers, and our foresters primarily. Whatever we do when it comes to policy in climate and agriculture, they need to be the primary beneficiaries. They need to be rewarded for, quite frankly, what they are doing today and what they

can do with more tools as we provide them for them, and helping them increase production, efficiency, and profitability.

Second principle is you can't have a healthier environment without a healthier economy. That is the fatal flaw of many proposals that have been floating around here for a couple of years in Washington, such as the New Green Deal. If it would happen to be implemented, which would be unfortunate, it wouldn't last a year because it would crush the economy. And we know that you can't have a healthier environment without a healthier economy and *vice versa,* actually.

And the third principle is that we should truly be science-based and not political science. For too long, the climate discussion has been based on political science. We need to be real scientists, as I like to say, according to God's law.

And finally, the fourth principle is that we need to start with what we know works and that is the farm bill's provisions, obviously, the conservation title, but there are other provisions within the farm bill as well that will contribute to that. Those are tools that help our farmers, our ranchers, and our foresters to be equipped with science, technology, innovation. I would put support for agricultural research, which is within the farm bill, as a part of those provisions that helps us achieve, helps farmers, ranchers, and foresters, American ones, achieve what they do.

Now, these voluntary, incentive-based programs and conservationists obviously have proven to be effective. However, it is important to note the impact the research title has on understanding and forming conservation practices. Since the 1940s, American agriculture has been able to increase production by 287 percent. It is amazing. It is the most productive agriculture in the world, while total farm inputs remain mostly unchanged. Now, this is an amazing success story for our farmers, ranchers, and foresters, who are supported by the farm bill programs.

One of our most effective—I think the most effective climate heroes not just in this nation but anywhere in the world is the American farmer. And I include ranchers and foresters under that title. They are, according to recent research, they have under the title of natural land solutions sequestered 6.1 gigatons of carbon annually. And I will be honest with you, I was never really sure how big a gigaton was, but I read a little deeper into that research and got in the weeds of it. It turns out that we sequester every bit of carbon that is emitted on what they call *natural lands,* which is farming, ranching, forestry, plus an additional 10.1 percent, which is just absolutely amazing and just reaffirms the role of what American farmers, ranchers, and foresters are doing today. And we need to further equip them.

Although they have traditionally by some have had a bullseye on their back that literally says climate criminals, that should be replaced with the mantle of climate heroes. And that is largely because American agriculture is defined by science, technology, and innovation. And our productivity has increased 287 percent since the 1940s.

I love the research out there, so I am looking forward to building on more research findings, as with all of your testimony. But the research today that shows that if today on this day, June 15, 2022,

we wanted to reduce greenhouse gas emissions around the world, truly the only way to accomplish that with the tools that are out there today is for the American farmers, ranchers, and foresters to produce more and export it overseas, because of the nature of our productivity and our application of science, technology, and innovation.

Now, we all know that American agriculture provides the safest, most sustainable, and most efficient food and fiber supply in the world while some countries have lower environmental standards, worse labor conditions, and fewer food safety considerations. And by promoting policies that continue to increase American productivity while reducing inputs, we can displace the production of those less-efficient countries and reduce global emissions from the agriculture industry.

And as we look to address climate solutions, we should be focused on programs and policies that unleash American production, provide certainty, increase profitability, and foster innovation. And I don't think there has been a better time in the world history to unleash that innovation. And thank you to our researchers, our land-grant universities, the scientists that help us develop those new tools.

We also need to ensure that we are avoiding burdensome regulations like the rewrite of WOTUS and proposed revisions to NEPA. And by doing these things, we can ensure our consumers will continue to have access to a safe and affordable food supply because I am not sure with food prices going up in the past 18 months of 40 percent that we are pushing the envelope on affordability for many American families. In fact, in a letter sent on Monday of this week to President Biden, I, along with Leader McCarthy and nearly 100 of my Republican colleagues, called on President Biden to the end his regulatory assault on rural America or, as I like to call it, essential America, because everything that American families need in life comes from those rural parts of the country. So it truly is a more appropriate term to refer to what I always referred to as rural America as essential America.

And earlier today, I introduced a bill that would force the President to change course and actually combat rising inflation and input costs while providing regulatory certainty to farmers and ranchers.

Before closing, I want to reiterate what I stated at the climate hearing that kicked us off back in March, that I will reject complicating our programs and making climate the focus of every title of the upcoming farm bill reauthorization. For years, programs included in the research title like the Agriculture and Food Research Initiative have been funding projects that address major issues impacting the agriculture industry and benefiting the environment without being specifically limited to climate change research.

That being said, I really once again want to thank our witnesses for taking the time to be with us here today. I am looking forward to hearing your testimony and benefiting from that experience and perspectives. And thank you, Mr. Chairman, and I yield back.

The CHAIRMAN. Thank you, Ranking Member.

The chair would also request that other Members submit their opening statements for the record so witnesses may begin their testimony and to ensure that there is ample time for questions.

Our first witness today is Dr. Thelma Vélez—I hope I got that correct—who is Research and Education Program Manager for the Organic Farming Research Foundation. She is joining the hearing virtually from Sunrise, Florida.

Our next witness today is Dr. Sylvie Brouder. I believe I got that correct. A Professor and Wickersham Chair of Excellence in Agricultural Research at Purdue University in West Lafayette, Indiana. Welcome Dr. Brouder. And Dr. Brouder is testifying today on behalf of the American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America.

And our third witness today is Dr. Ali Fares, the Endowed Professor of Water Security and Water Energy Food Nexus at Prairie View A&M University in Prairie View, Texas. And he hails from one of our wonderful 1890s land-grant institutions. Thank you.

Our fourth witness today is Dr. Benjamin Houlton the Ronald P. Lynch Dean and Professor of Ecology and Global Development at Cornell University in Ithaca, New York.

And our fifth and final witness today is Mr. Michael Vance, who is Managing Partner of Southern Reds, LLC in Gainesville, Texas. Mr. Vance is testifying today on behalf of the Noble Research Institute.

I just want to welcome all of you, our distinguished witnesses. And now without delay, we will proceed right to our testimony. And, Dr. Vélez, please begin when you are ready.

STATEMENT OF THELMA I. VÉLEZ, PH.D., RESEARCH & EDUCATION PROGRAM MANAGER, ORGANIC FARMING RESEARCH FOUNDATION, SUNRISE, FL

Dr. VÉLEZ. Thank you. Chairman Scott, Ranking Member Thompson, and distinguished Members of the House Agriculture Committee, I would like to first thank you for hosting this hearing on agricultural resilience and climate research, and for providing me the opportunity to share my expertise.

I have been involved in agriculture and food systems research for over 15 years, including various projects working with USDA programs and offices and alongside pioneers in sustainable agriculture within the land-grant university system. And I have also conducted research in mainland U.S., as well as abroad in the U.S. Territory of Puerto Rico post-Hurricane Maria.

Today, I am speaking to you on behalf of the Organic Farming Research Foundation, OFRF, where I am the Research and Education Program Manager. OFRF has been working closely with researchers, organic farmers, and policymakers across the U.S. for over 3 decades to understand the challenges organic farmers face and to provide the research and educational tools they need to help them thrive.

Our changing climate, the disruptions in weather patterns, whatever we would like to call it present new challenges for all of our farmers. Our recently published National Organic Research Agenda is a report where we surveyed all of the certified organic growers across the nation. We received responses from over 1,000 of them.

Half of these, 52 percent, said that they were concerned with adapting to climate change. In listening sessions and focus groups, they discussed the unpredictable precipitation, temperature changes, increased flooding, prolonged periods of drought, and earlier and later frost dates. All of these challenges negatively impact the stability of U.S. farms, which in turn does threaten our national security.

Despite these challenges, we know that organic growers lead the nation when it comes to climate resilience and adaptation and mitigation. Organic farming is the original climate-smart agriculture. Organic growers regularly implement practices that build healthy fertile soils, which are the foundation for resilience on a farm. For example, nearly 90 percent of organic farmers we surveyed plant cover crops regularly compared to just ten percent of conventional farmers. Other practices that organic growers lead the way in are diversified crop rotations, intercropping, green manures, all of which have research-backed methods to improve resilience and soil fertility.

OFRF has spent the past 7 years specifically researching and reviewing the literature on organic soil health management as it relates to climate resilience and mitigation. We have carried out this work through grants and through a partnership agreement with USDA NIFA. There is extensive evidence indicating that organic production systems help build resilience in various ways. For example, organic agricultural systems have been found to decrease soil erosion with soils under organic management having greater aggregate stability and water infiltration. In the case of extended drought, studies show that cover crops can reduce irrigation needs anywhere from 33 to 50 percent at the higher end. That is when there are integrating strategies such as diversified rotation, reduce tillage, and compost use. And with respect to climate mitigation, research indicates that organic farming systems can sustain higher levels of solar organic carbon and have lower per-acre greenhouse gas emissions than conventional systems.

While the organic method has been shown to have great potential to contribute to these issues, we need more research to make widespread adoption possible. Currently, less than one percent of USDA's annual research budget is spent on organic production. While this is not aligned with the organic sector's market share of six percent, NIFA's Organic Research and Extension Initiative, OREI; the Organic Transitions Program, ORG; as well as the ARS, Agricultural Research Service; and Sustainable Agriculture Research and Education, SARE program, have supported hundreds of studies that help both organic and conventional farmers.

But there is still more investment needed to help our farmers and ranchers implement the best practices specific to their operations and specific to their geographic regions and locales. Examples of this include breeding specifically like regionally adapted crop cultivars for organic systems, identifying the best cover cropping systems for those regions for commodities, as well as ideal times to terminate these cover crops to maximize benefits in soil health fertility. We also need to increase research on advanced rotational grazing systems and best strategies for integrating crop and livestock. One other additional area is research investment on

organic nutrient management that reduces our reliance on external inputs, which we know is a challenge.

In terms of recommendations, first, we believe it is crucial for Congress to recognize USDA-certified organic agriculture as a climate-smart and resilient system of production. Second, we believe it is imperative to increase funding for existing organic research programs such as OREI and ORG, and also integrate organic into other research programs across USDA's portfolio. We recommend expanding the amount of organic research happening within ARS, specifically expanding the work at the Long-Term Agroecosystem Research sites, the LTAR sites, including work underway at ARS Beltsville, and as well as the work being done at Salina Stations that can be models that can then be scaled out.

Last, we would like to recommend that cooperative extension be expanded upon. We know that it has been historically underfunded, and our National Organic Research Agenda shows that organic growers are struggling and they specifically cited that they lack technical assistance and extension support because those individuals do not have organic-specific knowledge.

To conclude, we deeply appreciate the USDA's commitment to helping farmers build resilience in climate disruption. Thank you all for the great work that you have done so far and you continue to do. I welcome any questions the Committee may have.

[The prepared statement of Dr. Vélez follows:]

PREPARED STATEMENT OF THELMA I. VÉLEZ, PH.D., RESEARCH & EDUCATION PROGRAM MANAGER, ORGANIC FARMING RESEARCH FOUNDATION, SUNRISE, FL

Chairman Scott, Ranking Member Thompson, and distinguished Members of the House Agriculture Committee, I would first like to thank you for hosting a hearing on agricultural resilience and climate research, and providing an opportunity to share my expertise on this important issue.

I have been involved in agriculture and food systems research for over 15 years, including various projects working with USDA programs and offices and alongside pioneers in sustainable agriculture within the Land-Grant University system. I have a Ph.D. in Environment and Natural Resources from the Ohio State University's College of Agriculture, Food, and Environmental Sciences. My research background is highly interdisciplinary. I have conducted agronomic experiments to help South Florida farmers sequester carbon and enhance soil fertility using biochar, I have researched and worked with farmers building resilience to a changing climate in the Caribbean, specifically in Puerto Rico post-Hurricane Maria, and have collaborated with multidisciplinary teams across the U.S.

I am speaking to you today on behalf of the Organic Farming Research Foundation (OFRF) where I am the Research and Education Program Manager. OFRF has been working for over 3 decades to expand the research being done on organic production systems. We work closely with researchers, organic farmers, and policy makers across the U.S. to understand the challenges farmers face, and to provide the research and education tools needed to help them thrive.

Our changing climate, and the disruptions in weather patterns it brings, present new and intensifying challenges to farmers. In our recently published 2022 National Organic Research Agenda (NORA), we received responses from over one thousand certified organic growers across the U.S. to produce a 230 page report identifying the needs of our domestic growers. Over half of these farmers were concerned with adapting to climate change. In listening sessions, they discussed challenges such as unpredictable precipitation, including increased flooding and prolonged periods of drought, earlier and later frost dates, and changing pest challenges (Snyder, Schonbeck, Vélez, 2022).* All of these challenges alter planting and growing cycles, negatively impact the stability of farms, and expose the fragile nature of our current

*__Editor's note:__ the in-text citations in Dr. Vélez's prepared statement do not have a corresponding descriptive "Endnotes" listing. It has been reproduced herein as submitted.

food system, which ultimately threatens national security (*ibid;* Petersen-Rockney, *et al.,* 2021).

Despite these challenges, we know that organic growers lead the nation when it comes to climate resilience, climate adaptation, and climate mitigation. Organic growers regularly implement climate-smart practices that build healthy, fertile soils. Soil is the foundation of our farms, and healthy soils have increased capacity to hold plant-available water and nutrients, suppress pathogens, and support vigorous crops and pasture. To build soil health, nearly 90% of organic farmers plant cover crops regularly, compared to just 10% of conventional farmers (Snyder, Schonbeck, Vélez 2022). Other practices organic growers lead the way in are crop rotation, intercropping, and green manures, all of which are research-backed methods to improve resilience and increase fertility (*ibid*). Organic farming is the original climate-smart agriculture, and continues to lead the way.

OFRF has spent the past 7 years researching and reviewing the literature to better understand the importance of soil health to climate resilience and mitigation. We have carried out this work with grants and through a partnership agreement with USDA NIFA. In reviewing the existing research, we found that there is extensive evidence showing organic production systems help farmers in various ways, including: increasing resilience to climate stress, such as droughts and floods, enhancing soil fertility and protecting against soil erosion, supporting increased biodiversity, and increasing soil carbon sequestration services. For example, in the case of extended drought, studies show that cover crops can reduce irrigation needs anywhere from 33–50%, particularly when using integrated strategies such as diversified rotation, reduced tillage, and compost application (Gaudin*, et al.,* 2018; Renwick, *et al.,* 2017; DeVincentis, 2019). Relatedly, organic agriculture systems have been found to decrease soil loss rates due to erosion, with soils under organic management having greater aggregate stability while increasing water infiltration rates (Morvan, *et al.,* 2018). Research has found that biodiversity on organically managed lands have higher rates of both species richness and abundance when compared to conventional cropping systems (Stein-Bachinger 2021). With respect to climate mitigation, research indicates that organic farming systems can sustain higher levels of soil organic carbon (SOC) and have lower per-acre GHG emissions than conventional systems (Schonbeck 2020; Crystal-Ornelas, Thapa, & Tully, 2021). There are multitudes of studies describing the importance of organic production systems in addressing both current and emerging climate challenges.

While the organic method has been shown to have great potential to contribute to both climate mitigation and climate resilience, much more action-oriented research is needed to make widespread adoption possible. Less than 1% of the USDA's annual research budget is spent on organic production topics, which is not aligned with the organic sector's continually growing market share of 6%. Organic farmers need greater research investment to continue to advance soil health and fertility management to better sequester carbon and reduce GHG emissions. To reduce risk and enhance resilience, they also need improved crop cultivars specific to organic production systems, including traits like disease-resistance, nutrient efficiency, seedling vigor, and competitiveness toward weeds. We at OFRF believe it is crucial for Congress to recognize and elevate USDA-certified organic agriculture as a climate-smart and -resilient system of production and provide the resources to meaningfully meet the need of organic producers. This is in line with Secretary Vilsack's recent comments when presenting the Food System Transformation Framework.

Moving forward, more research, education, and extension is needed to help farmers and ranchers implement the best practices for climate mitigation and adaptation specific to their operations and locales. This includes breeding regionally adapted crop cultivars and identifying the best cover cropping systems for specific regions and production systems. We also need to advance organic research on advanced grazing management and crop-livestock integration which are known to sequester carbon, reduce greenhouse gas emissions, and enhance climate resilience of livestock production systems. Further, we believe it is imperative to increase funding not only for existing organic research programs, but also integrate organic research into other research programs across the USDA's portfolio. Increasing mandatory funding for NIFA Organic Research and Extension Initiative (OREI), while also expanding the amount of organic research within the ARS, such as work underway at Long Term Agroecosystem Research sites, is imperative. Alongside investing in the research, investment in Extension and education is essential to getting new research-informed skills, tools, and technology into the hands of growers. Cooperative Extension programs have been historically underfunded, and organic producers are often at an additional disadvantage because the organic expertise of Extension agents is currently lagging. Therefore, we also recommend expanding technical assistance resources and Extension services available to organic growers.

In conclusion, these are challenging times for the people who grow our food. American farmers are no strangers to challenges, from the Dust Bowl to the 1980s farm crisis, but the scale of challenges facing our farmers are unprecedented. Destabilizing climate conditions only contribute to continually thinning margins and market disruptions that negatively impact the health of our agriculture industry. We deeply appreciate the USDA funding research, education, and extension that is crucial to helping farmers build resiliency. The Sustainable Agriculture Research and Education (SARE) program, the Organic Research and Extension Initiative (OREI) and the Organic Transitions Program (ORG) have supported hundreds of studies that help both organic and conventional farmers address the threat of climate disruption. But, there is still much more investment needed to meet the needs of our farmers if we want to make meaningful progress on mitigating and adapting to climate change. Thank you for all of the great work you have done so far and the work you continue to do. I welcome any questions the Committee may have on climate research and organic production.

Condensed Recommendations

Recognize and elevate USDA-certified organic agriculture as a climate-smart and resilient system of production.

- Research:
  - Increase funding for organic research programs administered by the National Institute for Food and Agriculture (NIFA), including the Organic Research and Extension Initiative, Organic Transitions Program, and the Sustainable Agriculture Research and Education (SARE) programs. These programs are ideally positioned to help producers sustain and increase production while contributing to climate adaptation and mitigation through expanded research in organic agriculture and food systems
  - Continue and expand research funding through the Agriculture Research Service's Long Term Agroecosystem Research (LTAR) Network. For example, organic systems research at the long term organic trials at the Beltsville, Maryland research station can be a model for expanding LTAR programming. This long-term research will continue to be critical in preparing farmers and ranchers, both organic and non-organic, to adapt to and mitigate the changing climate.
  - Fund organic farming research at levels commensurate with organic's market share. This will require at least a six fold increase that could be spread out over several years. We believe that increasing funding for organic research, building on the recently-released ARS strategic plan for organic research, will help the agency address this historical lack of investment in organic agriculture research and help organic and non-organic producers alike overcome challenges to realize their potential to adapt to and mitigate the impacts of the changing climate.
- Extension and Education:
  - Expand Extension services available to organic growers. Extension is essential to delivering new skills, tools, and technology into the hands of growers. As a country we are under-investing in Cooperative Extension programs, and organic producers are at an additional disadvantage because the organic expertise of Extension agents lags significantly.
  - Increase the level of coordination between USDA's research agencies and programs with their technical assistance agencies. Farmers depend on the continued and expanded capacity of NIFA and ARS to continue effectively sharing key research findings with NRCS and other technical assistance-focused agencies, so they can support the adoption of best practices and sustainable systems of production.

The CHAIRMAN. Thank you, Dr. Vélez.
And now we will hear from Dr. Brouder.

STATEMENT OF SYLVIE M. BROUDER, PH.D., PROFESSOR OF AGRONOMY, WICKERSHAM CHAIR OF EXCELLENCE IN AGRICULTURAL RESEARCH, DEPARTMENT OF AGRONOMY: CROPS, SOILS, AND ENVIRONMENTAL SCIENCES, PURDUE UNIVERSITY; PAST PRESIDENT, AMERICAN SOCIETY OF AGRONOMY, WEST LAFAYETTE, IN; ON BEHALF OF CROP SCIENCE SOCIETY OF AMERICA; SOIL SCIENCE SOCIETY OF AMERICA

Dr. BROUDER. Chairman Scott, Ranking Member Thompson, and Members of the Committee, thank you for inviting me to speak today. I am an agroecologist and past President of the American Society of Agronomy and speak on behalf of ASA's members and those of our sister societies, the Crop and Soil Science Societies.

With more than 8,000 scientists from public- and private-sectors and over 13,000 certified crop advisors, we are the largest U.S. coalition of professionals dedicated to the agronomy, crop, and soil sciences. We have a formal collective commitment to climate resilience and to diversifying our reach. ASA is committed to facilitating science translation for action.

Today, my focus is on challenges associated with achieving open and interoperable agricultural data to accelerate innovation for food security and resilience and to address the urgent need for capacity development to enable data-driven agriculture. Achieving free, open access to research data paves the way to equitable and inclusive solutions for all U.S. agricultural enterprises. Further, the quantity of data collected on farms is increasing exponentially. Harnessing these data for development of management recommendations is widely considered an untapped opportunity to leverage public research investments. Implementation of data-driven decisions requires public-private data networks that feed on-farm data back into decision support tools and assist farmers in choosing which practices will have the most significant effect on their land.

A large array of networks and repository initiatives are emerging to address infrastructure needs. These have potential to contribute to a solution, but at present, they are not well-coordinated, most do not yet have sustainable business models, and they use a variety of approaches to describe data. The key to ensuring interoperable, accessible data is the creation of and adherence to common metadata and data to standards and easy-to-use workflows. Currently, this is a common challenge across many scientific domains that scientific leaders, including myself at ASA, are seeking strategies and resources to overcome.

USDA competitive grants programs can and have supported the development of new architecture, tools, and apps, but these short-duration funds target innovation and currently cannot finance long-term maintenance of data infrastructure. With colleagues I have analyzed the data stewardship and its approaches, and we have proposed the USDA Research, Education, and Economics Office provide leadership in conjunction with AgARDA, which was envisioned to have the authority and investment needed to facilitate open research data. Full, robust, and sustained funding would position AgARDA to lead a partnership of agricultural data stakeholders in the development and implementation of infrastructure.

There are a host of additional issues that must be addressed when considering access and use of private data. However, other sectors have clearly demonstrated that private and personal data can be secured and used without risk to the individual. Borrowing these strategies from a high-stakes sector like medicine would be a natural starting place for building farmer trust.

Finally, significant quantities of relevant research already exist, yet practice adoption at scale remains low. We urgently need new educational materials that accurately characterize on-farm benefits and a large new cohort of extension specialists and service providers skilled in communicating the need for and potential uncertainties of climate-smart practices. NIFA currently has open calls related to capacity development, but the current investment level is too low to achieve sustained increased capacity.

Our societies are currently seeking partners for capacity development and have invested our own resources to build a new platform for open delivery of climate-smart materials. Our first priority is to provide trusted science-based information to address the confusion occurring on farms regarding the proliferation of carbon and ecosystem service markets. For content, we are drawing on the expertise of our members and the larger scientific community. We envision a scientific community where every person is able to achieve their professional potential, a vision accelerated by free access to both our science and data resources.

Additionally, advancing data-driven solutions requires new formal undergraduate and graduate curricula, that ensures students gain some understanding of data science and their use in agriculture and food systems research. In my experience, next-generation extension specialists require skills in the core methodologies of assessing data validity, unbound by a synthesis of studies and communicating scientific uncertainty. Reorienting traditional curricula to encompass data sciences creates the opportunity to recruit students with more diverse interests to the agricultural workforce.

Thank you for the opportunity to testify before this Committee. I look forward to addressing your questions and to the discussion.

[The prepared statement of Dr. Brouder follows:]

PREPARED STATEMENT OF SYLVIE M. BROUDER, PH.D., PROFESSOR OF AGRONOMY, WICKERSHAM CHAIR OF EXCELLENCE IN AGRICULTURAL RESEARCH, DEPARTMENT OF AGRONOMY: CROPS, SOILS, AND ENVIRONMENTAL SCIENCES, PURDUE UNIVERSITY; PAST PRESIDENT, AMERICAN SOCIETY OF AGRONOMY, WEST LAFAYETTE, IN; ON BEHALF OF CROP SCIENCE SOCIETY OF AMERICA; SOIL SCIENCE SOCIETY OF AMERICA

Chairman Scott, Ranking Member Thompson, and Members of the Committee, thank you for inviting me to speak to you today. My name is Sylvie Brouder, and I am an agroecologist and a Past President of the American Society of Agronomy (ASA). For the past 27 years, I have been a faculty member in the Department of Agronomy at Purdue University where I conduct research on cropping systems, their productivity and their impact on air and water quality. I am the Director of at Purdue's Water Quality Field Station, a highly-instrumented, long-term research facility. My appointment also includes teaching and Cooperative Extension; the latter emphasizing development of nutrient management recommendations for farmers.

As leadership representing ASA, I speak today on behalf of the interests of our members and the members of our sister societies: the Crop Science Society of America (CSSA), and the Soil Science Society of America (SSSA). Collectively, the "Tri-Societies" represent more than 8,000 scientists in academia, Cooperative Extension, industry, and government, over 13,000 Certified Crop Advisers (CCA), and 620 Cer-

tified Professional Soil Scientists (CPSS). We are the largest coalition of professionals dedicated to the agronomy, crop, and soil science disciplines in the United States. Our members engage in the science that has documented agriculture's contributions to climate change; they recognize agriculture's opportunity to contribute to climate and food security solutions and they are dedicated to advancing the science of climate-smart agriculture and to rigorous translation of that science into evidence-based agricultural management recommendations. Our current strategic plans reflect this commitment in key strategies highly relevant to today's hearing including pursuit of a common "Grand Challenge" of driving soil-plant-water-environment systems solutions for healthy people on a healthy planet in a rapidly changing climate as well as increased investment in "Knowledge to Action" and "Engagement, Inclusion, and Diversity." [1]

Research and Data Infrastructure and Security Needs

To accurately reflect our members' perspectives in the national dialogue on research needs for agricultural resiliency, we conducted a survey of the potential for various management strategies to facilitate farmer adaptation to or mitigation of climate change. Respondents identified improvements in soil, water and nutrient management, and crop diversification and improvement as practices with highest potential with 45 to 60+ percent indicating more research was needed for a practice or suite of practices. These research needs are summarized in a statement we released last year on "*Advancing Resilient Agriculture: Recommendations to Address Climate Change*" where we highlight the potential ecosystem services that working lands can provide as well their complexities, synergies and trade-offs, and the challenges associated with their measurement and monitoring.[2] On-farm practice efficacy, including magnitude and timeline to impact, will be influenced by both the environment and the attributes of the farm enterprise itself. Thus, new crop, soil and agronomic science is needed to address site-specific nuances and as well as to keep pace with the changing weather patterns and the rapid evolution of on-farm technology and its implementation.

However, to achieve rapid and efficient gains in climate science for agricultural resiliency, we will need to address the significant impediment posed by a lack of data infrastructure long fostered by a research culture that has eschewed data sharing. In 2019, I led an analysis of the limitations to agricultural decision-making posed by a pervasive lack of accessibility and sharing of research data; for agriculture, the scope of data-related opportunities and challenges is hard to overstate. Historically, agricultural progress has been achieved through incremental aggregations of "small science," hypothesis driven research conducted by individuals or small teams of researchers. The scientific reward and Federal funding systems have co-evolved with this small science model ensuring persistence of this research culture. Yet, the small science approach cannot characterize the nuances and trade-offs that are hallmarks of grand challenge questions. Further, the historic culture of data disposal once a knowledge fragment is created can lead to distrust as an analysis cannot be reproduced and to inefficiencies because datasets from similar, small studies cannot be synthesized into larger, more nuanced analyses and cannot be reused to address new questions not originally envisioned when the data were collected.[3] Achieving free, open access to research data paves the way to equitable and inclusive solutions for the diverse array of U.S. agricultural enterprises whose resiliency is now challenged by climate change.

For agriculture, organizing, standardizing and making publicly available non-sensitive raw data produced by small independent research studies is a critical first step to capitalizing on the opportunities and efficiencies afforded by the host of new "e-sciences" tools and technologies. Meta-analytical statistics can be applied to arrays of curated datasets from independent studies, an approach routinely used in medicine, education and other disciplines.[4] Results from such statistically powerful syntheses afford a more complete understanding of outcomes associated with a practice or intervention and provide a robust translation of science into practice. With sufficient data, artificial intelligence is widely expected to offer new insights into agricultural resiliency. Large datasets created by harmonization of small datasets can be explored with methods such as machine learning to detect patterns and uncover important characteristics in aggregated data that are simply not present in the individual component datasets.

Data-sharing infrastructure, including easy-to-use workflows, would also accommodate research data not currently represented in peer-review publications. Highly regarded peer-review journals covering the agricultural sciences currently adhere to a litmus test of research "novelty" in order for a manuscript to be accepted. Thus, researchers commonly are unwilling or unable to invest the substantial effort needed to publish studies with confirmatory (*e.g.,* studies that replicate results already

in journal articles) or negative results.[5] Yet such studies are critical to the characterization of how impactful a management practice will be in the real world and to the development of an unbiased foundation to evidence-based practice. Making this "file drawer" or "dark" data available ensures public investments are not lost and can increase the reach of research results beyond a given region or beyond the original research question. It also ensures that syntheses across studies with meta-analysis are not biased by a preponderance of positive results in the published literature.

The quantity of data collected on farms by farmers and their technical service providers is increasing exponentially. Harnessing these data for development of management recommendations is widely considered an untapped opportunity to leverage public research investments. The simple notion that a farmer's own data will both be useful in tailoring a recommendation to their farm and, when merged with research data, will strengthen and add needed nuance to recommendation frameworks currently motivates numerous projects. Much of my own ongoing research [focuses] on case studies to demonstrate the value of data sharing to spur development of agricultural data networks. At present, I lead a USDA NIFA-funded Coordinated Innovation Network to develop a cyber-infrastructure framework for integrating public and private data for evidence-based fertilizer recommendations.[6] Moving forward, most agricultural scientists now envision that implementation of data-driven decisions for climate-smart agriculture requires interoperable public-private data networks that feed on-farm data back into decision-support tools to assist farmers in choosing which practices will have the most significant effect on their land.[2]

Realizing Data Infrastructure Requires Partnerships, Investment and Trust

Designing a singular solution for agricultural data seems inherently untenable given a large array of networks and repository initiatives that are emerging to address infrastructure needs. In recent years, Federal agencies including USDA have instituted programs and policies to drive data sharing and reap its benefits. Funding requests by researchers must now be accompanied by a data management plan that details handling of data generated by projects during and after the completion of the project including details on how the data will be produced or acquired, managed, stored, shared, and protected.[7] The general expectation is that all data will be preserved and curated in a form that is reusable (*i.e.,* contains enough information and annotation for independent understanding). In the case of NIFA-funded projects, researchers are encouraged but not required to deposit data in USDA's Ag Data Commons.[8] However, most researchers have numerous options for data preservation including domain-specific databases,[9] general purpose publishing repositories, and institutional research repositories.[10] Many of these repositories provide curation and preservation and make data available for free but may be tailored to specific needs of their immediate stakeholders. They have potential to contribute to a data infrastructure solution for agriculture but at present they are not well coordinated and most do not yet have strong business models to ensure sustainability. Additionally, they use a variety of approaches to describing data.

The key to ensuring data are interoperable across datasets, networks, and repositories is the creation of and adherence to common metadata and data standards.[3] Such standards are currently under development but more engagement in standards development by researchers and their professional societies is needed. At ASA, leadership has been gleaning lessons-learned by other societies as they pursue development of standards for their membership.[11] For agriculture, the development of data standards and their broad adoption by existing infrastructures can be expected to remain a challenge in the foreseeable future and should be a high priority in the climate resiliency agenda. Ultimately, designing functional data architecture for agriculture requires partners in the research data value chain (*e.g.,* researchers, their institutions and sponsors, *etc.*) to commit to collaborative and iterative analysis of successes and failures in design and utility.

Competitive grants programs including NIFA can and have supported the development of new data architecture, tools and apps but these short-duration funds target innovation and are not currently positioned to finance long-term maintenance of databases and other data infrastructure. The cost of data infrastructure for agriculture is currently unknown. Databases with longevity almost always have core, institutional support.[12] Delivering data online for free—in keeping with goals of democratized access to publicly funded research—requires workflows and human resources for stewardship that will drive costs well beyond those needed for storage. One option is for public and private funding organizations to pay directly for stewardship in contributions that are proportionatal to the size of a grant.[13] In our analysis of data infrastructure needs,[3] we propose the USDA Research Education and Economics office provide leadership and oversight to piloting agricultural case stud-

ies exploring potential business models. The Agriculture Advanced Research and Development Authority (AgARDA) created by the 2018 Farm Bill was envisioned to have the authority and investment needed to facilitate sharing of research data. Full appropriation of authorized funds would position AgARDA to lead a partnership of agricultural data stakeholders in the development and implementation of data infrastructure.

Without question, there are a host of additional data-related issues that must be addressed when considering access and use of private data including the farmer-owned and on-farm data that is anticipated to greatly benefit the science of agricultural resiliency to climate change. For farmers, the marginal cost of data storage is low but the up-front costs to collect and manage these data can be expensive. These costs must be fully recognized when researchers solicit their use. Further, there is a pervasive concern, even among collaborators within farmer networks, that their data will be used for regulatory and/or punitive purposes. For example, many states have regulations pertaining to non-point sources of nutrients that exacerbate farmer unwillingness to share key management details needed for reuse of their data. However, numerous mechanisms already exist for data anonymization and other sectors have clearly demonstrated that private and personal data can be secured and used without risk to the individual. Medicine relies heavily on individual patient data to characterize the efficacy of clinical practices and has largely been successful in securing individual identity and developing trust through an array of personal protection legal instruments. Borrowing these strategies from a high-stakes sector like medicine would be a natural starting place for building farmer trust and willingness to engage.

Developing a Diversified Workforce for Climate Smart Agriculture

In our Strategic Plan, ASA's focus on "Knowledge to Action" [1] reflects our commitment to our CCA membership and recognizes that access to recommendations that align with and are transparent to the underpinning science is a major barrier to continually advancing agricultural sustainability and resiliency at scale. While there are significant knowledge gaps that require more research, there is already a large volume of existing scientific research on practices and their impacts on productivity and environmental outcomes. For example, numerous practices have been extensively studied for their ability to sequester carbon (C) in soil for climate change mitigation and/or to reduce soil C losses commonly associated with agricultural activities—critical to both climate mitigation and adaptation and a central tenant for regenerative agriculture. Yet practice adoption at scale remains low reflecting a dearth of science-based educational materials and human resources to facilitate technology transfer.

The C markets are currently targeting payments for practices that may require implementation of a decade or more for measurable change to occur, and farmers are understandably concerned about payment levels offered and legal liabilities associated with non-compliance.[14] Indeed, as revealed by our member survey, other practices for "4R" nutrient management,[15] on-farm energy efficiencies, *etc.,* may offer an as or more realizable approach to achieving on-farm climate mitigation even though soil C sequestration is a cornerstone for climate adaptation. For practice adoption to occur at scale, there is an urgent need for new education materials that accurately characterize potential benefits, including timelines to and magnitudes of measurable benefit and certainty of benefit realization for a particular purpose (*e.g.,* greenhouse gas emission mitigation, soil moisture conservation and adaptation to increased precipitation uncertainty).

The need to bolster capacity for technology transfer is widely recognized throughout the public- and private-sectors. Joint Policy Recommendations from the Food and Agriculture Climate Alliance highlight enhancing access to technical assistance to ensure producers can overcome barriers to the practices that can lead to improvements in soil health and reduce greenhouse gas emissions.[16] In 2020, the eXtension Foundation published an analysis of existing Cooperative Extension programs on climate and extreme weather and highlighted the urgent need for unified, nationally coordinated programming that wholistically addresses climate adaption and mitigation.[17] Of particular note was the current dearth of programs to address the needs of minority communities. Our Tri-Society statement *Advancing Resilient Agriculture* [2] also highlights the need for educational programs that are more directly responsive to on-farm realities, especially with respect to the confusing array of emerging carbon and ecosystem service markets.

NIFA currently has an open call for one competitively-funded Coordinated Agricultural Project to support farmers, ranchers and foresters in implementing climate-smart and nature-based solutions.[18] However, the current investment level is too low to achieve a sustained, increased capacity in climate-smart programming. In

keeping with our commitment to our Grand Challenge, the Tri-Societies are currently seeking partners to assist in climate-smart and food security capacity development. Last December, we collectively committed to investing $500,000 of our internal funds to building a new Carbon and Ecosystem Services Education Project, "Decode Six."[19] The first priority of this program is to provide trusted educational resources to address the confusion occurring on farms regarding the proliferation of carbon and ecosystem service markets. We are building a science-based, unbiased, open access website featuring materials from peer-reviewed science. For content, we are drawing on the expertise of our members and the science community writ large. Relevance and content inclusivity will be achieved through engagement of our CCAs and external partners including the Ecosystem Service Market Consortium[20] and their Producer's Circle and their Working Group on Inclusion and Racial Justice. Our programming will also be informed by the Tri-societies' renewed commitment to diversity, equity and inclusivity. We envision a scientific community where every person, regardless of their background and challenges, is able to achieve their professional potential; a vision accelerated by open access to both our science and data resources.[21] Our goal is to grow both our educational platform and the diversity of the membership we represent via partnerships. To that end, I represent the Tri-Societies on the Climate Priority Action Team of Extension Committee on Organization and Policy (ECOP). The Action Team seeks to build resource for climate Extension programs via partnerships with Federal Government agencies, nonprofits and philanthropic organizations.

Finally, advancing data-driven solutions in agriculture also requires new formal curricula at the undergraduate and graduate levels that ensures students gain some understanding of data sciences and their use in agricultural and food systems research. Current demand in the agricultural sector for students skilled in data and computational sciences is far outstripping supply. Indeed, the major, regional crop consultancy group that collaborates on my NIFA-funded cyber-framework project[6] employs agronomists and data/computer scientists at roughly equivalent rates. While not every student of agricultural sciences will need to be a "data scientist," they will all need some understanding of basic principles, data tools and ethics. Next generation Extension Specialists require curricula on core methodologies for assessing data validity, data wrangling, the transparent and unbiased synthesis of studies and communicating scientific uncertainty. As forecast for the general workforce,[22] agriculture will need individuals with appropriate domain knowledge but also individuals with the mathematical, computational and statistical skills to help manage and use the volume of data generated by research and on-farm monitoring networks. Reorienting traditional curricula to encompass data sciences creates the ancillary opportunity of recruiting a host of non-traditionally oriented students into agriculture, a key to diversification of the agricultural workforce.

Thank you for the opportunity to testify before this panel. I would be glad to address your questions and I look forward to the discussion.

[Endnotes]

[1] The Strategic Plan for the American Society of Agronomy is available at *https://www.agronomy.org/files/Governance/strategic-plan-asa-2020-2023.pdf*.

[2] Beyond food, feed and fiber, the ecosystem services that healthy agricultural systems can provide include air and water filtration, regulation of nutrient cycling, carbon sequestration and biodiversity promotion. Access *Advancing Resilient Agriculture* at *https://www.agronomy.org/files/science-policy/issues/2021-acs-climate-solutions-statement.pdf*.

[3] The full purpose of this analysis was to document the need for and anticipated benefits of developing data-sharing standards, incentivizing researchers to share data, and building a data-sharing infrastructure for agricultural research. For details, see Council for Agricultural Science and Technology (CAST). 2019. *Enabling Open Source Data Networks in Public Agricultural Research.* CAST Commentary QTA2019–1. CAST, Ames, Iowa.

[4] The Cochrane is a major resource for trusted evidence in medicine and is underpinned by meta-analyses. See *https://www.cochrane.org/*.

[5] It is common practice for Extension Specialists to conduct experiments to confirm the effectiveness of a new agricultural management practice in their state or region. Results from these field trials are used in local education programs but may never be formally published in a journal article and results are commonly not preserved or curated for future use.

[6] USDA's National Institute for Food and Agriculture (NIFA)—Agriculture and Food Research Initiative is a major funding source for Tri-Societies' members research on management practices that influence agriculture's resiliency to climate change. The Data Science for Food and Agriculture Systems Program funds my on-going cyber-framework project.

[7] For the guidance on Data Management Plans for NIFA-funded projects see *https://www.nifa.usda.gov/data-management-plan-nifa-funded-research-education-extension-projects*.

[8] USDA's National Agricultural Library created the Ag Data Commons is a data catalog and repository available to help the agricultural research community share and discover research data funded by USDA and meet Federal open access requirements.

[9] Domain data repositories are designed to house data of similar focus. An example is SoyBase, the USDA's soybean genetics database. See *https://www.soybase.org/sb_about.php*.

[10] An example of an institutional repository is the Purdue University Research Repository where any researcher with a Purdue affiliation can formally publish a dataset from any research domain. It was developed to meet the data management planning requirements of Federal funding agencies and currently houses 1,300+ publicly available datasets, many in the agricultural domain. *https://purr.purdue.edu/*.

[11] The Council of Scientific Society Presidents (*https://www.sciencepresidents.org/*) recently facilitated a year-long series of presentations and discussions on Data Sharing.

[12] Attwood, T.K., B. Agit, L.B. Ellis, 2015. *Longevity of biological databases.* EMBnet.journal 21.e803. *https://journal.embnet.org/index.php/embnetjournal/article/view/803/1209*.

[13] Gabella, C., C. Durinx, R. Appel. 2017. *Funding Knowledgebases: Towards a sustainable funding model for the UniProt use case. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5747334/.*

[14] For a recent Purdue Univ. analysis of Opportunities and Challenges Associated with "Carbon Farming" see *https://ag.purdue.edu/commercialag/home/wp-content/uploads/2021/06/202106_Thompson_CarbonMarkets.pdf.*

[15] 4R Nutrient Management focuses on apply the right rate and source of fertilizer in the right place and at the right time.

[16] The Food and Agriculture Climate Alliance is coalition of organizations representing farmers, ranchers, forest owners, the food sector and environmental advocates working to define and promote shared climate policy priorities. For their Joint Policy Recommendations, see *https://agclimatealliance.com/.*

[17] Extension Climate and Extreme Weather Programming. 2020. *ehttps://online.flippingbook.com/view/310442/Xtension Foundation.*

[18] This NIFA funding opportunity is in the Crosscutting Priority Area. The Program Area is Extension, Education, & USDA Climate Hubs Partnership and offers one $10M, 5 year award.

[19] "Decode Six" is in reference to decoding carbon, which has an atomic number of six on the Periodic Table of Elements.

[20] The Ecosystem Services Market Consortium is a nonprofit, member-based organization dedicated to advancing ecosystem service markets. See *https://ecosystemservicesmarket.org/.*

[21] Our Tri-Society DEI statement can be accessed at *https://www.agronomy.org/files/DEI/acs-dei-statement-2021.pdf.*

[22] The Business Higher Education Forum. 2017. *Investing in America's Data Science and Analytics Talent: The Case for Action. https://www.bhef.com/sites/default/files/bhef_2017_investing_in_dsa.pdf.*

The CHAIRMAN. Thank you, Dr. Brouder.

And now we will hear from Dr. Fares.

STATEMENT OF ALI FARES, PH.D., ENDOWED PROFESSOR OF WATER SECURITY AND WATER ENERGY FOOD NEXUS, COLLEGE OF AGRICULTURE AND HUMAN SCIENCES, PRAIRIE VIEW A&M UNIVERSITY, PRAIRIE VIEW, TX

Dr. FARES. Good morning. Thank you, Chairman David Scott, Vice Chair Alma Adams, and Ranking Member Glenn Thompson, for convening and inviting me to contribute to today's hearing. I am Dr. Ali Fares, Endowed Professor of Water Security and Water Food Energy Nexus at Prairie View A&M University. I want to thank you for your sustained support for research with the land-grant institutions such as Prairie View A&M University and the 1890 Institutions, specifically to allow us to train future leaders and professionals and conduct fundamental and applied research that addresses the needs of the over eight million limited resource farmers, ranchers, and community members in Texas through multiple funding programs, including the 2018 Farm Bill.

These rural and urban communities have been one of the most impacted portions of the society by climate change. Through the continued support of Congress and the extraordinary efforts of leaders of this Committee, PVAMU and the 1890 Institutions have been conducting state-of-the-art research, while training limited resources future leaders to address evolving needs of the U.S. population.

The 1890 Institutions have several active climate research projects. For instance, at Prairie View A&M University, I am leading the GetAgSmart Project, the USDA NIFA-funded project, in collaboration with colleagues from Texas A&M University. We have been working on building capacity and smart agricultural technologies to train Texas underserved communities and support them to start high-paying careers in this area. Through a second NSF-funded project I am jointly working with colleagues from the University of Texas at Austin training over 30 Ph.D. and M.S. students in the area of water, energy, food, and climate change.

The U.S. has been the global leader in research and development investment. The new economy is research and innovation-savvy and dominated by tech companies that continuously benefit from research and innovation, including agriculture, that heavily rely on research innovation and its mission to meet ever-increasing demand for food, fiber, clean energy, and ecosystem services while facing an array of climate change and use challenges that have

been compounded by the pandemic and regional wars in crucial food and energy influential areas.

The climate change crisis offers opportunity for research and innovation in agriculture energy and related sector to support the new economy with different infrastructure, workforce skills, financial tools, and governance. As a result, new careers will arise, a new market will develop. Embracing this new economy will result in the thriving of the U.S. economy where small and minority businesses and individuals will play a significant role.

Agricultural research and innovation helps the agriculture sector overcome many of its challenges, including the soil and water conservation efforts triggered by the 1930s Dust Bowl and the Green Revolution that benefited from the effort of legendary agronomists such as Dr. Norman Borlaug.

Although agriculture is a major greenhouse gas emitter, it is looked at as the sector that can not only reverse its course, but also can mitigate substantial amounts of greenhouse gases, via carbon sequestration in soil and biomass. Through the adoption of effectively proven management practices, it will help the U.S. achieve its emission reduction goals, strengthen its resiliency to climate change, and strengthen its global economic leadership.

The USDA NIFA and other institutions enumerated several climate research needs that require several actions to help the agriculture sector address the climate change crisis via a joint mitigation and adaptation approach. However, I am going to highlight a few that are deemed relevant to the 1890 Institutions and limited resource funds in communities: adequate funding to support and develop climate-smart practices and technologies; addressing water security; stronger support for research and innovation to develop tools and practices tailored to limited resource farms and communities; and support public-private partnership and international collaboration between U.S. and international academic and research institutions and industries. I encourage Congress to support robust funding increases for the 1890 land-grant program so that we can make even more positive impact on our country's citizens. Through our research program, we will be better able to address specific climate change needs of the underserved communities.

I look forward to answering questions from you and the Committee Members in the question-and-answer section, and thank you for having me.

[The prepared statement of Dr. Fares follows:]

PREPARED STATEMENT OF ALI FARES, PH.D., ENDOWED PROFESSOR OF WATER SECURITY AND WATER ENERGY FOOD NEXUS, COLLEGE OF AGRICULTURE AND HUMAN SCIENCES, PRAIRIE VIEW A&M UNIVERSITY, PRAIRIE VIEW, TX

Good morning. Thank you, Chairman David Scott, Vice Chair Alma Adams, and Ranking Member Glenn Thompson, for convening and inviting me to contribute to today's hearing, *"The Role of Climate Research in Supporting Agricultural Resiliency."* I am Dr. Ali Fares, Endowed Professor of Water Security and Water Energy Food Nexus at Prairie View A&M University (PVAMU). I want to thank you for your sustained support to research in the Land-Grant Institutions such as PVAMU and the 1890 Institutions, specifically to allow us to train future leaders and professionals and conduct fundamental and applied research that addresses the needs of the over eight million limited resource farmers, ranchers, and community members in Texas through multiple funding programs included in the 2018 Farm Bill. These

rural and urban communities have been one of the more impacted portions of society by climate change.

Through the continued support of Congress and the extraordinary efforts of leaders of this Committee, PVAMU, the 1890 Institutions, and other land-grant institutions have continued conducting state-of-the-art research while training limited-resources future leaders to address the evolving needs of the U.S. population.

The 1890 Institutions have several active climate research projects; at PVAMU, I am leading the GetAgSmart project, a USDA–NIFA funded project in collaboration with colleagues from Texas A&M University. We have been working on building capacity in smart agricultural technologies to train Texas underserved communities and support them start high-paying careers in this area. The second project is a joint effort with colleagues at the University of Texas at Austin, training over 30 Ph.D. and MS students in the area water-food-energy and climate change. Several of these students graduated and are already training others.

It is crucial to remind ourselves of the critical role research and innovation, R&I, have on the U.S. economy and the U.S. global leadership in this area. The U.S. has been the global leader in R&D investments; The U.S. continues to lead the nations in its spending on R&D; although currently, it was about 30% in 2019, its R&D was 40% of the global R&D in 1999. Our new economy, as many want to call it, is R&D savvy and dominated by tech companies that continuously benefit from R&D. The agricultural sector is one of those economic sectors that heavily rely on research and development (R&I) in its mission to meet ever-increasing demands for food, fiber, clean energy, and ecosystem services while facing an array of climate change-induced challenges, *e.g.,* droughts, flooding, fires, freezes, and pest infestation. Since 2020, the challenges have been compounded by the pandemic and regional wars in crucial food and energy influenceable areas, disrupted the supply chains, and introduced volatility to the food energy markets and the global economy.

The current climate change challenges offer opportunities for economic innovation and the implementation of new growth models. Substantially reducing GHG emissions in about 2 decades requires innovation in many sectors, especially agriculture, energy, and other related sectors. These innovations will support a new economy with different infrastructure, workforce skills, financial tools, and governance. As a result, new career opportunities will arise, and new markets will develop (*e.g.,* carbon market, resiliency indices), powered by new goods and services. Intentionally embracing this new economy will result in the thriving of the U.S. economy, where small and minority businesses and individuals will play a significant role.

Agricultural and natural resources research and innovation helped the agriculture and natural resources sector overcome many of its challenges, including the introduction of erosion control practices that resulted from the extensive soil and water conservation research triggered by the Dust Bowl in the 1930s of the last century. Results of those practical research have been implemented here in the U.S. and internationally to combat soil erosion and protect the environment. In addition, the green revolution, by introducing the crop breeding efforts of legendary agronomists such as Norman Borlaug, helped achieve food security in the U.S. and other countries such as India.

Although the agriculture sector has been one of the major greenhouses gases emitters, it is looked at as the sector that can not only reverse its course but also can mitigate substantial amounts of GHG via carbon sequestration in soil and biomasses through the adaption of effectively proven management practices.

This will help the U.S. achieve its emission reduction goals, strengthen our resilience to climate change, and strengthen our global economic and moral leadership.

Through R&I, we can develop and implement climate-smart and resilient agricultural practices that will help U.S. individuals, families, and communities weather the impact of climate change through adaptation and mitigation approaches. These approaches are interrelated and must be adopted simultaneously as they are needed to improve changing climate resiliency.

The USDA, through NIFA, enumerates several climate research needs that require several actions to help the agriculture sector and other stakeholders adapt to and address climate change crisis via a joint mitigation and adaptation approach, including:

- Adequate funds are needed to study and develop climate-smart practices and technologies that producers and land managers need to implement these practices and approaches.
- Research on the effectiveness of adaptive practices and technologies regarding productivity synergies, tradeoffs and mitigation co-benefits on soil carbon storage and GHG emission reductions.

- There is an urgent need to support site-specific research on fertilizer technologies, climate-resilient plants and trees, and fate of pollinator communities, and vector-borne livestock diseases.
- Support for reliable modeling efforts on the future affordability of climate-smart activities and project pest and disease outbreaks under different scenarios.
- Water security: long-term monitoring of snowpack, precipitation, and soil moisture networks data is essential to investigate trends and develop management options.
- Integrating climate and socioeconomic change with production and land-management outcomes while considering the secondary effects of climate's influence on pollinators, pests, diseases, invasive species, and extreme events such as flooding and drought.
- The advanced and integrated use of Artificial Intelligence and IoT-based technologies will help efficient and effective decision-making for climate-smart and sustainable agriculture.
- Limited resources and minority farmers have additional challenges besides climate change. They are last in adopting new technologies and practices as most of them lack the resources needed and most of the adopted technologies are costly and require a level of technical understanding, two elements lacking most of the limited resources farmers and ranchers.
- Intentional efforts are needed, especially for commodity-specific objectives (*e.g.,* common crops and animals, corn, wheat, beef, small animals) to develop tools and practices tailored to limited resources for farmers and communities.
- Support technology transfer on newly developed scientific information and tools at the local scale to help land and resource managers increase the resilience of those systems and the communities that depend on them.
- Given the enormity of the tasks, public-private partnerships and international collaborations between U.S. and international academic and research institutions and industries are viable options that it would be wise to consider.
- The 1890 institutions are significant players in this effort in helping the most fundable and impacted section of the population by climate change; however, their researchers and research infrastructure desperately need continued support to build capacity in conducting research and training the next generation of climate-smart agriculture experts.

I encourage Congress to support robust funding increases for the 1890 land-grant programs so we can make even more positive impacts on our country's citizens through our research programs. We will be better able to address specific climate change needs of the underserved farming communities and train future professionals in climate-smart agriculture discipline.

In summary, I request you invest in supporting America's future research and innovation leadership by strengthening the 1890s land-grant universities' research portfolio. PVAMU has a 146 year track record of excellence; it ranks as the No. 1 "best value" HBCU No. 4 among Texas universities.

I look forward to answering questions from you and the Committee Members in the question and answer session of this hearing.

Thank you.

The CHAIRMAN. Thank you, Dr. Fares.

And now we will hear from Dr. Houlton.

STATEMENT OF BENJAMIN Z. HOULTON, PH.D., RONALD P. LYNCH DEAN, PROFESSOR, ECOLOGY AND EVOLUTIONARY BIOLOGY, PROFESSOR, DEPARTMENT OF GLOBAL DEVELOPMENT, COLLEGE OF AGRICULTURE AND LIFE SCIENCES, CORNELL UNIVERSITY, ITHACA, NY

Dr. HOULTON. Great. Chairman Scott, Ranking Member Thompson, Members of the Committee, and everyone participating today, thank you for holding this hearing on the critical role of climate research to bolster our food and agricultural systems. I am grateful for this invitation to present on a topic which does two things. It keeps me up at night, and it gets me out of bed in the morning if that is possible. My name is Benjamin Houlton. I am the Ronald

P. Lynch Dean of the Cornell University College of Agriculture and Life Sciences. At Cornell, I hold appointments as a Professor of Ecology and Evolutionary Biology and as a Professor of Global Development.

For nearly 2 decades, I have been working on modeling the global environment and understanding climate change and its influence on society. For the past decade, I have been working explicitly with farmers, ranchers, indigenous tribes, and other partners on solutions for carbon dioxide removal, which is critical to bending the warming curve. This includes launching over 100 acres of farmland carbon sequestration projects to improve crop yields and create new financial markets for farmers, ranchers, and industry. And I am the scientific founder of a new soil carbon startup business. All views expressed in this statement are my own.

My main message today is this: Agriculture can be a powerful weapon in the battle against climate change. But we need to think about the opportunity. We need a human genome-level type investment in research and development to realize the opportunities for U.S. agriculture to take on climate leadership.

In my opening remarks, I will make three points. First, as we have heard, U.S. agriculture is the best in the world. From 1977 to 2007, the World Resources Institute estimates that increased efficiencies in U.S. agriculture have led to a 16 percent reduction in greenhouse gas emissions per pound of beef produced in the U.S. Recent studies estimate that gains in livestock and crop productivity have increased by about 30 percent from 1997 to 2017, while increasing greenhouse gas emissions by only seven percent. It is important to celebrate these advancements and recognize we can do even more to cut emissions, given that agriculture is currently around 11 percent of total emissions in the United States.

My second point, we are already witnessing the devastating impacts of climate change on food production in the U.S. and worldwide. Despite what my 16 year old daughter likes to believe, food does not come from DoorDash. It comes from very hardworking producers and growers who continue to battle heatwaves, droughts, flooding, pests, and pathogens. Cornell research has shown that we have experienced a 20 percent reduction in grain yields in the United States due to climate change. That is 7 years of productivity. And these losses could double by 2050. So we need significant investments in research infrastructure and farming communities to curb additional productivity losses.

Third, net-zero or net negative operations are in reach for farmers and producers, creating new jobs, new careers, and new forms of revenue. Some of the most promising technologies coming from research and innovation include anaerobic digesters that are converting manure into electricity; no-till and cover-cropping practices to increase carbon sequestration and improve soil health; agroforestry to sequester carbon and assist in flooding; soil amendments such as biochar, rock dust, and composted food, green waste, and manure, which can collectively sequester perhaps a billion tons of carbon in U.S. agriculture; and new fertilizer technologies that slowly release nitrogen to cut emissions.

In addition, we should be thinking about game-changing approaches in synthetic biology to boost photosynthesis in crops, the

deployment of digital agriculture and AI and new feed additives to cut methane from cow burps, offering promising suites of solution for cutting-edge research and innovation.

With these points in mind, if we make significant R&D investments across Federal and state agencies to incentivize university public-private partnerships, I envision a future where U.S. agriculture leads in climate solutions with carbon as a central commodity to uplift rural communities, while producing even better food with fewer environmental impacts. Given what we are witnessing today, we know these investments are essential for the U.S. to maintain a competitive advantage from an economic, human health, and food security perspective. Thank you.

[The prepared statement of Dr. Houlton follows:]

PREPARED STATEMENT OF BENJAMIN Z. HOULTON, PH.D., RONALD P. LYNCH DEAN, PROFESSOR, ECOLOGY AND EVOLUTIONARY BIOLOGY, PROFESSOR, DEPARTMENT OF GLOBAL DEVELOPMENT, COLLEGE OF AGRICULTURE AND LIFE SCIENCES, CORNELL UNIVERSITY, ITHACA, NY

Chairman Scott, Ranking Member Thompson, Members of the Committee, and everyone participating today, thank you for holding this hearing on the critical role of climate research to bolster our food and agriculture systems. I am grateful for the invitation to present on this important topic.

My name is Benjamin Houlton. I am the Ronald P. Lynch Dean of the Cornell University College of Agriculture and Life Sciences, known as Cornell CALS. At Cornell, I hold appointments as a Professor of Ecology and Evolutionary Biology and as a Professor of Global Development. My research interests include global ecosystem processes, climate change solutions and agricultural sustainability. I am also founding principal investigator for the Working Lands Innovation Center, directing approximately 100 acres of farmland carbon sequestration projects to improve crop yields and create new financial markets for farmers and ranchers. For nearly 2 decades I have been working on modeling the global environment and understanding climate change, and for the past decade working explicitly with farmers, ranchers, Indigenous tribes and other partners on solutions for carbon dioxide removal, which is critical to bending the carbon curve and avoiding the most dangerous climate impacts of the future. All of the views expressed in this statement are my own.

At Cornell CALS, we play a critical role in our university's Land-Grant mission to advance the lives and livelihoods of New York residents through our teaching, research and extension activities. New York—as Committee Members Maloney and Jacobs can attest—is an agriculturally vibrant state with a large and diverse array of fruit, vegetable, dairy and livestock production. Partnering with stakeholders statewide, our faculty are committed to translating research findings into evidence-based support for the wide range of farm sizes and types in our state and bringing findings from the field back to campus labs and classrooms. This two-way knowledge exchange is critical to enriching New York farmers, communities and industries with proven methods and technologies.

I believe our agriculture innovation ecosystem can power the breakthroughs needed to tackle society's most dire threat: a rapidly changing climate, which is severely disrupting U.S. and global food production. We have an urgent need for substantial and sustained investment in science-based solutions and strategies that can address our climate challenges while benefiting the farm communities that produce the foods that nourish us. Agriculture has enormous potential to help cool the planet while feeding it—but only if we accelerate development, testing and implementation of our most promising climate-smart farming innovations.

The threats our world and our farmers face

By accessing the expertise and innovation at Cornell and our partner Land-Grant universities, agriculture is poised to lead our next-generation climate solutions. But we cannot afford any further delay: The time to act is now, while there remains an opportunity to protect our food supply from climate extremes. A few examples highlight the urgency of our challenge:

- A recent analysis found that agricultural productivity over the past 60 years was *21 percent lower*[1] than it would have been without climate change—the equivalent of 7 years of lost productivity growth. This is a disturbing trend, especially when factoring in the growth of our global population, which could reach ten billion by 2050. This trend is only expected to worsen, with rising global temperatures projected to significantly reduce crop yields in coming decades.
- The western United States has battled increasing droughts and water shortages in recent decades—a trend that is also forecast to worsen in the coming decades. A *recent paper*[2] suggests that future megadroughts—extended dry periods lasting 2 decades or more—will last longer, occur more frequently and create more damage than today's conditions. Climate change is expected to accelerate these effects, pushing Earth nearer to an irreversible tipping point.
- At an average of 49.5° Fahrenheit, 2021 was the third-warmest year on record for the Northeast United States, according to the *Northeast Regional Climate Center*.[3] Since this record-keeping began in 1895, the 3 warmest years for the Northeast have occurred within the past 25 years. With increasing greenhouse gas concentrations in the atmosphere, these warming trends are expected to continue, along with more powerful extreme weather events.
- In February 2022, the Intergovernmental Panel on Climate Change—a group organized by the United Nations—*issued a report*[4] by leading scientists showing major impacts to our world's food systems due to increasing extreme weather events. They signaled a "brief and rapidly closing window to act" to prevent even more crippling consequences.

Every day we see fresh examples of our climate challenges and their dangerous effects. These examples illustrate that climate change is not a faraway or future threat—it is harming lives, businesses and communities right here and right now. And this problem is picking up steam with each passing day, week, month and year. The U.S. along with the rest of the world must act swiftly to address what another recent IPCC report deemed this "code red" crisis for our planet.

Nowhere are the perils more apparent than to our nation's farm and food communities, based predominately in rural areas. High operating costs, volatile commodity prices and stagnating yields are exerting major pressure on farmers, and many are struggling to survive. According to a recent estimate from USDA's Economic Research Service, nearly 90 percent of American farm families require off-farm income to keep their farms afloat.

Further contraction in the agriculture industry and losses in productivity will ultimately threaten our access to safe, affordable food and worsen global hunger, which is already on a menacing rise. Coupled with the fallout of unprecedented crop devastation caused by a *five-fold increase*[5] in extreme weather events over the past 50 years—triggering rising pest threats and hotter, wetter weather in the Northeast especially—our farming communities and the sectors they support need solutions, now.

Employing science-based solutions to help agriculture fight back and thrive

To put it directly: The global climate is changing steadily from bad to worse. But because we know why it is changing, we can do something about it. Working together, across industry and academia, with local, state and Federal Governments, hand in hand with our food and farming communities, I am optimistic we can bend the global warming curve to meet our Paris Agreement obligations while ensuring food security for coming generations.

For years the research community has debated whether the most important place to start is by mitigating greenhouse gas emissions or by removing carbon from the atmosphere. The reality is that we need to do both simultaneously: radically reduce emissions and deploy innovative carbon capture methods. Along with these steps, we need to pursue adaptation strategies to keep our farmers in business by helping them to adjust to the stressors of a changing climate. It is going to take every weapon in our arsenal to stop the dangerous warming of our planet and to safeguard our food systems. We are past the point of either/or thinking: We need solutions that

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[1] *https://www.nature.com/articles/s41558-021-01000-1*.
[2] *https://www.pnas.org/doi/10.1073/pnas.2108124119*.
[3] *https://news.cornell.edu/stories/2022/01/2021-was-northeasts-third-warmest-year-1895*.
[4] *https://www.ipcc.ch/report/sixth-assessment-report-working-group-ii/*.
[5] *https://public.wmo.int/en/our-mandate/climate/wmo-statement-state-of-global-climate*.

create real-time, local adaptation to weather extremes while slashing emissions and capturing greenhouse gases at scale.

This is a major challenge, yet what makes me hopeful are the many promising technologies and methods that are within our grasp. As climate change intensifies, researchers are working hard to help farmers adapt—developing a host of new climate-smart farming solutions, including new drought-resistant crop varieties, improved management practices to conserve water and digital tools to optimize input efficiency.

Significantly, we are finding that agriculture can be a powerful tool for mitigating climate change, and there is much success on which to build additional efficiency gains. The amount of food produced per acre has increased significantly in the U.S., resulting in fewer greenhouse gas emissions per unit of food. The World Resources Institute estimates that increased efficiencies in U.S. agriculture from 1977–2007 led to a 16% reduction in greenhouse gas emissions per pound of beef produced in the United States. Data indicate that livestock and crop production have increased by about 30% from 1997 to 2017 while increasing their greenhouse gas emissions by only 7%. It is critical to celebrate these advancements and recognize the need to do even more in the U.S. agrifood system.

Building on this success, it is clear that farms don't have to be victims of this challenge—they can take active steps to fight against it if the U.S. makes substantial new investments to support practices to capture and store carbon known as "carbon farming." We can increase carbon sequestration in soils by using natural additives such as biochar, compost and rock dust. Add to this such strategies as rotating crops, planting trees and shrubs alongside crops, and reducing soil turning, and farmers can capture and store atmospheric carbon in soils—benefiting our climate while offering new economic opportunity for rural communities.

With farmland making up approximately ½ of the United States, if American farmers adopted just some of these carbon farming practices today, they would not only reduce their current greenhouse gas contributions but also could capture and store an amount of carbon equivalent to 15% of annual emissions in the U.S. In the long term, carbon farming can even increase resistance to drought, cut fertilizer costs and boost crop yield.

Additional promising new techniques and technologies are under development to broaden farmers' ability to adapt to and combat climate change through reductions in methane, nitrous oxide and other greenhouse gases.

In one exciting example of this work, the Cornell CALS Department of Animal Science, with support from New York state, will install four climate-controlled respiration chambers on campus this year. The first of their kind in the United States, they will support experiments to reduce climate-warming methane emissions from cattle and other domestic animals, while examining how to optimize animal health, nutrition and production. This innovative project will provide New York dairy farmers with verified, responsible solutions for net-zero operations, ensuring that the technology delivers on its promise before being widely adopted in the marketplace. New science-based technologies to address enteric fermentation coupled with existing technologies, such as anaerobic digester systems and precision manure application strategies, have the potential to significantly reduce methane in the near future, a necessary step to help immediately reduce global warming.

Beyond the existing technologies and approaches, continued pioneering science in boosted photosynthesis can produce higher crop yields while sequestering carbon through new plant varietals. When combined with synthetic biology, artificial intelligence and machine learning, plant geneticists are finding new opportunities to increase photosynthesis and create more resilient seeds for farmers, which will be needed as climate impacts continue to mount.

Equally critical, we must increase financial incentives to support farmers' exploration of opportunities to commoditize carbon and other greenhouse gas emissions and adapt to weather extremes. Not enough farmers in America today can afford to embrace these practices and make a measurable impact. Committing to new practices presents financial risks for farmers already stressed by economic hardship and weather extremes.

As we peruse these strategies, we also need to ensure that we are developing an inclusive culture that delivers on the promise of a more just and equitable farm and food system. The 2017 New York state agriculture census *cites that only 1.3%*[6] of New York farmers and producers identify as people of color. The lack of money or margins to innovate with climate solutions is felt by farmers of color, many of whom have been historically excluded and tend to own smallholder farms, thus lacking the land and the financial capital to take advantage of these opportunities. Strategies

[6] *https://agriculture.ny.gov/farming/supporting-diversity-agriculture*.

employed by policymakers and granting agencies to target resource allocation for historically underrepresented farmers will be vital for a more just transition to net-zero agriculture.

Through public-private partnerships involving academia, business, government and civic organizations, we can advance the innovative research and scalable technologies needed to achieve this vision. And we can do so in ways that ensure farmers and foresters receive not just public praise for their efforts to sequester carbon, but also support that makes sound economic sense, provides equity and boosts overall farm profitability.

A time for action and investment in our future

As we pursue climate-smart agricultural practices to sustain our world, the Land-Grant system provides a critical research and development test bed to pilot and refine these approaches without placing another financial burden upon our farmers. For all of us to enjoy eating locally produced foods in the decades to come, we need to provide scientists with sufficient and sustained research funding and resources to ensure our crop varieties are climate-adapted in the future, and that we continue to innovate with new tools to help farmers increase production in the face of rapid climate extremities.

As the Committee works to develop new programs and policies to address climate change through research, I'd like to point to two exemplary USDA programs that are models of interagency cooperation and partnership between Land-Grant universities, farmers and communities. First, USDA's Climate Hubs allow collaboration across agencies and with external partnerships to develop and deliver science-based, region-specific decision making, information, and research-informed climate change response. The impacts of climate change span countless scientific disciplines and government programs, so continuing to fund models like this that support holistic research solutions across expertise and Federal agencies is key. Another exciting model, the USDA's new Partnerships for Climate-Smart Commodities program, offers grant funding to a wide variety of public and private entities to incentivize market opportunities for commodities that develop and adopt climate-smart practices.

Cooperative Extension programs, which have worked through the Land-Grant system in collaboration with farmers, producers and community groups for more than a century, will be essential to translating scientific research and developing new commercial opportunities from our labs out to the land. The relationships that Cooperative Extension has cultivated among farmers and in communities serve as necessary partners for university-based scientists—they enable us to understand the real-world needs of our stakeholders and assist in deployment of new opportunities, whether they be anaerobic digesters for dairy, new crop varietals for growers, new management practices, or carbon farming through the soil. Even as it is critical that Land-Grant universities continue to leverage Cooperative Extension, it is just as critical that Congress continue to bolster support for these programs. Otherwise, it will be more difficult to succeed at the scale and with the urgency that is necessary to avoid the most dangerous climate outcomes, preserve food security, and revitalize the farm sector and rural communities.

Though helpful, these programs alone are not enough; agricultural research is key to fighting climate change and protecting global food supplies, but pathways to innovation are under threat.

The U.S. has fallen behind competitors China and Brazil in public support for agricultural research, according to a *recent report*[7] commissioned by Farm Journal Foundation and the American Farm Bureau Federation. U.S. public funding for agricultural research has declined in real dollars since 2003, while investments in other forms of domestic research have risen.

This lack of support means that across the U.S., many potentially groundbreaking studies are significantly underfunded or even unfunded—which can delay or stifle important discoveries. Many universities are in desperate need of infrastructure investments to upgrade laboratories and other facilities for the 21st century. According to the Association of Public and [Land-grant] Universities, 69% of the buildings and facilities at U.S. schools of agriculture are at the *end of their useful life.*[8]

Scientific research takes years to refine and develop before new discoveries are ready for the market. Therefore, it is important to prioritize agricultural research funding today, to ensure that our nation's crop and livestock producers can stay one step ahead of the climate crisis. It is disappointing that the U.S.—which is one of

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[7] *https://www.farmjournalfoundation.org/post/report-highlights-how-stagnant-u-s-public-funding-for-agricultural-research-threatens-food-systems*.

[8] *https://www.aplu.org/library/a-national-study-of-capital-infrastructure-at-colleges-and-schools-of-agriculture-an-update/file*.

the largest and wealthiest consumers and producers of food on the planet—is not leading the world in research and development of climate-smart solutions for agriculture.

Just as important as supporting USDA-funded agriculture research, it is equally critical that Congress support cross-agency research and development programs. We should be encouraging more linkages between the National Science Foundation and its emphasis on translation; the Department of Energy and its focus on synthetic biology, carbon capture and renewable energy; and the National Institutes of Health and its focus on public health; among others. Like-minded Federal agency programs could be coordinated with the USDA to develop future-forward "moonshots" for agriculture with a focus on the development of new carbon-smart approaches that create healthier and more equitable food systems as well as energy deployment that empowers rural communities and historically marginalized and disadvantaged people in the United States. Cross-agency programs could spur new innovations and scientific discoveries across disciplines, from computer science to plant breeding, engineering to public health, landscape development and soil science to economics and finance. Just like with the Human Genome Project, we need a concentrated effort in agriculture and food of the future if we are to succeed in reducing emissions and capturing carbon from the air. Doing so will help ensure that the best and brightest scientific ideas make it from our university laboratories into farmers' hands—turning the agricultural industry into a climate change success story and creating a more food-secure future for all of us.

The CHAIRMAN. Thank you, Dr. Houlton.

And now our final witness, Mr. Vance, you are now recognized.

STATEMENT OF MICHAEL S. VANCE, MANAGING PARTNER, SOUTHERN REDS, LLC, GAINESVILLE, TX; ON BEHALF OF NOBLE RESEARCH INSTITUTE, LLC

Mr. VANCE. Chairman Scott, Ranking Member Thompson, distinguished Members of the Committee, thank you for this opportunity to offer testimony in collaboration with Noble Research Institute regarding the role of research in supporting agriculture resiliency.

To provide context for my testimony, it is important for you to understand the environment in which I work: the nation's grazing lands. Grazing lands are one of America's greatest natural resources. They account for more than 650 million acres and represent roughly 41 percent of the continental U.S. They contribute more than $70 billion annually to the U.S. economy by supporting over 60 million head of cattle and almost ten million sheep.

To sustain agricultural production, along with nationwide food security, grazing lands must be properly conserved and managed. This management starts below our feet with soil health, which is the foundation of our operations. The ecological function of these lands begins and ends with soil organic carbon. Soil carbon directly contributes to decreased erosion, improved drought tolerance, vigorous plant regrowth, decreased need for synthetic fertilizers, and improved water quality.

Unfortunately, the Green Revolution that began in the 1950s was premised on an oversimplification of a complex biological system. It applied a one-size-fits-all approach to increase production. Since that time, our agriculture industry and the research to support it has focused solely on the chemical and physical characteristics of soils, with little to no consideration of biological interactions therein. The consequence has been an ongoing degradation of our soil. Over the last 60 years, this approach to agriculture has resulted in a loss of more than 50 percent of our nation's soil carbon. Our soils today have diminished water-holding capacity, are more susceptible to erosion, and are dramatically less productive.

In response to these circumstances, I, as well as many other like-minded producers, have abandoned what are now referred to as conventional agriculture processes. We learned the hard way that these practices are too reliant on expensive inputs such as herbicides, fuel, and fertilizer. This is neither ecologically nor economically sustainable.

Alternatively, we have adopted a regenerative approach of working with nature by following six soil health principles. They include understanding our context, armoring our soil, minimizing soil disturbance, increasing biological diversity, keeping living roots in the ground all year, and most importantly, properly integrating livestock.

Grazing lands evolved with animal populations equal to or exceeding modern livestock populations. The fertile grasslands and rich soils of this country emerged in part due to the seasonal migrations of enormous herds of antelope, elk, and bison. These lands benefited from the impact of animals browsing, grazing, trampling, and recycling nutrients, their saliva and urine and manure. Their grazing and movement patterns created a natural disturbance benefiting the soil, plants, and ecological processes.

This is the same process regenerative ranchers like myself are successfully recreating today. In doing so, we are restoring our soil health, increasing our production efficiency, and restoring profitability to our operations. We are accomplishing this while supplying our growing nation with a healthy, nutritious, and enjoyable protein supply.

These are complex ecological systems. The impact of a changing climate on our agricultural productivity is equally as complex. Research is needed to enhance our understanding of these complexities. Unfortunately, the academic research standard of replicated, short-term, or reductionary studies is ill-suited to address these issues. These studies attempt to isolate and analyze a single issue within a complex and variable ecosystem. This scientific approach cannot account for the everchanging environment facing our farmers and ranchers. We need a new and different approach to agricultural research that transcends the normative boundaries of academia. We need researchers who are willing to partner with producers like my family and so many others who manage their production systems as an entire ecosystem so that we can better implement new conservation practices without damaging our long-term profitability. But even further, we need research to assist us in addressing changing consumer needs, volatile weather patterns, serving local markets, and managing socioeconomic well-being and resilience in rural America.

This is not a classical agricultural research portfolio, research found in current government-funding programs, or research focused solely on climate issues. To be successful, research programs must focus on outcomes that drive long-term, sustainable agricultural productivity, while simultaneously enhancing the economic viability of the producer in an everchanging environment. There can be no sustainable food supply in this great nation without having profitable producers working on regenerated soils.

Thank you, and I look forward to your questions.

[The prepared statement of Mr. Vance follows:]

PREPARED STATEMENT OF MICHAEL S. VANCE, MANAGING PARTNER, SOUTHERN REDS, LLC, GAINESVILLE, TX; ON BEHALF OF NOBLE RESEARCH INSTITUTE, LLC

Chairman Scott, Ranking Member Thompson, and distinguished Members of the Committee, thank you for this opportunity to join you and offer testimony, in collaboration with Noble Research Institute, LLC, regarding the role of research in supporting agricultural resiliency.

I am a rancher from north central Texas. I have been in the livestock business for all my of professional life. To provide context, after graduate school, I began to build my own cattle operation while also managing land holdings for others. In this capacity, I have managed up to 70,000 acres across five states. Without inheriting any land or ranching assets, I found it critically important to grow my own operations through strategic partnerships with others who valued the land and its health in equal measures to the profitability of the operation.

Today, I am the managing partner of Southern Reds, LLC, a 1,200 head seedstock operation. With the help of my wife and three young sons, we manage these livestock assets across 8,000 acres. We focus on raising climate-friendly cattle genetics that produce beef by recycling forage-grazable plant material—and water, without the need for added outside inputs that negatively impact the environment and our financial efficiency.

We seek landowner partners that understand the positive influence that livestock can have on the land. We see an increasing demand from those who desire to see their own land investments improved through true ecosystem management and regenerative grazing principles.

My experiences, these partnerships and my operations provide the background for what I will speak about today.

Before I address research to support agricultural resiliency in grazing lands, I want to provide context for its need and the environment in which I work—the nation's grazing lands.

Grazing lands are one of America's greatest natural resources. They represent the single greatest land use of this nation—found in all 50 states, grazing lands account for more than 650 million acres and represent about 41% of all U.S. lands in the lower 48 states.

Whether due to quality or ruggedness, less than 15% of these acres could support the production of human food crops or commodity crops, such as corn, which is often associated with agriculture. Nevertheless, the have a tremendous impact on human life.

Our grazing lands support those animals that deliver our nation and the world a high-quality protein source for human consumption, serve as a filtration system for our fresh water, deliver productive plants that nourish grazing animals and work to sequester carbon in our soils, and offer a robust wildlife habitat. The soils of these grazing lands serve as the foundation for our country's farming and ranching families. As of 2021, grazing lands contribute more than $70 billion annually to the U.S. economy by supporting more than 60 million cattle and almost ten million sheep. To sustain agricultural production, grazing lands must be conserved and properly managed to produce robust, resilient stands of grasses and forage. All of this starts below our feet with "soil health," the foundation of our operations.

Grazing lands are those lands not cultivated by man. As America developed westward in the 19th century, farmers began to cultivate soils by clearing timber and destroying many of the natural prairies that existed. This was to grow what are now known as "commodity crops." The fertile, productive prairies of the Great Plains that once teamed with diverse grasses, forages and large herds of bison were tilled and farmed. These practices depleted the soils of nutrients, organic matter, and biological life. The natural biological processes of grazing by roaming herds and periodic fire that created the natural grazing lands, were no longer at work.

Soil carbon is the center of overall ecological function in natural systems. Soil organic carbon directly contributes to decreased erosion, improved drought tolerance, plant root growth and production, the decreased need for synthetic fertilizers, and improved water quality.

Poor management practices combined with a decade-long drought contributed to the great Dust Bowl of the 1930s. This disaster brought about the birth of land conservation and the Conservation Act of 1935, which created the Soil Conservation Service, now the Natural Resource Conservation Service. Despite these efforts, in the 1950s the Green Revolution took hold, and advancements were made in agricultural technology, including the development of commodity and forage crops that responded well to fertilizer, advanced farm machinery, and other technological advancements that expedited crop production with less need for labor.

The nation demanded a cheap and efficient food supply system, and that is what we delivered.

The Green Revolution became more than an event; it became an agricultural philosophy. The United States built an agricultural sector based on four tenets that we now know are not true:

- Farmers and ranchers will have unlimited energy and cheap inputs.
- We will continue to enjoy stable climates and abundant water.
- Nature can be controlled by technology.
- Hunger will be solved by increasing production.

Premised on an oversimplification of a complex natural, biological system and our desire for a one-size-fits-all approach, our industry and our research during that time focused on the chemical and physical characteristics of soils with little to no consideration of biological interactions within the soil.

The consequence is an ongoing degradation of our soils. It is estimated that over the last 60 years, our approach to agriculture has resulted in the loss of more than 50% of our nation's soil carbon. The overall loss of soil carbon has a compounding effect—diminishing water holding capacity of the land and rendering the land more and more susceptible to erosion. Our reaction has not been to reduce our overall use of inputs that impact our soils. Instead, our blind reliance on technology and inputs has resulted in the increased use of inputs, such as fertilizer, to compensate for diminished land performance and resulting crop productivity.

With predictions for greater and more extreme weather events, landscapes that are low in organic matter naturally will not be able to cope with rain events and will soon become considerably more arid. These broken water cycles in crop and grazing lands will lead to desertification as well as continued depletion of important aquifers that maintain water cycles through the Great Plains.

We know an alternative exists.

Some producers have abandoned this production approach out of principal—knowing that is was ecologically unsustainable and/or because they sought a food system not reliant on these chemical inputs. For a growing number of producers, however, drought conditions (for example, as occurring in our Western states) and/or prices for feed, fuel, fertilizer and other inputs have increased to a point that has become economically unsustainable for their operations. For these producers, a choice was necessary: continue doing what they have always done or work with nature to find a new way to farm and ranch. Born out of equal parts necessity and frustration, producers began to experiment with farming and ranching techniques that limited the use of feed, fuel, and inorganic fertilizers and other inputs.

They began to see that (i) limiting or eliminating tillage reduced their fuel bill, (ii) using the ageless practice of "cover crops" to keep their fields covered provided numerous benefits to the soil (*e.g.,* preventing erosion, increasing water holding capacity and increasing biodiversity), (iii) converting marginal soils to perennial pasture land to eliminated tillage and minimized erosion, and (iv) through managed rotational grazing, the pastoral lands improved in composition and production due to the recovery allowed between grazing events.

In essence, they built a foundation of principles that many producers follow today to manage healthy soils and restore deteriorated soils. These soil health management principles were set forth to achieve specific goals that are inherent to all soils. They are based on mimicking highly diverse, heterogeneous, native grazing land plant communities by harnessing the power of biologic interactions among plants, soil microbes, fungi, and other forms of life in our soils, water, and animals. These principles build soil aggregation, which further builds soil structure. This soil structure enables the better utilization of any received moisture, whether through rain or applied irrigation.

These principles have proven the path forward for many innovative producers and substantiated that the conventional farming and ranching practices of the last 6 decades are not the only way.

The following six soil health management principles were developed by producers for producers, and these apply to both croplands and grazing lands:

(1) **Understand your context:** Develop an on-going relationship with the environmental, economic, and social context of the land to identify which applications produce the most total value relative to their full range of costs. Context is a state of constant change and can vary significantly across time and space. There is no one-size-fits-all approach.

(2) **Armor the soil:** Keep soil covered with growing plants, ungrazed trampled litter, or supplemental covers like hay or mulch. Uncovered, or bare, soil is

more susceptible to wind and water erosion and less able to absorb and retain water. Uncovered soil is also exposed to the sun, which can raise its temperature, killing beneficial microbes and evaporating soil moisture.

(3) **Minimize soil disturbance:** Physical soil disturbance, such as tillage, alters the structure of the soil and limits biological activity. Preserve the integrity and structure of soil and limit the amount of disturbance that can damage plant roots, harm the health and diversity of microbiological communities, and create soil compaction.

(4) **Increase diversity:** Support biodiversity above and below ground and limit the use of practices or chemical inputs that can damage it. Biodiversity in rangelands is critical to their productivity and resilience; specific soil microbes require specific plant types. Encouraging a variety of plant species and supporting macro- and micro-biological diversity can extend growing seasons, increase resilience to extreme weather, reduce livestock predation and livestock concerns, support wildlife habitats, and enhance ecosystem function.

(5) **Keep living roots in the ground all year:** Soil microbes feed on the carbon produced from living plant roots. Therefore, a living root in the ground is ideal for active soil health. Living plant roots contribute to soil structure, increase water infiltration, support plant regrowth, and increase soil organic matter by exuding photosynthesized carbon into the soil. Increasing the diversity of plants, better enables a mix of species that contributes to year-long soil activity.

(6) **Properly integrate livestock:** Use livestock to gaze and prune plants to promote plant growth, and then use the animals to provide beneficial nutrients back to the land. Thoughtfully managed livestock can both support and improve ecosystem function.

The byproduct from the integration of livestock from U.S. ranching operations is the production of red meat for human consumption. Red meat has been an important part of the human diet throughout human evolution. When included as part of a healthy, varied diet, red meat provides a rich source of high biological value protein and essential nutrients, some of which are more bioavailable than in alternative, plant-based food sources. Unprocessed, red meat provides a nutrient dense food that offer more protein, per calorie, than nuts, fruits, or vegetables.

It is recognized that an epic debate rages with respect to the impacts of beef cattle on the environment. This debate is fueled in two different directions: the first is meat *versus* nonmeat/reduced meat academics, and the second centers on a disagreement among animal, forage, range, and other ecological scientists with respect to best management practices of beef cattle production.

A quick search of the literature will reveal a competing division of academic studies slighting the role of livestock in the environment and others that recognize the importance of livestock in the environment. The conundrum is all supported by the science. Good and talented academics are researching these areas and presenting outcomes that pass peer review and publish in quality journals. Yet, a divide exists. Why?

Our grazing land environments are complex, and they are often ill-suited to be replicated for the purposes of short term or reductionary studies that attempt to isolate and look at one issue within a system. Reductionary research (*i.e.,* attempting to simplify a complex system) cannot account for everchanging environment facing our farmers and ranchers. Scientists, in general, attempt to "control" an uncontrollable system in small, replicated areas and often the results cannot translate to a broader landscape

Stepping outside academic studies, our world's grazing lands co-evolved with grazing animals in populations equal to or exceeding modern livestock populations. These grazing lands benefited from the impact of livestock browsing, grazing, trampling, and recycling nutrients through saliva, urine and manure. The fertile grasslands and rich soils of the Great Plains (and other regions of the U.S.) emerged, in part, due to the seasonal migrations of antelope, elk, and bison. During their migrations, these herd animals moved frequently for both fresh forage and to stay in advance of predators. **Their grazing and movement created a beneficial disturbance benefiting the soil, plants and ecological processes.**

Beef cattle comprise somewhere between 2–3% of the overall carbon-footprint of the United States (U.S. EPA, 2019).* However, global calls to action (*e.g.,* The Paris Agreement) require an indiscriminate and significant (*e.g.,* 30%) decreases in emissions across the board for signature countries. Across the world, livestock are being vilified in areas of academia and government. This creates irrational and long-term irresponsible actions imposed on the livestock and agricultural sector, which we have seen impact countries such as New Zealand (imposition of a tax on livestock) and Ireland (reduction).

These six principles inform management decisions and practices that *together* help build healthy soils and, in turn, improve air and water quality, increase biodiversity and wildlife habitats, increase water infiltration and retention, reduce soil erosion, support plant and animal health, **and build vital resilience in the system.**

Challenges to Future U.S. Ranch Viability

The viability of the U.S. ranching industry is challenged by:

- soil productivity in the face of climate change;
- profitability; and
- a shrinking base of farmers and ranchers.

These challenges are a direct result of the philosophies underpinning the U.S. agriculture industry for the past 60 years. These challenges cannot be ignored. Moreover, we can no longer continue to merely treat symptoms with practices (separate from principles), seek and use technology for the sake of technology, and rely blindly on costly inputs.

To be successful, we must focus on the root of the problem. It starts with the soil. We address ecological degradation by sharing and following principles that rebuild ecological processes and habitat from the ground up rather than focusing on specific singular species or indiscriminate management practices. Healthy soil is the cornerstone to any agricultural enterprise.

Principles over Practices: Applying the Principles

Building the soil with good grazing management is possible. It is being practiced across the nation, albeit in small numbers relative to the overall beef industry.

In properly managed grazing lands, the six soil health principles can actively build more productive, more profitable and more sustainable agricultural production systems. In fact, it is often easier to apply the soil health principles to grazing lands (rather than cultivated croplands) because the soil health principle of properly integrating livestock is already in place.

Healthy grazing lands begin with active management. This management is based on a philosophy that properly managed, grazing livestock addresses the physiological needs of the forages being grazed and contributes positively to the natural cycles of nature.

Soil health and its benefits cannot be left to chance. Intentional and active management is required, and the first step is often a grazing plan.

Grazing plans are, in essence, conservation plans for grazing lands. They include decisions for managing the plant community in view of the soil, water, air, plant and animal resources. A well-designed and well-managed grazing plan results in healthy soils and grazing plant material, proper nutrition for grazing animals, and greater livestock production at a lower cost.

There are four key elements to a grazing plan:

- carrying capacity/stocking rate,
- livestock rotation,
- utilization rate, and
- plant rest and recovery.

All of these elements must be managed together to be effective.

Carrying capacity/Stocking Rate—"Carrying capacity" is the amount of forage available for grazing animals for a specific time. Importantly, it can vary from year to year for the same area due to changes in forage production due to weather or other factors. The amount of forage produced in a given area is a function of many factors, including soil types, forage types (*e.g.,* grasses, legumes), pasture condition, and previous management. However, moisture and temperatures during the growing season also drive production.

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*__Editor's note:__ the in-text citations in Mr. Vance's prepared statement do not have a corresponding descriptive "Endnotes" listing. It has been reproduced herein as submitted.

Forage production is dynamic, and the entirety of the produced forage should not be fully consumed. With proper grazing management, only a portion is used and the rest is left to maintain the health and productivity of the grazing land. The portion of the forage that is allocated for grazing is called the *available* production.

"Stocking rate" is the number of animals on a given area of land over a certain period. For all practical purposes, stocking rate is a measure of the forage demanded by the livestock over a period of time. Of course, this requires consideration of specie(s), size, and needs of the consuming livestock.

It is important that the stocking rate not exceed the carrying capacity. Improper stocking of grazing lands leads to over-grazing or under-grazing, neither of which provides favorable outcomes. Over-grazing for extended periods of time leads to the degradation of the grazing land and an overall reduction in pasture productivity, soil health, and livestock production.

Grazing Rotation—A grazing rotation considers where to graze, when to graze, how long to graze, and how long to allow a grazed area to rest and recover. The purpose of a grazing rotation is to manage the impact of grazing on the grazing land while maintaining or improving livestock production.

Livestock are selective grazers. If left unmanaged, livestock tend to disproportionally graze certain plants over others. Livestock also prefer the fresh regrowth over mature leaves. In a continuously grazed pasture, plants that are grazed early in the growing season are grazed repeatedly without adequate time to recover. If plants are grazed too short for too long, these plants are not allowed to regrow leaves to supply needed energy to the roots (through photosynthesis). With impaired roots, the plant becomes less resilient and can ultimately die. Over time, the more-productive plants are grazed out leaving less desirable, less productive plants, which can lead to deterioration of the grazing land and the health of the soil.

Grazing Intensity—Grazing intensity is the amount of grass and forage removed before livestock are rotated to a new area. Stated another way, it is how short the pasture is grazed before removing the grazing animals. As but one example, consider "take half and leave half." Conceptually, this means graze the top half of the leaves and leave the rest to allow for rapid recovery and regrowth. Ideally, every plant in the pasture would be grazed evenly at this level. Taking more, negatively impacts root growth and requires additional recovery time. Grazing 50% or less (in this scenario), actually stimulates plant and root regrowth. This expedites recovery and increases the productivity of grazing lands.

The circumstances (*e.g.,* soil health, the availability of moisture) all impact these percentages. While some ranches can support "take half and leave half," other geographies may require taking less, or maybe, in the presence of healthy soils, an abundance of soil moisture, and the right forages, animals could consume more than 50%. Again, context matters.

Rest and Recovery—After being grazed, plants need an adequate recovery period (generally, 45 to 90 days). The more severe the grazing intensity, the longer it takes for the plants to fully recover. Soil moisture and seasonal temperatures also affect the rest and recovery period. In favorable moisture conditions, the recovery period is shorter than in low moisture conditions. As moisture becomes more limiting, longer rest and recovery periods are required.

It is important to determine the recovery period based on the key species in the grazing land being managed. In a native grass pasture, the key species are those more productive, more palatable species that have a longer recovery period than the less desirable species. Introduced pastures usually have a shorter recovery period than the native prairies and must be managed differently for optimum results.

Critically, grazing lands should not be *over-rested,* which removes the important aspect of grazing livestock from the land for extended periods of time beyond the recovery of the forages.

The practices and strategies of this grazing mimic how the grazing lands evolved over time with roaming herds of livestock, which yielded (without the assistance of man) some of the most abundant and lasting ecosystems on the planet.

Research Needs

Climate change is complex, and it is understood that research is needed to enhance our understanding. We need more than knowledge for the sake of knowledge.

The role of research can contribute to the knowledge and experiences of farmers and ranchers and assist them in understanding the impact of their management, offer alternatives, and contribute to their underlying economic viability. Research and its outcomes must play a part in equipping our farmers and ranchers to adapt to changing weather patterns but also address changing consumer needs, serving local markets, and building new resiliency in the soil and their operations.

This list is not exhaustive, but is representative of research needed:

- Quantify the effects of grazing management and the connections between soils, forages, and livestock across broad spatial and temporal scales.
- Evaluate the regenerative capacity of diverse grazing systems across a variety of conditions and geographies.
- Develop an evidence-based framework or index to measure ranch health that incorporates economic and ecologic measures.
- Develop practical, cost-effective farm-level carbon accounts for representative production systems across the U.S. to move toward carbon-neutral beef.
- Evaluate existing management approaches designed to reduce inputs/chemicals and their impact on profitability and grassland sustainability.
- Quantify the relationship between grazing management and socioeconomic well-being and resilience in rural America.

This is not a classic agricultural research portfolio found at U.S. universities.

The effective study of grazing management at the whole-ranch or landscape scale requires not only comparison of alternative management actions but also evaluation of the ways in which these actions and biophysical processes interact and evolve over time. The temporal and spatial variation inherent in biophysical processes and their interaction with management decisions precludes direct comparisons of grazing "systems" in classical, replicated grazing experiments. All the biophysical variables in the various processes are in a state of constant flux that is influenced by history, prevailing conditions and chance and, therefore, their manifestations are unique in time and space as they are modified by ever-changing contexts and conditions. This is the real world in which our farmers and ranchers operate.

We further need a new and different approach to agricultural research, one that transcends the normative boundaries of research that is conducted within academia and simply disseminated out to others. We need researchers who are not removed from the land, its ecosystems, or the people who manage it. For the benefit of rural America, we seek interdisciplinary, interpretative as well as analytical research that is performed in partnership with the rancher to co-produce new knowledge about productive and regenerative agriculture. In this model, ranchers and their communities are not separate from the research or the researchers themselves. They are part of the transformative process.

Producers seek research outcomes that will fuel the critical-thinking, problem-solving farmer and rancher. We seek outcomes that might allow us to mitigate risks or refine our experimentation for our own properties, animals, or markets. And we seek new knowledge and skills to arm us to manage soil productivity in the face of climate change and to achieve our financial goals. It is the path forward.

This path cannot be achieved with traditional agricultural research and/or with classic agricultural-directed government research funding programs. To be successful, research programs must focus on outcomes that drive long-term, sustainable agricultural productivity that enhances the profitably of the producer.

Universities and other academic research institutions, both in the U.S. and abroad, are ill-equipped to undertake research at a whole-ranch or landscape level. Faculty are pushed to succeed within a discipline with success being measured by grants accrued and manuscripts written. The idea of actually helping a rancher, as the land-grant institution was designed, has been dwarfed by these pressures and generally forces scientists into chasing dollars. State and Federal funding levels are often insufficient and inconsistent, driving research away from the critical needs of farmers and ranchers and instead toward popular or politically-motivated trends. Industry funding tends to be discipline driven and is linked to direct economic returns to the funder. The outcome is that there is always something new for the farmer to buy or implement, which quite simply continues to push output/input, disregarding the fact that natural resources and money are finite.

The opportunity exists to address these challenges with a new perspective and approach. This will require a radical shift from traditional academia. American farmers and ranchers need such a shift. We need more organizations to shift from the norm and affirm their dedication to guiding and assisting the nation's farmers and ranchers to achieve both improved soil health and profitability in equal measures, much like the work of Noble Research Institute.

Barriers to Widespread Adoption

If the problem is known and the solution is at hand, why can't significant reform involving the soil health and economic viability occur?

Farmers and ranchers that seek an alternative way are surrounded by those—industry, academia, and peers—that are entrenched in a 60 year tradition.

Our agricultural industry was designed and constructed to move low-cost, indistinguishable commodity products from the field to the consumer in the most efficient and cost effective means possible. This marginalizes the producer-entrepreneur in this industry. Moreover, this value chain is built to distribute value throughout the chain, returning less and less to the livestock producer. Technology and input providers are members of this industry, and their incentive is driven by the adoption of the latest and greatest new tools to address problems often created by the older tools.

Our universities are training producers and industry members to meet the needs of this historic agricultural industry. This impacts research (as noted above) as well as those training to be future scientists, researchers, and agribusiness professionals.

Many of our government programs do not encourage long-term land stewardship and building soil health, integration of livestock, or adaptive management. Instead, the programs prescribe a series of practices irrespective of ecological impact or consequence.

From peer farmers and ranchers, some have responded but many have not. In all fairness, the idea of soil health and our understanding of the world that lives beneath the soil is relatively new. It wasn't something ignored, perhaps, it was something that wasn't considered. Consequently, many just associate the loss of topsoil, poor productivity, and the lack of profitability with simply the *status quo* or something else beyond their control—bad luck or the weather.

Admittedly, conditions of the soil changed slowly and most didn't recognize that dust storms and erosion could be prevented or reduced. When some did recognize and begin to talk and write about the problem, others couldn't imagine that they were part of the problem. However, leaning again on the tools of the day, producers can employ fertilizer, herbicides, and insecticides to masks the problem for many years. Finally, for others (and really any industry faced with such dramatic alternatives), we are at a place where some just don't want to learn or believe.

Barriers to adoption are largely personal to each producer. Recent studies (Hannah Gosnell, 2019) suggest that adoption and practice of land stewardship based on soil health principles involves more than a suite of "climate-smart" mitigation and adaption practices supported by technical innovation, policy, education and outreach. Rather, adoption and sustained practice involves subjective, nonmaterial factors associated with culture, values, ethics, identity and emotions that operate at individual, household and community scales.

Equipping the Stewards

We all should be dedicated to removing, mitigating or avoiding the barriers deterring the lasting use of profitable land management practices to improve soil health in grazing animal production.

This is not simply achieved through a single educational program, research initiative, or social media campaign. Rather, this is a transformative shift in continuing education, academia, peer networks, industry support, markets, and consumer expectation. At the heart of this transformation is the premise that we seek to preserve our grazing lands (and the ecological connection of land, water, plant and animal), and we seek to do so through dedicated stewardship and management for soil health.

We need to find new ways to engage multi-generational ranchers, young ranchers and first-generation ranchers—where they are and how they learn—to introduce these management practices and their lasting benefits. With knowledge comes confidence and with confidence comes application.

To create a critical mass for change, it won't be easy. But America's farmers and ranchers rarely look for easy. We will need everyone's assistance to preserve the landscapes that we have been blessed with—not for the sake of preservation, but to provide a productive and economical living for those charged as being land stewards.

Conclusion

U.S. ranching is a complex system intertwining people, soil, plants, animal, water, history, and economics. Future research must avoid reducing this system to any one of its parts but rather reflect this system as a whole, knowing that it is dynamic and ever-changing. Research outcomes should focus on providing producers with the confidence and tools they need to be ecologically and economically successful while continuing to provide quality, nutritious food to consumers, in the U.S. and abroad.

In this regard, the key to increasing system resiliency and profitability in ranching begins with adaptive management. Management of grazing lands is a dynamic process with a complex set of variables that must be taken into account. However, as the science of grazing management has evolved, innovative producers work with

the natural cycles of the land with the goal of improving soil health through the application of principles. For the viability of the industry and our nation's grazing lands, more producers are needed. Thus, it is critical that we foster an environment of like-minded peers, academia, industry, and government that supports and encourages a soil health-based management of grazing lands to achieve long-term economic viability and ecological sustainability of the U.S. ranching industry. The benefits extend beyond our rural communities to impact our landscapes, our economy, our domestic food system, and the consumers that enjoy safe, nutritious food produced on our U.S. farms and ranches.

The CHAIRMAN. Thank you. And thank each of you for your very informative testimonies.

Let me now open it up to questions. At this time, Members will be recognized for questions in order of seniority, alternating between Majority and Minority Members. And you will be recognized for 5 minutes each in order to allow us to get to as many questions as possible.

And again, let me remind Members to please mute your microphones until you are ready to speak. And let me begin with the questions here.

Dr. Fares, let me ask the first question. Our 1890 land-grant institutions and other minority-serving institutions are playing a very critical role in conducting cutting-edge research on human issues related to climate change, as well as agriculture resilience, mitigation, and adaptation. And you are a leader at one of our 1890s, a very significant and important school, Prairie View A&M University, among 1890 land-grant institutions and other institutions. What is it that you believe is needed most to support the evolving needs in climate research?

Dr. FARES. Thank you, Chairman Scott, for the question. As you mentioned, Prairie View A&M University and other 1890 Institutions play a greater role in educating and finding solutions that are needed by minority and limited-resources farmers, ranchers, and communities. As I stated in my testimony, this is a new area that we do have needs for a new infrastructure, for a new support because we cannot solve issues of the future, issues that really need high technology with old technology, with crumbling infrastructure, with infrastructure that doesn't have the internet, for instance, doesn't have the connectivity that you need, doesn't have the laboratory or the equipment that are needed to conduct cutting-edge research and finding solutions. So we need financial support on this to allow us to solve the greatest challenge that we are facing and to be able to train the future leaders, the future, and empower them with cutting-edge technology so that they can be able to find the solution that they can be able to use this technology.

I will give you an example. For example, we are talking about clean energy. There is a new area called agrivoltaic, where we need to grow and reuse the lands that are used for solar energy. So these lands needs a new way of looking at how to manage them to both produce energy and at the same time continue their vital role in producing agriculture be it for crops or animals or combined.

The CHAIRMAN. Thank you very much for that. And I know our scholarship program is helping you all greatly there.

Dr. Houlton, you mentioned two phrases that I would love for you to explain. You mentioned something you referred to as human genome. What is that?

Dr. HOULTON. Great. Well, thank you so much for the question. So what I am thinking about here is the opportunity for agriculture to not only assist in adapting our food supply, promoting food security, but turning carbon into a commodity. And I think we need to imagine this problem differently than we ever have before. Classically, we might have a funding program that goes through NIFA, USDA, ARS. We might have other agencies thinking about various aspects of life sciences and carbon. What if we think bigger at the level of what we did with the Human Genome Project in the early 1990s, which resulted in a constellation of experts working together across universities, pioneering solutions, and learning quickly from one another, and infusing that mentality into what we think can happen with agriculture if we have research, science, and verification tools to turn carbon into a commodity and assist in adaptation? So it is more of reframing our thinking around something that promoted an incredible collaboration within academia, within industry, and then resulted in many breakthroughs for humans.

The CHAIRMAN. Well, thank you very much on that. And now I recognize the gentleman from Georgia, Mr. Austin Scott, is recognized for 5 minutes.

Mr. AUSTIN SCOTT of Georgia. Thank you, Mr. Chairman. And I am from Tifton, Georgia, the home of the National Environmentally Sound Production Agriculture Lab, and so I have seen some of the great work that comes out of that institution. And I do think that we can and should do a better job of taking care of the environment. I do think that we also have to be very careful that we make sure that the science is there before we do things that reduce the amount of production agriculture that we have in this country.

And Dr. Brouder, in August of 2021, you were tapped by EPA Administrator Regan to serve as a member of the EPA Science Advisory Board Agricultural Science Committee that is authorized to review the quality and relevance of the scientific and technical information being used by the EPA, review EPA research programs and plans, and provide science advice, as requested by the EPA Administrator, and advise the agency on broader scientific matters. And I want to speak to specifically the issue of recommendations on production agriculture when I get to this next part of the question.

The actions from this Administration's EPA, ranging from what they have done on crop protection tools and the politicization there, attempting, again, *Waters of the United States.* How much does Administrator Regan consult the Science Advisory Board and its Agricultural Sciences Committee on which you sit when making these decisions? And how much is the impact on agricultural production weighing into the recommendations and the decisions?

Dr. BROUDER. Thank you for your question. I have to preface my response by saying that, at this point in time—I was appointed last year, but the EPA has only just started meeting again. So the Science Advisory Board has so far met twice this year to discuss, including the *Waters of the United States.*

How much does the EPA use our advice? I am not on the other side. We have the authority to look at questions, the Science Advisory Board does, or look at the quality of the science that is being used. And we do a fairly rigorous job. If there is a need for a subcommittee to assess the science, we will convene a subcommittee, upcoming. It is not yet. We haven't convened our first one, but there is going to be a series of meetings concerning biosolids applications to land applications including to agricultural lands, and I will be chairing that subcommittee. And we will be looking very hard at the science. And our job is simply to say what the science says and whether or not the science supports a policy or a strategy that the EPA wants to pursue. They are not required to take our advice, but from my perspective, they are very appreciative of the analyses we provide them.

Mr. AUSTIN SCOTT of Georgia. Dr. Brouder, thank you for your testimony there, but you have only met twice in the last how many months?

Dr. BROUDER. We have for two multiday sessions, one in March and one 2 weeks ago.

Mr. AUSTIN SCOTT of Georgia. Okay. And have you provided any recommendations to the EPA?

Dr. BROUDER. We have provided review of—I am, again, just reappointed, so there was an ongoing group of people. But we just provided information on the redefinition of *Waters of the United States,* as well as their strategy for environmental justice that would be in their risk assessment programs, in their environmental risk assessment programs.

Mr. AUSTIN SCOTT of Georgia. Would you provide that to the Committee? I would like to see what your committee provided to the EPA.

[The information referred to is located on p. 75.]

Mr. AUSTIN SCOTT of Georgia. And I want to say this. There are certain practices like no-till that I think virtually all of us agree are good for the environment and are compatible with production agriculture and good yields. But those practices require certain chemicals be used. And when you have one agency saying or courts saying we are going to take Roundup and Dicamba off of the market, that impacts the ability to use no-till production practices. And the lack of coordination among the agencies, I think it is a threat to our food supply in this country and production agriculture. And it is something where I think the Committee is going to have to work together to make sure that there is a cohesive strategy that is good for the economy and good for the environment, I should say, and good for production agriculture. And I am concerned that that lack of cohesiveness is going to reduce ag production in this country.

The CHAIRMAN. Yes. Thank you, Mr. Scott.

And now I recognize the gentleman from California, Mr. Costa, who is also the Chairman of the Subcommittee on Livestock and Foreign Agriculture, is now recognized for 5 minutes.

Mr. COSTA. Well, thank you, Mr. Chairman. And I think it is appropriate that you have set the tone this morning with the role of climate research in supporting agricultural resiliency as we look toward setting the table for next year's farm bill reauthorization.

And it is not only our land-grant universities and our 1890 schools in which you have been a leader in promoting these scholarships in an effort, but I would also add a lot of state universities that have specialized in agriculture in many parts of the country. Certainly in California, we have universities like Fresno State, my alma mater, Cal Poly, and others that are leading agricultural schools that also are doing important and valuable research.

I think the challenge here as a third-generation farmer, as I look at it, notwithstanding the remarkable progress that we have made and looking at agriculture, American agriculture, contributing to reducing our CO_2 footprint and our resiliency as it relates to the impacts of our climate. Certainly, in the West, in California, extreme droughts, fires, and a host of other natural-occurring events that are changing how we work, how we operate, we have to be mindful of.

But I think it all comes down to sustainability. Farmers, ranchers, dairymen and -women have been for generations practicing sustainability. And at the end of the day, that is going to determine how we do it in a way that economically make sense.

Dr. Houlton, you talked about the genome example. I think, frankly, a lot of good research needs to be done. I think in the next farm bill we need to add on how we can enhance the efforts of this public-private partnership between our educational institutions and our farming efforts on a regional basis. I think what is lacking is an overall plan on how this all fits together with goals that are obtainable in the next 5 years and in the next 10 years that are based on good sound science and economically capable to work.

Let me give you an example. In the California dairy industry, which produces 20 percent of all the milk products in America, we have taken tremendous steps. It includes 1.7 million dairy cows, only four percent of the state's total greenhouse emission. And that is in part because dairy farmers in California, through efforts to reduce methane through investments and innovation according to a 2020 study published in the *Journal of Dairy Science,** we have been able to produce per gallon of milk more and decreased our emissions by 45 percent. The use of anaerobic digesters has really made tremendous advances for natural gas or hydrogen fuel that has driven much of this project. We have over 206 digesters in projects capturing methane from 217 dairy farms with 89 digesters currently in operation.

Over the next 25 years, collective dairy methane reduction projects across California include digesters and alternative manure management projects are estimated to reduce more than 55 million metric tons of greenhouse gases. Think about that. That is an annual emissions reduction of equal to taking more than ½ million cars off the road.

The list goes on and on. And, Mr. Chairman, I ask unanimous consent to submit this article for the record because I think it is an example of what we can do when we work together.

But, I will go back to any other witnesses.

The CHAIRMAN. Without objection.

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*__Editor's note:__ the article that Mr. Costa was referencing is, *Dairy farmers are working to address climate change,* in the June, 1, 2022 AGALERT, and is located on p. 75.

Mr. COSTA. Without objection?

The CHAIRMAN. Yes, without objection.

[The article referred to is located on p. 75.]

Mr. COSTA. Thank you. I got ahead of myself. But, Mr. Houlton, since you talked about the genome project, how do we connect this all together, this research and academia, this application to the private-sector of American agriculture, with goals that are attainable in the short-term and the long-term that will lead us to the sustainability level that is so critical?

Dr. HOULTON. Great. Well, thank you for the question. I believe that the best pathway is one where we demonstrate opportunities using sound science, working hand-in-hand with the private-sector, with extension, and with government policies that are going to underpin the opportunity to convert carbon into a commodity, to verify that carbon is being absorbed from the air and going into the soil. And through that refinement process across regions set up as teams within a constellation, I believe we can make incredible progress on this challenge. So that would be one way to start thinking about the solution sets and how they can convert into opportunities as quickly as possible.

The CHAIRMAN. And thank you for that.

And now the gentleman from Illinois, Mr. Davis, is now recognized for 5 minutes.

Mr. DAVIS. Thank you, Mr. Chairman. I first want to start with a quick question for Dr. Brouder. You are on the EPA Science Advisory Board. How long have you been on the board?

Dr. BROUDER. I was reappointed——

Mr. DAVIS. How long have you been on before the reappointment?

Dr. BROUDER. I was on for a session previously 2014 through 2017.

Mr. DAVIS. 2014. So you were on 2014 to 2017——

Dr. BROUDER. Yes, that is correct.

Mr. DAVIS. I actually passed a provision in the 2014 Farm Bill to allow someone from production agriculture to have a seat on the EPA Science Advisory Board. Has that provision been implemented? Do you have somebody——

Dr. BROUDER. Yes, yes, there was a representative in fact who is a colleague from Purdue who was appointed back at that point and joined the Science Advisory Board.

Mr. DAVIS. Okay. And that person is still on?

Dr. BROUDER. I think it shifted to somebody else.

Mr. DAVIS. But there is somebody from production agriculture?

Dr. BROUDER. Yes, yes, yes.

Mr. DAVIS. Is that next person somebody also associated with academia though?

Dr. BROUDER. I would have to check for you.

Mr. DAVIS. I would appreciate that.

[The information referred to is located on p. 76.]

Dr. BROUDER. I think so. I am fairly certain.

Mr. DAVIS. Yes, that has been my concern. I mean, my provision was to get somebody outside of academics, somebody within production agriculture to be on board to be that voice.

Dr. BROUDER. Yes.

Mr. DAVIS. And it seems that has not taken place.

Dr. BROUDER. Well, but please don't—I mean, I can't tell you off the top of my head who is——

Mr. DAVIS. You don't remember the background of every individual?

Dr. BROUDER. No, sir.

Mr. DAVIS. Okay, no, I jest, of course, but I would love some feedback and be able to work with you and the Science Advisory Board in the future to really put production agriculture's ideas forward. So thank you for responding to my question, Doctor.

I just want to be blunt about this hearing, though. I can't think of a more tone-deaf hearing to be having today. Talking about resiliency should be in the context of inflation and global supply chain issues that have caused food prices to skyrocket. They are the highest they have been in 40 years, inflation is over eight percent, gas is over $5 a gallon. We refuse to make people get back to work. And yet here we are once again discussing climate change in the House Agriculture Committee.

Tomorrow on the House floor we are going to vote on what I think should be called the Bait and Switch Act. The bill will pit industries against each other before the good parts are sent to die in the Senate, getting the hopes up of industries who can contribute to solutions to the problems our local communities are facing. And yet, here we are again. We are discussing climate change. People aren't going to be taking summer trips when gas gets to $6, $7 or $8 a gallon. And that is exactly what the Biden Administration ultimately wants out of this climate crisis that they have manufactured by banning domestic energy production, or the radical left likes to call it, the Green New Deal.

Conversations about infusing conservation programs with money because people think that it is woke to talk about climate change is a solution in search of a problem. The programs being discussed here today can be used to combat the supply chain issues we are seeing to bring down costs and ease these issues, and we aren't discussing that either. Until this Administration focuses on moving people forward, lowering gas prices, tackling inflation, and disincentivizing the COVID gravy train, these problems are going to persist. And I think any of our constituents would say that is a much more serious threat to them, their families, and their communities than a climate crisis.

Mr. Chairman, thank you, and I yield back.

The CHAIRMAN. The gentlewoman from North Carolina, Ms. Adams, who is also the Vice Chair of the Committee on Agriculture is now recognized for 5 minutes.

Ms. ADAMS. Thank you, Mr. Chairman. Thank you, Ranking Member Thompson for hosting the hearing, and as well to our witnesses. We appreciate your input as well.

Dr. Fares, I know that you are from a small country in North Africa that has one of the few self-sufficient agricultural sectors on the continent. And so I want to take a moment to note the diverse and specialized expertise you have to offer the 1890 Institutions. Just yesterday, USDA signed a Memorandum of Understanding with the 1890s President's Council to reaffirm and commit to opportunities for land-grant HBCUs.

So, Dr. Fares, through the MOU, what actions can USDA take to support 1890s that have tackled major agricultural challenges?

Dr. FARES. Thank you. Thank you, Vice Chair Adams. I appreciate the question. And thank you for recognizing Tunisia, where I come from originally 35 years ago. I think I am very happy to see that there is this MOU between USDA and between the 1890 Institutions. I think there is opportunity here for us to support the great work that 1890 Institutions are doing in training future experts and future professionals who are going to address this climate change, who will address equally our food security, our energy security, and our health security, too. So opportunities are helping us with our, as I mentioned, infrastructure, helping us to support more funding for our Research Center of Excellence, for instance, in climate and related area. There are more scholarships for our students so that these limited resources, first year, first generation college students can attend colleges and can have jobs in this new and vibrant economy that is shaping up. These are some of the few ideas that come to my mind now, but I will be happy to add more to this discussion and help in the process of supporting this MOU and this collaboration further with some crucial and critical steps that we can take.

Ms. ADAMS. Okay. So let me ask you, and thank you for that. So to follow up, what kind of work have 1890s embarked on to promote and protect water quality and security in the agriculture sector?

Dr. FARES. Can you repeat the question again, please?

Ms. ADAMS. Sure. What kind of work have the 1890s embarked on to promote and protect water quality and security in the ag sector?

Dr. FARES. Well, we have been working in different areas of that area. We have been working on how to optimize irrigation for different crops, how to make use of rain-fed agriculture and minimize the use of a pumping of water, how we can curve soil erosion and enhance soil health so that we can minimize the erosion of our soils, and also protect our surface water and groundwater issues. So these are a few projects that we have been doing in this area that——

Ms. ADAMS. Okay. Thank you, sir. Let me move on to another issue.

Dr. Vélez, good to see another OSU graduate here. You work with a population in the climate resilience space. Organic growers are in the forefront of implementing climate-neutral practices. We know that agricultural lands hold tremendous capacity. So I would like to make sure that we are doing so in an efficient way. So given the research that you have done, do you have any thoughts on how we can make sure that producers have the tools they need to remove carbon efficiently?

Dr. VÉLEZ. Thank you, Ms. Adams. I really appreciate that question. I think one of the most important things that we can focus on beyond just the research, which I do think is important for organic research to get out there specific to climate resilience, mitigating greenhouse gases, sequestering carbon, it is really important to invest in extension and education. And so we have recognized and we have heard from a lot of organic growers that they do not

have the extension support that they need when it comes time to adopt the new tools and technologies. And so if we can invest more in cooperative extension, which is already historically underinvested, and making sure they are prepared to support organic growers as well——

The CHAIRMAN. Thank you.

Ms. ADAMS. I apologize but I am out of time. Thank you so much.

The CHAIRMAN. Thank you, Ms. Adams.

And now the gentleman from Nebraska, Mr. Bacon, is recognized for 5 minutes.

Mr. BACON. Thank you, Mr. Chairman. And I appreciate all of our panelists. Today, we appreciate your expertise and you sharing it with us.

A couple of comments up front and I have one or two questions. I was raised on a farm in rural Illinois. It is still in the family. And in this capacity, the job I am in today, I get to visit with Nebraska farmers and ranchers all over the state. I know firsthand how serious they take conservation. They know that the health of the soil is vital to their future, the future of our industry. When you go to the ranchers, they will tell you the most important thing that they look at is the health of the grass because that is vital to the ranching industry. So I think we can credit our farmers and ranchers for leading the way on conservation. They know how important it is to them.

I also would say, and just to piggyback with Mr. Davis' comments, when I talk to farmers and ranchers today, the number one issue is inflation. I was talking to some before traveling out here on Monday. Pesticides are up 300 percent, and most of those key ingredients come from China. When it comes to fertilizers, they have also skyrocketed. Most of those ingredients come from Russia. We have to restore these industries back in the United States or at least with our key allies. We can't depend on Russia and China for what is vital to our ag industry. So I just want to say that upfront.

My first question is to Mr. Vance. In your written testimony, you mentioned livestock producers are being vilified by academia and the government, which in turn causes irrational and irresponsible regulations imposed on the livestock sector. You mentioned specifically New Zealand and Ireland. And will you elaborate on these policies and why are they irresponsible, and the impact they could have on our agriculture if they were implemented here? Thank you.

Mr. VANCE. Thank you, Mr. Bacon, for the question. I will start by saying we work with quite a few producers from Nebraska from the Sandhills and it is because that is a very regenerative part of the world. And so you definitely have some of the better ranchers in the country right there in Nebraska.

Mr. BACON. Thank you.

Mr. VANCE. As far as New Zealand goes, what we have seen happen there with their tax on livestock, it is really unnecessary. And then also, we feel like it is unrealistic. And it is something that if we brought into this country, it would be devastating. First of all, it would lower our production. So in environments like our own production system where we are sequestering carbon, we would ac-

tually add to the problem if we took livestock out of our personal production model.

Also, we would see drastically increased food prices, and so that creates a concern not only for me as a producer, but, as a family of five, that is a major concern for me as well because we are already seeing supply shortages on protein. And so if we are going to cut supply out of that food chain nationally due to these taxes, then we are definitely going to see that. The consumers are going to be the bearer of that, at the end of the food chain.

The most disheartening part of that, though, is it is really disproportionate. The levies that they are placing on livestock in New Zealand, they are disproportionate to the damage that the livestock have on the overall damage to the environment, especially in respect to carbon. It is a very small footprint, carbon footprint there in New Zealand, but they are carrying the bulk of the demand to change. And we are starting to see that some in this country, and that is something we have to curb at some point.

Mr. BACON. Thank you. Here is another question for you, Mr. Vance. Our productivity in agriculture since the 1940s has gone up 287 percent. It is incredible. And the inputs have been roughly the same. So we have really just led the way in the world for productivity, research, and getting more out of our land than anybody else can. Can you talk a little bit about what kind of research we need to keep pushing us down the road and even expanding this productivity?

Mr. VANCE. So, first of all, we have to have research that works hand-in-hand with the producer. It has to be research that is very applicable and very usable. And so that research has to start on the ranch. It can't start in a small plot on a university campus. It has to work hand-in-hand with producers. And when we implement those production practices, we are not misled. A lot of times now when we see practices that are being advocated for that nobody has proven them in a true production model and so we are leveraging our own profitability when we try those practices. And so, that is the number one thing we have to see.

But then also, what we are starting to see in our style of production is we are actually seeing some land come out of not having any production for years and years, and it is coming back into production because private landowners, foundations that normally did not like to see livestock on the land because they thought it was a detriment, now they have been educated partly due to some research that, hey, they can be good for the land. They are good for the environment. So we have had the opportunity to lease quite a bit of acres that are being brought back into production, and so that is one key component to adding back to the food chain.

Mr. BACON. I am sorry. I just ran out of time. I appreciate your inputs. Thank you, Mr. Chairman.

The CHAIRMAN. Thank you. And now the gentlewoman from Ohio, Ms. Brown, is now recognized for 5 minutes.

Ms. BROWN. Thank you, Chairman Scott and Ranking Member Thompson, for holding this hearing today. And thank you to our expert panel for being here. Your perspectives are very helpful as we look ahead to the next farm bill.

We know that farmers are on the front-lines of the climate crisis. Extreme weather events like the devastating floods we have seen in the Midwest and wildfires and heat waves out West are already affecting the way our farmers produce and distribute food. These extreme events have also proved to contribute to inflationary increases in the prices of food and energy, saddling working families with higher cost and lower wages, property loss, and significant health problems.

Dr. Vélez, with all the extreme weather events we have been experiencing in recent years, many farms are facing crop losses and declining soil health. How can sustainable and climate-smart farming practices help farmers and ranchers improve their resilience and reduce risk?

Dr. VÉLEZ. Thank you, Representative Brown. I think that is a very important question to tease apart. And the reason I say that is because our research indicates that organic agriculture is actually one of the most resilient when it comes to dealing with these disasters, the droughts, the wildfires, the flooding, the hurricanes. Using sustainable practices, whether it is diversified crop rotations or cover cropping to prepare the soil, and so building soil health is critical.

At a fundamental level, organic agriculture is focused on building soil health and restricting the harsh agrochemicals that harm soil biota. As Mr. Vance said, soil biology is critical to that stability, and making sure that we improve the soil is going to be what makes these farms more resilient to these disasters. And so organic agriculture does result in higher yields, even after extreme environmental stresses.

Ms. BROWN. Thank you for that. I want to switch to the livestock perspective. Mr. Vance, what USDA conservation programs have you participated in, and do you think they have encouraged your operation to be more resilient?

Mr. VANCE. So currently, I do not participate in very many of the conservation programs just because of the way we are set up. But I think there are quite a few programs that are very helpful out there, one being the implementation of cover crops. And cost-sharing on cover crops has been very instrumental, especially in row crop operations.

Some of these practices we are not eligible for because we were kind of early on innovators with these practices. And so that, I would say that that is one thing I would like to see change is some of the ones that were early innovators, we haven't really been rewarded by being able to cost-share, going forward, because we had already adopted those practices. But I would definitely say that that is one of the largest programs that we like to see. Cross-fencing is another one. That was very helpful as far as allowing a soil just to rest. And then third, definitely some of the programs they have to slow soil erosion are very vital to our areas.

Ms. BROWN. Well, thank you very much. And I appreciate your responses. And I am pleased to see that the Department of Agriculture, as well as my colleagues on the Committee, have been so committed to encouraging and incentivizing producers to take part in climate-smart farming practices. So I look forward to working on more of these issues with more of my colleagues.

And with that, Mr. Chairman, I yield back.

The CHAIRMAN. Thank you, Ms. Brown.

And now the gentleman from Iowa, Mr. Feenstra, is recognized for 5 minutes.

Mr. FEENSTRA. Thank you, Chairman Scott and Ranking Member Thompson.

We have seen how agricultural productivity and efficiency can be enhanced through scientific research and applications of new technologies. An example from my district being Iowa State's Digital Ag, which specializes in developing new technologies to improve agricultural practices. Digital agriculture and data analytics can help improve the resiliency in the agricultural sector and can help farmers make informed decisions about how to best protect their soil, manage nutrients, and select crop varieties, all of which are vital to food production and the efficiency of producers.

So my question first to Dr. Brouder. If we look at the 2023 Farm Bill, how can we connect the dots from research academia to actually producers? What do we need to do in the farm bill to make this happen?

Dr. BROUDER. Thank you for that question. I think that anything that encourages the development of the next-gen extension specialist who can actually deal with data wrangling, data analytics, *et cetera,* is hugely important. We just completed teaching a first-time course, supported by a USDA grant, on research methods for synthesizing on-farm data, research data, that kind of thing. And, our take-home message as instructors was students don't know what they don't know and what they need to know. Not everybody is going to need to be a data scientist, but we need technical service providers, and honestly, our undergrad programs, too. People need to be more aware of the tools and how to use them to manage their enterprise. So that is on-farm, as well as the technical service providers, future farmers.

I will just add one more comment. We work in a case study with an extremely large consulting group in the Midwest, and they are hiring right now half agronomists and half data analytics people. And so we need to bring that capability to the farming sector. And from my perspective, it is the management on the farm, but it is throughout the supply chain.

Mr. FEENSTRA. Yes, and I would agree with that. I mean it really comes down to farm management. And there is this *minutia,* right? We have all this *minutia* of data. And you brought up an interesting point that we also have for us, we have the Iowa State Extension. We have farm managers. So we have maybe the conduits. I sometimes get concerned that academia is running way ahead. I see this at Iowa State, which is great. But Joe, Mary producer has a hard time capturing it and then actually applying it. And I think there is something missing. And I don't know if—I mean, I just look at the farm bill if there needs to be some incentivization or what can be done to connect the dots.

Dr. BROUDER. I think it is the synthesis, and that includes the synthesis of research data. We recognize the problem of what we call small science and research where you have small studies. But when you bring together data streams from on-farm with research data, you have an opportunity, especially with new tools in AI and

machine learning, to really advance our understanding of what we need to manage and how to go about it.

Mr. FEENSTRA. Yes, and I will go a step further. I mean, so now with precision farming, I mean, to help the environment, it is just amazing what we can do to figure out, okay, how much fertilizer we need to put on, how deep our soil goes, that increases production, knifing in fertilizer. I mean, there are just so many things that are happening currently in the farming arena for conservation and protection of the environment.

And now I look at the farm bill and say, okay, these farmers get it. A, they get it because of the efficiency part of it, but they also understand that it is good for the soil.

Just a last comment to you. Is there anything that we can do to connect those dots to incentivize the farmer for more conservation or to say, hey, you have done great conservation practice. What else can we do to help them?

Dr. BROUDER. I am not sure I can answer that quickly. What else can we do to help them? Well, I think it is both the access to expertise and their own tools on the farm so that they don't have to spend as much time as people are spending right now trying to deal with their data.

Mr. FEENSTRA. Yes.

Dr. BROUDER. There is a lot of unused data out there on farm.

Mr. FEENSTRA. Yes. Thank you so much. I yield back.

The CHAIRMAN. And thank you very much, Mr. Feenstra.

And now the gentleman from Illinois, Mr. Rush, is now recognized for 5 minutes.

Mr. RUSH. I want to thank you, Mr. Chairman, for this hearing. And I want to thank all of our witnesses for appearing before us today.

This question, Mr. Chairman, is for each of the witnesses if they care to answer. I am representing the south side of Chicago, and the vast majority of my district is urban. And according to the most recent Census, over 80 percent of Americans live in urban areas. So as we approach this all-hands-on-deck moment for research into an interaction between climate and agriculture, what research is happening today into how urban agriculture, some form of urban agriculture can help to reduce the carbon footprint of our nation's farming enterprise? And what role, if there is any, for researchers into the area of urban ag? And I will ask that question to any of our witnesses.

Dr. HOULTON. I am happy to jump in. Thank you so much for that question. So I will talk about some of the programs we are operating through in New York State. Through Cornell Cooperative Extension, we have four members of a team who are focused entirely on urban agriculture in New York City, and we have an additional team through our associations in Buffalo, among many other communities. They are focused on this question. How do you grow soil in a way that brings about local community resilience, nutrition, and food sovereignty? So that is something that is incredibly important to continue to do not only from a food security perspective but also from a justice and equity perspective.

Second, we are also working in controlled environment agriculture in some of these communities because there are new inno-

vations in businesses that are emerging through the ability to grow food in indoor operations, which is critical also to thinking about urban societies as they develop because of their food needs and the challenges of climate that are happening and harming our ability to continue to grow food.

Mr. RUSH. Does any other witness want to jump in on this?

Dr. FARES. Yes, Congressman. Oh, go ahead, please.

Dr. VÉLEZ. Thank you. Yes, Mr. Rush, I wanted to speak to the important work that is being done both within the organic sector and also just within urban agriculture in general. And I know that a lot of the urban agriculture space is really focused on sustainability and sequestering carbon. And of course it is at a smaller scale. However, these projects, for example, throughout, again, Chicago and then extremely urban areas, Detroit, Black Farmers Association. There are a lot of organizations that are working to build soil health, nutrient management. They are working to suppress weeds. They are working to make sure that their communities have access to food that is safe and also contributing to the environment in positive ways. And many of them are practicing organic agriculture to do so.

Mr. RUSH. Anyone else?

Dr. FARES. Yes, I would like to share with you some of our work that has been done by Prairie View A&M University and the Texas A&M University system. There is an initiative called Houston Healthy Initiative that is funded by a grant from the Texas A&M University system and also Prairie View A&M University system to address a clinical issue facing minorities and African Americans in the Houston area, what we call *food deserts* where people don't have access to fresh food, don't have access to fresh produce. So connecting them back with their food, helping them raise their own food, their fresh food so they can be healthy and they can stay outside of the doctor's offices, also connect them by helping minimizing carbon emission because one of the more important thing in carbon is the transportation of the produce. So if they can produce it locally, if they can—so that reduces in that. So this is an initiative where we can help achieve several things in addition to food security, health security, and other important things, especially for minority and limited-resources communities.

The CHAIRMAN. Thank you, Mr. Rush, very good question and very good responses from our panelists.

And now the gentleman from Arkansas, Mr. Crawford, is recognized for 5 minutes.

Mr. CRAWFORD. Thank you, Mr. Chairman, and thank you all for being here today.

Mr. Vance, I want to direct this question to you. Farmers are inherently market-responsive. I think they have to be environmentally sensitive. I think they have to be. Sustainability to me is not just about the environment; it is also about the economic conditions that are necessary for them to be sustainable over time. Many of the practices that are employed and their investments made in their operations aren't necessarily manifested in a positive way on the balance sheet.

And so my question is, how do we create more value for the farmer and ideas like, for example, low-carbon grain? How do you

certify low-carbon grain? Is there a market for it? Much like you see in the protein sector, where you have grass-fed beef that commands a premium in the marketplace? Certified organic is another label that consumers can make that choice to upgrade if they want to. And that is manifest to the producer.

The other question I have is, how do we turn data into a revenue stream, an additional commodity to what they are already producing? These are the things that I think that we are going to have to incentivize farmers to be able to avail themselves of if they are going to be sustainable, not just environmentally, but economically and on the environmental front. I mean, look, we have been doing conservation tillage for decades. That was not as much environmentally driven as it was economically driven. But now it fits really well with an environmental sustainability program. And I am just wondering how we capitalize on this to make it profitable and not just a feel-good initiative. Certainly, it is a sustainability issue. But how do we make these things more of a return on those investments that they are making in the long-term?

Mr. VANCE. Thank you for the question, Mr. Crawford. I fully agree with you that we are very fortunate to live in a time period where consumers are driven. The ones that can afford it are driven to pay for value in terms of what our climate footprint is and what our environmental footprint is. I think the main importance is we have to have that verified. The data has got to be legit. And I think it is important for the producers to be incentivized through the consumers and not be demanded to implement certain practices but be rewarded for those practices, and that way they can be economically sustainable in our operations.

And, I would like to see research done to help us verify some of these processes, verify some of the data, especially when it comes to carbon and water. And we are already starting to see that. I have producers that I work with that are already seeing their first carbon market checks this year, which is remarkable. But even as a taxpayer, you hope that stays in the private-sector, and I think that is very important that it stays in the private-sector.

But the incredible thing about that, as long as our people want that from a political standpoint, they also should be willing to pay for it with their dollar. And so I think we have to take the data, and we have to link it back to the land. And kind of the offshoot of that, we are going to see more value go back to the land. So a lot of these producers, a lot of these large landowners that don't have any producers on their property now, are going to be incentivized. And we are already starting to see it there in Texas. They are being incentivized. There is value there. Like, for instance, carbon, there is value there for the producer and the landowner. And you almost split that value. And so we are going to see an increase in production land. And honestly, behind inflation, a loss of production land is our biggest obstacle.

Mr. CRAWFORD. Let me throw something else out there. Various stages of crop production, there is carbon capture opportunities, correct?

Mr. VANCE. Yes, correct.

Mr. CRAWFORD. So my question is, so we have looked at conservation through the lens of programs like CRP. Is there in there

room for waivers or permits to produce on land that has historically been set aside for CRP and other conservation programs, whereby a producer can do those practices and do the carbon capture and still achieve the same goals in conservation so that they can also increase their economic sustainability, their profitability?

Mr. VANCE. You are identifying a real barrier there. I mean, that is the awesome thing that for so long we have been in this mindset that you can't have both, but you can, and the science will back to that.

Mr. CRAWFORD. Right.

Mr. VANCE. I think as we see more and more regenerative producers emerge, and we are definitely seeing that across our nation, like you can have significant livestock production without having any negative effects to other wildlife like in the CRP program. Matter of fact, we lease a property in Wyoming, and one of the things we have seen there is because there hasn't been grazing out on some of those CRP properties, we are seeing a reduction in farm crops on antelope due to a loss of palatability with mature plants that they can't utilize. I think the biologists that we work with on that property there, he is actually looking to do some research to identify if grazing would actually help the antelope. And I think that is the kind of thing that we need to see emerge quickly and build up, apply those things.

Mr. CRAWFORD. Thank you. I appreciate feedback. I yield back.

The CHAIRMAN. Yes, thank you.

And now the gentlewoman from Maine, Ms. Pingree, is recognized for 5 minutes.

Ms. PINGREE. Thank you very much, Mr. Chairman, for holding this hearing, and thank you to all the witnesses. You guys have done a great job and had some very interesting testimony, and I appreciate the work that you are doing.

My first question for Dr. Vélez from the Organic Farming Research Foundation. I really appreciate the work that you do. And coming from Maine where we have a large percentage of organic farmers, we are particularly interested in this. And we were able to host Under Secretary Moffitt in our district last week to talk about some of the concerns that our farmers are bringing forward, which are many, but we see them as sort of the original climate-friendly agriculture and want to be there to support the work that they are doing.

I am very engaged in this topic and introduced the Agricultural Resilience Act (H.R. 2803), really just to better empower farmers with the best-available science and conservation tools and so many of the things that we are talking about today. But one of the portions of it is around climate research, and it would authorize the Long-Term Agroecosystem Research Network for the first time ever, providing new funding, new research goals and capacity to adapt to climate change.

So I am curious, from your perspective, what other research goals would you like to see in the Long-Term Agroecosystem Research Network prioritized as it relates to climate resiliency?

Dr. VÉLEZ. Thank you, Ms. Pingree. That is a wonderful question. And it is indeed one of the comments that I made both in my testimony, verbal and written, is to expand the research and in-

crease funding towards the long-term agricultural research sites within the ARS. And specific to climate resilience, climate mitigation, I think agronomic research on these stations and at these sites and across other USDA facilities and institutions really needs to focus on soil health and nutrient management. Within these sites, I would like to see regional seed cultivar development particularly for organic systems, methods for weed suppression that are less disruptive to the soil, particularly for these organic growers who already struggle with weed suppression, integrated pest management systems. Something that came up in our National Organic Research Agenda is that a lot of organic growers would like to see more work being done on crop-livestock integration. They would also like to see more research on advanced rotational grazing, which may not be something that is going to be conducted at these LTAR sites.

But another thing is just to make sure that the connection between, so, for example, at ARS in the Beltsville, Maryland station, they have these field days, and these field days are critical to get that research out to the communities and making sure that that is reaching extension and other education networks.

Ms. PINGREE. Yes, thank you for that. Each one of those are areas that that we hear about and really want to expand the work that is being done. And particularly, as you mentioned in the end, making sure that some of the good research that is being done is available to farmers who want to make these transitions but need more technical assistance or advice along the way.

I am a big fan of the Sustainable Agriculture Research Education Program, SARE. I think it does really good work and provides some great opportunities to engage farmers in these practices. And I would just like to ask anybody on the panel, what kind of research would you like to see SARE focus on going forward? Anybody want to tackle that one?

Dr. FARES. I think I can try. There is a need for more integrated agriculture research projects where you have connection between more than one component. What we have been doing is dealing with issues in a silo research mode. What we need to do is an integrated and a nexus approach where you can have—where we talk about water, soil, plant health, animals contribution. So the integrated approach that will help us address the needs because many of these topics, they overlap. There are some overlaps between them. So dealing with them in a silo mode really doesn't help us. What we need is an integrative approach that addresses all these issues in one. So supporting that type of research, I think this is one of the suggestions that I recommend.

Ms. PINGREE. Yes, very good point. Anyone else?

Dr. VÉLEZ. Yes, I would like to advocate for more organic dollars within the SARE programs or more organic folks on these review panels to make sure that organic is being represented within those spaces as well and not just with research kind of devoted and segmented off into the OREI and ORG, but making sure that organic has its space within all of these programs.

Ms. PINGREE. Very good point. I have 20 seconds. Go ahead.

Dr. HOULTON. I will add just one other point that I think is critical to the Northeast region, and that is as climate change con-

tinues to change with warming about twice the national average, we are seeing more pests and more pathogens moving into our tree cropping systems, and we need to find biodynamic solutions to these challenges, so really critical to get that research.

The CHAIRMAN. Thank you both very much.

And now the gentleman from Pennsylvania, Ranking Member Thompson, is now recognized for 5 minutes.

Mr. THOMPSON. Mr. Chairman, thank you so much. Thank you to all of our witnesses. We will start with you, Mr. Vance. As the only producer on today's panel, I would like to hear your perspective on research that increases productivity and profitability and how that research relates to the environmental co-benefits. Can you speak to that?

Mr. VANCE. Thank you, Mr. Thompson. Thank you for the question. I think I think there are a couple of things we can look at. One is if we are looking at soil health and we are increasing soil quality, we are going to see increased production. There is a bridge, and we are going to bridge that gap. But I think that is where research comes in, to help us quickly bridge that gap. When you first get into some of the production cycles that we have, you kind of slow production until you get it figured out until your soil starts increasing, your organic matter starts increasing. And then you can start adding numbers. We have seen that. We have been able to add stocking rates. We have a farm this year that we don't have near enough cattle on. And we didn't plan for it. It is a positive, but next year, we can plan and we can have more head, produce more beef per acre. And so that is one part of it.

The other part of it, I mentioned it earlier, but as research verifies that there are different production systems that actually contribute to positive influences in several different environmental aspects. And we are seeing it with some of the mitigation companies, and we are seeing it on conservation easements. But as private property owners see the value in having production systems added back to their land, that is going to increase production alone, right there.

And in our section of the world, that is what we have seen the biggest incentive to do what we do. And you are talking about large land masses at times, especially for producers of our size, and we are talking about big, big ranches that were set aside for purely conservation. And then after 5 to 10 years in conservation, they are starting to see detrimental effects to no grazing. And so by adding grazing back there is so many benefits to that.

Mr. THOMPSON. Well, thank you for that. Healthy soils really is the tool that we achieve through American agriculture and all forms of American agriculture. Livestock, you have made a great, great point on livestock, which is something that I don't think many Americans recognize, and I would hope more Americans would understand. But it is farming, ranching, and forestry.

You have worked with researchers, or they have visited your ranch. And any recommendations that you have for the researchers for engaging with farmers and ranchers such as yourself, and perhaps engaging more effectively, *more,* being more on the farms or the ranch?

Mr. VANCE. So the research that we have been seeing that is successful and that is helpful to us, it has always come through private-public partnerships it seems like. Nobel Research is a good example of that. And so it seems like some of the private groups out there are really good at linking the two together. And so I think we need to see more and more partnerships with the private-sector to allow opportunities for real-world data, real-world research.

Mr. THOMPSON. Very good, and this for all, and I probably don't have time for response, but I am going to tee up my question. And if we don't get a chance for a response, I would love to hear from each of our witnesses. The Biden Administration, and inside the beltway think-tanks, have been pushing a climate agenda that creates new programs and added what I see commonly unnecessary bureaucracy. However, when producers, when you talk with those folks that are farmers, ranchers, and foresters talk about climate solutions, they mention the importance of research, boots-on-the-ground support, access to precision agriculture, and the need for broadband technology. It kind of goes hand-in-hand with precision agriculture. To me this all sounds like assistance available within the farm bill programs. And for all the witnesses, is the solution as simple as doubling down on these proven programs? And what research is being done to further technologies and practices that we know are already working? And I apologize, I probably have just about 40 seconds for a response from anyone who would like to take that, and then anyone else, I would love to hear in writing.*

Dr. VÉLEZ. Thank you. I will take a quick stab at that question and just say that I think the research is really important for farmers. And, as an organization, we try to connect as closely with our growers as possible and our constituents to hear their needs. And what we are finding is that the research and doubling down on farm bill programs that exist are really important when it comes to mitigating climate change and becoming more resilient. But increasing the funding and also expanding programs so that there is more capacity for those growers to get that information is key as well.

Mr. THOMPSON. Very good. Well, I would just encourage everyone to check out the SUSTAINS Act (H.R. 2606) because it does that. It uses public-private partnerships, brings private-sector dollars to expand more farm bill opportunities.

The CHAIRMAN. And thank you, Ranking Member. That was a very good question. And I certainly would appreciate you all, each of you responding in writing to the Ranking Member. Very good question, sir.

And now, the gentlewoman from Washington, Ms. Schrier, is now recognized for 5 minutes.

Ms. SCHRIER. Thank you, Mr. Chairman. I first would love to focus on water issues. And thank you to our witnesses for being here. Twenty twenty-one brought extreme temperatures and near record low precipitation to much of Washington State, and last summer, 96 percent of Washington State was experiencing drought. In this year, a cool and wet spring has brought some relief to many

*__Editor's note:__ the responses to the information referred to are located: for Dr. Brouder, on p. 76; for Dr. Fares, on p. 78; for Dr. Houlton, on p. 80; for Mr. Vance, on p. 81.

areas, but drought conditions persist in about ½ of my home state, including a few counties in my district. And our changing and warming climate is only going to bring more of these tough conditions for farmers.

Washington State University, including the Tree Fruit Research and Extension Center in my district, is leading the way on research that will inform farmers and our agriculture industry on the best practices to face the challenges posed by a changing climate. For example, Washington State University is developing new techniques for irrigating wine grapes with less water, and this has actually resulted in bigger, higher quality grapes. This can include the use of precision irrigation to inform the availability and timing of water supply, including options for managing projected shortfalls in future supply. It can involve the use of deficit irrigation where water is applied or withheld at specific developmental stages of the crop in order to conserve water without compromising growth. And deficit irrigation can actually help reduce the incidence of bitter pit, a growth disorder in apples, by controlling the size of an apple at maturity. So giving growers these tools can help them simultaneously conserve water and improve yields by managing crop quality challenges in a changing climate.

Mr. Vance, in your testimony, you mentioned that the U.S. built an agricultural sector based on reliably stable climates and abundant water. And this has, as you stated, changed, and it is continuing to change. So I am wondering how we can shift policy and the core of the industry to reflect what we know now about climate change and where we are headed?

Mr. VANCE. So thank you for the question. I think as far as policy is concerned, we just need to continue to furnish research that works with producers that are living in these everchanging environments. I think to really experience an everchanging environment, you have to work within a production cycle to experience some of those to where you can learn the intricacies of them. I mean, just like in our own personal operation, drought is a real thing in north Texas, and it is built into our management plan. And, some of that has been learned through the school of hard knocks, but I would hope for a new producer coming along would not have to learn from—they wouldn't have to experience some of the same mistakes that I have made. And so I think we need to do a better job capturing a lot of that data that I experienced. I don't have time to capture a lot of that data or log it, and I really don't have the know-how at times. But I think if we can create more partnerships where we work with for-profit, full-time operators, I think there can be very much a benefit to where we can collect that data and then use it to move forward.

Ms. SCHRIER. I appreciate that. I appreciate the importance of research in all of this discussion and watching for more than just one cycle. I would like to just highlight this issue of research infrastructure in our country. The ability, as you mentioned, for researchers to conduct experiments on plants under various environmental stressors is really critical for understanding crop responses to new climate conditions and those that might be coming down the line. And modern facilities can help researchers screen new crop varieties and understand the impacts of a changing climate on

those specific plants, including insects and disease pests. But 69 percent of research facilities at U.S. colleges are at the end of their useful life. Our research facilities not only generate solutions, but they aid in recruiting a whole new generation of scientists and innovators and agricultural leaders. And they have the potential to keep us at the forefront of international research and a real leader. So a multiyear investment will just reposition the United States for long-term success and competitiveness and leadership around the world. And this issue stays top of mind for me as the Appropriations Committee works on writing Fiscal Year 2023 funding bills, and I will continue to push for research at our universities. Thank you. And I yield back.

The CHAIRMAN. Thank you.

And now, the gentleman from Georgia, Mr. Allen, is recognized for 5 minutes.

Mr. ALLEN. Thank you, Mr. Chairman. And thank you to our witnesses for joining us today.

We are in a real debate and a dilemma in this country right now. And the American people are really hurting. I mean, I don't know how much they have to sacrifice to this climate God to deal with these issues, but obviously we were created to adapt to and have dominion. But, this thing, I mean, the whole economy is upside down. And, I mean, you have been in the grocery store. I mean, I was on the elevator coming up here today and the talk on the elevator—and I didn't know these folks—was do you know how much I paid for eggs yesterday? $12 a dozen, Mr. Chairman. I mean, where is this going to end?

And of course, we have a war on fossil fuels, which has created a lot of this, and now we have this, we are going to have a war on—and to walk into a grocery store and see empty shelves and no baby formula. I mean, what is this country coming to? The American people are in fear of what is going to happen next. And so I think it is important that we have a serious debate on where this country is going.

Dr. Vélez, how do you propose that farmers can focus on new technology and production methods in order to combat climate change when the world's food supply needs to increase by more than 70 percent in the next 30 years? How is that going to happen?

Dr. VÉLEZ. Thank you for your question, Mr. Allen. I think the biggest benefit that organic agriculture has to offer is that it is not reliant on fossil fuel-dependent external inputs, which are one of the biggest struggles that now is facing the conventional growers. They are really reliant on these increasing prices for these external inputs. And organic producers have for a very long period of time been reducing that and building soil health so they have soil fertility and nutrient management. And as we continue to invest in organic, we can equalize that price premium that is there. And I believe that that is one of the biggest things that we can have to offer for this. We understand and we recognize that inflation is occurring, and it is occurring within our market as well. And so we need to find a way to bring more of that production internally and have the system work holistically and work with that. Mr. Vance said that as well, it is important to manage a farm as a system,

and that system should have the resources within the farm operation. And that is the focus of organic growers.

Mr. ALLEN. Yes, but I can't get anybody to tell me that we can be assured that, through this process, that you are going to be able to furnish the needs of the food for this country, like I said, 70 percent in the next 30 years. I have had nobody give me any kind of data that indicates that through these means and methods, we are going to be able to do this. We know the progress we have made over the last 30 years. Dr. Vélez, can you honestly state that funding for climate change research and the innovation of new technology is more important than dedicating funding and research to increase the production amounts of our world's food supply, particularly when our national debt is over $30 trillion?

Dr. VÉLEZ. Mr. Allen, I would like to follow up with findings, research that indicate that organic systems that address climate change have similar or higher yields in some circumstances. This has been found from Rodale Institute's organic and conventional crop rotations. They have had similar yields over a 35 year period. And so when they are managed correctly, in some cases, the organic systems actually had better crop yields, 31 percent higher grain yield of corn during drought years. And so when we are faced with these climate conditions, the organic systems are performing better. Thank you.

Mr. ALLEN. The issue of climate change is not only the responsibility of the U.S. to solve. Dr. Fares, you mentioned the need for other countries to develop research initiatives as well. Can you tell us more about the likeliness of another country to devote funding or simply adopt practices?

Dr. FARES. I think some of the issues that we are facing would be helpful to address them in collaboration, basically, a process. I mean, other countries, I don't have the statistics before me here about what other countries are spending in research and development. But I think we need to synergize in certain areas where we can work with other countries in crops that are common. For example, take corn for instance. We are not the only people who are growing corn. We have other countries. So if we can work collaboratively with other countries, that will be helpful to us.

Mr. ALLEN. Yes, well, I am out of time but I can tell you this. The American people have sacrificed an awful lot to lead the world in carbon reduction, okay? And we are far ahead of the rest of the world. Thank you very much, and I yield back.

The CHAIRMAN. Yes. And thank you, Mr. Allen. And you raise a very good point, Mr. Allen, and that is why we are addressing this high cost of food and fuel with our food and fuel costs bill that will be on the floor tomorrow. That is a leading priority of our Agriculture Committee. And thanks to C–SPAN, the nation will see we are very concerned, and we will move to bring down the high cost of both food and fuel with the enaction of our legislation, which will be debated on the floor of the House of Representatives tomorrow.

And now the gentlewoman from New Hampshire, Ms. Kuster, is recognized for 5 minutes.

Ms. KUSTER. Thank you, Mr. Chairman. I am so grateful for you and for this hearing, and I appreciate your leadership on this issue and your attention to climate change. As I often say, our farmers

and foresters are on the frontline of climate change. They are already experiencing the ramifications, and they will continue to. They feel the consequences of our changing climate long before other sectors are hit equally as hard. As such, they deserve tremendous credit for the work they have already done to take full advantage of farm and forest lands as carbon sinks.

But of course, there is much more we can do, and I am so pleased that the agricultural research extension and grant project are continuing to make fresh progress in this space. A great example is the USDA's Hubbard Brook Experimental Forest in my district in New Hampshire. They have provided top-notch analysis through their work studying New Hampshire's climate for the past half century, 50 years. They found that our average annual temperature has already risen a staggering 2.6° Fahrenheit, that rainfall has increased often in condensed periods of heavy storms, and that flooding has become much more common where I live.

As challenging as these realities are, it is important for farmers to know what they are facing and that they have the tools to plan accordingly. We have an incredible opportunity to build this research capacity out in the next farm bill, and we cannot squander it. We must continue to provide incentives to help producers maximize the carbon capture potential of their land.

So in that vein, Dr. Vélez, we have seen farmers adopting practices such as reduced tillage, increased cover crops, crop rotation, and the integration of conservation measures. What is the role of research, education, and extension in shifting culture and supporting the adoption of these sustainable agriculture practices?

Dr. VÉLEZ. Thank you, Ms. Kuster. I appreciate the question. I believe firmly that one of the most important things that can be done is to build the connection between the researchers and the research that is being done and the adoption of all of these carbon sequestration practices, carbon mitigation and climate, recognizing that the research is out there. There is still more research that needs to be done to enhance soil carbon sequestration, but we also need to make sure that that gets into the hands of the people who are doing the work. And so this is why I will again continually push for more investment in extension and education, and in many cases even creating networks and hubs because we have learned from our National Organic Research Agenda, that farmer-to-farmer information is one of the best ways to share and spread new innovation. And so for adoption of innovation, diffusion of technology to occur, we need to be connecting more closely with the farmers, the growers, the ranchers, who are doing these carbon sequestration practices to get that information out there and making sure that organic growers are being recognized for that great work.

Ms. KUSTER. Great. Thank you. And Dr. Brouder, let's zero in on this thread a bit more. You have done extensive research on the nutrient requirements of crops in changing environments and on fertilizer efficiency and balance. Can you speak to how soil health plays into nutrient demands and what the research has shown in terms of building soil health and ensuring appropriate nutrient balances for crops under changing climate conditions?

Dr. BROUDER. So if I understood the question correctly, the research has shown that there is a pretty strong relationship be-

tween what you get in yield and the amount of nutrients required by plants. And those nutrients can be supplied in a variety of ways. Some of the strategies that we have result in more loss than others in terms of the portion that goes to the plant *versus* the portion that ends up in air or water. When you increase the soil's carbon, you increase the soil's ability to supply nutrients and to cycle nutrients. And so there is some very direct benefits of increased soil carbon to nutrient retention and maintained availability to plants. But the practices and the efficiencies are nuanced. And the research has not always been done it really needs to be done with farms, farmers on farms, is to understand the environment by management interactions.

The CHAIRMAN. Thank you very much. The gentlelady's time has expired.

And now the gentlelady from Florida, Mrs. Cammack, is now recognized for 5 minutes.

Mrs. CAMMACK. Thank you, Mr. Chairman. And thank you to our witnesses for appearing before us here today. It is a great topic, and I am excited to dig in. But before we do, I do want to recognize the fact that tomorrow we will be voting on the Lower Food and Fuel Cost Act (H.R. 7606). Now, unfortunately, this bill is in name only and will do nothing to lower the cost of food or fuel but rather increase them. And I think more broadly, we need to start thinking that government is the answer to every single one of our problems. Expansion and meddling by government does not often help problems; it expands them. And one example is the special investigator that we are going to be seeing as part of this package that will then be placed in our processing facilities, our processing facilities that I believe are some of the safest, most efficient processors in the world.

And while there can always be improvements, putting more burdens on an already strained market is not going to help. In fact, when we see these energy costs going up, that is going to increase food prices. And this investigator is just one example of many of why this bill is seriously misguided.

But, what we are talking about today, the role of climate research, I look at American agriculture, and I see America as a leader in reducing greenhouse gases. And I definitely believe wholeheartedly that America is the most efficient when it comes to production, and I think that that should be celebrated.

I really have only two questions, and I want to jump in with you, Mr. Vance. In your written testimony, you mentioned that there is a debate regarding the impacts of beef cattle on the environment. As you know, American beef production accounts for only 3.3 percent of the nation's total greenhouse gas emissions, but the story that we often hear in the media often paints the opposite. In your opinion, is there a disconnect? And how do we change the public discourse?

Mr. VANCE. Thank you for that question. So there is definitely a disconnect. I think the most interesting part of that if you really dig into the research, a lot of that carbon footprint is brought about by the transportation of that food to the consumer. So if we replace that with another food ingredient, you are still going to have the same issue. And so I think we need to have research that really

verifies that, and I think we need to see people in this country go back to the soil. It is really interesting when people get disconnected from the land and the soil, they get disconnected from their food systems. And they need to understand that it is really easy to make comments and remarks until you show up on one of our operations and you see the butterflies and the wildflowers and you jump a baby deer out of the grass, which is a daily occurrence in our operation. It is much harder to throw bullets at that point whenever you see what really goes on in our entire ecosystem.

Mrs. CAMMACK. Well, and thank you for that. I mean, as someone who grew up on a small cattle operation and now represents the number two state for cow-calf operations, I can tell you that our agriculture producers are some of the best conservationists around. So I am really glad to hear you say that, and thank you for making that public.

Dr. Vélez, who I think is on the screen, in your written testimony, you mentioned that you have conducted experiments to help south Florida farmers sequester carbon and enhance soil fertility using biochar. Now, while biochar is not a recent innovation, there is an increased interest in using biochar as a natural climate solution. I am particularly interested in this coming from a state, a hurricane state where debris is in abundance most times of the year, and so this is a very interesting opportunity. Can you talk more about these experiments that you conducted and how biochar can be used to sequester carbon?

Dr. VÉLEZ. Yes, thank you for your question, Mrs. Cammack. My research happened at the USDA–ARS Subtropical Horticulture facility while I was doing my master's, and I was using an invasive tree species *Melaleuca* to sequester carbon. I converted that tree species to biochar at different temperatures. And some of the findings and the research, I will say, came about because the farmers were telling me, this is something I am employing. And I said, well, let's actually test and see.

Interestingly, my findings said that the higher we applied the biochar, the more detrimental it was to actual crop production for *Phaseolus vulgaris,* which is green beans. And I think one of the reasons is that we need more research on the different types of biochar, so temperature, volatile organic matter, all of these affects. And the pH of the soil is also very critical to whether or not a biochar is going to sequester carbon and also increase crop growth. And so we need to make sure we invest more in understanding the role of biochar and how that biochar is produced and how it will impact specific soils.

The CHAIRMAN. Thank you very much. The gentlelady's time has expired.

And now the gentleman from California, Mr. Panetta, is recognized for 5 minutes.

Mr. PANETTA. Great. Thank you, Mr. Chairman, I appreciate this opportunity to talk about such a timely topic. And I also want to give a shout-out to the Ranking Member for his comments and what he said about our producers and our farmers, especially having the producers that I have in my district on the Central Coast of California, who I find to be some of the most progressive producers when it comes to dealing with climate change but when it

comes to having that balance that I think I need in my district, that everybody in my district understands, because obviously on the Central Coast of California, if you have been there, you understand it is the most beautiful Congressional district in the nation, I will say myself. So we value our environment, but we also have our agriculture and we have our bounty. So we have a lot of beauty, we have a lot of bounty, and therefore, there is a lot of balance that needs to go on.

And unfortunately, I do believe that my producers understand that balance because I can tell you, if anybody, if anybody wants fresh air, clean water, and pure soil, it is our farmers. And so I think people need to understand that and appreciate that but also work with them, when it comes to ensuring that we have all of those. And we can do that with advancements in technology and research and education, and yes, of course, organics.

First question goes to Dr. Brouder. I recently was proud that I joined my colleague from Indiana Mr. Baird, who you may hear from pretty soon. He is on the screen there waiting to ask questions—to introduce a bill called the Plant Biostimulant Act (H.R. 7752), which aims to provide some regulatory certainty to the plant biostimulants industry, allowing them to move forward with introducing even more input alternatives. Can you go ahead and just kind of speak to this Committee and how this Committee and how the USDA can invest in biostimulant research, especially around pesticide and herbicide alternatives and if there is anything else out there awaiting regulatory certainty that we could also provide?

Dr. BROUDER. Could you explain a little bit more about your last point awaiting——

Mr. PANETTA. If there are any other opportunities basically needing legislative action when it comes to biostimulants.

Dr. BROUDER. Biostimulants. Having worked myself in, and having done field trials on products that are considered nontraditional, I think it is very important that they be demonstrated to work because there are a lot of things out there that—just as there are in the human supplements industry that don't necessarily do much for human health. But, there are things that are in this biostimulant category that need investigation and demonstration. So I think the important part of what needs to be codified is that for something to be used as a replacement for a fertilizer or herbicide or something, its efficacy needs to be clearly demonstrated for its purpose and likely in head to head with the existing strategy. That is very similar for medicine. I was part of a medical trial that they wanted to demonstrate a medical device.

Mr. PANETTA. Great. Let me move on to the next area. And I want to talk to Dr. Houlton, who is on camera. As you have noted that basically not every climate solution will work for every producer but that definitely our producers or farmers can be part of the climate solution. Now, I am heartened by your comments in your opening testimony, especially the role that farmers can play in addressing climate change. I want to ensure that the producers in my district who grow fresh fruits and vegetables on relatively expensive acres are included in this vision. So can you talk about what conservation programs can best affect climate change goals, while also keeping in mind the limited resources available to spe-

cialty crop producers outside of the mainstream general farm commodities that are often overlooked when it comes to Federal programs?

Dr. HOULTON. Great. Thanks for the question. Well, from my experience working on over 100 acres of farmland carbon sequestration projects, I can tell you that there are many different commodities that can work through carbon sequestration, soil amendments, taking compost and manure and repurposing it in the soil, taking biochar and putting it into the soil and rock dust, which can dissolve in the soil and be repurposed from the mining industry through a process called enhanced weathering to trigger carbon removal. So all those are available.

The challenge that I see is that the U.S. has fallen behind China and Brazil in funding for research. And this is putting tremendous strain on our ability to translate knowledge, educate the next generation, and continue to grow our production systems through efficiencies and carbon sequestration.

Mr. PANETTA. Great. Thank you. I am out of time. I yield back. Thank you everybody.

The CHAIRMAN. The gentleman from California, Mr. LaMalfa, is now recognized for 5 minutes.

Mr. LAMALFA. Thank you, Mr. Chairman. To Mr. Vance here, I was looking at some numbers here on livestock in the United States. So the estimates were back in about 1800, we had about 60 million bison in North America. And currently, we have approximately 9.5 million dairy cows and about 30 million beef cattle, and probably about ½ million bison, so that adds up to about 40. So we had 60 million bovine animals in North America in 1800. We have 40 million now. What do you think of those numbers when we have the vilification of the livestock industry being the cause of global climate change?

Mr. VANCE. Well, I can't speak really to the dairy sector, so I will kind of stick with the beef cattle sector. And one thing I would add is that I think we have to take into account also elk and other large mammals that were once rangeland animals before they became more mountainous animals at one time. But also like in the dairy sector, those animals are more confined, and so I can only speak to open rangeland animals, like we operate in the system with which we operate in. I will admit, it is a much easier system, and it is much easier to be environmentally friendly when you are out on the land and you are recycling nutrients. And that is all I have to say about that.

Mr. LAMALFA. So you don't think the numbers would indicate that livestock are being unfairly targeted when you had back in 1800 half again as more livestock that are bovine creatures as what it is now?

Mr. VANCE. Oh, definitely, I would agree with that 100 percent. And even when you have people that want to preach conservation and adding land animals, there is going to be a trade-off with that. We replace bovine that we can use in production agriculture and produce the greatest protein in the world for our nation, and then you replace that with the animal that you can't harvest for protein, then that is going to create a food shortage as well. So yes, you are definitely correct there.

Mr. LAMALFA. There doesn't seem to be much fuss about the various shortages right now being caused by Washington.

Dr. Brouder, when we talk about the issues of people come into agriculture—I am in agriculture myself, so we get approached a lot by people with bright ideas about how we should manage our land and what we should use on our crops, *et cetera.* So talk to me a little bit about the cycle of carbon, when you have a plant that takes CO_2 out of the air and sequesters it into the plant itself, maybe a little bit in the soil. We have heard a lot of folks saying, oh, we need to push towards no-till or amendments to the soil. But then when that plant dies or is harvested or burns up like our trees are burning up all the time in California after having sequestered carbon, isn't it kind of a zero sum deal when you have pulled the carbon into the plant and then the plant dies or burns or its cycle renews? Talk about that a little bit.

Dr. BROUDER. Well, it is true. It does cycle that way. Plants put carbon into the soil predominantly via the root systems, via what they both excrete through their roots to grow through soil. They excrete organic acids——

Mr. LAMALFA. How deeply over time can they put the carbon into the soil? Does it stay on the surface of the root system or——

Dr. BROUDER. It depends on what type of plants, how deeply they root. Some root very shallowly, but prairie grass can root very deeply down into the soil, and so they contribute that way.

When we till the soil, we do accelerate the aeration and turnover and breaking up of carbon, which accelerates the rate of loss of carbon back to the atmosphere. So, yes, it is true that you are constantly cycling, but when you do some of these practices, you are minimizing the rate of return of some of that initially captured carbon, and you are putting it into a stable form of soil that is those stocks that we are so interested in, soil carbon stocks that we are so interested in increasing.

Mr. LAMALFA. Certainly, but what happens when you change a crop and you have to till differently, which requires maybe more tilling? Like such as some of the crops in my neighborhood, you don't have the option of no-till, what do you do at that point?

Dr. BROUDER. If you don't have the—I mean, tilling—that is the consequence of tilling. But let me be very clear that in agriculture, we don't do practices—there is a purpose for practices that farmers have adopted, right? And most practices do have trade-offs. But when you no-till, you also keep the soil in place, and with keeping it in place, you keep the carbon in that soil in place. You are not eroding it off the surface.

Mr. LAMALFA. Certainly, until the next time that you are required to till.

The CHAIRMAN. The gentleman's time has expired.

Mr. LAMALFA. The cycle continues. Always has. Thank you.

The CHAIRMAN. And now I recognize the gentlewoman from Minnesota. Ms. Craig is now recognized for 5 minutes.

Ms. CRAIG. Thank you so much, Mr. Chairman. And thank you for calling this hearing. I think it is a really important topic to talk about climate research and how we support ag resiliency. Thank you to our witnesses for your testimony today and your work on climate resiliency.

The family farmers in my district in Minnesota and across the country are part of the solution in my mind when it comes to addressing climate change. No one knows about the importance of resiliency, and no one is better situated to implement those solutions than America's farmers and ranchers. Research plays a key role in their ability to help us collectively respond to climate change. From land-grant universities like the University of Minnesota working with farmers on the ground, to innovative public-private partnerships, like the ones we will see out of USDA's Climate-Smart Commodities Program, collaboration is absolutely critical when it comes to research dollars being effective and leading to implementable solutions.

With that collaboration in mind, I would like to turn first to Dr. Houlton for my first question. Dr. Houlton, in your testimony, you talked about how researchers are working with farmers to develop improved management practices. Can you talk a little bit more specifically about any of those efforts? And can you share more about how research into input optimization might help farmers with both per acre yield increases and lowering carbon intensity?

Dr. HOULTON. Great, thanks for the question. Having grown up in Minnesota and coming from a long line of farmers in the Midwest, it is great to have your question.

So first of all, the carbon that comes into a soil can stick around from years to decades to millennia. And what we really need to do is work with farmers, with science, and verification tools to understand how to push it into those types of carbon that can stick around for thousands of years and be an essential part of bending the carbon curve.

Now to your question on input optimization, there are many strategies. For example, using new data-driven tools at Cornell and many other land-grants, we are working with growers to reduce the amount of fertilizer that is required through fertilizer efficiency gains, which helps the environment, it helps climate, and it reduces the input costs that our farmers are bearing, which obviously are going up right now. So there are many tools in the toolkits through extension, through data-driven analytics, and through improved efficiencies with fertilizer.

Ms. CRAIG. Excellent, thank you so much. Now, I don't want to leave anybody out here, so let's go next to something that really always is exciting to me. What is, for each of you, the most promising area of current ag research where you see the most opportunity for outcomes that create implementable, impactful solutions that can enable American farmers and ranchers to continue that important work of both feeding the nation and combating climate change? And I will go through you one by one, just a few words on the most promising areas of current ag research. Let's start with Dr. Vélez.

Dr. VÉLEZ. Yes, thank you, Ms. Craig. I think one of the most important areas within the organic sector is weed suppression. Our growers do struggle a lot with weed suppression. We do not use the synthetic inputs and herbicides that many other people rely on. And so finding best ways to manage weeds on these operations and to also manage nutrient levels and increased soil fertility would be the best area of focus.

Ms. CRAIG. And Dr. Brouder?

Dr. BROUDER. I would have to say synthesis research. We talked about small studies, we have talked about how things vary from place to place, and we have invested in individual small studies but not quite so much in all the synthesis work that will allow us to bring nuance to a recommendation.

Ms. CRAIG. Thank you so much.

Dr. Fares?

Dr. FARES. Thank you, Congresswoman, for the question. I think the idea that I would like to share is the nexus approach of dealing with these resources. Energy, water, food, health is the approach that we need to adapt to increase those types of studies to help us go through this crisis.

Ms. CRAIG. Mr. Vance?

Mr. VANCE. Ecosystem service markets, it is going to bring more private dollars and private land access to producers, and I think that is going to provide lots of solutions for us.

Ms. CRAIG. And with 10 seconds left, Dr. Houlton?

Dr. HOULTON. Net-zero dairies, net-zero dairies, cutting emissions, circular systems, incredible research opportunity.

Ms. CRAIG. Thank you to all of you for being here today. And with that, Mr. Chairman, I am out of time, and I will yield back.

The CHAIRMAN. Thank you, Ms. Craig.

And now, the gentleman from South Dakota, Mr. Johnson, is recognized for 5 minutes.

Mr. JOHNSON. Thank you, Mr. Chairman. My questions will be for Mr. Vance. And, Mr. Vance, in your testimony, you noted that your seed stock operation is focused on raising climate-friendly cattle genetics. For those folks who don't know as much about it as you do, tell us a little bit more about what you mean and where you are headed.

Mr. VANCE. Thank you for that opportunity. This is fun to talk about here. So just last year, we estimated we raised about 340,000 pounds of beef on our operation with just my family. We don't have any full-time help. That was using one tractor, one truck, and one ATV. That is efficient from a profitability standpoint and definitely from an environmental standpoint.

Second, we raise an animal that can thrive and survive on forage only in diverse forage climates. This has taken years and years to cull and to adapt these type of animals to an environment that doesn't need added inputs. And so we were able to take those cattle and sell those seed stocks into other places, currently into about 13 states with current producers.

And then third, whenever you have a network of producers like that, we all have a relationship with one another to where we are able to gather information and share it very quickly. And so it gives us the ability to quickly learn and quickly grow together. You can't put a value on that.

Mr. JOHNSON. And so, Mr. Vance, I am from South Dakota, so I understand what words like *culled* mean or what the term *genetics* mean in the context of cattle. But we have some city folks on the Committee, too, so talk to us about—when we talk about developing genetics, talk to us about how do you build this herd. How do you make sure that these animals and that their progeny are

frankly well-positioned to succeed in the environment you are talking about?

Mr. VANCE. So it is a two-part, complex process. We are working on degraded soils, and we are working with animals that are more adapted to a conventional operation with lots of inputs and that require lots of feeds to finish into marble and create a good eating experience for our consumers. And so, during that two-part process, we are working on building our soils. We are learning, experimenting, trying new methods to improve our soil, improve our plant diversity, and then we are also putting a lot of pressure on our cow herd to find the ones that are efficient and that are profitable for our operation within that system that doesn't have the added inputs. And so what we have seen over the last 10 years is a steady growth. It is slow. It doesn't happen overnight. But it is a long-term goal and long-term profitability within that realm is very real.

Mr. JOHNSON. Yes, and what I was struck, when you talked about how much beef you are able to raise with an operation that doesn't have a ton of hired hands and doesn't have a ton of equipment. I mean, just your family over generations has really been able to build cattle that put on weight, build that great marbled protein in a way that is efficient, as well as, as you mentioned, just rely on forage alone. It is really an incredible success story. What else do you want to make sure we understand about this progress you have been able to make?

Mr. VANCE. I think the biggest thing is continuing to work to allow us to be able to grow in this sector, whether it be through funding for research, for public entities, and then getting those public entities to partner with private-sectors and private farmers and ranchers and work with us to gather more recent information. I think there is definitely a lag in information between real-time producers, at least in the beef cattle world, and the researchers that we work with. And so I think we need to speed that up and we need to bridge that gap. And that way, we can work with more traditional operators that are wanting to bridge their own gap into more climate-friendly practices and more profitable practices. In a time like this where inputs are so expensive for a lot of operators, we have a lot of newer adapters that are paying attention whenever markets were better and when inputs were cheaper. They may not have been so quick to pay attention to our types of operations. But now we are in a time where we are much needed. There are going to be many operators that are going to have to innovate to survive, and that is the only way they are going to survive.

Mr. JOHNSON. Very well said, Mr. Vance. Thank you, Mr. Chairman. I yield back.

The CHAIRMAN. Thank you, Mr. Johnson.

And now the gentlewoman from Iowa, Mrs. Axne, is recognized for 5 minutes.

Mrs. AXNE. Thank you so much, Chairman Scott. And thank you to our witnesses for being here today to share your expertise on this incredibly important subject.

At the very first hearing we held within the Committee in this Congress, we discussed the increased unpredictability and devastating effects that climate change poses and the serious threat

that it has on how we grow and produce our food in this country. So we are focused single handedly on this issue to make sure that we address this. While we are dealing with the weather and we know that this is nothing new for farmers in general, climate change has absolutely led to a dramatic increase in extreme weather events over recent years, which has greatly increased our costs and the risks and the uncertainty.

In the few short years that I have been here in office, my home State of Iowa has experienced major droughts and a derecho, a storm we hadn't heard of until a few years back, and, of course, unprecedented flooding. And with almost 90 percent of family farmers needing off-farm income just to make ends meet, we absolutely need to make sure that we are addressing this because there is no room for error.

So farmers are definitely on the frontline of climate change. And we know that. And while there have been significant improvements in increasing efficiencies and inputs, ultimately allowing us to produce more food with less inputs, we can and we have to do more. In fact, without some action, researchers expect crop yields to decline by the end of the century due to climate change. So we have to make sure that every single option is on the table here.

One area I am particularly interested in is how we can equip our farmers to further reduce their inputs such as more timely application of nitrogen to help reduce runoff and emissions. And of course, as fertilizer costs have skyrocketed, reducing the need for nitrogen or any input will go a long way with improving profitability as well.

So before I ask my questions, first thing I want to do is thank my friend and fellow Representative Harder for his legislation to provide additional assistance for nutrient management practices through the EQIP program. I look forward to passing that bill tomorrow, as well as many other important bills to lower food and fuel costs.

And my first question goes to you, Dr. Brouder. I believe you are working on efforts to integrate public and private data to make it easier for farmers to make data-driven decisions, particularly when it comes to fertilizer use. Can you expand on that work and hopefully what you think it can accomplish?

Dr. BROUDER. So recommendations that have been produced by land-grant universities and extensions over the years, they tend to be fairly generalized. And in the era of precision agriculture, there is a strong desire for site- and soil-specific recommendations. I can't, as an extension specialist and applied researcher at Purdue, do the research on all the different acres out there, even just within the State of Indiana. So what we are doing with a NIFA-funded grant is collaborating with a big ag consultant who works directly with farmers and trying to use a combination of on-farm data or using in a case study on-farm data with our research data to generate a site- and soil-specific recommendation that is beyond the current guidelines and the approach that land-grants have to developing guidelines.

Mrs. AXNE. Okay. Okay. So I appreciate that. So let me just combine a couple of last questions here, then. What are some of the challenges of getting this into the farmers' hands? It sounds like

we can, but we have some challenges there. And then second, I want to reference Rep. Craig's question of the promising research that is out there. What type of support do we need for our land-grant universities, the research capabilities that you could have if you have the support you needed? I met with Iowa State yesterday, and I know that we could be working on a lot of key issues. So what do we need to do across the board?

Dr. BROUDER. Well, I think across the board, there is a need to reinvest in our research and its infrastructure. I can assure you that my colleagues at Purdue would say the same probably as the people you met with that at Iowa. In terms of getting to a point where farmers' own data can be used to develop a customized recommendation within a framework that is based on scientific evidence and you can understand how it works, that kind of thing. One of the biggest challenges is pulling the data together and using it together. And so farmers need tools and researchers need tools to wrangle that data. They need workflows, they need infrastructure, such that you go to a recommendation app, put it in there, and it ingests your information and gives you that customized recommendation.

The CHAIRMAN. Thank you very much. The gentlelady's time has expired.

And now the gentleman from Indiana, Mr. Baird, is recognized for 5 minutes.

Mr. BAIRD. Thank you, Mr. Chairman and Ranking Member Thompson. And I always appreciate all the witnesses taking time to share their expertise with us about the important issues facing agriculture.

And I especially want to welcome Dr. Brouder from Purdue University, which is in my district in Indiana, so welcome.

And my first question goes to Dr. Brouder. In your written testimony, you discussed the importance of improving data sharing and some of the challenges that impede complete and efficient sharing of agriculture data. You mentioned the need for support for initiatives like the Agricultural Advanced Research and Development Authority, or AgARDA, to enhance partnerships between ag data stakeholders and facilitate the development of improved data infrastructure. So could you elaborate on the important progress that could be made through using the proper funding for AgARDA, please?

Dr. BROUDER. So data is a huge issue in agriculture. There is a lot of it, but it is not prepared to be used in an easy, seamless way. It is not like you can just go find various bits and pieces of data. So the reason in our analysis that we focused on AgARDA as a pathway forward is that AgARDA, Office of the Chief Scientist, *et cetera,* has the convening power to bring together all of the stakeholders in the agricultural data value chain to address a huge array of issues that range from data ownership and data privacy for on-farm data to simply the human resource capacity and infrastructure needed to organize and house agricultural research data. We have repositories all over the place now. They don't necessarily talk to each other.

Mr. BAIRD. So let's take that one step farther, because my next question that you mentioned is the fact that these data-driven solu-

tions in agriculture, how do we make sure that we have students that understand this and know how to apply the data and the computation for science?

Dr. BROUDER. We work on our curriculum and we get some data skills infusion into the agricultural curricula, as well as students—not everybody—I think I said this already—is going to need to be a data scientist, but they need to have an understanding of what data is and how to look at a piece of data and understand whether or not that represents what they think it does. That is a very simple thing, but students need to know how to evaluate data and to use it correctly. And then they need to have some understanding of the computational tools that allow them to handle and wrangle data and the programs that they are pushed into. So they have to have an appreciation that is more than this is just a box, a black box, and I put my data in and something comes out. They have to have the intellectual ability to understand whether what comes out of the black box makes sense.

Mr. BAIRD. Well, thank you for that very, very important information. And thank you for being here. Do any of the other witnesses—we have about 50 seconds left. Any of the other witnesses have any comments in that regard?

Dr. VÉLEZ. Yes, Mr. Baird, I have a comment specific to data. And I think the importance—and Dr. Brouder mentioned this earlier—is to make data more accessible is really important. But as she is speaking about students understanding the science, we also need to equip people to make that data accessible. And so when we talk about data science, that data needs to be presented to farmers and to ranchers and growers and foresters in ways that they can readily understand, and I think that is something that needs capacity building within our nation and our land-grant institutions as well.

Mr. BAIRD. Thank you. Anyone else? I have about 10 seconds.

Dr. FARES. I think building capacity in this area is important, human capacity especially, so we have to train our teachers who are going to teach these students and provide them with the infrastructure they need to train these students for the future jobs that they will be holding, not to train them for the past jobs or the jobs of the past.

The CHAIRMAN. Thank you. The gentleman's time has expired.

And now the gentlelady from Ohio, Ms. Kaptur, is now recognized for 5 minutes.

Ms. KAPTUR. Thank you, Chairman Scott. And this has just been an excellent panel of witnesses this morning. I am just so proud to have been able to listen to them in person this morning.

I wanted to say a word if I might about key concerns of my own based on the testimony. Dr. Fares, I was very interested in the discussion about the 1890s land-grants and the HBCUs. And all I am saying as we move toward a new farm bill, I hope we can find greater connectivity between them and between our urban food deserts and our urban school systems. I think we have to go back to raising and teaching young people what good food is. I think that in many communities that are deprived—because all the agriculture technology was in the countryside, the city was given help to try to get food to people, but we need to move some of those

skills back into places that have been literally abandoned. So that is just a point of view.

Number two, I represent many, many companies that are involved in climate-controlled agriculture, big companies on both sides of the Great Lakes, which we share with Canada are companies like Nature Fresh, Mucci, and so forth. And because of the rising rainfall and the pounding of our fields by really flood-level conditions many times, our climate-controlled agriculture becomes more important to us. But one of the challenges is 40 percent of the bottom line is power. And in addition to that, the houses, as currently designed, emit CO_2, so we have a problem. And we have put in a decade of effort trying to get the Department of Agriculture and the Department of Energy to work together. Good luck if you can do it. But in effect, we need to perfect the growing chamber and make it affordable for business.

That is not happening right now even though I represent companies that have over 200 acres under cover. So Michigan and Ohio, Ontario, Canada, we're big producers and we can help to produce what California is unable to produce now. So I just wanted to mention that area of cooperation between the Department of Energy and the Department of Agriculture. And, Dr. Fares, I was interested in the convergence of those words, *energy* and *water* in your title as you testified this morning.

Finally, and this will be my last point, and a little bit of a question. For the Western Basin of Lake Erie we have witnesses from Purdue and also Dr. Vélez graduated from Ohio State University. I really think there needs to be an Indiana-Ohio connection for the Western Basin of Lake Erie. This is the largest watershed in the entire Great Lakes. And it is fragile, and it needs more attention. And field practices have been adapted, but we have so much phosphorus and nitrogen that is now going into our lake. The lake is sick. And Toledo's water system was turned off for 3 days a couple of years ago, and that was a very rude awakening for people in our area.

So my question is to anyone, where might I go to obtain a detailed map of the tiling of the Western Basin of Lake Erie, which is the most tiled area in the country, so that we can take a look at better control of rising water, as well as filtration of the nutrients that come off the fields with it?

Dr. BROUDER. Can you clarify, you were asking for where can you go to get the most up-to-date mapping of tile drains?

Ms. KAPTUR. Drainage tile underground. It is the most tiled in the country. I think we need a separate title in the farm bill to deal with Lake Erie's Western Basin because it is so sick.

Dr. BROUDER. Okay. Yes. I mean, I understand the issue. And I can't tell you off the top of my head, but I certainly have colleagues who can tell you where the updated maps for tiles are easily accessed.

Ms. KAPTUR. Well, then you would do better than the U.S. Department of Agriculture if you could help me with that.

Dr. HOULTON. If I could add a comment. So if you look at some research going on through the Great Lakes Restoration Initiative, you will find an ensemble of researchers, including Cornell and other land-grants, working together, and it is a great repository for

information on agricultural efficiencies, how to reduce phosphorus and nitrogen loading, and work in a collaborative model. So there is great, great information there.

Ms. KAPTUR. I just want to say also, we need to manage manure in a much better way and make it a product. I have seen a revolution here in Washington at the D.C. wastewater treatment plant. I just put that on the record. And it would be great if that could happen around the country if we could help those folks who raise beef cattle and dairy and so forth to be able to have more technologies to help them turn that manure into a marketable product. It is happening in some places but not everywhere. Thank you all very much. I think my time has expired.

The CHAIRMAN. Yes. And thank you, Ms. Kaptur, excellent points that you have made.

And now the gentleman from Florida, Mr. Lawson, is recognized for 5 minutes.

Mr. LAWSON. Thank you, Mr. Chairman and Ranking Member Thompson. This is a great group of witnesses testifying to the Committee today. It has been great listening to everyone.

Dr. Houlton, in your testimony, you mentioned that many farmers, particularly farmers of color, cannot afford to embrace climate-smart practices that create *measurable impact,* underline that measurable impact. Requiring an increased need for higher financial incentives to support farmers. To your knowledge, are there current programs that Congress can use to target resources to historically underserved farmers to better help them transition to net-zero agriculture? What additional support should Congress provide for these type programs?

Dr. HOULTON. Great, great question. So, the Climate-Smart Commodities Grant that is open for proposals is one that is encouraging the active participation of minority farmers, those that have lost land over time, to engage in climate-smart solutions so that they can be a part of the opportunity through which carbon can bring new forms of revenue to farmers. So that is one specific way that the USDA is beginning to engage in this incredible challenge.

Mr. LAWSON. Thank you. And, Dr. Fares, I see that you have done a lot of work at Prairie View A&M University. Would you like to comment on that area? Because I know particularly you probably interact with a lot of HBCUs under the same circumstances about what kind of incentives that can be given to encourage minority farmers and farmers of color to get involved in this climate change fight.

Dr. FARES. Thank you, Congressman, for this question. And I think I echo what my colleague just mentioned. We appreciate the initiative that USDA has been doing in the bill that you referred to on the funding where it is recommended to have limited-resources farmers involved in this type of solution. So that type of initiative, that type of requirement is key to help limited-resources farmers be in the forefront of the solution. So these type of decisions and policy are helpful to us to make sure that limited-resources farmers are part of this. And if we remember that 80 percent of the world population of farmers in the world are limited-resources farmers, small farmers, so I think any solution that is developed here in the states for limited-resources farmers have far

reach beyond the states. And the technology evolved here will also help businesses who develop this technology to be applicable outside and overseas. So it is a win-win situation for the limited-resources farmers and also for the industry to be competitive globalwide.

Mr. LAWSON. Okay, thank you. And, Dr. Fares, the unpredictable weather conditions and climate changes have emerged as a major concern for farmers and ranchers. To address these conditions, USDA created a Cooperative Extension System, CES, which operates through the land-grant university system and particularly with the Federal, state, and local government to translate climate resources and knowledge into action, practice, and product. Doctor, can you explain in more detail the impact a program like CES through growing partnerships with land-grant institutions to address these climate changes challenges?

Dr. FARES. It is for me, right?

Mr. LAWSON. Yes.

Dr. FARES. Okay. The cooperative agriculture experiment stations are doing a great job in connecting with farmers and helping them adopt research-based solutions. So supporting them and training them and giving them the tools that they need to reach these limited-resource farmers that they don't have the same needs, they don't have the same technology, and they don't have the same support that other farms do is very critical. So they need special attention because the circumstances of the population that you deal with have different circumstances than others. So special attention to limited resources through the extension program is key for this process. And we would like to echo that they need help in this regard to have the tools, to have the training, and to have the right information that they need to deliver to help limited resources.

Mr. LAWSON. Okay. Thank you very much. And I would just like to say my time has run out, but I have worked with the Chairman on HBCUs and getting the resources even with Congressman Adams and something that has been overlooked for many, many years, and now become very prevalent that we need to do a great deal more. With that, Mr. Chairman, I yield back.

The CHAIRMAN. All right, thank you all very much.

And now, I would like to recognize the gentlewoman from the Virgin Islands, Ms. Plaskett. You are now recognized for 5 minutes.

Ms. PLASKETT. Thank you very much, Mr. Chairman. And thank you to the witnesses and to my colleagues for what I think has been a very productive discussion.

I wanted to ask question to Dr. Vélez of the Organic Farming Research Foundation. Dr. Vélez, we know that agriculture looks different around the country with different crops and production practices. The U.S. Territories have unique ecological, cultural, and agricultural practices that are also on the front-lines of climate change. Can you speak about the importance of climate research in U.S. Territories, given the unique challenges these communities face?

Dr. VÉLEZ. Yes, and thank you for your question, Ms. Plaskett. I think, as some of you may know, I did research in Puerto Rico post-Hurricane Maria. And all of the Territories, the U.S. Virgin Is-

lands included, are just facing extreme climate-related disasters, hurricanes, changes with respect to drought, and flooding in some regions.

One of the bigger things that I have heard from the growers on the ground with respect to addressing climate resilience is to have solutions rooted in farmer-led work and so having researchers work closely with the farmers on the ground to breed specific crop cultivars that are adapted for those regions. It is also important to recognize that there is a reliance on imports, which is too risky when facing climate-related disasters. Land access is something that is an issue. We need to increase domestic production within those Territories to address that. And there is extensive evidence showing that organic practices, which do align with a lot of the agroecology, the science of agroecology can help growers respond to climate change in various ways, whether that means rebounding quickly from a hurricane and being able to use specific commodities that are resilient, whether that is cassava or plantains, things that will produce very quickly, but then they do also help adapt to drought. And so I think making sure that climate research is specific to the U.S. Territories, building that out, that is something that I think the southern SARE region can do more of and trying to make sure that there is more capacity building for the folks on those island nations.

Ms. PLASKETT. Thank you. Since the Tropical-Subtropical Agricultural Research Program, TSTAR, expired in 2011, it has been difficult for tropical specialty crops to compete for research funding *vis-à-vis* other crops. Can you speak to the importance of tropical-subtropical agricultural research and its benefits to agriculture in the Caribbean region?

Dr. VÉLEZ. Yes, I think that having specific crops we know for each region we hear those organic growers and conventional growers have been saying that they need specific cultivars bred for their regions. We cannot use crop cultivars of tomatoes, for example, or something else that is bred for Ohio or California where much of the breeding happens, or Maine, for example. We cannot use those varieties within the subtropical and tropical regions. We do need more research investment in developing breeds and crops for those regions. And I think having more research funding going to these areas is critical, and it is something that we internally at OFRF have been exploring how can we better get more resources out to the U.S. Virgin Islands and Puerto Rico as well.

Ms. PLASKETT. Thank you.

And to, Dr. Fares, Dr. Ali Fares, thank you so much for the information you have provided thus far to the Committee. I wanted to ask you about the idea that studies have shown that climate change disproportionately impacts underserved and under-resourced communities who are least able to prepare for and recover from climate-related disasters. As the Virgin Islands Representative to Congress, and indeed speaking on behalf of so many communities like them, I am acutely aware of the unique challenges our Islands face, including more severe weather patterns, long-term prospect of rising sea levels, as well as ecosystem changes. What additional research and engagement needs to be done to help address socioeconomic issues related to climate change

adaption and mitigation and to assure equity and environmental justice, sir?

Dr. FARES. Thank you. And I appreciate the question. I appreciate the question, especially about TSTAR. I was in Hawaii for 11 years, and it was beneficial of that program. And I understand the problems of small islands' issues. So they have different issues, especially when it comes to size of farm. They only have very limited size of farm that can only and usually these farms are prone to flooding, prone to other diseases that are not exist. So having site-specific research being conducted on those topics, under those conditions of limited resources is very, very helpful. Also providing them with additional fundings that being able to find solution for their problems is another important issue. Also dealing with the issue of flooding and other resources as it related to many of them are in urban areas. Look at Houston, for instance. You have a large population of underserved, limited resources in urban areas where they have specific needs different from those in rural or other conditions. So these are some of the issues that are being faced by limited resources and minorities in urban areas. I think, yes, I would like to—these are some of my thoughts about this topic.

The CHAIRMAN. Thank you.

Ms. PLASKETT. Thank you so much, and thank you. I yield back.

The CHAIRMAN. Yes, thank you, Ms. Plaskett.

And now, ladies and gentlemen, it comes to the end of our hearing. And I just want to thank you. I want to thank each of you. This has been a very informative and helpful hearing. We are determined that we are on the right track of being able to answer the challenges that this climate is providing. It is obvious. It has an impact on everything, all the way down to the cost of our food. If we can't produce it, just look at the damage that it does.

We have to understand that there is no industry that is impacted by climate change more than agriculture. We produce our food from the climate, from the sunshine, from the natural healthy oxygen supply that is provided. When we look across our nation and see our ranches and farms burning up on the West Coast and in the mountains, we see them. And so it is so important that we understand the significance when I say, when this Committee says that agriculture is the most important industry that we have, because it is the food we eat, and it is the clothes we wear, it is our shelter, and beginning more and more, our alternative fuel sources. All this is our survival. And the greatest threat to it is our failure to address climate change.

And it is urgent that we overcome this challenge by supporting you, our researchers, our developers, our land-grant institutions, and the United States Department of Agriculture's research efforts. This is a team, and we have to work together. And we got to do it across party lines. And as you can see, I am working hard to pull this together.

And one of the demonstrations that you will see is tomorrow, when we put on the floor a bill that expresses our nation's two number one concerns, and that is the rising cost of food, which this bill will bring down, and the rising cost of gas and fuels, that this bill tomorrow will bring down.

And so I just want to thank you for that. I am very proud of this hearing. And I want to thank each of our witnesses.

First, let me thank Dr. Thelma Vélez, who is the Research and Education Program Manager with the Organic Farming Research Foundation from Sunrise, Florida. Thank you very much.

And to you, Dr. Sylvie Brouder, Professor and Wickersham Chair of Excellence in Agriculture Research at Purdue University on behalf of the American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America. Boy, that title speaks volumes for exactly why we are here.

And to you, Dr. Ali Fares, Endowed Professor of Water Security and Water Energy Food Nexus at the distinguished 1890s Institution Prairie View A&M University in Prairie View, Texas.

And to you, Dr. Benjamin Houlton, Ronald P. Lynch Dean and Professor of Ecology and Global Development at the distinguished Cornell University in Ithaca, New York.

And to you, Mr. Michael Vance, thank you, Managing Partner of Southern Reds, LLC of Gainesville, Texas. Thank you all so much. Let's give our panelists a hand, won't you? Didn't they do a remarkable job? Thank you so much.

And now, I wouldn't have been able to put this together, we couldn't have done this without our hardworking staff. They did a wonderful job. So I want to thank our Staff Director, Ms. Anne Simmons. She is wonderful. Our Deputy Staff Director Ms. Ashley Smith, she is great. And Ms. Malikha Daniels, Mr. Michael Stein, Mr. Paul Babbitt, Ms. Emily Pliscott, and Mr. Ellis Collier, give them a hand, won't you? They put it together.

And now under the Rules of the Committee and the record of today's hearing—oh, I did not want to forget my Chief of Staff. Give her a hand, too, Catherine Kuerbitz. Raise your hand, Catherine. She works hard, too.

And so under the Rules of the Committee, the record of today's hearing will remain open for 10 calendar days to receive additional material and supplementary written responses from the witnesses to any questions posed by a Member.

And now, ladies and gentlemen, this hearing of the Committee on Agriculture is now adjourned. Thank you, and God bless you.

[Whereupon, at 1:10 p.m., the Committee was adjourned.]

[Material submitted for inclusion in the record follows:]

SUBMITTED ARTICLE BY HON. JIM COSTA, A REPRESENTATIVE IN CONGRESS FROM CALIFORNIA

COMMENT

Dairy farmers are working to address climate issues

By John Talbot

Each year we use the month of June to recognize our dairy farm families and the delicious, nutritious foods they help bring to the table. On the heels of Earth Day, we are leaning into the topic of dairy sustainability for this year's Dairy Month celebration to showcase California dairy's commitment to slowing climate impacts.

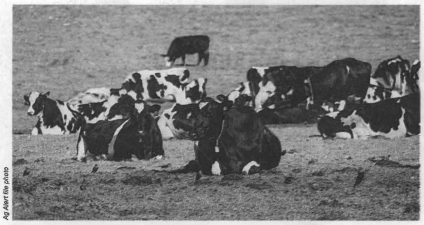
John Talbot

Our state remains one of only two major global regions to establish a statutory mandate to reduce methane from the dairy sector and is on track to meet its ambitious target of a 40% reduction in manure methane by 2030.

California dairy farm families have a long commitment to providing products that keep the state's finite resources and environmental balance in mind. For example, the amount of water used per gallon of milk produced has decreased by more than 88% over a 50-year period, due to improved feed crop production, water use efficiency and the use of byproducts as feed ingredients.

Dairy is the leading agricultural product in California, making it crucial to the well-being of the fifth-largest economy in the world. However, California's dairy sector, which includes 1.7 million dairy cows, accounts for only 4% of the state's total greenhouse gas emissions.

That's due to California dairy farmers' continued strides in reducing methane emissions through investment and innovation. According to a 2020 study published in the Journal of Dairy Science, greenhouse gas emissions per gallon of milk produced in California have decreased by more than 45% over the past 50 years.



Ag Alert file photo

The California Milk Advisory Board reports that state dairy farmers are embracing sustainable practices, reducing methane gas emissions, conserving water and protecting the health of their cows.

The use of anaerobic digesters, which turn manure methane into renewable electricity, renewable natural gas or hydrogen fuel, are driving much of this progress. California has roughly 206 digester projects capturing methane from 217 dairy farms, with 89 digesters currently in operation and the rest in various stages of development.

Over the next 25 years, collective dairy methane reduction projects across California, including digesters and alternative manure management projects, are estimated to reduce more than 55 million metric tons of greenhouse gases. That's an annual emissions reduction equal to taking more than half a million cars off the road.

At Calgren Dairy Fuels in Pixley, biogas from cow manure collected at 16 Tulare County dairies is converted to renewable compressed natural gas, or CNG, and introduced directly into the Southern California Gas Co., which serves 21.7 million customers.

Phase one of this dairy digester pipeline cluster is capturing 150,000-plus tons of carbon dioxide equivalent greenhouse gases and displacing more than 3 million gallons of fossil fuel-based transportation fuel annually. The CNG is made available as a near-zero emissions fuel for heavy-duty trucks, replacing existing fossil-diesel.

Another step is innovation to reduce methane emissions from the source. Researchers at the University of California, Davis, are conducting studies to help dairy farmers adjust their cows' diets. For example, diets that include alfalfa, flax and other plants high in omega-3s such as seaweed have shown to reduce enteric methane from cattle digestion.

Cattle have a unique digestive system that enables them to unlock nutrients from plants in a way we cannot. This means dairy cows can upcycle byproducts of food and fiber production that are inedible for humans, minimizing waste and reducing emissions from landfills. These byproducts, including almond hulls and citrus pulp, account for upward of 40% of a California dairy cow's diet in the state.

Dairy farms are also focused on water-smart management practices. Water recycling is commonplace on California dairies, with the same drop of water used four to five times.

Clean water cools milk tanks and is then used to water and wash the cows. The same water heads to a holding pond for storage, where it is used multiple times to flush manure out of barns, becoming rich with plant nutrients such as nitrogen. It is then blended with irrigation water to "fertigate" crops in the fields.

Dairy farmers experimenting with drip irrigation to grow feed crops are using 47% less water while increasing crop yields. Regenerative agriculture practices such as crop rotation and no-till farming are also critical.

Farmers depend on cows for their livelihood. To produce high-quality milk, dairy cows must be healthy and cared for, which is why farmers focus on a nutritious diet, appropriate veterinary care and healthy living conditions. In turn, cows produce one of the healthiest and most sustainable products on the market.

Because 99% of the dairy farms in California are family-owned, many of these sustainability practices have been passed down from generation to generation and improved upon over time.

The time-tested, future-forward approach of the Golden State's dairy industry is focused on continued success on its journey toward climate neutrality and—ultimately—net zero emissions.

(John Talbot is the CEO of the California Milk Advisory Board. He may be contacted through communications@cmab.net.)

The Weekly Newspaper for California Agriculture
AgAlert
California Farm Bureau
VOL. 49, NO. 21
June 1, 2022
AG ALERT® weekly newspaper is an official publication of the CALIFORNIA FARM BUREAU
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SUPPLEMENTARY MATERIAL SUBMITTED BY SYLVIE M. BROUDER, PH.D., PROFESSOR OF AGRONOMY, WICKERSHAM CHAIR OF EXCELLENCE IN AGRICULTURAL RESEARCH, DEPARTMENT OF AGRONOMY: CROPS, SOILS, AND ENVIRONMENTAL SCIENCES, PURDUE UNIVERSITY; PAST PRESIDENT, AMERICAN SOCIETY OF AGRONOMY; ON BEHALF OF CROP SCIENCE SOCIETY OF AMERICA; SOIL SCIENCE SOCIETY OF AMERICA

Insert 1

Mr. AUSTIN SCOTT of Georgia. Okay. And have you provided any recommendations to the EPA?

Dr. BROUDER. We have provided review of—I am, again, just reappointed, so there was an ongoing group of people. But we just provided information on the redefinition of *Waters of the United States,* as well as their strategy for environmental justice that would be in their risk assessment programs, in their environmental risk assessment programs.

Mr. AUSTIN SCOTT of Georgia. Would you provide that to the Committee? I would like to see what your committee provided to the EPA.

The SAB reports providing advice to EPA including this report on the *Waters of the United States* are available for downloading from the EPA SAB website (SAB Public (*epa.gov*). This particular report (EPA–SAB–22–005) is available via the "Re-

cent Reports" link off the homepage: *https://sab.epa.gov/ords/sab/f?p=114:12:12204432494965.** †

As a matter of procedure, as reports are drafted, they are discussed in open meetings of the SAB, notifications for which are posted in advance on the SAB webpage along with draft materials and instructions for how the general public can participate.

Insert 2

Mr. DAVIS. I actually passed a provision in the 2014 Farm Bill to allow someone from production agriculture to have a seat on the EPA Science Advisory Board. Has that provision been implemented? Do you have somebody——

* * * * *

Mr. DAVIS. Is that next person somebody also associated with academia though?

Dr. BROUDER. I would have to check for you.

Mr. DAVIS. I would appreciate that.

As this question pertains to provision implementation, the question of how it was implemented is beyond my purview as an SAB member. I encourage you to contact one or both of the following individuals to gain a better understanding of how agricultures' interests are represented in EPA activities:

THOMAS ARMITAGE, PH.D., *Designated Federal Officer,* EPA Science Advisory Board Office, 202–564–2155, (**Redacted**).

VENUS WELCH-WHITE, *Designated Federal Officer,* Farm, Ranch, and Rural Communities Advisory Committee (FRRCC), U.S. EPA, 1200 Pennsylvania Avenue NW, Mail Code 1101A, Washington, D.C. 20460, 202–564–7719, (**Redacted**).

Insert 3

Mr. THOMPSON. Very good, and this for all, and I probably don't have time for response, but I am going to tee up my question. And if we don't get a chance for a response, I would love to hear from each of our witnesses. The Biden Administration, and inside the beltway think-tanks, have been pushing a climate agenda that creates new programs and added what I see commonly unnecessary bureaucracy. However, when producers, when you talk with those folks that are farmers, ranchers, and foresters talk about climate solutions, they mention the importance of research, boots-on-the-ground support, access to precision agriculture, and the need for broadband technology. It kind of goes hand-in-hand with precision agriculture. To me this all sounds like assistance available within the farm bill programs. And for all the witnesses, is the solution as simple as doubling down on these proven programs? And what research is being done to further technologies and practices that we know are already working? And I apologize, I probably have just about 40 seconds for a response from anyone who would like to take that, and then anyone else, I would love to hear in writing.

In terms of the "translational research" that specifically targets furthering already proven technologies, there is a critical need for investment in "synthesis" science. Common barriers to moving a technology off the shelf and onto a large number of farms include inconsistent messaging from scientists regarding how well a practice works and consequent distrust in science. Often the source of this messaging/trust problem can be traced to very real differences in the results achieved by an array of small studies conducted across regions with highly variable farming conditions, which can generate strongly held beliefs regarding practice incompatibility with operations on an individual's farm. Not all technologies work equally well everywhere and recommendations for technologies need to be nuanced for the array of different contexts in which they may be deployed. Synthesis science entails rigorously organizing and statistically synthesizing all the existing studies that have been done for a particular management technology (1) to characterize how well it works as a function of common attributes or features of agricultural systems, and (2) to identify key knowledge gaps for additional research. Such meta-analyses are seminal to understanding where and why a particular practice does and doesn't work, to providing the foundation for recommendations on technology use that is transparent to the supporting science, and to promoting public trust in the science.

As mentioned in my original testimony, this synthesis step has been routinized in medicine for tailoring research results for optimal use in a clinical setting; the

* **Editor's note:** entries annotated with † are retained in Committee file.

Cochrane Collaborative serves as a trusted resource for clinical doctors and patients alike seeking information to personalize options for medical interventions.[1] However, although a few meta-analyses of studies documenting the effectiveness of new technologies are now being undertaken, agriculture has yet to prioritize this synthesis step. Furthermore, the costs of good syntheses are akin to those of conducting a new experimental study and resources to facilitate this step are sparse. Competitive grant programs specifically targeting synthesis science *versus* new field or laboratory research could greatly accelerate the movement of science to practice. However, ongoing support is and will be needed to develop and maintain the supporting data infrastructure and user interfaces required for continuous recommendation updating as new studies are completed and for equitable and inclusive access by the public. To facilitate technology transfer and translational research, my original testimony also highlighted the need for new curricula that encompasses both data and synthesis sciences; this curricular reorientation could also serve to attract a more diversified workforce to agriculture.

In regards to doubling down on original 2018 Farm Bill programs with respect to the resources they supply to incentivize and facilitate practice adoption (*e.g.,* the Environmental Quality Incentives Program, EQIP, *etc.*), I am aware of a fair amount of recent survey work that explores why farmers **do not** adopt practices that will improve their resilience to climate change despite these existing programs. In addition to perceptions of risk and uncertainty regarding which practices are most important to implement and where (discussed above), barriers include the high prevalence of rented farmland (currently 54% of U.S. cropland is rented on short-term contracts),[2] and complex and burdensome application and reporting requirements including ones that may constrain future decision making.[3] Studies dating back more than a decade suggest many also consider available payments to be insufficient. In our 2021 survey of our membership (scientists and practicing professionals), economics, policies, and/or regulations were all identified as major barriers to adopting strategies for protecting the soil, improving water and nutrient management, and diversifying cropping systems.[4]

Last, insufficient funding for Extension programs has greatly hampered timely delivery of science-based resources for climate-smart agriculture. To alleviate confusion and mistrust regarding emerging programs like carbon markets, there is a critical need for wholistic, unified, nationally coordinated programming that meets the needs of all farmers and ranchers irrespective of the size and scale of their enterprise. At present, climate-smart outreach efforts are not only constrained by a lack of human resources but also by a pervasive lack of connectivity among existing programs and resources. Indeed, I suspect the sparsity of resources is likely exacerbating siloing within outreach entities rather than fostering collaborations as entities compete for resources to sustain themselves.

USDA's NIFA Agriculture and Food Research Initiative has one Program Area Priority targeting Extension, Education and Climate Hubs Partnership. Proposals are due in October and there is an opportunity to fund *one* national scale Coordinated Agricultural Project Grant for Climate Smart Extension at a 5 yr. funding level of $10M.[5] The stated goal is "to build and enhance existing climate Extension networks, while identifying synergies among existing programs, and catalyzing new resources and tools that provide accessible, usable, and actionable science, . . ." However, while the goal is laudable, the funds allocated are completely insufficient to build a national-level program from where we currently stand. The short duration nature of the funds also do not bode well for lasting success. We need deliberate and sustained resources for a unified agenda that builds bridges among outreach

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[1] For more information on The Cochrane see *https://www.cochrane.org/*.

[2] For a rented acres of cropland see *https://www.ers.usda.gov/topics/farm-economy/land-use-land-value-tenure/farmland-ownership-and-tenure/*.†

[3] The following are two academic publications summarizing survey work to identify barriers to adoption: Ranjan, P., Church, S.P., Floress, K., & Prokopy, L.S. (2019). *Synthesizing conservation motivations and barriers: what have we learned from qualitative studies of farmers' behaviors in the United States?*.† SOCIETY & NATURAL RESOURCES, 32(11), 1171–1199 and Ranjan, P., Wardropper, C.B., Eanes, F.R., Reddy, S.M., Harden, S.C., Masuda, Y.J., & Prokopy, L.S. (2019). *Understanding barriers and opportunities for adoption of conservation practices on rented farmland in the U.S.* LAND USE POLICY, 80, 214–223.

If you would like more and updated information on barriers, I highly recommend contacting co-author Linda Prokopy (**Redacted**)

[4] A one page summary of our member survey on strategies for climate change mitigation and adaptation can be found here: *https://www.agronomy.org/files/science-policy/letters/climate-change-survey-one-pager.pdf*.†

[5] See pages 93–97 of the *Request for Applications, Agriculture and Food Research Initiative Competitive Grants Program, Foundational and Applied Sciences*† available here: *https://www.nifa.usda.gov/sites/default/files/2022-05/FY22-AFRI-FAS-RFA-MOD1-508.pdf*.

entities including among Climate Hubs, the Extension entities of Land Grants and minority serving institutions, and the Natural Resource Conservation Service.

Collectively, the farmer survey work and our membership survey suggest that "doubling down" on existing programs may offer some benefits provided the doubling down includes the following:

(1) Increasing the amount of incentive payments at least for initial years when farmers may experience the strongest urge to dis-adopt a practice with which they lack familiarity;

(2) Increasing technical service resources to increase capacity and unify the messaging across evidence-based technical service providers including Land-Grant Extension, the Natural Resource Conservation Service, and independent certified crop advisors;

(3) Specifically target resources to the unique needs of non-operating landowners such that they are empowered to participate in the decisions regarding practices that are implemented on their own lands, and

(4) Explicitly supporting synthesis science either by creating dedicated funding opportunities to ensure that research is synthesized for practice at scale or by embedding this objective in competitive funding opportunities for Extension and outreach.

Certainly, care should be taken to resources don't get wasted to support building new infrastructure where infrastructure already exists. For example, where entities already have a broad geographic footprint and local trust (*e.g.,* the county level Extension Offices) resources should go to updating and modernizing capacity and broadening the reach to underserved populations *versus* creating entirely new entities to fill voids.

SUPPLEMENTARY MATERIAL SUBMITTED BY ALI FARES, PH.D., ENDOWED PROFESSOR OF WATER SECURITY AND WATER ENERGY FOOD NEXUS, COLLEGE OF AGRICULTURE AND HUMAN SCIENCES, PRAIRIE VIEW A&M UNIVERSITY

> Mr. THOMPSON. Very good, and this for all, and I probably don't have time for response, but I am going to tee up my question. And if we don't get a chance for a response, I would love to hear from each of our witnesses. The Biden Administration, and inside the beltway think-tanks, have been pushing a climate agenda that creates new programs and added what I see commonly unnecessary bureaucracy. However, when producers, when you talk with those folks that are farmers, ranchers, and foresters talk about climate solutions, they mention the importance of research, boots-on-the-ground support, access to precision agriculture, and the need for broadband technology. It kind of goes hand-in-hand with precision agriculture. To me this all sounds like assistance available within the farm bill programs. And for all the witnesses, is the solution as simple as doubling down on these proven programs? And what research is being done to further technologies and practices that we know are already working? And I apologize, I probably have just about 40 seconds for a response from anyone who would like to take that, and then anyone else, I would love to hear in writing.

Farmers are faced with several challenges in their effort to meet the ever-increasing demands for food and renewable energy, despite dwindling water resources and multiple biotic (pests) and abiotic (extreme temperatures, droughts, and floods) stressors. The USDA predicts that variable precipitation and rising temperatures will harm crop production and quality. Also, it forecasts a surge in weeds, diseases, and extreme weather events driven by climate change that will further hinder crop growth and yields. Animal production will also be negatively impacted by making them vulnerable to diseases and water stress due to higher temperatures.

Farmers have an opportunity to adopt climate-smart practices that mitigate and adapt the negative impacts of climate change. Reducing NO_2 and CH_4 emissions while sequestering CO_2 through climate-smart farming will mitigate the leading greenhouse gases effect. Soil is the largest terrestrial C pool; it can hold about 2,500 gigatons of C, three times the amount of C in the air and four times the amount of C in living matter. Estimates suggest that U.S. cropland soils are only sequestering less than 10% of their potential. Adopting more resilient cropping systems will lessen the effect of climatic change-induced damages. Protecting and maintaining soil health is vital to reducing soil carbon sequestration and NO_2 and CH_4 emissions.

A 2019 National Academy of Sciences report estimated that increased conventional cropland and grassland management practices could potentially remove .25 Gt/y CO_2 Equivalents in the U.S. and that frontier technologies like high C crop phenotypes and C burial could reduce emissions by .8 Gt/y CO_2 Eq. in the U.S. and 8 Gt/y CO_2 Eq. globally.

Cover crops, permanent land cover (no or minimum tillage), alternative and perennial crop rotations, and optimum water and nutrient management are essential management practices to ensure healthy soils. Regarding animal production, optimum grazing, modifying animal feeding programs by including oils and concentrates, and improving manure management using anaerobic digesters are proven to reduce greenhouse gases (GHG) emissions. Vegetated and riparian buffers are proven to minimize GHG emissions and improve water quality. Accelerated adoption of precision agriculture and the use of renewable energy sources can revolutionize American agriculture.

The 2018 Farm Bill supported adopting these practices to mitigate and adapt to climate change. However, the impacts of these practices on climate change have been treated as non-essential goals instead of main goals to ensure the most effective practices are being endorsed and continued.

These are some of the recommendations for your consideration:

- Given the importance of U.S. farming, there is a **need to support more farm-based research to adapt and mitigate climate change** through climate-smart and precision farming practices.
- Research is needed to **develop more accurate methods of measuring, reporting, and verifying GHG emissions and sequestration** on U.S. farmlands across various soils, weather regimes, and cropping systems. Without this research, **farmers will continue to receive low payments** for adopting practices that mitigate GHG emissions and sequester C.
- Research is needed to accelerate the adoption of climate-smart and precision farming practices that mitigate GHG emissions and increase C sequestration. **Better decision support tools are needed to assist farmers in identifying where and when these practices** are practical and **what tradeoffs exist with these practices relating to sequestration of carbon, mitigation of GHG emission, and crop yield or quality.** In other words, where and when is it possible to adopt these practices to increase the sequestration of carbon in the soil, decrease the emission of GHG, and increase the production of food, feed, fuel, or fiber?
- A better understanding of soil health impacts is needed to implement the practices effectively on all land and soil types and make a strong case for scaling up adoption.
- Supporting innovation in soil health is needed by exploring alternative, non-conventional practices to understand better farmers' ability to capture and store GHG emissions.
- NRCS should pursue longer-term monitoring to understand and practice permanent soil carbon sequestration potential.
- There is a need for a comprehensive understanding and quantification of how soil parameters, *e.g.,* aeration, microbes, soil properties, and plant residue affect GHG mitigation and sequestration from the soil surface to the bottom of the soil profile.
- **Fundamental knowledge of soils and their dynamic evolution** with external factors, including cultural practices, cropping system, and temperature rise, among others, is needed. Such dynamic knowledge is essential to better manage soils for the complex and interaction challenge of water, food, and climate securities
- Water and food security are closely interconnected as most fresh water supply goes to the food system. A better understanding of climate and its role in this nexus is critical to **the future of water and food security.**
- Design of policies through rigorous **cost-benefit analysis** to incentivize climate-smart agriculture.

SUPPLEMENTARY MATERIAL SUBMITTED BY BENJAMIN Z. HOULTON, PH.D., RONALD P. LYNCH DEAN, PROFESSOR, ECOLOGY AND EVOLUTIONARY BIOLOGY, PROFESSOR, DEPARTMENT OF GLOBAL DEVELOPMENT, COLLEGE OF AGRICULTURE AND LIFE SCIENCES, CORNELL UNIVERSITY

Mr. THOMPSON. Very good, and this for all, and I probably don't have time for response, but I am going to tee up my question. And if we don't get a chance for a response, I would love to hear from each of our witnesses. The Biden Administration, and inside the beltway think-tanks, have been pushing a climate agenda that creates new programs and added what I see commonly unnecessary bureaucracy. However, when producers, when you talk with those folks that are farmers, ranchers, and foresters talk about climate solutions, they mention the importance of research, boots-on-the-ground support, access to precision agriculture, and the need for broadband technology. It kind of goes hand-in-hand with precision agriculture. To me this all sounds like assistance available within the farm bill programs. And for all the witnesses, is the solution as simple as doubling down on these proven programs? And what research is being done to further technologies and practices that we know are already working? And I apologize, I probably have just about 40 seconds for a response from anyone who would like to take that, and then anyone else, I would love to hear in writing.

Congressman Thompson:

Thank you for this important and vital question. Agricultural research will be the critical key to providing farmers with proven ways to reduce greenhouse gas emissions while also sustainably intensifying food production for the United States and the world. In the last farm bill, spending on agricultural research and development represented approximately 2% of the total appropriations. The United States has fallen significantly behind on its investment in agricultural research, with a budget that has remained relatively stagnant since the 1970s. A recent USDA ERS report determined that the United States is, in fact, behind both China and Brazil in its investments in public agricultural public research. It is vitally important that the next farm bill significantly ramp up the investment in agricultural research. Speaking as, a climate scientist, I recommend creating a new agricultural research program that focuses specifically on climate adaptation and mitigation with an eye toward developing tools to help farmers manage emerging risks while mitigating greenhouse gas emissions. For example, adaptation research can help dairy farmers address climate-related problems like the enhanced heat stress on dairy cows that causes losses in milk production. Similarly, it can help growers cope with changing climate and weather patterns through the development and improvement of drought resistant crops. Mitigation research to develop and improve precision agriculture strategies and tools, for example, can help farmers decrease emissions of short-lived climate pollutants, like methane and nitrous oxide.

If the U.S. is serious about improving the ability of the agricultural sector to address climate change, the Committee must make it a priority over the long-term to reinvest in the research and infrastructure capacity of Land-Grant Universities. For example, climate models all predict that current extremes in weather will only increase, adding demand for development of publicly-available plant varieties that can withstand greater extremes in temperature and moisture conditions. As you point out, we already compensate farmers for adopting conservation practices. It will take research to build on existing programs and develop science-based mechanisms that allow—and pay—farmers to draw carbon from the atmosphere and sequester it in the soil. Another example from my home state: New York is a major dairy producer, with an ambitious goal to develop net-zero dairies. To succeed, it will be critically important for Cornell to find new ways to help dairy farmers reduce methane emissions—perhaps through development of appropriate feed additives—caused by the natural processes of animal digestion, as well as to develop improved and innovative systems of manure management.

USDA programs, as well as market-based incentives, will be critical to help farmers implement and pay for science-based climate solutions. Until a market develops for climate-forward food, farmers will need cost-share and technical assistance to implement environmental solutions. Hence, the farm bill and agricultural appropriations process will be singularly important in the next few years. Existing conservation programs like EQIP will be critical to ensure sustained food production in a changing climate. At the same time, it is important to ensure that these programs are flexible and responsive enough to provide appropriate incentives for farmers to adopt practices that are science based, verifiable, and have durable climate benefits. You will have to determine whether that requires the Committee to create addi-

tional incentive programs, like the USDA's recent climate-smart commodities partnership grants, or simply to give the USDA more flexibility to change the incentives for farmers as research leads to more innovative technology in the future. Giving USDA the ability—along with the resources—to change and innovate in voluntary cost-share and incentive programs to include the latest science-based strategies would be wise in my view.

SUPPLEMENTARY MATERIAL SUBMITTED BY MICHAEL S. VANCE, MANAGING PARTNER, SOUTHERN REDS, LLC; ON BEHALF OF NOBLE RESEARCH INSTITUTE, LLC

> Mr. THOMPSON. Very good, and this for all, and I probably don't have time for response, but I am going to tee up my question. And if we don't get a chance for a response, I would love to hear from each of our witnesses. The Biden Administration, and inside the beltway think-tanks, have been pushing a climate agenda that creates new programs and added what I see commonly unnecessary bureaucracy. However, when producers, when you talk with those folks that are farmers, ranchers, and foresters talk about climate solutions, they mention the importance of research, boots-on-the-ground support, access to precision agriculture, and the need for broadband technology. It kind of goes hand-in-hand with precision agriculture. To me this all sounds like assistance available within the farm bill programs. And for all the witnesses, is the solution as simple as doubling down on these proven programs? And what research is being done to further technologies and practices that we know are already working? And I apologize, I probably have just about 40 seconds for a response from anyone who would like to take that, and then anyone else, I would love to hear in writing.

Chairman Scott, Ranking Member Thompson, and distinguished Members of the Committee, thank you for this opportunity to provide a formal reply to Ranking Member Thompson's questions cited above.

To build resiliency in American agriculture, doubling down on existing programs in the farm bill is not the solution.

As noted in my written testimony, programs that continue to fund classic agricultural research portfolios are not successfully supporting agricultural resiliency. Because these programs focus on reductionary studies that attempt to isolate one issue within a complex, everchanging environmental ecosystem, they rarely result in practical applications. Moreover, very few programs (including technical assistance programs) in the current farm bill promote the six principles of soil health—a proven tool in building resiliency in the soil and agricultural operations.

Research programs must be reimagined and redesigned to study agricultural management at the whole-ranch or landscape scale, not only assessing alternative management actions but also evaluating ways in which these actions and biophysical processes interact and evolve over time.

Programs must be interdisciplinary, interpretative, as well as analytical and must be performed in partnership with agricultural producers to achieve new knowledge about productive and regenerative agriculture. This research will drive future education and guide the boots-on-the-ground (or technical assistance) that benefits the nation's farmers and ranchers. These outcomes—the application of research knowledge—will advance agricultural resiliency.

Why is change needed? Classic academic research programs define success based on a faculty member's number of grants received or number of manuscripts written. Industry-based research programs define success based on the direct economic returns to the company funding the research. Consequently, very few organizations are focused on landscape-scale research that enhances soil health, leading to increased productivity and resiliency, ultimately leading to increased profitability for the producer.

To my knowledge, Noble Research Institute, a small number of like-minded collaborators, and a handful of innovative land-grant professors are leading the charge in conducting research to scientifically demonstrate that intentional management practices based on all six soil health principles at a landscape-scale can lead to agricultural resiliency and increased producer profitability.

Just as we need innovation to address and feed a changing world, we need to step outside the shadow of the past and seek innovation in the design of this farm bill and future USDA programs. We need to promote a soil-based research agenda to build resiliency not only in the land but the operations and economics of American farmers and ranchers.

Thank you again for the opportunity to respond to this question.

SUBMITTED LETTER BY LOTANNA OBODOZIE, CLIMATE CAMPAIGN DIRECTOR, NATIONAL YOUNG FARMERS COALITION

Date: June 24, 2022

Hon. DAVID SCOTT,
Chairman,
House Committee on Agriculture,
Washington, D.C.;

Hon. *Glenn Thompson,*
Ranking Minority Member,
House Committee on Agriculture,
Washington, D.C.

Re: In Regards to *The Role of Climate Research in Supporting Agricultural Resiliency* hearing before the U.S. House of Representatives

The National Young Farmers Coalition (Young Farmers) thanks the U.S. House of Representatives for holding this hearing on the important role of climate research in supporting agricultural resiliency. As farmers are on the front-lines of the climate crisis, climate research is a critical tool for farmers to discover and test best practices and build on-farm resiliency. We thank the Honorable David Scott and Glenn 'GT' Thompson for holding this hearing to discuss the impact of and opportunities for climate research in the agricultural sector.

The National Young Farmers Coalition works closely with young farmers across the country to assist them in building resilience to climate change through training, building nation-wide farmer networks, and advocating for policy change at the state and Federal levels of government. Our campaigns focus on key issues, identified by our members, to address the major obstacles young farmers face. In a 2017 national survey of our coalition, 66% of respondents reported experiencing unpredictable weather, and 53% attributed those changes to climate change.[1]* Furthermore, in a 2020 survey of policy issues, our members across the country identified addressing climate change as their number one priority.[2] Young farmers, particularly Black, Indigenous and other people of color (BIPOC) farmers, are on the front-lines of experiencing and responding to this crisis. Our farmers have experienced increased pest pressure, droughts and floods, and rates of plant and animal disease, with seemingly no end in sight. Young farmers have lost crops and livestock and have dealt with sustained damage to their farms due to extreme weather events, causing them to suffer severe economic losses. Some farmers have even shut down their operations due to droughts and unsafe conditions from uncontrolled wildfires. However, farming is a huge opportunity for mitigating the harmful effects of climate change. Farmers have the transformative power to sequester carbon on their farms by using climate-smart methods, including no- and reduced-till methods, managed grazing, and soil health practices.

At the National Young Farmers Coalition, we believe that climate action should be science-based and data-driven while prioritizing the experiences of Indigenous and traditional knowledge systems that have proven histories of placing agriculture in the right relationship with the environment. Quality public research is a crucial tool for farmers, and young and BIPOC farmers know the important role that research plays in managing and operating a farm. The Sustainable Agriculture Research and Education (SARE) program is the only farmer-led research program and a critical tool in helping farmers fight climate change. In addition to providing grant funding for farmers to lead research on sustainable agriculture, the program also supports peer-to-peer learning by sharing the research findings with other farmers across the country. Research from SARE helps small-scale, diversified farmers implement conservation practices and measure their climate mitigation impacts. The SARE program funds on-farm research into sustainable agricultural farming systems, including organic systems. Increased funding for SARE would put more money directly into the hands of farmers and allow them to create more and new innovative grant programs that are responsive to their needs and the issues they confront in the field daily. This is particularly important, as public investment in agriculture research is declining despite farmers facing increased challenges due to climate chaos.

USDA Climate Hubs are another important resource for farmers in fighting climate change. Climate Hubs, led by the Agricultural Research Service and the Forest Service, support applied research and development and work closely with extension

[1] Sophie Ackoff, Andrew Bahrenburg, and Lindsey Lusher Shute, *Building a Future with Farmers II,*† National Young Farmers Coalition, November 2017, *https://www.youngfarmers.org/wp-content/uploads/2019/03/NYFC-Report-2017_LoRes_Revised.pdf.*

* Footnotes annotated with † are retained in Committee file.

[2] National Young Farmers Coalition, "2021 Climate Policy Recommendations,"† May 2021, *https://www.youngfarmers.org/2021/05/2021-climate-recommendations/.*

providers to deliver research, tools, and information to farmers and other professionals. Climate hubs have the potential to make a significant impact in providing young and BIPOC farmers with up to date and accurate information, specific to the geographic region in which they are located. An increase in funding to Climate Hubs to support enhanced outreach will allow more farmers to engage with their work through extension providers and gain access to additional resources to support on-farm climate mitigation, adaptation, and resilience that is relevant to their region.

Young Farmers would like to thank the Honorable David Scott and Glenn 'GT' Thompson for convening this hearing to discuss the role of climate research in agricultural resilience. Sound research is critical for assisting farmers in the fight against climate change. We look forward to working with you to find ways to improve climate and agriculture research for young, beginning, and BIPOC farmers.

Sincerely,

LOTANNA OBODOZIE,
Climate Campaign Director,
National Young Farmers Coalition.

SUBMITTED LETTER BY EARTHJUSTICE

June 24, 2022

Hon. DAVID SCOTT,
Chairman,
House Committee on Agriculture,
Washington, D.C.

Thank you for the opportunity to testify on the role of climate research in supporting agricultural resiliency. We believe there is a unique opportunity in the 2023 Farm Bill to increase funding for research and development related to climate-friendly practices with the ultimate goals of advancing the adoption of these practices and improving agricultural resiliency while mitigating climate change. This testimony highlights some of our recommendations for areas on which to focus increased research and development (R&D) funding.

Over the last several decades, Federal funding for agricultural research has fallen sharply; at the same time, the need to address the carbon footprint of the agricultural sector and to shift to climate-friendly systems and practices has become essential. It is critically important that we increase our investment in publicly funded agriculture research to recover from decades of declining investments. According to a 2018 report from the United States Department of Agriculture (USDA) Economic Research Service, the Federal share of overall R&D spending as a percentage of gross domestic product is now at its lowest point since the 1950s, and food and agriculture lags even further behind most other Federal R&D areas.[1]* Between 2003 and 2011, public funding for agricultural research fell from $6 billion to $4.5 billion after adjusting for inflation.[2] Among total agricultural R&D investments by high-income countries, the U.S. share has decreased from 35 percent in 1960 to less than 25 percent by 2013.[3] Today, the United States is the only advanced economy where private-sector agricultural research funding exceeds that of the public-sector.[4] This funding lag in public R&D investment has long-term implications for America's food security, farmers' incomes, economic growth, and resilience of the agricultural sector which accounts for over ten percent of total U.S. employment.[5]

In addition to the need for increasing publicly funded agricultural research support in general, there is an urgent need to focus this research on building climate resiliency and reducing agriculture's climate footprint. Declining and inadequate

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[1] Heisey, Paul W., and Keith O. Fuglie. *Agricultural Research Investment and Policy Reform in High-Income Countries,*† ERR–249, U.S. Department of Agriculture, Economic Research Service, May 2018.

* Footnotes annotated with † are retained in Committee file.

[2] Matthew Clancy, *et al., U.S. Agricultural R&D in an Era of Falling Public Funding,*† AMBER WAVES, Nov. 10, 2016, at *https://www.ers.usda.gov/amber-waves/2016/november/us-agricultural-rd-in-an-era-of-falling-public-funding/*.

[3] *See supra* note 1.

[4] *See supra* note 2.

[5] See USDA, *Economic Research Service. 2021. Agriculture and its related industries provide 10.3 percent of U.S. employment.*† *https://www.ers.usda.gov/data-products/chart-gallery/gallery/chart-detail/?chartId=58282.*

public funding for agricultural research has hindered our capacity to transition to an agricultural system that mitigates climate change and adapts to changing resource threats. For example, less than 15 percent of USDA National Institute of Food and Agriculture (NIFA) funds include any element of agroecology.[6] Additionally, USDA-funded research grants consistently favor major commodity crops, which receive three to 4.5 times more funding and three to five times as many grants as the minor commodity crop groups that can help diversify our food system and build climate resiliency.[7]

Investments in climate research can and should bolster our food and agriculture research capacity, and in the process can enhance agricultural resilience. The next farm bill should ensure that existing and expanding publicly-funded research efforts focus on soil health, diversified cropping systems (including agroforestry and silvopasture, where ecologically appropriate), advanced grazing management, crop-livestock integration, organic agriculture, on-farm and food system energy efficiency, renewable energy production, manure management, high efficiency irrigation, feed efficiency and enteric methane emission reduction, farmland preservation and viability, and food waste reduction are all critical to reducing net greenhouse gas (GHG) emissions from agriculture.

Publicly funded research plays a unique role in solving the climate crisis. The private-sector generally invests in research leading to processes and products that can provide profits for investors, while the public-sector funds more foundational R&D that can reduce reliance on purchased inputs like fertilizer, promote ecosystem services, or result in innovations that cannot easily be commercialized. Private-sector agroecological research is not an effective or adequate substitute for publicly funded research. Declining and inadequate public funding for agricultural research has hindered our capacity to transition to an agricultural system that mitigates climate change and adapts to changing resource threats.

To reverse this trend and increase funding for R&D that is essential to addressing the climate crisis, we recommend the following:

- Rebuilding USDA's Research Education and Economics (REE)' science capacity and increasing support for publicly funded climate related food and agriculture research.

The next farm bill should dedicate funding to rebuild USDA's research capacity, in particular, to increase the staff of the REE subagencies NIFA and Economic Research Service (ERS) which in 2019 were relocated from Washington, D.C. to the Kansas City Region. This geographic move resulted in massive staff attrition, which led to delayed grants and discontinued research—including climate related food and agriculture research. Recovering from this setback and ensuring that all REE science agencies are fully staffed and operating at full capacity is necessary to support publicly-funded climate related food and agriculture research. REE should use increased funding from the farm bill to focus research efforts on agricultural practices to reduce GHG emissions, increase soil carbon sequestration, and improve efficiency for all farms—including small and mid-sized farms.

- Adding climate resilience to the overall purpose of National Institute of Food and Agriculture's Sustainable Agriculture Research and Education (SARE) competitive grants program and creating a new SARE Agriculture and Food System Resilience Initiative (AFSRI) as described in Section 203 of the Agriculture Resilience Act (H.R. 5861).

The 2023 Farm Bill should increase funding for SARE, the only USDA research program focused entirely on sustainability and the only farmer driven competitive research grant program at USDA. Through its regional Administrative Councils, SARE provides Research and Education Grants, Professional Development Grants, Graduate Student Grants, and other small grants for sustainable agriculture research. Although research related to climate resilience is tangentially supported within SARE, it should be centered as a separate overall purpose of the SARE grants program to ensure a dedicated funding stream for climate resilience research.

In addition, the next farm bill should include support for AFSRI, which would establish a research, education, extension, and outreach initiative as laid out in H.R.

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[6] DeLonge, M.S., Miles, A., & Carlisle, L. (2016). *Investing in the transition to sustainable agriculture.*† In ENVIRONMENTAL SCIENCE & POLICY (Vol. 55, pp. 266–273). Elsevier BV. *https://doi.org/10.1016/j.envsci.2015.09.013*.

[7] *See* Bollington, A., DeLonge, M., Mungra, D., Hayek, M., Saifuddin, M., & McDermid, S.S. (2021). *Closing Research Investment Gaps for a Global Food Transformation.*† In FRONTIERS IN SUSTAINABLE FOOD SYSTEMS (Vol. 5). Frontiers Media SA. *https://doi.org/10.3389/fsufs.2021.794594*.

5861. This initiative may include farmer and rancher research and demonstration grants. It should use an interdisciplinary approach and increase the resilience of agriculture and the food system in the context of a changing climate and related economic, social, and environmental shocks. This initiative would also encourage Tribal colleges to enter into research and extension project agreements.

- Fully supporting NIFA's Agriculture and Food Research Initiative (AFRI) program and creating a new climate change adaptation and mitigation subprogram within AFRI as described in Section 208 of the Agriculture Resilience Act (H.R. 5861).

As the largest Federal agricultural research competitive grant program that funds projects across six farm bill priorities, AFRI has the power to shape the national agricultural research agenda. Thus, the 2023 Farm Bill should increase funding for AFRI. REE should then focus this increased funding on greater allocations for projects that contribute to our understanding of mitigating, adapting to, and building resilience to climate change. It can use some of this funding to create a dedicated subprogram to track research related to climate adaptation and mitigation.

- Adding a new tenth purpose to Federal Investment in Agriculture Research, Extension, And Education dedicated to carbon sequestration.

In addition seeking more funding for R&D, the next farm bill should add a new climate-focused purpose to the Federal Investment in Agriculture Research, Extension, and Education. Currently, there is no statutory purpose for Federal investment in agriculture and the food system to contribute to reductions in GHG emissions or increase carbon sequestration. Adding this 10th purpose will increase public funding for climate research, which is needed to meet climate targets and enhance the health of soils, forests, grasslands, wetlands, waters, and oceans and the ecosystem benefits they provide.

- Authorizing Climate Hubs, expanding Climate Hubs, making them permanent, and seeking increased funding for them.

The 2023 Farm Bill should also designate separate funding for the Climate Hubs, which have successfully integrated research, outreach, and technical assistance programs across USDA subagencies yet currently lack legislative authorization. Climate Hubs provide a mechanism to align research, data, technical assistance, and outreach with regional needs and effectively work towards climate goals. Legislative authorization for the USDA Climate Hubs should specify that they be administered by ARS and the USFS in coordination with other USDA and Federal agencies and in cooperation with educational institutions, NGOs, private entities, and state and local agencies. Regional hubs should solicit stakeholder input, work with extension programs, conservation districts, and NGOs to assist farmers with business and conservation planning which specifically address climate change. Additionally, Climate Hubs should facilitate a better understanding of climate risks by working closely with the Risk Management Agency ("RMA") to improve accounting of climate risk in RMA's actuarial tables.

- Expanding extension, technical assistance, and outreach efforts for GHG-reducing, climate-friendly, and carbon sequestering practices.

Outreach, technical assistance, and extension efforts are among the most effective ways to increase adoption of climate-friendly practices. REE can bolster these efforts by strengthening and broadening Climate Hubs, establishing regional agroforestry and diversified cropping centers, and expanding funding for the Cooperative Extension System. In improving these outreach and extension resources, special consideration should be given to ensure they are made available to communities that shoulder disproportionate burdens of environmental pollution and climate change.

- Permanently establishing the Long-Term Agroecological Research (LTAR) Network and seeking funding for it.

The 2023 Farm Bill should also permanently establish the LTAR Network and seek funding for it. Long-term site-based research networks such as the National Science Foundation's Long-Term Ecological Research (LTER) Network have been productive for coordinating ecological research efforts and sharing data across regions, primarily in unmanaged ecosystems. The next farm bill should establish the ARS's LTER Network, as recommended in the Agricultural Resilience Act (H.R. 5861 Sec. 205). This network would coordinate continuous research related to agroecological practices in the context of climate change adaptation and mitigation at experimental and observational sites distributed across the nation. Long-term field studies are particularly important for characterizing the lifecycle of environ-

mental effects associated with shifting agricultural practices and optimizing conservation programs accordingly.

These networks also facilitate collaborations across sectors and play a key role in outreach and education. ARS currently manages several datasets and sites spanning hundreds of years of critical data collection, particularly related to water quality, which can be used to form the core of the LTAR Network.

- Expanding funding for the National Agroforestry Center (NAC) and other agroforestry research and outreach, and permanently establishing regional agroforestry centers.

The next farm bill should expand support for the NAC to ensure that farmers and ranchers have access to the tools and expertise they need to adopt agroforestry practices, and it should expand the focus of the NAC to include a broad array of crop diversification practices as well. Agroforestry offers the highest carbon sequestration potential among agricultural practices on a per-acre basis, and provides multiple benefits for farmers and rural communities, yet agroforestry research and extension receive little public support. As a result, farmers and ranchers rarely have access to professionals with the training and expertise necessary to help them implement these practices. Since its authorization in the 1990 Farm Bill, the NAC has helped to fill this gap, spurring the sector's rapid growth throughout the country. However, the NAC has been chronically underfunded, leaving it unable to match the growing need for agroforestry research, extension, and technical assistance. The 2018 Farm Bill authorized only $5 million for NAC and it has never been fully funded.

The farm bill should also include funding to establish regional agroforestry centers in each of the 12 major ecoregions of the United States. These regional agroforestry centers will help implement agroforestry plans while also helping to develop new markets for agroforesters. With sufficient funding, these centers could also work closely with, and provide resources to, 1890 institutions and Tribal land-grant institutions to ensure the communities they serve benefit from agroforestry's financial and environmental impacts. And they should incorporate a variety of diversified cropping systems into their work so that farmers and ranchers can learn about and have access to tools related to practices that are most ecologically appropriate for their geography.

- Doubling funding for the Cooperative Extension System (CES).

Funding for the CES has fallen by more than half in real terms since the early 1980s. This has severely damaged the ability of the CES to disseminate information on new practices or reach underserved populations. The number of extension agents in some regions, for example, has declined by more than 80 percent in the past thirty years. As a result, farmers must increasingly turn to agribusiness dealers focused on making sales for information about crops, practices, and services. These private-sector advisors are unlikely to help farmers adopt the most climate-friendly practices, which often reduce the need for the products they sell. The next farm bill should reverse these cuts, doubling Federal support for the CES and focusing these new funds on climate mitigation and adaptation and underserved communities.

- Expanding soil health demonstration trials.

The 2018 Farm Bill created the Soil Health Demonstration Trial, a program that pays farmers to adopt practices that will sequester carbon in the soil. The program collects data from participating farmers to feed into climate models, to better understand the relationship between soil carbon sequestration and climate. The program aims to help develop new revenue streams for farmers, who could be paid for verifiable carbon sequestered. This program has tremendous potential to increase the amount of carbon sequestered in the soil, improve soil health, and build climate resilience. It has the added benefit of improving farm productivity and thus increasing farmer profits. The 2023 Farm Bill should increase funding to expand this program.

- Funding the monitoring and evaluation of conservation programs.

Aligning conservation programs with climate goals will require improved monitoring and evaluation of practices. Monitoring and evaluation programs can help optimize conservation efforts to maximize climate benefits. The next farm bill should include funding for comprehensive monitoring and program evaluation programs to assess progress in reaching natural resources and environmental objectives and the contribution of those programs to that process, as proposed in H.R. 4751, the

Healthy Fields and Farm Economies Act and S. 3429, the Farmer Driven Conservation Outcomes Act.

* * * * *

In sum, we urge the Committee to push for increased funding for climate-related R&D and related programs in the 2023 Farm Bill given the critical role research plays in agricultural resiliency and climate mitigation. The farm bill provides a ready-made tool that has powerful potential to make real and lasting change that will better equip the agricultural sector to address and adapt to climate change.

Respectfully submitted,

Earthjustice.

CC:

RANJANI PRABHAKAR,
Senior Legislative Representative,
Earthjustice.

SUBMITTED QUESTIONS

Response from Thelma I. Vélez, Ph.D., Research & Education Program Manager, Organic Farming Research Foundation

Question Submitted by Hon. Salud O. Carbajal, a Representative in Congress from California

Question. Climate change is without a doubt one of the biggest challenges facing the entire world. Addressing this challenge will take innovative solutions, collaboration, and decarbonatization of every sector. Agriculture is no exception.

In California, like many states across our nation, we are already experiencing the consequences of climate change. Severe drought and frequent fires pose a legitimate threat to our hardworking farmers and our nation's food supply.

The time for action is now. The longer we wait, the harder it is going to be to react.

In Congress, we look to experts, like you all, to best inform public policy so that we can work to enact laws that will bring about real, meaningful change. I want to stress the importance of listening to scientific experts, especially when it comes to climate change, because the distrust in the scientific community over the last few years.

My district is home to a number of organic growers. What lessons do you think the agriculture can learn from organic growers? What investments from Congress would be most helpful?

Answer. August 18, 2022

Representative Carbajal, thank you for the opportunity to highlight the promise of organic agriculture in responding to the climate crisis. Below is a narrative description of the importance of organic agriculture in light of our changing climate, from both a mitigation and adaptation perspective; a condensed recommendations section; and a list of scientific papers that support a policy recognizing organic agriculture as an effective climate strategy.

The Organic Farming Research Foundation (OFRF) has been working for over 3 decades to expand the research being done on organic production systems. We work closely with researchers, organic farmers, and policy makers across the U.S. to understand the challenges farmers face, and to provide the research and education tools needed to help them thrive.

Our changing climate, and the disruptions in weather patterns it brings, present new and intensifying challenges to farmers. In our recently published 2022 National Organic Research Agenda (NORA), we received responses from over one thousand certified organic growers across the U.S. to produce a 230 page report identifying the needs of our domestic growers. Over half of these farmers were concerned with adapting to climate change. In listening sessions, they discussed challenges such as unpredictable precipitation, including increased flooding and prolonged periods of drought, earlier and later frost dates, and changing pest challenges (Snyder, Schonbeck, Vélez, 2022).* All of these challenges alter planting and growing cycles, negatively impact the stability of farms, and expose the fragile na-

*__Editor's note:__ the in-text citations in Dr. Vélez's response do not have a corresponding descriptive "Endnotes" listing. It has been reproduced herein as submitted.

ture of our current food system, which ultimately threatens national security (*ibid;* Petersen-Rockney, *et al.,* 2021).

Despite these challenges, we know that organic growers lead the nation when it comes to climate resilience, climate adaptation, and climate mitigation. Organic growers regularly implement climate-smart practices that build healthy, fertile soils. Soil is the foundation of our farms, and healthy soils have increased capacity to hold plant-available water and nutrients, suppress pathogens, and support vigorous crops and pasture. To build soil health, nearly 90% of organic farmers plant cover crops regularly, compared to just 10% of conventional farmers (Snyder, Schonbeck, Vélez 2022). Other practices organic growers lead the way in are crop rotation, intercropping, and green manures, all of which are research-backed methods to improve resilience and increase fertility (*ibid*). Organic farming is the original climate-smart agriculture.

OFRF has spent the past 7 years researching and reviewing the literature to better understand the importance of soil health to climate resilience and mitigation. We have carried out this work with grants and through a partnership agreement with USDA NIFA. In reviewing the existing research, we found that there is extensive evidence showing organic production systems help farmers in various ways, including: increasing resilience to climate stress, such as droughts and floods, enhancing soil fertility and protecting against soil erosion, supporting increased biodiversity, and increasing soil carbon sequestration services. For example, in the case of extended drought, studies show that cover crops can reduce irrigation needs anywhere from 33–50%, particularly when using integrated strategies such as diversified rotation, reduced tillage, and compost application (Gaudin, *et al.,* 2018; Renwick, *et al.,* 2017; DeVincentis, 2019). Relatedly, organic agriculture systems have been found to decrease soil loss rates due to erosion, with soils under organic management having greater aggregate stability while increasing water infiltration rates (Morvan, *et al.,* 2018). Research has found that biodiversity on organically managed lands have higher rates of both species richness and abundance when compared to conventional cropping systems (Stein-Bachinger 2021). With respect to climate mitigation, research indicates that organic farming systems can sustain higher levels of soil organic carbon (SOC) and have lower per-acre GHG emissions than conventional systems (Schonbeck 2020; Crystal-Ornelas, Thapa, & Tully, 2021). There are multitudes of studies describing the importance of organic production systems in addressing both current and emerging climate challenges.

While the organic method has been shown to have great potential to contribute to both climate mitigation and climate resilience, much more action-oriented research is needed to make widespread adoption possible. Less than 1% of the USDA's annual research budget is spent on organic production topics, which is not aligned with the organic sector's continually growing market share of 6%. Organic farmers need greater research investment to continue to advance soil health and fertility management to better sequester carbon and reduce GHG emissions. To reduce risk and enhance resilience, they also need improved crop cultivars specific to organic production systems, including traits like disease-resistance, nutrient efficiency, seedling vigor, and competitiveness toward weeds. We at OFRF believe it is crucial for Congress to recognize and elevate USDA-certified organic agriculture as a climate-smart and -resilient system of production and provide the resources to meaningfully meet the need of organic producers. This is in line with Secretary Vilsack's recent comments when presenting the Food System Transformation Framework.

Moving forward, more research, education, and extension is needed to help farmers and ranchers implement the best practices for climate mitigation and adaptation specific to their operations and locales. This includes breeding regionally adapted crop cultivars and identifying the best cover cropping systems for specific regions and production systems. We also need to advance organic research on advanced grazing management and crop-livestock integration which are known to sequester carbon, reduce greenhouse gas emissions, and enhance climate resilience of livestock production systems. Further, we believe it is imperative to increase funding not only for existing organic research programs, but also integrate organic research into other research programs across the USDA's portfolio. Increasing mandatory funding for NIFA Organic Research and Extension Initiative (OREI), while also expanding the amount of organic research within the ARS, such as work underway at Long Term Agroecosystem Research sites, is imperative. Alongside investing in the research, investment in Extension and education is essential to getting new research-informed skills, tools, and technology into the hands of growers. Cooperative Extension programs have been historically underfunded, and organic producers are often at an additional disadvantage because the organic expertise of Extension agents is currently lagging. Therefore, we also rec-

ommend expanding technical assistance resources and Extension services available to organic growers.

In conclusion, these are challenging times for the people who grow our food. American farmers are no strangers to challenges, from the Dust Bowl to the 1980s farm crisis, but the scale of challenges facing our farmers are unprecedented. Destabilizing climate conditions only contribute to continually thinning margins and market disruptions that negatively impact the health of our agriculture industry. We deeply appreciate the USDA funding research, education, and extension that is crucial to helping farmers build resiliency. The Sustainable Agriculture Research and Education (SARE) program, the Organic Research and Extension Initiative (OREI) and the Organic Transitions Program (ORG) have supported hundreds of studies that help both organic and conventional farmers address the threat of climate disruption. But, there is still much more investment needed to meet the needs of our farmers if we want to make meaningful progress on mitigating and adapting to climate change. Thank you for all of the great work you have done so far and the work you continue to do.

Condensed Recommendations

- Research:
  - Increase funding for organic research programs administered by the National Institute for Food and Agriculture (NIFA), including the Organic Research and Extension Initiative, Organic Transitions Program, and the Sustainable Agriculture Research and Education (SARE) programs. These programs are ideally positioned to help producers sustain and increase production while contributing to climate adaptation and mitigation through expanded research in organic agriculture and food systems
  - Continue and expand research funding through the Agriculture Research Service's Long Term Agroecosystem Research (LTAR) Network. For example, organic systems research at the long term organic trials at the Beltsville, Maryland research station can be a model for expanding LTAR programming. This long-term research will continue to be critical in preparing farmers and ranchers, both organic and non-organic, to adapt to and mitigate the changing climate.
  - Fund organic farming research at levels commensurate with organic's market share. This will require at least a six fold increase that could be spread out over several years. We believe that increasing funding for organic research, building on the recently-released ARS strategic plan for organic research, will help the agency address this historical lack of investment in organic agriculture research and help organic and non-organic producers alike overcome challenges to realize their potential to adapt to and mitigate the impacts of the changing climate.
- Extension and Education:
  - Expand Extension services available to organic growers. Extension is essential to delivering new skills, tools, and technology into the hands of growers. As a country we are under-investing in Cooperative Extension programs, and organic producers are at an additional disadvantage because the organic expertise of Extension agents lags significantly.
  - Increase the level of coordination between USDA's research agencies and programs with their technical assistance agencies. Farmers depend on the continued and expanded capacity of NIFA and ARS to continue effectively sharing key research findings with NRCS and other technical assistance-focused agencies, so they can support the adoption of best practices and sustainable systems of production.

Up-To-Date Scientific Literature on Soil Carbon in Organic Systems of Production

Agricultural soils have been increasingly recognized as a crucial piece in the response to our changing climate, both for their capacity to draw down and store carbon, as well as their ability to create a more-resilient landscape. Organic systems of production offer substantial benefits in both mitigating and adapting to climate change, and should be employed at a greater scale. Updates in the field of soil science have found that soil life plays a central role in soil fertility and carbon (C) sequestration. Managing soils to enhance microbial biomass, biodiversity, and activity builds reserves of both active (mineralizable) and stable (sequestered) soil organic carbon (SOC). Following are recent pieces of research on SOC dynamics in agricultural soils managed organically to inform the design of agricultural policies,

programs, and practices that optimize the mitigation and adaptation capacities of agricultural soils.

Rethinking soil carbon:

1. Dynarski, Katherine A., *et al.* "Dynamic Stability of Soil Carbon: Reassessing the 'Permanence' of Soil Carbon Sequestration."† * *Frontiers in Environmental Science,* vol. 8, 2020, *https://doi.org/10.3389/fenvs.2020.514701.*

   The scientific world's understanding of how soil carbon behaves has fundamentally changed over the past decade, but policy makers and implementers have not kept pace with these advances. This Review Article provides a general overview of the advances in our understanding of soil-C, finding that the overwhelming majority of soil-C is made up of microbial communities and their necromass. Current debates on this topic fall prey to two outdated concepts: that "stable" SOC is composed of complex macromolecules ("humic substances") that remain in the soil permanently, and that any SOC accrued through improved practices is rapidly lost through any amount of tillage or other changes in management. Recent research has shown that SOC accrual is a dynamic process based on microbial processing of plant-derived organic carbon (Dynarski, *et al.,* 2020). Rather than focus on the permanent nature of soil-C, this review suggests that we should be looking at the persistence of carbon in our soils, and that this persistence is driven by the flow of carbon regulated and facilitated by the microbial community in the soil. Put another way, it is not necessarily how much humified carbon locked in the soil that matters, but the abundance and vibrancy of the life in soil that can draw down carbon. Key findings include:

   - Most soil organic matter (SOM) is derived from microbial consumption and transformation of root exudates and plant residues into metabolites and necromass (dead microbes) that bind to soil clays and silt, forming *mineral-associated organic matter* (MAOM).
   - SOM can leach down into the subsoil before adsorbing to soil minerals. In deep soils, more than half of total SOC (~SOM × 0.5) occurs as MAOM below 30 cm depth. Near-surface measurements miss this SOC.
   - MAOM is not "permanent." It exists in a dynamic equilibrium, but it can last 1,000 years or longer, especially at depths below 30 cm depth if the health of the soil can be maintained.
   - Microbial activity supports *both* crop nutrient release through SOM mineralization and MAOM formation. Providing crop nutrients and sequestering SOC are directly correlated, rather than contradictory goals.
   - Organic inputs that include sufficient nitrogen (N) and other nutrients along with C support a robust microbial community.
   - Frequent tillage results in net loss of SOC, but infrequent or low intensity tillage usually does not. Ending the use of C sequestering practices may not result in immediate loss of SOC accrued.
   - Informing farmers on the multiple benefits of SOC building practices—improved nutrient cycling, greater moisture capacity, and increased yield stability—can motivate them to continue the practices after financial incentives expire.
   - Additional research on SOC and MAOM accrual in different soil types, textures and climates, and C dynamics throughout the soil profile (surface to 200 cm) can help realize the full SOC sequestration potential.

2. Gunstone, Tari, *et al.* "Pesticides and Soil Invertebrates: A Hazard Assessment."† *Frontiers in Environmental Science,* vol. 9, 2021, *https://doi.org/10.3389/fenvs.2021.643847*.

   This scientific review found that the use of pesticides overwhelmingly negatively impacts soil invertebrates (arthropods and other multicellular organisms), whose activities enhance the functions of the soil microbiome, including carbon sequestration (Gunstone, *et al.,* 2021). Soil invertebrates comprise a crucial aspect of a vibrant soil ecosystem.

3. Bhattacharyya, Siddhartha Shankar, *et al.* "Soil Carbon Sequestration—an Interplay between Soil Microbial Community and Soil Organic Matter Dy-

* Numbered entries annotated with † are retained in Committee file.

namics." *Science of The Total Environment,* vol. 815, 1 Apr. 2022, p. 152928., *https://doi.org/10.1016/j.scitotenv.2022.152928*.

Based on a review of 197 peer-reviewed publications, Battacharyya, *et al.* (2022) concludes that, given the central role of soil life in soil carbon cycling, agricultural practices must restore the soil microbial community in order to enhance and stabilize SOC sequestration.

Advances in understanding soil-C dynamics in organically managed systems:

4. Crystal-Ornelas, Robert, *et al.* "Soil Organic Carbon Is Affected by Organic Amendments, Conservation Tillage, and Cover Cropping in Organic Farming Systems: A Meta-Analysis." *Agriculture, Ecosystems & Environment,* vol. 312, 1 June 2021, p. 107356., *https://doi.org/10.1016/j.agee.2021.107356*.

   In a global meta-analysis of 36 organic farming systems studies, adoption of a single best management practice enhanced SOC by an average of 18% and microbial biomass carbon (MBC) by 30%. SOC concentration increased 24% with the use of organic amendments, rose 14% under conservation tillage, and showed gradual growth in rotations that include cover crops, which were significant after 5 years. (Crystal-Ornelis, *et al.,* 2021) The report suggests more research is needed on the benefits of longer or more diverse crop rotations, biochar applications, and systems of multiple practices such as cover crop + reduced till + organic amendment.

5. Smith, Olivia M., *et al.* "Organic Farming Provides Reliable Environmental Benefits but Increases Variability in Crop Yields: A Global Meta-Analysis." † *Frontiers in Sustainable Food Systems,* vol. 3, 2019, *https://doi.org/10.3389/fsufs.2019.00082*.

   In a global meta-analysis comparing organic *versus* conventional production in developed countries, organic systems maintained about 12% higher SOC, 30% greater biodiversity, and more consistent soil and ecosystem health. Though this analysis found that conventional systems sustained 25% higher yields with lower yield variability due to access to synthetic fertilizers and pest controls, it also found that organic systems were more profitable than conventional systems (Smith, *et al.,* 2019).

6. Krauss, M., *et al.* "Reduced Tillage in Organic Farming Affects Soil Organic Carbon Stocks in Temperate Europe." † *Soil and Tillage Research,* vol. 216, Feb. 2022, p. 105262., *https://doi.org/10.1016/j.still.2021.105262*.

   In nine organic farming systems trials, researchers compared SOC stocks under reduced tillage (non-inversion, 2–6″) *versus* moldboard plowing (8–12″). Reduced tillage increased SOC at 0–6″ and 28–39″ yet decreased SOC at 6–12″ (Krauss, *et al.,* 2022). Reducing tillage resulted in a net SOC sequestration of 80–240 lb/ac-year. However, crop biomass decreased while weed biomass increased, indicating a need for more research into optimizing organic reduced tillage management.

7. Mandal, Agniva, *et al.* "Impact of Agricultural Management Practices on Soil Carbon Sequestration and Its Monitoring through Simulation Models and Remote Sensing Techniques: A Review." † *Critical Reviews in Environmental Science and Technology,* vol. 52, no. 1, 2020, pp. 1–49., *https://doi.org/10.1080/10643389.2020.1811590*.

   This review found that organic systems of management significantly increase the ability of agricultural soils to sequester carbon, and that individual practices commonly adopted by organic producers—cover cropping, reduced tillage, diverse rotations, compost and other organic amendments, and more recently biochar—each contribute to increasing the amount of SOC (Mandal, *et al.,* 2020). Additional research and improved Extension and technical assistance are needed to support wider adoption of organic systems that maximize SOC sequestration.

8. Prescott, Cindy E., *et al.* "Managing Plant Surplus Carbon to Generate Soil Organic Matter in Regenerative Agriculture." † *Journal of Soil and Water Conservation,* vol. 76, no. 6, Nov. 2021, *https://doi.org/10.2489/jswc.2021.0920a*.

   Managing crops to provide surplus photosynthetic carbon and organic N to soil microbes via root exudates enhances SOC sequestration by stimulating microbial activity and MAOM formation (Prescott, *et al.,* 2021). Three key strategies include:

   - Maintain plant available N, P, and water at levels *slightly below the optimum for top growth,* which can reduce fertilizer and irrigation inputs.

- Include legumes in crop rotations and grazing land vegetation.
- Manage rotational grazing to occur when forages approach the end of the rapid growth stage, during which root exudation is greatest.

9. Franzluebbers, A.J. "Short-Term C Mineralization (Aka the Flush of CO_2) as an Indicator of Soil Biological Health." *CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources,* vol. 13, no. 017, 2018, *https://doi.org/10.1079/pavsnnr201813017*.

   Soil Test Biological Activity (STBA), defined as soil respiration measured over a 3 day period under controlled laboratory conditions, is a reliable indicator of other soil health metrics such as microbial biomass and N mineralization potential (Franzluebbers, 2018). Studies conducted at multiple sites within a state or region with similar soil types have shown very strong correlations between STBA and total SOC. Although high soil microbial activity manifests as greater CO_2 emissions from soil, it also drives SOC sequestration, likely through formation of MAOM.

10. Morugán-Coronado, Alicia, *et al.* "The Impact of Crop Diversification, Tillage and Fertilization Type on Soil Total Microbial, Fungal and Bacterial Abundance: A Worldwide Meta-Analysis of Agricultural Sites."† *Agriculture, Ecosystems & Environment,* vol. 329, 1 May 2022, p. 107867., *https://doi.org/10.1016/j.agee.2022.107867*.

    This meta-analysis by Morugán-Coronado, *et al.,* (2022) documents the impacts of several agricultural practices on fungal, bacterial, and total microbial biomass in cropland soils. Findings include:

    - The use of organic fertilizers *in lieu of* synthetic NPK doubled total microbial biomass.
    - Reduced tillage (non-inversion, 4–6″) doubled bacterial, fungal, and total microbial biomass compared to moldboard plowing (8″ or deeper).
    - Compared to plowing, no-till somewhat increased fungal biomass but not total microbial biomass. Increased compaction and reduced aeration under continuous no-till may have depressed bacterial activity (Morugán-Coronado, *et al.,* 2022).
    - Crop diversification (rotation or intercropping) tended to enhance microbial biomass, especially fungi.

    Given the central role of soil microbes in formation of MAOM, the use of organic nutrient sources, reduced tillage, and diversified cropping systems likely play key roles in enhanced SOC sequestration in organic production.

Response from Sylvie M. Brouder, Ph.D., Professor of Agronomy, Wickersham Chair of Excellence in Agricultural Research, Department of Agronomy: Crops, Soils, and Environmental Sciences, Purdue University; Past President, American Society of Agronomy; on Behalf of Crop Science Society of America; Soil Science Society of America

Question Submitted by Hon. Jahana Hayes, a Representative in Congress from Connecticut

Question. Your testimony highlighted the low levels of adoption of new practices and pointed out the current level of investment is too low to increase capacity in climate-smart programming. In 2019, a Five-Year Review of USDA Climate Hubs listed the Hubs' work with new audiences to help build climate resilience across the country, particularly underserved and small-scale farms, as a strength.

Do you agree that this outreach is a strength for USDA Climate Hubs, and what recommendations would you make to improve outreach and adoption for small farms?

Answer. Initially, I did not feel qualified to answer this question based on my own experiences as an Extension Specialist in Indiana. Therefore, I solicited feedback from Agronomy, Crops, and Soil Science Societies of America members through our Science Policy Committees. Unfortunately, I did not receive much feedback. However, rather than interpret this as an indication I should raise concerns about this claim of value of Climate Hubs to small and underserved farmers, I believe it represents a much larger and more general problem in "climate-smart" outreach and Extension.

As I originally noted in my written testimony, the need to bolster capacity for technology transfer is widely recognized throughout the public- and private-sectors. For climate-smart agriculture, the need is for wholistic, unified, nationally coordinated programming. A truly wholistic program would necessarily encompass the

specific needs of big and smaller entities alike and therefore address the needs of underserved and small-scale farms. Unfortunately, at present, climate-smart outreach efforts are not only constrained by a lack of human resources but also by a pervasive lack of connectivity among existing programs and resources. Indeed, I suspect the sparsity of resources is likely exacerbating siloing within outreach entities rather than fostering collaborations as entities compete for resources to sustain themselves.

At present, USDA's NIFA Agriculture and Food Research Initiative has one Program Area Priority targeting Extension, Education and Climate Hubs Partnership. Proposals are due in October and there is an opportunity to fund *one* national scale Coordinated Agricultural Project Grant for Climate Smart Extension at a 5 yr. funding level of $10M.[1]* The stated goal is "to build and enhance existing climate Extension networks, while identifying synergies among existing programs, and catalyzing new resources and tools that provide accessible, usable, and actionable science, . . ." However, while the goal is laudable, the funds allocated are completely insufficient to build a national-level program from where we currently stand. The short duration nature of the funds also do not bode well for lasting success. We need deliberate and sustained resources for a unified agenda that builds bridges among outreach entities including among Climate Hubs, the Extension entities of Land-Grants and minority serving institutions, and the Natural Resource Conservation Service.

Question Submitted by Hon. Salud O. Carbajal, a Representative in Congress from California

Question. Climate change is without a doubt one of the biggest challenges facing the entire world. Addressing this challenge will take innovative solutions, collaboration, and decarbonatization of every sector. Agriculture is no exception.

In California, like many states across our nation, we are already experiencing the consequences of climate change. Severe drought and frequent fires pose a legitimate threat to our hardworking farmers and our nation's food supply.

The time for action is now. The longer we wait, the harder it is going to be to react.

In Congress, we look to experts, like you all, to best inform public policy so that we can work to enact laws that will bring about real, meaningful change. I want to stress the importance of listening to scientific experts, especially when it comes to climate change, because the distrust in the scientific community over the last few years.

You know the importance of soil health better than just about anyone. Can you elaborate on the importance soil health plays in producing nutritious food and maintaining water quality? Do you think there is a need to improve educational outreach to farmers on the importance of soil health?

Answer. Without doubt, soil health is critical to the sustained production of nutritious food and to the maintenance of water quality. Two key characteristics of a healthy soil are:

1. The ability for rainfall to infiltrate (*versus* run off the soil surface carrying nutrient rich surface soils) and for soil to hold that moisture within the root zones of plants so that they can use that water to continue growth between rainfall (or irrigation) events.
2. The ability to filter water entering the soil of nutrients and contaminants and to cycle nutrients, making them available to plant roots to support growth but retaining them against losses including in water running off the soil surface or leaching through the soil profile thereby protecting water.

These characteristics are facilitated by maintaining a wide diversity in soil organisms and good physical structure of the soil. Healthy soils can contribute to the suppression of pests and pathogens. Lastly, for a soil to be considered healthy it must be free of an array of introduced contaminants (*e.g., E. coli* and other bacteria from manure, heavy metals, *etc.*). These contaminants can enter the food supply when plant roots take them up and transport them to the marketable portion of the plant and/or they transfer and adhere to tissue surfaces during harvest and post-harvest handling.

In the U.S. and throughout the world, the two factors most likely to limit crop production are water and nutrients. Thus, enhancing soil health is a "no regrets"

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[1] See pages 93–97 of the *Request for Applications, Agriculture and Food Research Initiative Competitive Grants Program, Foundational and Applied Sciences*† available here: *https://www.nifa.usda.gov/sites/default/files/2022-05/FY22-AFRI-FAS-RFA-MOD1-508.pdf.*

* Footnotes annotated with † are retained in Committee file.

risk-reduction strategy to stabilizing yields and enhancing food and nutritional security in a changing climate. Soils that have improved water infiltration and storage can both reduce field flooding during extreme rainfall events and increase plant-available soil moisture to prolong growth during droughts. Improved cycling of nitrogen and phosphorus not only protects water quality but may permit farmers to reduce inputs of fertilizers.

A unifying goal of practices that regenerate soil health is maintaining and increasing the soil's organic carbon (SOC) as SOC is the linchpin to soil physical structure, moisture retention and nutrient cycling. Thus, in our 2021 Agronomy-Crops-Soils statement "Advancing Resilient Agriculture: Recommendations to Address Climate Change" we highlight the importance of USDA incentivizing practices that reduce soil disturbance, keep soil covered, increase biodiversity and tighten nutrient cycles.[2] Unfortunately, messaging to farmers on the importance of maintaining soil health has become conflated with the political agenda surrounding soil carbon and associated opportunities to mitigate climate change by using soil as a sink for the increases in atmospheric carbon dioxide associated with fossil fuel use.

At present, there is a great deal of excitement regarding the potential for management practices that improve soil health to be viewed primarily through the lens of SOC accrual and the potential for farmers to profit from new carbon credit markets. This has driven a precipitous proliferation of programming focused on the measurement and monitoring of soil carbon despite the scientifically well-known fact that it can take years to decades for changes in SOC to be measurable in routine soil testing.[3] Indeed, in our 2021 survey of our membership (scientists and practicing professionals), enhancing the health of the soil was identified as the most important pathway for farmers to *both* mitigate and adapt to climate change but it was also identified as among the slowest pathways to direct impact.[4]

The predominant reason to encourage farmers and ranchers to adopt practices to improve soil health is the more immediate benefits they will accrue in terms of resilience in the face of extreme weather. While it can take years for the direct indicators of changed SOC and quality to be measurable, other benefits to row-crop farmers and to water quality of practices such as no-till and cover cropping can be realized more immediately. Such benefits include rapid reductions of nutrient and sediment loads to water from reduced runoff and potential reductions in on-farm energy use. In recent studies on why farmers do not adopt soil conserving practices, barriers cited include perceptions of risk *versus* cost, a high prevalence of rented farmland,[5] and complex and burdensome application and reporting requirements including ones that may constrain future decision making.[6]

In sum, there is clearly a need for educational programming that (1) highlights risk-reduction benefits *versus* participation in carbon markets, (2) addresses the landlord-renter relationship, and (3) focuses on tailoring practices for adoption in the context of the real-world constraints imposed by other aspects of a farm enterprise.

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[2] As noted in my original written testimony, our A–C–S statement on *Advancing Resilient Agriculture: Recommendations to Address Climate Change*† is available at *https://www.agronomy.org/files/science-policy/issues/2021-acs-climate-solutions-statement.pdf*.

[3] In my original written testimony, I provided the following link to a recent Purdue Univ. analysis of *Opportunities and Challenges Associated with "Carbon Farming":*† *https://ag.purdue.edu/commercialag/home/wp-content/uploads/2021/06/202106_Thompson_Carbon Markets.pdf*. If you desire more information on carbon markets, I can highly recommend Nathanael Thompson (**Redacted**) and co-author Carson Reeling (**Redacted**).

[4] A one page summary of our member survey on strategies for climate change mitigation and adaptation can be found here: *https://www.agronomy.org/files/science-policy/letters/climate-change-survey-one-pager.pdf.*†

[5] Currently it is estimated that 54% of U.S. cropland is rented on short-term contracts. See *https://www.ers.usda.gov/topics/farm-economy/land-use-land-value-tenure/farmland-ownership-and-tenure.*†

[6] The following are two academic publications summarizing survey work to identify barriers to adoption: Ranjan, P., Church, S.P., Floress, K., & Prokopy, L.S. (2019). *Synthesizing conservation motivations and barriers: what have we learned from qualitative studies of farmers' behaviors in the United States?.*† SOCIETY & NATURAL RESOURCES, 32(11), 1171–1199 and Ranjan, P., Wardropper, C.B., Eanes, F.R., Reddy, S.M., Harden, S.C., Masuda, Y.J., & Prokopy, L.S. (2019). *Understanding barriers and opportunities for adoption of conservation practices on rented farmland in the U.S.* LAND USE POLICY, 80, 214–223.

If you would like more and updated information on barriers, I highly recommend contacting co-author Linda Prokopy (**Redacted**)

Response from Benjamin Z. Houlton, Ph.D., Ronald P. Lynch Dean, Professor, Ecology and Evolutionary Biology, Professor, Department of Global Development, College of Agriculture and Life Sciences, Cornell University

Questions Submitted by Hon. Jahana Hayes, a Representative in Congress from Connecticut

Question 1. In your testimony, you pointed out that nearly 90% of American farm families require off-farm income to keep their farms afloat. You also point out that committing resources to new farming practices presents financial risks for farmers.

Dr. Houlton, what are the costs associated with climate-resilient farming, and how much should Congress invest in these programs to ensure family farms have the financial security to implement new, climate change resilient practices?

Answer. The USDA's FY23 budget request included over $2 billion for the Environmental Quality Incentives Program (EQIP), which provides financial and technical assistance to farmers to address natural resource concerns—including improved water and air quality, conserved ground and surface water, and increased soil health and soil erosion prevention. EQIP remains one of the most popular conservation programs in my state, but the high demand for this program means that many applications for funding and technical assistance do not get approved. Increasing funding for the program is one way to meet this demand.

Question 2. The USDA's FY23 budget request included over $2 billion for the Environmental Quality Incentives Program (EQIP), which provides financial and technical assistance to farmers to address natural resource concerns—including improved water and air quality, conserved ground and surface water, and increased soil health and soil erosion prevention.

EQUIP remains one of the most popular conservation programs in my state, but the high demand for this program means that many applications do not get approved. Increasing funding for the program is one way to meet this demand. What strategies can Congress employ to ensure small farmers are fairly represented among program participants or incentivized to participate in conservation programs with Federal funding?

Answer. Congresswoman Hayes:

Thank you for asking how USDA programs, particularly those providing climate and environmental stewardship incentives, can be scaled appropriately so that smaller sized and underserved farmers can participate freely. In New York, 20% of our farms produce 80% of the value of the food grown in New York. These larger and largely family-held farm operations are exceptionally important to providing fresh, local, agricultural foods and to creating a robust regional foodshed (that includes our neighbors in Connecticut). Because our larger farms steward the most farmland acres, and tend to have the more concentrated livestock and dairy operations, it is not surprising that they receive the largest share of benefits from EQIP and other Federal conservation programs. That said, most of the farms in New York State are smaller, employ few non-family workers, and farm an average of 200 acres. Our underrepresented farmers, in particular, struggle with profitability, as net returns for farmers of color tend to be lower than white-owned farms.

From an environmental perspective, it is critical that the U.S. provide incentives to larger farms to reduce greenhouse gas emissions and sequester carbon in soils, which will help ensure the largest amount of "climate benefit" due to issues of scale. At the same time, from an equity perspective, these conservation programs must be available for smaller-scale and traditionally underserved farmers. The cost share requirements of conservation programs, however, are often a barrier to participation for small and underrepresented farmers—who, as I noted, operate on the thinnest of margins and do not have access to the same resources (capital, collateral) as larger operations. The best way to achieve greater participation of small farmers in Federal conservation incentive programs, is to make more resources available across the board to farmers of all size for environmental protection and climate-smart agricultural practices. Funding increases, such as those contained in the new *Inflation Reduction Act,* will be a significant tool to assist farmers of all size in adopting climate-smart production and conservation practices, until a greater private-sector market is created to incentivize climate friendly practices in food production. Absent additional resources, the programs could be modified to allow smaller and underrepresented farmers to contribute a small cost-share, lowering the most significant barrier to participation. Funding agencies could also re-think their scoring criteria to incorporate a measure that adds "bonus points" for farms that are smaller scale or underrepresented to address equity concerns.

I am not aware of any academic studies that recommend a specific dollar amount by which funding for environmental and climate focused incentive programs to farmers should be increased. The current social cost of carbon dioxide, in terms of its climate impact, is estimated to be more than $100/ton of CO_2 emitted on average. This cost, when internalized, would suggest a similar value frame for level setting carbon sequestration payments for farmers. Speaking as a climate scientist, ensuring that the science behind Congressionally-funded agricultural conservation and climate incentive programs is accurate, verifiable, and returning innovative climate benefits will be key to their long-term success. Provision of scientifically-sound public-sector incentives to farmers—regardless of their size—will ensure they are a vital part of the climate solution while continuing to produce a steady supply of food for all.

Question Submitted by Hon. Salud O. Carbajal, a Representative in Congress from California

Question. Climate change is without a doubt one of the biggest challenges facing the entire world. Addressing this challenge will take innovative solutions, collaboration, and decarbonatization of every sector. Agriculture is no exception.

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In Congress, we look to experts, like you all, to best inform public policy so that we can work to enact laws that will bring about real, meaningful change. I want to stress the importance of listening to scientific experts, especially when it comes to climate change, because the distrust in the scientific community over the last few years.

Climate change is impacting our water, air, soil, food and farming system, and our communities. Given the immense scale, what areas need additional research to develop a more complete understanding of how the world can work to develop climate solutions?

Answer. Thank you for this broad ranging and holistic question. As a former Californian, who came to Cornell from the UC system, I have great empathy and firsthand knowledge of the challenges faced by farmers and all residents of your beautiful state. I believe research is needed to provide the marketplace with science-based, verified, and permanent ways to sequester carbon in soils, as well as to mitigate greenhouse gas emissions. Incentives, whether from the public-sector or from the emerging private-sector carbon markets, need to be provided in accordance with science-based strategies that can be verifiably proven to draw down carbon from the atmosphere and mitigate emissions. The Land-Grant system can not only develop these cutting edge scientific climate-focused innovations, but can also serve as a demonstration site and test bed to de-risk the technology before it is widely adopted by producers. For example, in my own work as a climate scientist, I am conducting an over 150 acre trial in both California and New York, on larger scale and smaller scale research and private-sector farms (including one urban location) to assess whether utilization of "rock dust" can draw down carbon from the atmosphere and store it in our soils. This work—which has already been tested in lab and greenhouse settings—is now being tested on actual working farms. The outcome of these practical tests will provide farmers, land managers, and private-sector carbon markets and public-sector incentive programs with a precise and verified calculation of the climate emissions mitigation benefit of this specific intervention.

I share this level of detail to illustrate the possibility, given adequate investment in climate science and nature-based climate solutions research infrastructure, of a new and valuable tool and income stream for farmers. It is important, however, that the Committee not lose sight of the importance of the basic research that underpins every innovative new climate mitigation and adaptation strategy. For example, the concept of exploring further the genetic structure of plants to enable enhanced photosynthesis is a promising climate solution that is not yet at the stage where it can be tested in a more applied setting. Enhanced photosynthesis through innovations in synthetic biology is an example of an emerging strategy to breed food crops that are capable of drawing down additional carbon from the atmosphere through photosynthesis and storing it through more deeply rooted plant structures into the soil. To counteract the very real and growing climate extremes that Californians and others are facing, it is vitally important to work on climate solutions holistically. In other words, the Committee should support both development of more immediate techniques to draw down carbon naturally, as well as investment in fundamental research into longer term strategies that have innovative potential.

New York, similar to California, has set a highly ambitious goal to become a net zero economy. To do that, we will need to reduce steeply emissions of short-lived climate pollutants like methane and nitrous oxide. From this perspective, creating an adequately-funded competitive research that is targeted at developing strategies that mitigate those pollutants—for example, precision agriculture tools for smart, precise usage of agricultural fertilizers to reduce nitrous oxide emissions, or methane reduction strategies for dairy and livestock farmers—is an should be a top priority.