Testimony of Brise Tencer
Executive Director, Organic Farming Research Foundation

Submitted to the U.S. House of Representatives, Agriculture Committee, Subcommittee on Biotechnology, Horticulture, & Research

June 12, 2019 hearing on "Increasing Resiliency, Mitigating Risk: Examining the Research and Extension Needs of Producers"

Chairwoman Plaskett, Ranking Member Dunn, and distinguished members of the Subcommittee on Biotechnology, Horticulture, and Research, thank you for your time and attention on the pressing issues of resiliency and risk in agriculture.

Since 1990, OFRF has been working to foster the continuous improvement and widespread adoption of organic farming systems. Organic producers have developed innovative strategies that support agricultural resiliency and show potential to mitigate greenhouse gas (GHG) emissions and lessen the impacts of climate change on production. In addition, strong market demand and high prices for certified organic farm products can help reduce economic risks for organic producers.

Even in the best circumstances, farmers are managing a variety of risks, including fluctuating markets, increasing production costs, and annual weather variations that may cause production challenges. Climate disruptions are increasing in intensity and frequency, which exacerbates existing risks. For instance, life cycles and geographic ranges of crop pests and pathogens are rapidly shifting, and soil health is degrading at a concerning rate (IPCC 2014, Kirschbaum, 1995; Montanarella et al., 2016). These shifts in abiotic and biotic stressors are already contributing to crop losses and threatening food security (Myers et al., 2017).

In fact, climate disruptions are having a significant impact on family farmers and ranchers around the country. In the face of global climate change, extreme weather events are becoming more common. Increasingly, farmers have to contend with severe droughts and flooding, increased heat waves, warmer winters that allow pest and disease pressures to intensify, and loss of winter chill hours that regulate bud break and fruit development in tree crops. This spring, flooding left farm fields across the Midwest under water; preliminary analysis of satellite data from the National Aeronautics and Space Administration's (NASA) Near Real-Time Global Flood mapping tool estimates 1 million acres of U.S. farmland were flooded (Huffstutter & Pamuk, 2019). Meanwhile, growers across the Southeast and the islands are continuing the hard work to recover from devastating hurricanes and tropical storms. In my home state of California, farmers and ranchers are still dealing with the aftermath of last year's record-breaking wildfires intensified by increasingly warm and dry weather. We need science-based solutions that will help farmers adapt and become more resilient to these changes.

OFRF's national survey of organic farmers and ranchers, published in the National Organic Research Agenda (NORA) report, provides an authoritative understanding of the research needs of the organic community (Jerkins & Ory, 2016). Together with Taking Stock, our analysis of USDA funded organic research, NORA informs USDA researchers, universities, agricultural extension agents, farmers, ranchers, and others to ensure research, education, and extension activities are relevant and responsive to the organic sector (Schonbeck et al., 2016).

More than 1,000 organic farmers and ranchers across the U.S. participated in OFRF's online survey. Additional input was gathered through 21 listening sessions. Based on their stated priorities, OFRF recommends intensified research funding in the areas of soil health and fertility management, weed, insect, and disease management, plant breeding to develop public cultivars better suited to organic production systems, and meeting the challenges of climate change.

Farmer-identified topics related to climate disruptions included water and soil management to cope with drought and flooding, managing new insect pest and weed species, and adapting to fluctuations in chill-time for nuts and fruit crops. One farmer put it bluntly, *"climate change is about to put me out of business. 2011 was too wet, 2012 too dry, 2013 and 2014 too wet…plus devastating extreme cold temps in Jan 2014 and Feb 2105. How can I, as the manager deal with it?"* Another farmer lamented, *"Sadly, I think climate change is going to catch up with all of us: it is getting hard to produce crops that have been routine to me over the decades."*

The main difference between organic and conventional approaches to these new challenges is that organic producers cannot rely on synthetic inputs. Rather, they must experiment with and tailor biological and ecological approaches to fit their unique farming practices. To be successful, organic farmers need an intimate understanding of the lifecycles and biological interactions of crops, livestock, soil life, pests, and their natural enemies, as they rely on ecological processes to address production challenges. The organic approach has potential to sequester C, mitigate GHG emissions, reduce environmental impacts related to fertilizers and pesticides, and build resiliency to changing and unpredictable weather patterns. An increased investment in research for organic systems is essential to realize this potential.

We greatly appreciate USDA's funding of research, education, and extension that is crucial to helping farmers build resiliency and address risk. The Sustainable Agriculture Research and Education (SARE) program, as well as the Organic Research and Extension Initiative (OREI) and Organic Transitions Program (ORG) have supported hundreds of studies that help both organic and conventional farmers around the country address the threat of climate disruption. Now, it is critical to increase our investment in research that will help farmers increase resiliency.

Building Resiliency to Climate Disruptions

Organic systems that build soil organic matter and soil health, diversify crop rotations and farm enterprises, and utilize biological and cultural approaches to nutrient, pest, weed, and disease management can make agricultural production more resilient to abiotic stresses, including those related to climate change (Blanco-Canqui and Francis, 2016; Lal, 2016). These systems are inherently knowledge-intensive and site specific, and the challenges all producers face in managing crops, livestock, soils, nutrients, and both beneficial and harmful organisms in this time of climate change are highly interconnected. Therefore, it is essential for Congress to continue supporting integrated research, education, and outreach to provide farmers with the tools, technology, and support they need to build healthy resilient farming systems that can withstand climate disruption, and to steward the land for generations to come.

Healthy Soils

As documented in our recently published Reducing Risk Through Best Soil Health Management Practices in Organic Crop Production (with funding from the USDA Risk Management Agency), soil health plays a key role in reducing production costs and risks, and will become ever more critical as climate disruption continues to unfold. The USDA Natural Resources Conservation Service (NRCS) has established four science-based principles of soil health management: keep the soil covered, maximize living roots, enhance cropping system diversity, and minimize soil disturbance. Management systems that address all of these principles build organic matter and overall soil health more effectively than adopting a single practice such as no-till or green manuring (Schonbeck et al., 2017, 2018).

Sustainable organic systems that maintain higher soil organic matter and biological activity, improve moisture infiltration and storage, and foster efficient nutrient cycling result in greater yield stability through weather extremes and other stresses. For example, while organic and conventional crop rotations in the Rodale long term farming systems trials gave similar yields over a 35-year period, the organic systems sustained much better crop condition and 31% higher grain yield in corn during drought years (Rodale, 2011a, 2015). In another instance, regenerative range management helped a Texas ranch maintain its herd through the extreme drought of 2012 that forced other ranchers to sell livestock (Lengnick, 2016).

Healthy soils have good structure (tilth), which allows them to absorb and hold moisture, drain well, maintain adequate aeration, and foster deep, healthy crop root systems. Such soils sustain crops through dry spells, require less irrigation water, and undergo less ponding, runoff, and erosion during heavy rains (Magdoff and van Es, 2009; Moncada and Sheaffer, 2010; Rodale, 2015).

During California's recent drought, vegetable growers were faced with irrigation water use restrictions. In an OFRF-funded study conducted with Dr. Amelie Gaudin and colleagues at UC Davis, organic farmer Scott Park showed that his integrated approach to soil building, including diversified rotation, winter cover crops, minimum tillage, and applications of compost and beneficial microbes doubled his soil's moisture capacity and reduced irrigation water needs for tomato production by 6 to 11 inches per season (Gaudin et al., 2018).

Healthy, biologically active soils support plant root symbionts such as mycorrhizal fungi, and other beneficial soil micro-organisms that help crops obtain nitrogen, phosphorus, and other nutrients from soil organic matter and other slow-release organic sources, thereby reducing the need for soluble nutrient applications that can threaten water quality (Kloot, 2018; Rosolem et al., 2017; Sullivan et al., 2017; Hamel, 2004; Wander, 2015b; Wander et al., 2016). In a study of 13 organic tomato fields in central California, four of the best-managed fields showed "tightly coupled nitrogen cycling" in which soil soluble nitrogen levels were low enough to protect water resources yet the crop absorbed sufficient nutrients for top yields (Bowles et al., 2015). Tight nutrient cycling not only reduces fertilizer bills and enhances crop resilience to weather extremes, but also minimizes emissions of the powerful greenhouse gas nitrous oxide from soils.

Research recommendation: Development of management strategies to promote tightly coupled nutrient cycling in other crops and regions appears quite feasible, and should be considered a top research priority for agricultural resilience to climate change.

Cover Crops

Idle, bare soil is at risk. Protracted fallow periods such as a corn-soy or vegetable rotation without winter cover crops, or the traditional wheat-fallow system for dry farming in semiarid regions can deplete soil organic matter, starve-out mycorrhizal fungi and other beneficial organisms, aggravate soil erosion and compaction, and increase fertilizer and irrigation costs (Kabir, 2018; Rillig, 2004; Rosolem et al., 2017; Six et al., 2006). Growing cover crops during the off-season can sustain soil life, conserve nutrients, sustain soil health, and increase cash crop yields.

In Mediterranean climates such as central California and the Pacific Northwest, most of the rainfall occurs in winter while intensive vegetable production takes place from spring through fall, often depending on irrigation. Currently, few of these acres are planted in winter cover crops, yet cover crops can play a vital role in water and nutrient management. During the wet winter of 2017, cover crops made the difference between prompt infiltration and prolonged ponding in fields and orchards (Kabir, 2017). In the Salinas Valley of California, an organic vegetable double crop system of spring lettuce followed by fall broccoli sustained high lettuce yields only if a winter cover crop was planted after the broccoli to recover surplus nitrogen and deliver it to the following lettuce crop; winter fallow often led to a lettuce crop failure (Brennan et al., 2017). In addition to greatly enhancing resilience, the cover crop protected water quality and reduced greenhouse gas emissions.

Organic systems studies have shown that cover crops enhance soil health, nutrient cycling and crop nutrition, crop rooting depth and moisture acquisition, and overall stress resilience in other locations, including Illinois, Minnesota, Maryland, North and South Carolina (Gruver et al., 2016; Hooks et al., 2015; Hu et al., 2015; Marshall et al., 2016; Moncada and Sheaffer, 2010; Rosolem et al., 2017). Farmers in Montana, New York, and across the U.S. are gradually increasing their use of cover crops, citing soil health, yield stability, and reduced production costs (Jones et al., 2015; Mason and Wolfe, 2018; USDA SARE, 2017).

Research recommendation: Selecting the right cover crops and management methods can be challenging, especially in low rainfall regions where cover crops can deplete soil moisture and reduce yield in the following crop (Miller, 2016). While farmers and researchers have had good results with winter pea in dryland grain rotations (Olson-Rutz et al., 2017), more research is urgently needed to develop a menu of best cover crop options for limited-rainfall regions throughout the western half of the U.S.

Crop Rotation

The importance of crop rotation and diversification in improving soil health, managing weeds, pests, and diseases, and reducing risks of catastrophic financial losses when one crop fails, have been well documented in both conventional and organic systems (Mohler and Johnson, 2009; Moncada and Sheaffer, 2010; Ponisio et al., 2014). Adding a perennial grass-legume sod phase (one to three years) to a rotation of annual crops can be especially effective in restoring soil health and fertility, and reducing weed populations. Crop-livestock integrated farming systems can recover much of the income foregone by rotation cropland into perennial sod through grazing and haying. Farming systems studies funded through the Organic Research and Extension Initiative and other USDA National Institute for Food and Agriculture (NIFA) programs have demonstrated the soil health and climate resilience benefits of sound crop rotations, and provided practical guidelines for designing rotations for organic systems (Cavigelli et al., 2013; Moncada and Sheaffer, 2010; Wander et al., 1994).

Management-intensive rotational grazing systems can restore grassland soil health and moisture capacity, improve forage quality, protect water resources, and greatly enhance resilience in livestock production as well as sequestering carbon in the soil. For example, North Dakota rancher Gabe Brown (2018) restored 5,000 acres of degraded crop and rangeland by applying the four NRCS principles to his crops, rotationally grazing multispecies livestock, and nearly eliminating synthetic inputs. Over a 20-year period, soil organic matter recovered from 2% to 7%, representing about 125,000 tons of carbon removed from the atmosphere; meanwhile the ranch continues to thrive economically. Other success stories with regionally-adapted rotational grazing systems abound from across the U.S. (Teague et al., 2016; The Natural Farmer, 2014-15 and 2016-17).

Research recommendation: Additional research is needed to address educational, economic, social, and logistical barriers to transitioning more of the nation's livestock production to this promising approach.

Compost and Organic Nutrient Sources

Compost, manure, and other organic sources of nutrients has long been a hallmark of organic systems, and can, when used judiciously, contribute to soil health, agricultural resilience, and mitigation of greenhouse gas emissions. In organic farming systems trials in Hawaii, Iowa, Maryland, and elsewhere, cover cropping in conjunction with compost or manure applications enhanced soil health and organic matter to a greater degree than either practice alone (Delate et al., 2015; Hooks et al., 2015). A single compost application to grazing lands in California substantially improved forage vigor and carbon sequestration (Ryals and Silver, 2013). A life cycle analysis confirmed that diverting manure from storage lagoons and yard and food wastes from landfills for composting greatly reduced net greenhouse gas impacts (DeLonge et al., 2013).

Research recommendation: Research is needed to end "organic waste" in the U.S. and ensure that municipal leaves, yard waste, food waste, and confinement manure is composted and returned to the land at rates consistent with sound nutrient management.

Crop and Livestock Breeding

Crop breeding for development of new crop varieties that perform well in soil health-enhancing organic and sustainable production systems, and that show increased resilience to drought, temperature extremes, and other weather-related stresses. In a 2015 project to identify plant breeding needs for the Northeastern U.S., farmers and breeders noted, "*Cultivars are most productive under the conditions for which they were bred. Northeast growers [need] regionally-adapted varieties that were bred to thrive in the Northeast, with the climate and pests unique to our region. Furthermore, cultivars bred under conventional management—aided by synthetic fertilizer, herbicides and pesticides—will likely not be as productive under organic management.*" (Hultengren et al., 2016, page 26). Scientists have even documented a loss in the capacity of some modern crop cultivars to partner with beneficial soil microbes for nutrient uptake and disease resistance. In their work with organic producers to develop new cultivars, they have begun to restore this capacity, which can play a key role in overall agricultural resilience to climate change (Goldstein, 2015, 2016; Zubieta and Hoagland, 2016).

Over the past 15 years, several farmer-scientist participatory plant breeding teams funded through the USDA Organic Research and Extension Initiative (OREI) and Organic Transitions Program (ORG) have begun to address the need for new crop cultivars better suited to organic systems.

For example, the Northern Vegetable Improvement Collaborative or NOVIC (three rounds of OREI funding from 2010-2018) has released several new cultivars of tomato, sweet corn, squash, and broccoli for organic systems, with more on the way, including cucumber, cabbage, and pepper. NOVIC has produced two books to help farmers enhance organic seed systems: Organic Crop Breeding and The Organic Seed Grower.

Other OREI funded projects focus on wheat, soybean, and dry bean, including selecting improved strains of N fixing nodule bacteria (rhizobia), and development of vigorous, weed-competitive strains. One new food-grade soybean cultivar has been released (Orf et al., 2016; Place et al., 2011; Worthington et al., 2015).

Based on research confirming genetic regulation of plant root depth and extent, Kell (2011) has recommended breeding crops for larger, deeper root systems to build SOM, sequester carbon deep in the soil profile, and enhance nutrient and moisture use efficiency. Each of these plant breeding developments can contribute to soil health and risk reduction by increasing climate resilience, reducing nutrient and water input needs, and enhancing organic matter inputs to the soil.

Research recommendation: Additional long-term research investment in plant breeding for sustainable and organic systems is essential for realizing potential to enhance beneficial plant-soil-microbe interactions, nutrient use efficiency, soil carbon sequestration, and resilience to drought and other stresses. Farmers especially need regionally adapted cultivars equipped to withstand anticipated region-specific climate change stresses.

Identifying and developing livestock breeds that can tolerate weather extremes and thrive in management intensive rotational grazing systems is also a top research priority. We appreciate that, in recent years, OREI Requests for Applications include animal breeding for pasture-based organic production, and urge Congress to continue and expand funding for USDA development of public livestock breeds and crop cultivars to help all farmers and ranchers meet the climate challenge.

Conservation Agriculture and Organic

Conservation agriculture integrates crop rotations, cover crops, and organic soil amendments with no-till practices to build soil health and protect soil organic carbon from physical disturbances. However, continuous no-till production of annual crops relies on synthetic inputs for weed control and fertility. This chemical disturbance can harm soil biota and negatively impact the surrounding environment and human health. For example, normal use rates of glyphosate herbicides have been shown to inhibit mycorrhizal fungi, which play significant roles in soil carbon sequestration, nutrient cycling, and overall resilience (Druille et al., 2013; Hamel, 2004).

While organic systems require some level of physical disturbance to control weeds, they eliminate synthetic inputs and can significantly reduce tillage as well. Reduced tillage coupled with the full suite of soil health practices—crop diversification, cover cropping, organic amendments, and sound nutrient management—can enhance carbon sequestration and build climate resiliency in organic agricultural systems.

Concern has been raised that large-scale farms that adopt USDA certified organic practices through input substitution may not reduce net GHG footprints (Lorenz and Lal, 2016; McGee, 2015). What we are recommending today is research, education and extension to support a holistic approach to implementing the National Organic Standards that embraces the NRCS Soil Health Principles. One research priority is to address the socio-economic, logistical, and policy barriers to implementation of *sustainable* organic systems that will enhance soil carbon sequestration, mitigate greenhouse gas emissions, and improve resilience on both large and smaller scale farms.

Organic Practices and Climate Mitigation
All farmers have a major stake in efforts to curb further climate change and improve the resilience of farming and ranching systems. Resilient, diversified agriculture systems, including crop-livestock integration, can help maintain and even improve economic, ecological, and social benefits for farm families in the face of dramatic exogenous changes such as climate change and price swings; and will thereby maintain and improve the nation's food security.

In addition to improving resilience to the impacts of climate changes already underway, the soil health practices outlined thus far can sequester carbon and reduce direct agricultural greenhouse gas emissions. Estimates of potential climate mitigation through widespread adoption of sustainable farming range from reducing U.S. agriculture's GHG footprint in half (Chambers et al., 2016), to making U.S. agriculture carbon negative. Organic production methods also significantly reduce greenhouse gas emissions through decreased use of fossil fuel-based inputs.

Several USDA supported studies have conducted in-depth comparisons of C sequestration or total net greenhouse gas footprint in organic versus conventional systems, which clearly show that organic systems can effectively sequester soil organic carbon and build resilience to climate disruption by implementing the NRCS principles of keeping soil covered, maintaining living roots, enhancing biodiversity, and minimizing soil disturbance. However, other greenhouse gas emissions, especially nitrous oxide from fertilized or manured soils, show more complex responses to management practices. For example, while optimal soil and nutrient management of organic production of lettuce in

Colorado and tomato in California have virtually eliminated nitrous oxide losses, broccoli required so much N from organic sources to reach optimum yield that nitrous oxide emissions were estimated to negate soil carbon sequestration from best organic practices (Bowles et al., 2015; Li and Muramoto, 2009; Toonsiri et al., 2016).

Research recommendation: More research, education, and extension is needed to help farmers and ranchers implement the best practices for climate mitigation and adaptation for their locales, climates, soils, crop mixes, and production systems. Research is critical to developing effective tools for organic farmers and ranchers, but we need to ensure this information is verified, delivered, demonstrated, and adopted by the agricultural community. The funding and support of the University Extension system is critical to completing this cycle and ensuring that federal research funding produces farming strategies that are widely adopted. We need trained Extension personnel to do this work. Farmers obtain their information from many sources, but they need trusted scientific resources to be successful.

Conclusion

We greatly appreciate the support Congress has provided for key USDA programs that address research, education, and extension for organic and sustainable agriculture. These programs have been on the cutting edge of addressing climate change and helping farmers build resiliency and manage risk. The Sustainable Agriculture Research and Education (SARE) program, as well as the Organic Research and Extension Initiative (OREI) and Organic Transitions Program (ORG) have supported hundreds of studies that help both organic and conventional farmers build soil health, reduce greenhouse gas emissions, sequester carbon, and address the threat of climate disruption. Thanks to these programs, farmers are using more efficient irrigation systems and adopting organic management practices to limit the application of fertilizers and pesticides as well as build the health and resiliency of their soil.

SARE, ORG, and OREI programs invest in innovative research that helps farmers be more resilient and adaptable to climate disruptions. The SARE program has made huge contributions in many areas, especially cover cropping, rotational grazing, local and regional food systems, and agroecology systems research. In general, SARE has a strong focus on delivery of information to the farming community. ORG has prioritized research related to the impacts of crop rotation, livestock-crop system integration, tillage, cover crop, and fertility inputs on greenhouse gas mitigation and other ecosystem services. ORG has also helped address barriers to successful transition to organic practices. OREI has greatly advanced our understanding of best soil, nutrient, crop, weed, pest, and disease management for organic systems, and has provided vital support for development of crop cultivars and, more recently, livestock breeds suited to organic production. OFRF thanks Congress for investing in these crucial programs.

However, adaptation strategies will require both short- and long-term changes, including cost-effective investments in new technologies, water infrastructure, emergency preparation for response to extreme weather events, development of resilient crop varieties that tolerate temperature and precipitation stresses, building soil health, and adopting new or improved land use and management practices. More research is necessary to understand the challenges, and to create solutions.

Researchers have identified some promising new strategies that merit further research and development into practical guidelines for producers. Additional research is needed to bridge the remaining gaps between findings to date and practical application in the context of a particular farm, soil type, climate, crop mix, and production system. Producers need guidance on context-specific management practices, including a menu of options that they can apply to their specific agricultural systems. Farmers also need practical, reliable tools to monitor soil organic carbon (SOC) and measure the impact of their practices on greenhouse gas (GHG) emissions.

Research is only the first step. Farmers will require continued and enhanced support to take the results of the research and integrate relevant components into their farming operations. It is critical to our success that farmers are provided adequate education, training, and technical assistance. Building and expanding our current Extension programs to support farmers during these difficult transitions is essential for farmers to acquire new skills, tools, and technology necessary to adapt to climate change. Programs that support the delivery and dissemination of information into the hands of America's farmers and ranchers are more important than ever. Extension and education for farmers is key, yet organic expertise of Extension agents varies significantly state by state. Organic producers in all parts of the country need to be served effectively by Extension. Congress has worked hard to increase the funding for important research programs at USDA; much more support is needed to ensure that both basic and applied research is available and more easily adopted by the farmers and ranchers around the country that are on the front lines of climate change.

We urge federal policy-makers to prioritize support and oversight of federal farm bill policies and programs that enable farmers and ranchers to adopt sustainable and organic agricultural production systems to address the challenges posed by a rapidly changing climate. We encourage USDA research, education, and economic divisions such as the Agriculture Research Service (ARS) and National Institute of Food and Agriculture (NIFA) to invest more in the improvement and adoption of organic farming systems, and to prioritize addressing solutions that help farmers be more sustainable and successful in the face of changing agricultural conditions. The capacity of NIFA to support outstanding research, and the Economic Research Service to provide unbiased analysis of agricultural economics, helps support farmers and strengthen our agricultural system. Maintaining this capacity and expertise in a centralized location will help ensure these agencies continue to serve the agriculture community in a coordinated and efficient manner.

Coordination and sharing of key research findings with agencies such as the National Resources Conservation Service (NRCS) and Risk Management Agency (RMA) is critical to ensuring farmers can implement these best practices. Both NRCS and RMA programs provide support for farmers managing and addressing risk. In the past, NRCS has struggled to support organic producers in simultaneously planning, implementing, and complying with conservation and organic standards. Although NRCS has expanded and significantly improved their outreach and services to organic producers across the country, several conservation measures that help farmers build resilience are sometimes penalized in crop insurance programs. The farm bill did make it easier for farmers to integrate cover cropping practices on their farms. Thanks to new language in the farm bill, it will be easier for RMA to include cover cropping in their list of Good Farming Practices. We believe the time is now for RMA to amend Good Farming Practices and conservation practice guidance to provide that all NRCS conservation practices and enhancements are automatically recognized as Good Farming Practices by RMA, without any caveats or qualifications. In our view, no farmer should be penalized or lose coverage under any crop insurance policy for using conservation practices and enhancements that are approved by NRCS.

These are challenging times for the people who grow our food, and we urge Congress and USDA to ensure federal programs that include research, education, extension, and program implementation support organic producers and other farmers and ranchers that seek to integrate organic practices into their operations. Thank you for your commitment and support of policies that will help our country's agricultural producers manage risk, increase resiliency, and provide food security for our population.

References:

Blanco-Canqui, H., and C. A. Francis. 2016. Building resilient soils through agroecosystem redesign under fluctuating climatic regimes. J. Soil & Water Conserv. 71(6): 127A-133A.

Bowles, T. M., A. D. Hollander, K. Steenwerth, and L. E. Jackson. 2015. Tightly-Coupled Plant-Soil Nitrogen Cycling: Comparison of Organic Farms across an Agricultural Landscape. PLOS ONE. http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0131888.

Brown, G. 2018. Dirt to Soil: One Family's Journey into Regenerative Agriculture. Chelsea Green Publishing, White River Junction, VT. 223 pp.

Cavigelli, M. A., Teasdale, J.R., and J. T. Spargo. 2013. Increasing Crop Rotation Diversity Improves Agronomic, Economic, and Environmental Performance of Organic

Grain Cropping Systems at the USDA-ARS Beltsville Farming Systems Project. Crop Management 12 (1) Symposium Proceedings: USDA Organic Farming Systems Research Conference. https://dl.sciencesocieties.org/publications/cm/tocs/12/1.

Chambers, A., R. Lal, and K. Paustian. 2016. Soil carbon sequestration potential of US croplands and grasslands: implementing the 4 per Thousand Initiative. J. Soil & Water Conserv. 71(3): 68A-74A

Delate, K., C. Cambardella, and C. Chase. 2015. Effects of cover crops, soil amendments, and reduced tillage on carbon sequestration and soil health in a long term vegetable system. Final report for ORG project 2010-03956.

DeLonge, M. S., R. Ryals, and W. L. Silver. 2013. A lifecycle model to evaluate carbon sequestration potential and greenhouse gas dynamics of managed grasslands. Ecosystems 16: 962-979.

Druille, M., Cabello, M.N., Omacini, M., and Golluscio, R.A. 2013. Glyphosate reduces spore viability and root colonization of arbuscular mycorrhizal fungi. Applied Soil Ecology 64:99–103; doi: https://doi.org/10.1016/j.apsoil.2012.10.007.

Gaudin A., Park S., Lloyd M., Azimi A., Velasco R., and Renwick, L. 2018. Developing integrated irrigation management strategies to improve water and nutrient use efficiency of organic processing tomato in California. Final report to Organic Farming Research Foundation.

Goldstein, W. 2015. Breeding corn for organic farmers with improved N efficiency/N fixation, and protein quality. Proceedings of the Organic Agriculture Research Symposium, LaCrosse, WI February 25-26, 2015. http://eorganic.info/node/12972

Gruver, J., R. R. Weil, C. White, and Y. Lawley. 2016. Radishes A New Cover Crop for Organic Farming Systems. http://articles.extension.org/pages/64400/radishes-a-new-cover-crop-for-organic-farming-systems.

Hamel, C. 2004. Impact of arbuscular mycorrhizal fungi on N and P cycling in the root zone. Can J Soil Sci. 84(4):383-395.

Hooks, C. R., K. H. Wang, G. Brust, and S. Mathew. 2015. Using Winter Cover Crops to Enhance the Organic Vegetable Industry in the Mid-Atlantic Region. Final report for OREI project 2010-01954. CRIS Abstracts.*

Hu, S., S. Hu, W. Shi, A. Meijer, and G. Reddy. 2015. Evaluating the Potential of Winter Cover Crops for Carbon Sequestration in Degraded Soils Transitioning to Organic Production. Project proposal and final report for ORG project 2010-04008.

Huffstutter, P.J, and Pamuk, H. 2019. “1 Million Acres of Midwest Farmlands Flooded as Corn Planting Deadlines Approach.” Insurance Journal. https://www.insurancejournal.com/news /midwest/2019/04/01/522389.htm

Hultengren, R., M. Glos, and M. Mazourek. 2016. Breeding Research and Education Needs Assessment for Organic Vegetable Growers in the Northeast. (Dataset). eCommons Digital Repository at Cornell University, 35 pp.

Intergovernmental Panel on Climate Change (IPCC). 2014. Climate Change 2014: Mitigation of Climate Change, Working Group III Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. https://www.ipcc.ch/report/ar5/wg3/.Chapter 11 Agriculture, Forestry, and Other Land Use (AFOLU), and Annex II Metrics and Methodology.

Jerkins, D. and J. Ory. 2016. 2016 National Organic Research Agenda: Outcomes and Recommendations from the 2015 National Organic Farmer Survey and Listening Sessions. Organic Farming Research Foundation (www.ofrf.org).

Jones, C., R. Kurnick, P. Miller, K. Olson-Rutz, and C. Zabinski. 2015 Montana Cover Crop Survey Results. Dept. of Land Resources and Environmental Sciences, Montana State University. 15 pp.

Kabir, Z. 2018. Rethinking the nutrient management paradigm for soil health. NRCS webinar, August 14, 2018. Science and Technology Training Library. http://www.conservationwebinars.net/listArchivedWebinars

Kell, D.B. 2011. Breeding crop plants with deep roots: their role in sustainable carbon, nutrient and water sequestration. Ann. Bot. 108(3): 407–418.

Kirschbaum, M.U.F. 1995. The temperature dependence of soil organic matter decomposition, and the effect of global warming on soil organic C storage. Soil Biology and Biochemistry. 27(6): 753–760.

Kloot, Robin. 2018. Using adaptive nutrient management to answer “how much fertilizer do you actually need?” NRCS webinar May 8, 2018. Science and Technology Training Library. http://www.conservationwebinars.net/listArchivedWebinars

Lal, R. 2016. Beyond COP21: Potential challenges of the “4 per thousand” initiative. J. Soil & Water Conserv. 71(1): 20A-25A.

Lengnick, L. 2016. New Times, New Tools: Cultivating Climate Resilience on Your Organic Farm. http://articles.extension.org/pages/73466/new-times-new-tools:-cultivating-climate-resilience-on-your-organic-farm.

Li, C., Salas, W. and Muramoto, J. 2009. Process Based Models for Optimizing N Management in California Cropping Systems: Application of DNDC Model for nutrient management for organic broccoli production. Conference proceedings 2009 California Soil and Plant Conference, 92-98. Feb. 2009. http://ucanr.edu/sites/calasa/files/319.pdf.

Lorenz, K., and R. Lal. 2016. Environmental Impact of Organic Agriculture. Advances in Agronomy. 139: 99-152.

Magdoff, F. and van Es, H. 2009. Building Soils for Better crops, 3rd ed. Sustainable Agriculture research and Education (SARE). http://www.sare.org/Learning-Center/Books/Building-Soils-for-Better-Crops-3rd-Edition

Marshall, M.W., P. Williams, A. Mirzakhani Nafchi, J. M. Maja, J. Payero, J. Mueller, and A. Khalilian. 2016. Influence of Tillage and Deep Rooted Cool Season Cover Crops on Soil Properties, Pests, and Yield Responses in Cotton. Open Journal of Soil Science, 6, 149-158.
http://dx.doi.org/10.4236/ojss.2016.610015

Mason, C. W., and D. W. Wolfe. 2018. Survey of Costs, Constraints, and Benefits of Soil Health in New York: Initial Report and Summary. Reduced Tillage in Organic Systems Field Day Program Handbook, July 31, 2018, Cornell University Willsboro Research Farm, Willsboro NY, pp 8-9.
https://rvpadmin.cce.cornell.edu/uploads/doc_699.pdf

McGee, J.A., 2015. Does certified organic farming reduce greenhouse gas emissions from agricultural production? Agric. Hum. Values 32, 255–263.

Miller, P., 2016. Using cover crop mixtures to improve soil health in low rainfall areas of the northern plains. Final report for Western SARE project SW11-099, 40 pp.
http://landresources.montana.edu/soilfertility/documents/PDF/reports/CCMFinalRptSW11-099Apr2016.pdf

Mohler, C. A. and S. E. Johnson. 2009. Crop Rotations on Organic Farms. Sustainable Agriculture research and Education (SARE) and Natural Resource, Agriculture and Engineering Service (NRAES). 156 pp. http://www.sare.org/Learning-Center/Books

Moncada, K., and Sheaffer, C., 2010. Risk Management Guide for Organic Producers. U. Minnesota. 300 pp. Chapter 13, Winter Cover Crops.
http://organicriskmanagement.umn.edu/

Myers, S.S., Smith, M. R., Guth, S., Golden, C. D., Vaitla, B., Mueller, N. D., Dangour, A. D., Huybers, P. 2017. Climate change and global food systems: Potential impacts on food security and undernutrition. *Annual Review of Public Health*. 38. 259-277.

Olson-Rutz, K., C. Jones, and P. Miller. 2010. Soil nutrient management on organic grain farms in Montana. Montana State University Extension bulleting EB0200, 16 pp. http://msuextension.org/publications/AgandNaturalResources/EB0200.pdf

Orf, J. H., T. E. Michaels, M. J. Sadowsky, and C. C. Sheaffer. 2016. Improving soybean and dry bean varieties and Rhizobium strains for organic systems. Final report on OREI project 2011-01942.

Place, G.T., S.C. Reberg-Horton, D.A. Dickey and T.E. Carter. 2011. Identifying soybean traits of interest for weed competition. Crop Science 51:2642-2654.

Ponisio, L.C., M'Gonigle, L.K., Mace, K.C., Palomino, J., de Valpine, P., Kremen, C., 2014.
Diversification practices reduce organic to conventional yield gap. Proc. R. Soc. B 282, 20141396.

Rillig, M.C. 2004. Arbuscular mycorrhizae, glomalin, and soil aggregation. Can. J. Soil Sci. 84(4): 355–363.

Rodale Institute. 2014. Regenerative organic agriculture and climate change: a down-to-earth solution to global warming. 16 pp. https://rodaleinstitute.org/assets/RegenOrgAgricultureAndClimateChange_20140418.pdf.

Rosolem, C. A., K. Ritz, H. Cantarella, M. V. Galdos, M. J. Hawkesford, W. R. Whalley, and S. J. Mooney. 2017. Enhanced plant rooting and crop system management for improved N use efficiency. Advances in Agronomy 146: 205-239.

Ryals, R., and W.L. Silver. 2013. Effects of organic matter amendments on net primary productivity and greenhouse gas emissions in annual grasslands. Ecol. Appl. 23(1): 46–59.

Schonbeck, M., Jerkins, D., and J. Ory. 2016. Taking Stock: Analyzing and Reporting Organic Research Investments, 2002-2014. Organic Farming Research Foundation (www.ofrf.org).

Schonbeck, M., Jerkins, D., and J. Ory. 2017. Soil Health and Organic Farming: Building Organic Matter for Healthy Soils: An Overview. Organic Farming Research Foundation (www.ofrf.org), 39 pp.

Schonbeck, M., Jerkins, D., and Snyder, L.D. 2018. Soil Health and Organic Farming: Organic Practices for Climate Mitigation, Adaptation, and Carbon Sequestration. Organic Farming Research Foundation (www.ofrf.org), 79 pp.

Six, J., S.D. Frey, R.K. Thiet, and K.M. Batten. 2006. Bacterial and Fungal Contributions to Carbon Sequestration in Agroecosystems. Soil Sci. Soc. Am. J. 70(2): 555 – 569.

Sullivan, D. M., E. Peachey, A.L. Heinrich, and L.J. Brewer. 2017. Nutrient Management for Sustainable Vegetable Cropping Systems in Western Oregon. Oregon State Extension Bulletin EM 9165.

Teague, R. 2016-17. Regeneration of soil by multi-paddock grazing. Transcript of Sept 7, 2016 presentation at Harvard by Jack Kittredge. The Natural Farmer, winter 2016-17: B26-B30.

The Natural Farmer 2014-15 Grazing and 2016-2017 Carbon Farming.

Toonsiri, P., S. J. Del Grosso, A. Sukor, and J. G. Davis. 2016. Greenhouse Gas Emissions from Solid and Liquid Organic Fertilizers Applied to Lettuce J. Environmental Quality Vol. 45 No. 6, p. 1812-1821.

USDA Sustainable Agriculture Research and Education (SARE) 2017. Annual cover crop survey reports. http://www.sare.org/Learning-Center/Topic-Rooms/Cover-Crops/Cover-Crop-Surveys

Wander, M. M., 2015b. Soil Fertility in Organic Farming Systems: Much More than Plant Nutrition. http://articles.extension.org/pages/18636/soil-fertility-in-organic-farming-systems:-much-more-than-plant-nutrition

Wander, M., N. Andrews, and J. McQueen. 2016. Organic Soil Fertility. http://articles.extension.org/pages/18565/organic-soil-fertility

Worthington, M., S.C. Reberg-Horton, G. Brown-Guedira, D. Jordan, R. Weisz, and J. P. Murphy. 2015. Morphological Traits Associated with Superior Weed Suppressive Ability of Winter Wheat against Italian Ryegrass. Crop Science 55:50-56.

Zubieta, L. and L. A. Hoagland. 2017. Effect of Domestication on Plant Biomass and Induced Systemic Resistance in Tomato (*Solanum lycopersicum* L.). Poster Number 1209, Tri-Societies Meetings, Tampa, FL, Oct 24, 2017.