Leading with Soil

Scaling Soil Carbon Storage in Agriculture

Carbon180

ABOUT CARBON180

Carbon180 is a new breed of climate-focused NGO on a mission to fundamentally rethink carbon.

We partner with policymakers, scientists, and businesses around the globe to develop policy, promote research, and advance solutions that transform carbon from a pollutant to a resource and foster a prosperous, carbon-conscious economy that removes more from the atmosphere than we emit.

ACKNOWLEDGEMENTS

We would like to thank all the people and organizations across the Rocky Mountains whose generosity, kindness, and openness made this report possible. Many producers welcomed us to their farms and ranches and shared with us their stories of soil health. The people doing this work are facing increasingly thin margins, uncertain markets, and a rapidly changing climate. Times are tough for U.S. agricultural producers. These stories of the agricultural way of life — the challenges, what works, what doesn't, and a vision for the future — inspired and formed the foundation of this report. Though a lot of this report focuses specifically on policy recommendations, we want to acknowledge what is at stake: a way of life and the communities of people who produce our food, fuel, and fiber.

We express our sincerest appreciation for the people moving soil health work forward, from producers and on-the-ground partner organizations to state agencies and scientists who are working together to ensure soil health practices are implemented and soil carbon storage is durable.

Many thanks to the contributors and reviewers of this report.

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Section One

Executive Summary

Agricultural practices that build soil health and increase carbon storage offer a significant economic and environmental opportunity for farmers and ranchers across the United States. The National Academies of Sciences found that soil carbon storage could offset up to 10% of U.S. emissions at a low cost[1]— making it a powerful climate solution. Beyond the climate benefit, soil carbon practices can strengthen U.S. agricultural production by building producer resilience to climate impacts, reducing inputs costs, increasing yields, and improving water quality.[2] Despite the significant opportunity, such practices have been slow to gain traction at a meaningful scale.

Carbon180's Leading with Soil initiative aims to accelerate the adoption of practices that store carbon by working with agricultural producers on the ground to identify and address key barriers. Specifically, we found that despite growing interest in soil carbon storage in many states, the insufficient technical assistance, scientific knowledge gaps, and lack of strong and reliable incentives significantly hinder the implementation of these agricultural practices. As a result, current adoption continues to fall short on a time and scale relevant for addressing climate change.[3] Existing federal government programs aimed at removing these barriers, while extremely popular, are insufficient to meet the growing demand across the agriculture sector and are not explicitly focused on carbon outcomes. Fully scaling such practices will require federal support to alleviate the remaining barriers facing agricultural producers today.

1. Fargione, J. E., Bassett, S., Boucher, T., et al. (2018). Natural climate solutions for the United States. *Science Advances* 4(11): eaat1869.
2. Smith, P., Adams, J., Beerling, D.J., et al. (2019). Land-management options for greenhouse gas removal and their impacts on ecosystem services and the Sustainable Development Goals. *Annual Review of Environment and Resources* 44, 255–286.
3. Chambers, A., Lal, R. & Paustian, K. (2016). Soil carbon sequestration potential of U.S. croplands and grasslands: Implementing the 4 per Thousand Initiative. *Journal of Soil and Water Conservation* 71(3), 68A-74A.

Despite significant interest, three core barriers continue to impede the scale of soil carbon storage:

EDUCATION

Technical assistance and education resources are critical for farmers and ranchers to implement new practices and capitalize on the value of soil health.

SCIENCE

Practices need to be linked with soil health and soil carbon outcomes in an accessible and reproducible way.

INCENTIVES

New financial incentives and tweaks to existing incentives can reduce barriers to adoption and encourage durable carbon storage.

In this report, we translate lessons learned on the ground from farmers and ranchers across the Rocky Mountains into a menu of federal policy recommendations. We break these recommendations into three categories: education, science, and incentives. We provide high level recommendations here, but provide more detail in the sections below and in the policy recommendations section (page 18) and appendices (page 42).

Education

Agricultural producers rely on technical assistance providers such as the NRCS to support decision-making and practice adoption. Despite increasing demand, technical assistance providers often are short-staffed and lack specific knowledge of soil carbon storage. With ample funding and a simplified application process, the NRCS could serve as a more salient resource — equipping producers with the information they need to transition their operations.

HIGH-LEVEL RECOMMENDATIONS

- Fund demonstration projects.
- Bolster the technical capacity of local NRCS offices.
- Increase support for peer networks.

Science

Producers lack accessible and complete scientific information to inform decision-making for their operations. In addition, markets for soil carbon are difficult for producers to access because of inconsistent, onerous, and expensive soil carbon quantification methodology. Significant research is needed to develop improved soil carbon assessment methodology, prove out soil carbon practices across agricultural contexts and geographies, and better understand the economic costs and benefits of practice implementation.

HIGH-LEVEL RECOMMENDATIONS

- Develop cost-effective and accessible soil carbon assessment methodology.
- Solidify soil health metrics across the U.S.
- Fund research and demonstration projects across agricultural contexts and geographies.
- Pave the way for better policy design through economic research.
- Build a national carbon observatory.

Incentives

The benefits of soil carbon storage vary across operations and often take time to manifest. There is also no robust financial payoff explicitly for soil carbon storage. These factors make it difficult for farmers to absorb the upfront cost of transitioning practices. Subsidizing necessary infrastructure, expanding and adjusting existing financing support, and creating new, durable market incentives can bring these practices to scale.

HIGH-LEVEL RECOMMENDATIONS

- Subsidize infrastructure to scale soil carbon storage.
- Expand programs to non-owner operators.
- Adjust existing incentives to account for the speed of soil carbon accrual in agricultural soils.
- Adapt the Federal Crop Insurance Program to address climate impacts.
- Simplify access to incentives.
- Improve financing mechanisms and fully fund soil health programs.
- Create new, more durable market incentives.

Long-term soil carbon storage is only achievable with durable changes to our entire agricultural production system. While in this report we provide single policy recommendations to address single barriers, we recommend enacting a suite of policies that reinforce each other and marshall a system of change. Beyond the climate benefits of soil health and decarbonization of the agriculture sector, working closely with agricultural producers also builds a constituency for broader climate policy—a win for the climate, agricultural sustainability, and food security.

Section Two

Leading with Soil

Background

Agriculture in the United States is at a critical inflection point. Farmers and ranchers across the country are already facing significant climate impacts from droughts,[4] floods,[5,6] and wildfires. Combined with fluctuations in global commodity markets, it is becoming increasingly challenging for farms and ranches to remain profitable.[7] There is a growing recognition that our current agricultural systems need to evolve to meet the demands of a growing population in the face of a rapidly changing climate.

Agriculture is a complex sector that in the past has had difficulty aligning with ambitious climate objectives. Recent changes, however, have begun to shift the story. After decades of demonstration, producers have begun to see the benefits of agricultural practices that store carbon. At the same time, younger generations of producers are taking on a larger role in managing operations, and they are increasingly making use of advanced technologies — especially those that can monitor soil outcomes and tie them directly to changes in their operations. In addition, producers in many parts of the country are already experiencing the realities of climate change and are looking for approaches that can help them become more resilient, productive, and profitable. Some producers have also begun to capitalize on emerging markets for carbon and are experimenting with business models that explicitly reward carbon-rich soils. While this momentum is promising, these shifts are happening in a disconnected and incremental way, impeding our ability to improve agricultural resilience and address the climate crisis in a timely manner.

4. Medellín-Azuara, J., MacEwan, D., Howitt, R. E., Sumner, D. A. & Lund, J. R. (2016). *Economic Analysis of the 2016 California Drought on Agriculture.* Center for Watershed Sciences, University of California - Davis.
5. Tigchelaar, M., Battisti, D.S., Naylor, R.L. & Ray, D.K. (2018). Future warming increases probability of globally synchronized maize production shocks. *Proceedings of the National Academy of Sciences* 115(26), 6644-6649.
6. Rosenzweig, C., Tubiello, F.N., Goldberg, R., Mills, E. & Bloomfield, J. (2002). Increased crop damage in the U.S. from excess precipitation under climate change. *Global Environmental Change* 12(3), 197-202.
7. Prager, D. L., Tulman, S. & Durst, R. (2018). *Economic Returns to Farming for U.S. Farm Households.* USDA.

Management Practices for Soil Carbon Storage:

CONSERVATION TILLAGE:	Minimize soil disturbance.
PERENNIALIZATION:	Develop and grow perennial crops, which reduce the need to till.
COVER CROPPING:	Grow crops during the off-season to maintain plant cover and reduce erosion.
DOUBLE CROPPING:	Grow an additional crop during the growing season.
CROP ROTATION:	Rotate the crop(s) between growing seasons.
MANAGED GRAZING:	Rotate grazing of livestock between pastures to stimulate plant regrowth and add manure to the soil.
COMPOST APPLICATION:	Add compost to a field or pasture.

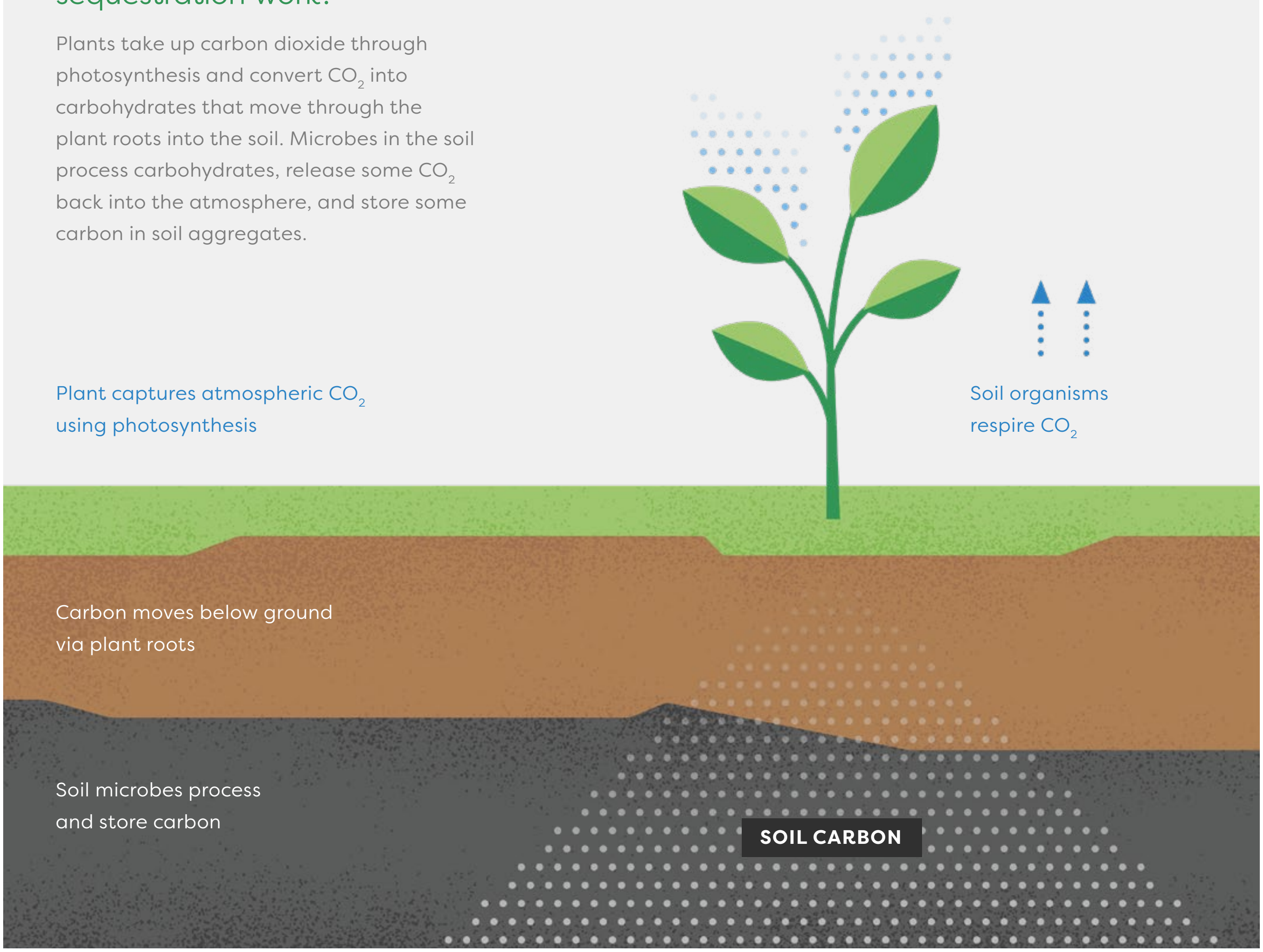
Soil Carbon Storage

Over the past few centuries, agriculture and land-use changes have depleted soil carbon globally and in the United States.[8] With a shift in agricultural management practices, there is an opportunity to build back almost half the soil carbon we have lost,[2] presenting a huge climate, economic, and agricultural opportunity. Carbon-rich soils improve agricultural bottom lines by lowering reliance on external inputs such as fertilizer, increasing crop yields, enhancing land and water resources, and building greater resilience to climate impacts.[9] In the United States, agricultural soils have the capacity to sequester up to 10% of domestic greenhouse gas emissions annually for as little as $10 per ton.[10]

8. Sanderman, J., Hengl, T. & Fiske, G.J. (2017). Soil carbon debt of 12,000 years of human land use. *Proceedings of the National Academy of Sciences* 114(36), 9575-9580.
9. Smith, P., Adams, J., Beerling, D.J., et al. (2019). Land-management options for greenhouse gas removal and their impacts on ecosystem services and the Sustainable Development Goals. *Annual Review of Environment and Resources* 44, 255–286.
10. Fargione, J.E., Bassett, S., Boucher, T., et al. (2018). Natural climate solutions for the United States. *Science Advances* 4(11): eaat1869.

How does soil carbon sequestration work?

Plants take up carbon dioxide through photosynthesis and convert CO_2 into carbohydrates that move through the plant roots into the soil. Microbes in the soil process carbohydrates, release some CO_2 back into the atmosphere, and store some carbon in soil aggregates.



Soil Health and Carbon Storage

Carbon is an essential, and often forgotten, soil resource. It drives soil fertility by improving soil structure,[11] increasing water infiltration, and helping release nutrients for plant growth. Healthy soils are carbon-rich and deliver a double benefit: improving agricultural production while simultaneously helping to address climate change. Because of this, many healthy soils practices also help sequester more carbon in soil. These include practices that reduce soil disturbance and maintain plant cover, helping increase carbon uptake and reduce carbon loss — at the same time, enhancing overall productivity.[12,13] We use the terms "soil carbon" and "soil health" interchangeably in this report.

11. Six, J., Paustian, K., Elliott, E. T. & Combrink, C. (2000). Soil Structure and Organic Matter I. Distribution of Aggregate-Size Classes and Aggregate-Associated Carbon. *Soil Science Society of America Journal* 64, 681-689.

12. Grandy, A.S. & Robertson, G.P. (2007). Land-Use Intensity Effects on Soil Organic Carbon Accumulation Rates and Mechanisms. *Ecosystems* 10, 59–74.

13. Nunes, M.R., van Es, H.M., Schindelbeck, R., James, A., Ristow, A. & Ryan, M. (2018). No-till and cropping system diversification improve soil health and crop yield. *Geoderma* 328(15), 30-43.

Carbon180's Leading with Soil Initiative

Carbon180's Leading with Soil initiative was founded on a community-rooted strategy to scale carbon storage in agricultural soils. Our goal was to work with local organizations across the Rocky Mountain states to understand and address the obstacles that limit widespread adoption of soil health practices that store carbon. Beyond gathering information, we wanted to understand what inspires and sustains change in agricultural systems.

During our stakeholder engagement in the Rocky Mountains, we consistently came across three key interconnected barriers that prevent producers from implementing practices that build healthy, carbon-rich soils: (1) education, (2) science, and (3) incentives.

EDUCATION

Technical assistance and education resources are critical for farmers and ranchers to implement new practices and capitalize on the value of soil health.

SCIENCE

Practices need to be linked with soil health and soil carbon outcomes in an accessible and reproducible way.

INCENTIVES

New financial incentives and tweaks to existing incentives can reduce barriers to adoption and encourage durable carbon storage.

Why the Rocky Mountains?

The Rocky Mountains—a mix of rangelands, pastures, and croplands—have been an ideal place to delve into scaling soil carbon storage in agriculture. We found a burgeoning interest in soil health from producers, technical assistance groups, researchers, businesses, and policymakers, despite a paucity of local demonstration projects.

Addressing barriers to wide-scale adoption of soil health practices requires system-level change that no one organization can accomplish alone. To help scale soil carbon storing practices on a local level, we helped create state soil health coalitions or joined existing ones and worked in close collaboration with local partners (Appendix 1) to elevate an ecosystem of changemakers who can create and sustain system-level change and an ecosystem that starts and ends with agricultural producers.

MONTANA

Working closely with several state organizations, we coordinated four soil health convenings and organized three workshops, reaching more than 150 producers.

WYOMING

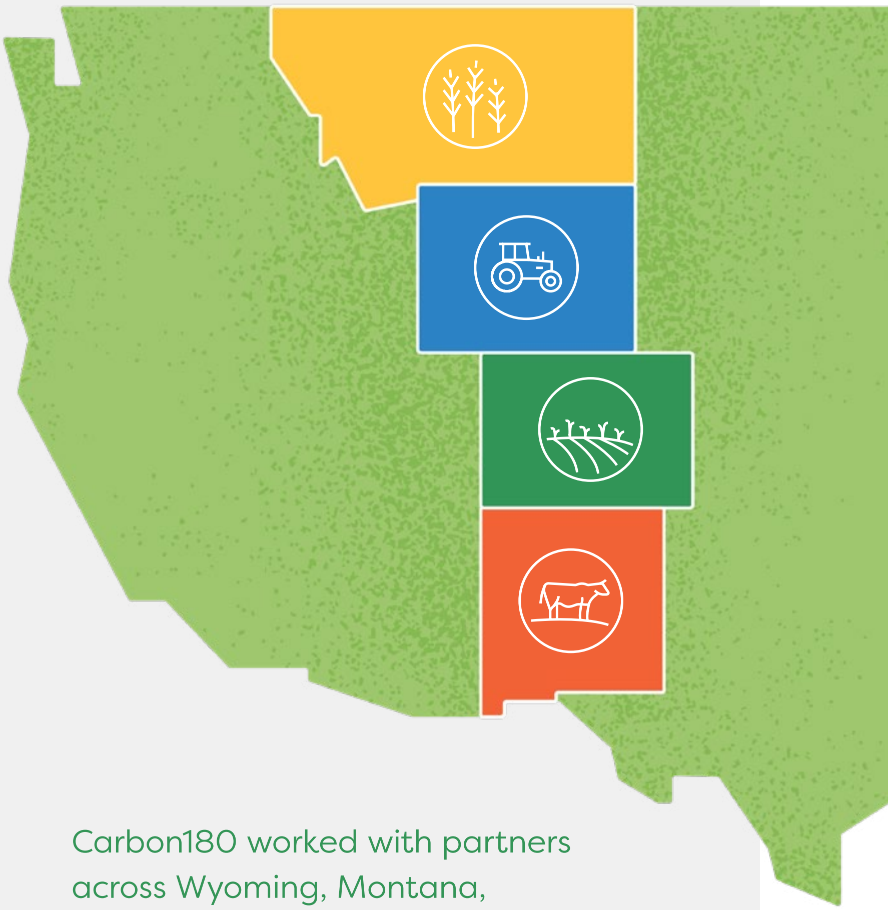
In 2019, we continued to scope interest in soil health across the state and assessed in-state technical assistance capacity.

COLORADO

Working closely with Mad Agriculture, we supported soil health convenings across the state and helped form a coalition with more than 250 participants, including producers, technical assistance providers, NGOs, academics, and state agencies who are meeting regularly and working toward statewide soil health legislation.

NEW MEXICO

Working closely with the Quivira Coalition, we helped organize two workshops, reaching more than 50 producers, and provided scientific advice that yielded two successful proposals to support soil health demonstration projects.



Carbon180 worked with partners across Wyoming, Montana, Colorado, and New Mexico to understand and address barriers to scaling soil carbon storage.

On-the-Ground Activities

Local engagement can help overcome the cultural inertia that prevents producers from adopting new practices. Across the Rocky Mountain states, the Leading with Soil initiative focused on connecting producers with each other and with local experts to help them gain experience and comfort with new agricultural practices and business approaches.[14] To do so, we helped organize and host soil health workshops working with local experts and National Resources Conservation Service (NRCS) staff to share locally relevant healthy soil practices, present methods for soil carbon quantification, and discuss emerging opportunities to capitalize on soil carbon storage. Producers were interested in hearing how others have implemented soil health practices in their operations locally, from the practical aspects of changing management to the financial and soil outcomes. Workshop attendees were also interested in discussing potential new carbon markets or opportunities for them to supplement their income or fund a transition to soil health management.

14. For more information on cultural barriers, see Appendix 4.

Common Soil Health Principles

- Keep the soil covered
- Keep living roots in the soil
- Reduce or eliminate disturbance
- Grow a diversity of crops to foster diversity in the soil

Education

Because many local technical assistance providers do not have specific training or capacity to help producers optimize soil carbon or soil health, we helped provide specific training to producers and technical assistance providers that introduced them to techniques and planning frameworks that prioritize soil health and carbon storage. The soil health producer workshops in Montana, Colorado, and New Mexico had high levels of attendance and engagement from local producers. In these workshops, producers articulated specific challenges they faced in implementing new practices or changing their operations. Technical assistance providers shared some barriers they faced in supporting producers looking to transition their operations. We worked with our local partners to synthesize lessons learned from producer workshops to structure future state activities, including technical assistance training and policy development. The challenges and opportunities articulated in local workshops have guided the federal policy recommendations laid out in this report.

Science

To help local coalitions organize on-farm demonstrations, we connected local scientists and soil experts with producers who were interested in implementing soil health practices and tracking outcomes. We also worked with local researchers to design data collection approaches for locally relevant agricultural operations and provided guidance to producers who had been measuring aspects of their soil health. We synthesized the scientific results to help guide future recommendations for practices that improve soil health and help maximize soil carbon sequestration in the Rocky Mountains, focusing specifically on the dominant crop production systems and livestock grazing.

Incentives

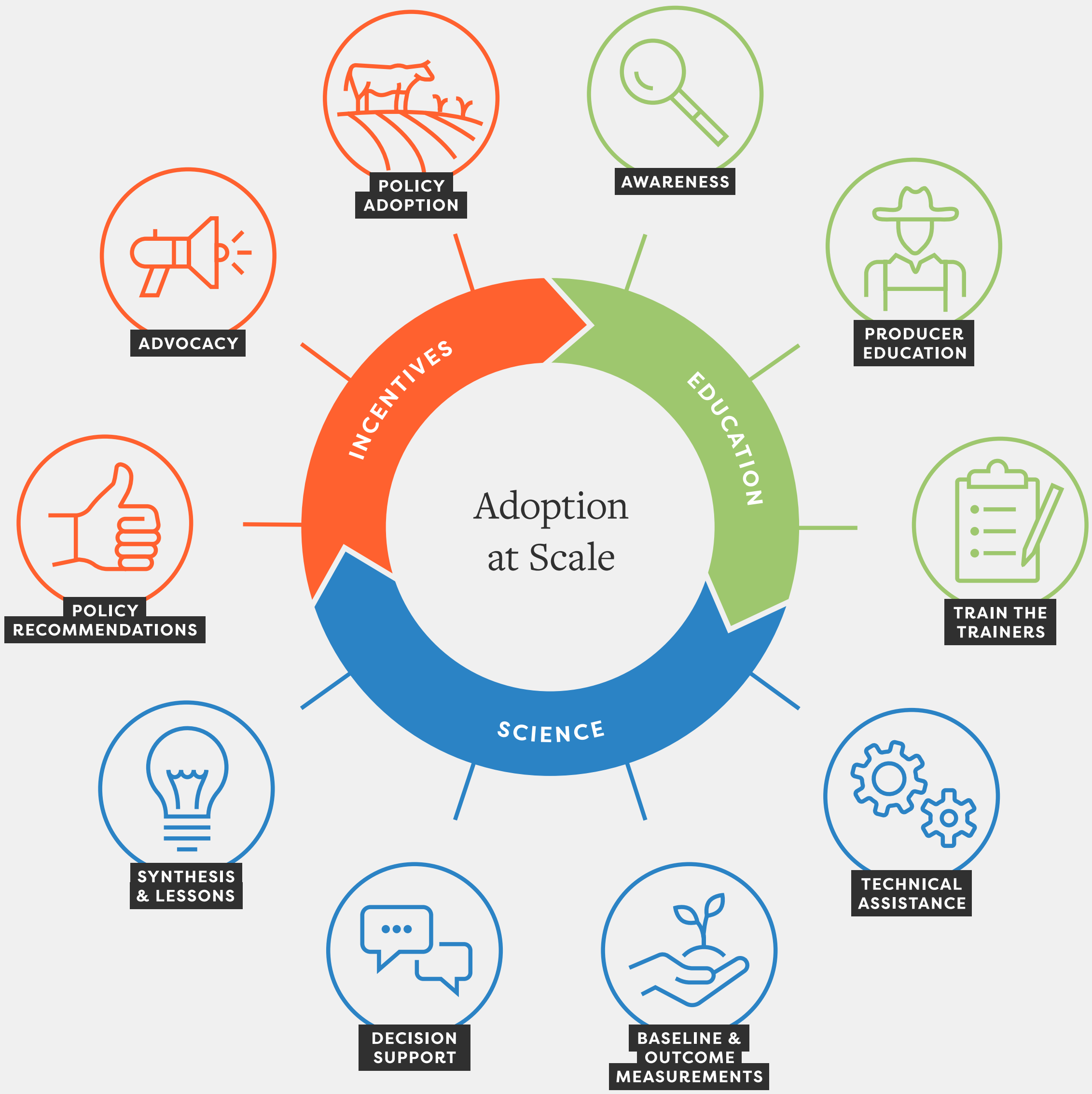
Finally, in the last two years, we have been able to work with our local partners to deliver outcome-based policy recommendations that support the continued transition to soil carbon practices within each state and across the Rocky Mountains. These policy recommendations present a synthesis of lessons learned from local coalitions and producer workshops, as well as our work with private companies that are seeking to understand the opportunities associated with improved soil health.

Driving a System of Change

Alleviating any one barrier is unlikely to shift the entire system, but alleviating these challenges simultaneously can help scale soil carbon storage. We see change as a reinforcing cycle that starts with early adopters: farmers and ranchers who need technical assistance and data on how their changes in management affect their yields and soils. Technical assistance providers then work directly with producers to help teach and implement new practices. As new practices are implemented, researchers track outcomes to determine if changes in management are having the desired effect. The outcomes are shared with other stakeholders and policymakers who can help create appropriate incentives to support these kinds of soil health practices for more farmers and ranchers in the future. Scaling soil carbon storage in the agricultural sector will require addressing all of these barriers in a coordinated way and creating a reinforcing system of support. Without such coordination, previous efforts to scale the adoption of soil health practices have faltered.

Driving a System of Change

Access to timely and consistent education, science that links practices with outcomes, and incentives are all needed to help scale agricultural practices that store carbon. By addressing multiple needs at once, we can create a self-reinforcing cycle of change that brings practices to scale faster and more durably.



State of Existing Policy

While working with stakeholders on the ground, we observed firsthand the importance of local, state, and federal action. Interest in soil carbon storage is growing across the United States, and many states have introduced or passed soil health legislation.[15] Though there are distinct differences among states, most of the state policies include:

- High-level goals;
- Definition of soil health and related practices;
- Funding for research, development, and demonstration; and
- Requirements for state agencies to coordinate on implementation.

State policy can provide funding to demonstrate practices with geographic and operational specificity, which can de-risk practices and increase the speed at which they can be adopted. In addition, states can serve as policy laboratories — ideas developed at the state level can be exported to other jurisdictions and scaled up to regional and federal action.

Corporate Action

There is significant interest from food companies in incorporating soil health practices and soil carbon storage into their supply chains. By procuring these products, businesses can reduce their supply chain risk and meet corporate climate commitments. While we do not address private sector demand levers in this report, there are opportunities for the federal government to unlock additional private sector investment.

Despite the growing interest and action at the local and state level, significant gaps remain, and current adoption continues to fall short.[16] Insufficient technical assistance, scientific knowledge gaps, and lack of strong and reliable incentives all mean that implementation of agricultural practices that store carbon and build healthier soils is moving too slowly to address climate change. Scaling practices will require federal support to alleviate the full suite of remaining barriers facing agriculture producers today.[17]

15. Nerds for Earth. (2019, August 27). State Healthy Soil Policy Map.

16. LaRose, J. & Meyers, R. (2019). *Adoption of Soil Health Systems Based on Data from the 2017 U.S. Census of Agriculture.* Soil Health Institute.

17. Doane, M., Clemens, L., Dell, R., et al. (2016). *ReThink Soil: A Roadmap to U.S. Soil Health.* The Nature Conservancy.

The federal government has already begun to address some of the barriers faced by farmers looking to shift their operations.[18] For example, programs such as the U.S. Department of Agriculture's Environmental Quality Incentives Program (EQIP) and Conservation Stewardship Program (CSP) were originally designed to meet general conservation objectives, but have more recently supported soil health and soil carbon objectives. These programs alone, while extremely popular, are not sufficient to meet the growing demand from producers across the United States and maximize soil carbon storage.[19] Scaling soil carbon storage will require concerted support from the federal government to address education, science, and incentives.

18. Stubbs, M. (2019). *Agricultural Conservation in the 2018 Farm Bill.* Congressional Research Service.

19. Ibid.

Section Three

Policy Recommendations

This report presents the translation of lessons learned on the ground into federal policy recommendations. Throughout our conversations with partners, the farmers and ranchers themselves identified a few key components of policy design, which are fleshed out in more detail in the recommendations below:

1. Encourage innovation by focusing on outcomes and not overly prescribing specific solutions
2. Ensure incentives are easy for farmers and ranchers to access
3. Design incentives in line with the cadence of the agriculture industry (e.g., setting application deadlines outside of planting and harvest seasons)
4. Address cash flow and upfront financing barriers

In this report, these principles underscore a menu of potential policy solutions that address the three main barriers to the wide-scale adoption of soil health practices. We believe simultaneously expanding access to education, improving soil carbon quantification methods, and creating a suite of incentives can help accelerate the adoption of agricultural practices that store carbon and improve the livelihoods of farmers across the United States.

Policy Recommendations for Education

Technical assistance is a form of producer education that is provided by agencies such as the NRCS, university extension services, nonprofits, and chemical and agriculture companies. Despite a range of potential assistance providers, these organizations often have limited knowledge of soil carbon practices and thus many agricultural producers lack access to technical assistance to implement them on their land. In addition, it is often unclear to producers how to capitalize on the value of soil health and soil carbon.

One of the most consistent and effective providers of soil health technical assistance across the United States is the NRCS. This agency, and its on-the-ground partners, the Conservation Districts, have more than 80 years of experience working with farmers and ranchers to provide technical assistance and education.[20] However, the NRCS has not been able to meet the growing demand for technical assistance — especially as federal funding levels continue to decline[21] as interest in conservation programs grows.[22] With ample funding and a simpler and more accessible application process, the NRCS could serve as a more salient resource — equipping producers and local technical assistance providers with consistent, up-to-date information. Ultimately, this kind of assistance can help producers build resilient operations and make full use of emerging markets. The recommendations below address specific barriers to education and technical assistance.

20. Natural Resources Conservation Service. (n.d.). More Than 80 Years Helping People Help the Land: A Brief History of NRCS.

21. Biardeau, L., Crebbin-Coates, R., Keerati, R., Litke, S. & Rodriguez, H. (2016). *Soil Health and Carbon Sequestration in U.S. Croplands: A Policy Analysis*. Goldman School of Public Policy, University of California - Berkeley.

22. Root, K. (2017, July 3). USDA Conservation Programs: Underfunded and oversubscribed. *Iowa Agribusiness Radio Network*.

Rec. 1 *for Education*

Barrier:

Producers are not widely familiar with soil health practices and/or do not have enouvgh confidence in the benefits of soil health practices to make long-term decisions about their operations.

Policy Recommendation:

Fund demonstration projects.

Getting producer buy-in requires de-risking the implementation of new or innovative agricultural practices, including demonstrating how different agricultural practices affect soil carbon storage in different contexts.[23] The federal government should increase funding for NRCS soil health demonstration trials[24] and Conservation Innovation Grants[25] that span geographies and crop types. Soil health demonstration trials should aim to fill knowledge gaps around carbon storage for specific agricultural practices (especially grazing) and soil amendments. These trials should also be done in partnership with the USDA's Economic Research Service (ERS) and focus on answering key economic questions about the cost of implementation, financial outcomes, potential yield increases, and on-farm and on-ranch soil health benefits from implementation.

New USDA analyses are likely needed to assess existing demonstration projects — including the Long-Term Agroecosystem Research (LTAR) Network[26] and the soil health demonstration trials funded by the 2018 Farm Bill — and identify high-priority gaps. In the Rocky Mountains, for example, there is a need for compost trials on rangelands that vary in application rates, application timing, and grazing management. There is also a need for rigorous evaluation of managed grazing in semi-arid and arid lands, focused on developing appropriate management options to achieve soil health and soil carbon outcomes. The USDA Climate Hubs may be well positioned to carry out these analyses and make recommendations.

23. NRCS. (2020). CIG On-Farm Conservation Innovation Trials. Retrieved from https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/programs/financial/cig/?cid=nrcseprd1459039

24. For funding recommendations, please see Appendix 3.

25. Ibid.

26. USDA. (2020). The LTAR Network. Retrieved from https://ltar.ars.usda.gov/

Rec. 2 *for Education*

Barrier:
Producers lack access to quality, consistent technical assistance.

Policy Recommendation:
Bolster the technical capacity of local NRCS offices.

Farmer interest in soil health and carbon storage is growing. However, technical assistance programs at many regional and local NRCS offices are under-resourced, and staff levels have been steadily decreasing.[21] The number of unfilled vacancies continues to grow, reducing the capacity to evaluate and fund projects.[27] For example, farmer loan processing times have increased over the last five years, in lockstep with reductions in staffing.[28] Existing staff capacity does not meet the growing interest and need, and staff are not widely familiar with soil health and soil carbon storage.

The federal government can expand funding specifically to support additional local and regional staff who can provide technical assistance to farmers and ranchers on soil health and carbon storage.[29] Staff should be trained broadly in conservation planning and have specific knowledge of soil health planning and soil carbon outcomes. In addition, we suggest removing the barriers to hiring additional staff at the local and regional NRCS offices — providing support for Conservation Districts to train and maintain staff and allocating funds for cost-sharing with outside organizations for partner biologist programs.

We also suggest a new program that funds collaborative projects between local and regional NRCS staff and local universities and extension agents to ensure the latest regional science is incorporated into technical assistance provisions.

27. Stubbs, M. (2020). *FY2020 Appropriations for Agricultural Conservation.* Congressional Research Service.

28. U.S. Department of Agriculture. (n.d.). *FY 2020 Annual Performance Plan and FY 2018 Report.*

29. For funding recommendations for FY21, please see Appendix 2.

Rec. 3 *for Education*

Barrier:

Producers have difficulty accessing expertise they trust.

Policy Recommendation:

Increase support for peer networks.

Early adopters are often perceived as radical and sometimes face ridicule for shifting to new production practices or products.[30] Producers become more comfortable and learn from trusted sources, largely other producers. Existing funding programs, such as the USDA's Sustainable Agriculture Research and Education[31] program, support producer peer networks, and we suggest expanding those programs, with an explicit goal of providing the means for mentorship and technical knowledge sharing.[32]

30. For more information on cultural barriers, see Appendix 4.
31. Sustainable Agriculture Research and Education. (n.d.). Sustainable Agriculture Grants. Retrieved from https://www.sare.org/Grants?gclid=EAIaIQobChMIiuiNuem45wIVA9vACh1hFAAFEAAYASAAEgJ2mvD_BwE
32. For funding recommendations for FY21, please see Appendix 2.

Policy Recommendations for Science

Today, there remain knowledge gaps that will need to be filled in order to bring soil carbon storage to scale. First, producers need to be able to access information about how practice changes will impact their operations in order to make educated decisions about transitions. After implementation, producers need to be able to easily measure and interpret soil health and soil carbon metrics to support management decisions and access any related incentives. Policymakers and companies who want to incentivize carbon storage need better data on the link between practices and carbon outcomes across geographies and operation type, economic research to guide incentive design, and low-cost options for carbon measurement and verification. Below, we outline some of the science barriers witnessed on-the-ground in more detail.

There was frequent confusion about soil health metrics, and current soil analyses are often not directly relevant for decision-making. Inconsistencies in terminology, measurement protocols, and practice implementation make it difficult to draw clear conclusions about the efficacy of practices and their influence on soil carbon storage.[33] This kind of confusion can lead to disengagement and undermines efforts to link implementation of soil health practices with outcomes.[34]

In addition, early adoption of soil health practices has largely been driven by anecdotal evidence and in some instances needs to be scientifically verified. While soil carbon storage can be a cheap and accessible carbon removal solution,[35] the efficacy of agricultural practices in building soil health and promoting soil carbon storage can vary across geographies, crops, operation types, and practices, making it difficult to implement one-size-fits-all solutions.

Though many conservation practices already have sufficient scientific basis to project carbon outcomes (i.e., through the COMET-Planner and COMET-Farm platforms), many promising solutions require testing and field demonstrations to collect consistent, high-quality data. This is especially true in rangeland systems where different livestock management approaches can yield different soil health and carbon outcomes.[36] There are not enough demonstration projects across the United States, especially in semi-arid Western rangelands, which are representative of the region. Geographic and land-use history complexity makes it difficult to

33. Cotrufo, M.F., Ranalli, M.G., Haddix, M.L., et al. (2019). Soil carbon storage informed by particulate and mineral-associated organic matter. *Nature Geoscience* 12, 989–994.

34. Byrnes, R.C., Eastburn, D.J., Tate, K.W. & Roche, L.M. (2018). Global Meta-Analysis of Grazing Impacts on Soil Health Indicators. *Journal of Environmental Quality* 47, 758-765.

35. Fargione, J. et al. (2019). Natural climate solutions for the United States. *Science Advances* 4(11): eaat1869.

36. Byrnes, R.C., Eastburn, D.J., Tate, K.W. & Roche, L.M. (2018). Global Meta-Analysis of Grazing Impacts on Soil Health Indicators. *Journal of Environmental Quality* 47, 758-765.

apply outcomes from one demonstration project to another. This area of research is needed to build confidence in different management practices and support decision-making.

Existing research (ecological, biological, economic, and social science) that would inform adoption only applies to specific practices, geographies, or crop type, and is therefore hard to apply broadly.[37] In addition, soil carbon measurements vary from year to year, making it difficult to benchmark incentives annually. To ensure recommendations for optimal soil health and carbon storing practices are rooted in the best available science, we need demonstration projects that test the efficacy of different management practices in different contexts and geographies.[38]

Many soil health practices can be implemented in concert, reinforcing soil health benefits. However, few farmers integrate more than one practice, let alone the full suite of recommended soil health practices, and few studies report the outcomes from implementing multiple practices. In addition, producers are interested in using data on soil health indicators to make on-farm and on-ranch decisions but often do not have the knowledge, accessible tools, or reliable assistance to decipher their soil data to drive decisions. Despite a growing need, accessible soil sampling and carbon monitoring tools are currently lacking.[39]

Finally, there is a distinction between improving overall soil health and the rigorous monitoring, reporting and verification required to engage with carbon markets.[40] Meeting both goals requires accurately measuring or modeling soil carbon outcomes of agricultural practices, and accurately accounting for the cost of practice implementation is critical for structuring incentives. However, specific protocols required to achieve broad soil health and carbon market goals differ. Investing in tactical scientific and economic research to address these gaps today can help pave the way for more effective incentives for producers in the future. The recommendations below address specific barriers around science.

37. Baker, N.T. & Capel, P.D. (2011). Environmental factors that influence the location of crop agriculture in the conterminous United States. *U.S. Geological Survey Scientific Investigations Report* 5108, 72.

38. Paustial, K., Collier, S., Baldock, J., et al. (2019). Quantifying carbon for agricultural soil management: from the current status toward a global soil information system. *Carbon Management* 10(6), 567-587.

39. Smith, P., Soussana, J., Angers, D., et al. (2019). How to measure, report and verify soil carbon change to realize the potential of soil carbon sequestration for atmospheric greenhouse gas removal. *Global Change Biology* 26(1), 219-241.

40. See citation 38.

Rec. 1 *for Science*

Barrier:

Scientific methods to assess and monitor soil health and carbon are inconsistent and difficult for producers to implement.

Policy Recommendation:

Develop cost-effective and accessible soil carbon assessment methodology.

The federal government can support R&D efforts to develop cost-effective and accessible soil carbon assessment tools for agricultural producers to quickly assess the health of their soils and track soil carbon changes over time. At the same time, the USDA should create free or highly subsidized soil testing services co-located at existing regional NRCS offices and train NRCS staff to provide such testing as a service to producers. This could also include additional training for NRCS staff to communicate and use test results to help producers plan for soil health outcomes.

On rangelands, soil carbon quantification continues to be a barrier, especially in grazing systems — rangelands are expansive and encompass a huge variation in soil types, land use histories, current management practices, climates, and capacity to improve soil carbon storage. The NRCS should develop specific soil health guidelines that are applicable on rangelands. Advancements in soil health and carbon quantification and verification in rangelands can be applicable broadly across the United States and can help provide clarity in other production systems.

Rec. 2 *for Science*

Barrier:

Soil health metrics are not widely applicable across agricultural systems and geographies.

Policy Recommendation:

Solidify soil health metrics across the United States.

Soil health metrics include soil characteristics and important aspects of soil function, such as water-holding capacity, chemical and biological analyses, and diversity indices. Existing soil health metrics were developed by the NRCS[41] in Midwestern agricultural systems and do not easily apply in dryland systems that encompass much of the Western United States. While NRCS guidance serves as a critical template for building soil health in agriculture, there is a need to identify which soil health metrics work in dryland and irrigated agricultural systems. The NRCS should reassess the existing soil health metrics and make them encompass the geographic diversity of the U.S. agriculture industry.

41. Stott, D. E. (2019). *Soil Health Technical Note No. 450-03: Recommended Soil Health Indicators and Associated Laboratory Procedures.* USDA NRCS.

Rec. 3 *for Science*

Barrier:

Existing science is not geographically specific enough to inform incentives and markets for soil carbon.

Policy Recommendation:

Fund research and demonstration projects across agricultural contexts and geographies.

The federal government should prioritize funding research and demonstration projects that assess the impacts of different agricultural practices on soil health and carbon storage across underrepresented geographies and agricultural contexts.[42]

42. For funding recommendations, please see Appendix 3.

Livestock grazing is an important agricultural sector, but the impacts of different grazing management practices on soil carbon storage remains largely unresolved. A number of ranchers across the United States have implemented advanced grazing practices (adaptive, rotational, mob and holistic management practices) for more than 10 years, providing the opportunity to assess the impacts of those grazing management methods on soil carbon storage across a range of geographies. The USDA's Agricultural Research Service and Climate Hubs are likely well positioned to carry out the necessary research to understand how different grazing management practices influence soils. Direct field soil collections and analyses can be combined with existing experimental datasets to create a more comprehensive understanding of how grazing management affects soil carbon and immediately use that information to direct future management policy and incentives.

Rec. 4 *for Science*

Barrier:

Existing programs are not based on the economic realities of practice implementation.

Policy Recommendation:

Pave the way for better policy design through economic research.

The cost of implementation of soil health practices varies across agricultural systems and location. The USDA ERS should fund research that quantifies the variation in implementation cost and make that research available to guide incentive design. In addition, other ecosystem processes, including water, soil nutrients, soil erosion, and crop yields all shift when soil carbon is increased. The USDA ERS and National Institute of Food and Agriculture (NIFA) should support research that examines the costs and benefits of systems of change.

Economic incentives are not the only barriers to wide-scale implementation of soil health practices. The federal government should support research to understand the social and behavioral factors that influence how agricultural producers think about risk and implement new practices, potentially as a partnership across agencies such as NRCS, NIFA, and the Foundation for Food and Agriculture Research.[43]

Finally, the federal government should direct the USDA to lead a cross-agency effort with the U.S. Geological Survey and Department of Energy to estimate the cost of storing one ton of carbon in agricultural soils across practices, geographies, and crop types. This cost information should be used to guide future incentive design.

43. For more information on cultural barriers, see Appendix 4.

Rec. 5 *for Science*

Barrier:
Physical carbon measurements are expensive and burdensome.

Policy Recommendation:
Build a national carbon observatory.

Efforts to support wide-scale adoption of soil health and carbon storing agricultural practices will require robust quantification, monitoring, and reporting of soil organic carbon stocks. Current soil carbon quantification methods require physical collection of samples at time and geographic scales that adequately represent variation in soil carbon. This can be expensive, time-consuming, and infeasible for most producers and land managers. To get beyond the need for physical sampling, we need to develop remote sensing tools and models that are accurate enough to represent the variation and changes in soil carbon. There is currently no comprehensive government effort or system to quantify soil carbon reliably and cost-effectively across the United States.

We recommend restoring soil carbon measurement within the National Resources Inventory,[44,45] We also recommend that the federal government (likely at the national labs) build and maintain an integrated soil information system to bring together existing data, tools, and technologies, and facilitate transparency and coordination among scientists, modelers, and land managers.[46]

44. For funding recommendations for FY21, please see Appendix 2.

45. National Academies of Sciences, Engineering, and Medicine. (2019). *Negative Emissions Technologies and Reliable Sequestration: A Research Agenda*. Washington, D.C.: The National Academies Press.

46. Paustian, K., Collier, S., Baldock, F., et al. (2019). Quantifying carbon for agricultural soil management: from the current status toward a global soil information system. *Carbon Management* 10(6), 567-587.

Policy Recommendations for Incentives

Healthy carbon-rich soils deliver many benefits for farmers and ranchers, including reduced reliance on external inputs, improved water filtration and nutrient efficiency, increased resilience to extreme weather, and the ability to support higher stocking rates[47,48] in grazing systems. However, these benefits vary across operations, often take time to manifest, and don't immediately offset the upfront cost of practice implementation. In addition, there is no robust financial payoff for soil carbon storage and no clear market premium for products grown using soil health practices — making it difficult to convince producers to absorb the upfront cost of transitioning practices. Due to these factors, producers need support to help transition their operations. Investing in farmers and ranchers today can enable them to continue to power America through food, fuel, and fiber production, while also protecting their livelihoods and our environment.

To compound issues, producers are already working on thin margins, and the market is volatile for many commodity crops. Shifting the cultivation methods for crops has the potential to impact yields and incur additional cost. The impacts on yields can be inconsistent across geographies and agricultural contexts — in some cases, temporary yield declines are followed by yield stabilization or increases as soil carbon is accrued. At the same time, adding cover crops to a cropland operation means paying for cover crop seed, additional labor, and potentially water for irrigation. In grazing systems, implementing rotational grazing requires fencing and water infrastructure as well as time to move animals frequently and monitor their impacts on forage production.

Beyond direct incentives and support programs, there are existing policies that disincentivize soil health practices. For example, the current definition of "good farming practices" under the Federal Crop Insurance Program does not include the full suite of NRCS soil conservation practices, making it challenging for producers implementing practices such as conservation tillage to get crop insurance. Integrating new practices into ongoing operations will require investment in infrastructure, removing existing market barriers, streamlining access to existing incentives, and providing new incentives that effectively account for soil carbon benefits. The recommendations below address specific barriers to incentives.

47. Schmalz, H.J., Taylor, R.V., Johnson, T.N., Kennedy, P.L., DeBano, S.J., Newingham, B.A. & McDaniel, P.A. (2013). Soil Morphologic Properties and Cattle Stocking Rate Affect Dynamic Soil Properties. *Rangeland Ecology & Management* 66(4), 445-453.

48. USDA NRCS. (2016). *Grazing Management and Soil Health: Keys to Better Soil, Plant, Animal, and Financial Health.*

Rec. 1 *for Incentives*

Barrier:
Producers lack the financial resources to implement soil health practices.

Policy Recommendation:
Subsidize infrastructure to scale soil carbon storage.

The implementation of new agricultural practices can carry additional costs, including capital costs for new equipment (such as seed, fencing, and irrigation infrastructure) and operating costs (such as increased labor costs). The federal government should expand programs that provide cost-sharing for new agricultural practices and equipment (EQIP and CSP) and link cost-share programs with soil health and carbon verification.[49]

The USDA should also support the creation of regional and rural compost facilities to redirect organic waste from the farm waste stream and help ensure local supply of compost.[50] This would help resolve the logistical challenges farmers face in sourcing compost to apply to their fields and can also provide an economic development opportunity for rural communities.

The key Farm Bill programs should include specific allocations for different cropping systems and perennial crops beyond the major commodity crops to support the diversification of cropland systems. This will help ensure that the United States has resilient agricultural production systems and is able to expand into new markets and opportunities, especially under a changing climate.

49. For funding recommendations, please see Appendix 3.

50. Environmental Protection Agency. (n.d.). Wasted Food Programs and Resources Across the United States. Retrieved from https://www.epa.gov/sustainable-management-food/wasted-food-programs-and-resources-across-united-states

Rec. 2 *for Incentives*

Barrier:

Landowners and non-owner operators require different incentive structures to enact soil health practices.

Policy Recommendation:

Expand programs to account for non-owner operators.

Government programs and incentives should be open to non-owner operators and/or provide incentives to landowners that can be easily passed on to non-owner operators.

In the context of federal land leases, the Bureau of Land Management (BLM) can support carbon storage on the 155 million acres of land leased for livestock grazing.[51] Specifically, BLM could provide preferential leasing rates to ranchers implementing carbon storage or include soil health as a component of allotment management plans. These policy options can be a win-win for the producer and the government as forage and overall land quality improve.

51. Bureau of Land Management. (n.d.). Rangelands and Grazing: Livestock Grazing. Retrieved from https://www.blm.gov/programs/natural-resources/rangelands-and-grazing/livestock-grazing

Rec. 3 *for Incentives*

Barrier:

The duration of current incentive programs do not match timelines for soil health benefits to accrue.

Policy Recommendation:

Adjust existing incentives to account for the speed of soil carbon accrual in agricultural soils.

Existing incentive programs should match the duration it takes for soil health practices to fully yield benefits for producers. It can take five years, or even longer in dryland ecosystems, to register meaningful changes in soil health and increases in soil carbon. Government incentive programs, including NRCS cost-share programs, should be implemented on timelines of five years or more to ensure durable support in a regionally specific way and include safeguards to help producers who experience "bad" years. For example, the USDA EQIP program can provide cost-share contracts for up to 10 years, but in practice it typically gives contracts for one to three years.[52] The EQIP should be required to give contracts for a minimum of 3 years. .

52. National Sustainable Agriculture Coalition. (2019, May). Environmental Quality Incentives Program. Retrieved from https://sustainableagriculture.net/publications/grassrootsguide/conservation-environment/environmental-quality-incentives-program/

Rec. 4 *for Incentives*

Barrier:

The suite of federal support mechanisms create perverse incentives that prioritize conventional practices.

Policy Recommendation:

Adapt the Federal Crop Insurance Program to address climate impacts.

Across the USDA, there is a lack of consistency on what constitutes "good farming practices." This has forced many farmers to choose between implementing conservation practices (e.g., cover cropping) that are endorsed by NRCS or staying in compliance with their federal crop insurance policies. While the last Farm Bill began to give farmers some additional flexibility to implement resilience-building practices, the federal government should establish all conservation practices approved by the NRCS as "good farming practices."

In addition, the Federal Crop Insurance Program should reward producers for reducing their climate risk by implementing practices that protect yields from increased instances of drought, flooding, and variable temperatures.[53] Current premiums do not take into account the most recent data to appropriately reflect the resilience benefits of different soil health practices. We suggest the USDA be directed to collect relevant data to make premium adjustments for producers who implement risk-reducing conservation practices. A discounted crop insurance model is being piloted in Iowa[54] and may serve as a useful case study for broader crop insurance realignment with soil health goals.

In addition, the Conservation Reserve Program (CRP) and Transition Incentive Program[55] should expand eligibility beyond beginning and socially disadvantaged farmers to include all land owners who have land coming out of CRP. This can ensure that soil health practices that have supported the accrual of soil carbon stay in place, and we do not lose carbon that has been stored in soils.[56]

53. Bryant, L. & O'Connor, C. (2017). Creating Incentives to Improve Soil Health Through the Federal Crop Insurance Program. In: Field, D.J., Morgan, C.L.S., McBratney, A.B. (editors). Global Soil Security. Progress in Soil Science. Springer, Cham, 403–409.

54. Steimel, D. (2017, November 20). Iowa program offers discount on crop insurance for farmers who plant cover crops. *Iowa Farm Bureau.*

55. Farm Service Agency. (n.d.). Transition Incentives Program. Retrieved from https://www.fsa.usda.gov/programs-and-services/conservation-programs/transition-incentives/index

56. Bigelow, D. & Hellerstein, D. (2020, February 3). In Recent Years, Most Expiring Land in the Conservation Reserve Program Returned to Crop Production. *Amber Waves.*

Rec. 5 *for Incentives*

Barrier:

Existing government incentives are complex and carry a heavy administrative burden. Applications are complicated and require significant time and expertise to complete.

Policy Recommendation:

Simplify access to incentives.

The USDA should simplify the application process for soil health programs and create an application format that allows farmers and ranchers to fill out one application to be eligible for multiple USDA programs.

Rec. 6 *for Incentives*

Barrier:
The integration of new practices into ongoing operations is perceived as economically risky.

Policy Recommendation A:
Fully fund soil health programs.

The federal government already has several programs that support farmers in maintaining carbon-rich, healthy soils. However, these programs are significantly oversubscribed, especially as interest in soil health grows.[57] The federal government should increase funding for CSP and EQIP to allow more farmers to receive financial support to adopt new conservation practices that bolster soil health.[58]

57. Root, K. (2017, July 3). USDA Conservation Programs: Underfunded and oversubscribed. *Iowa Agribusiness Radio Network*.

58. For funding recommendations, please see Appendix 3.

Policy Recommendation B:
Create new, more durable market incentives.

The federal government should expand financing mechanisms beyond CSP and EQIP to incentivize farmers to implement carbon storing practices and track outcomes. Incentives should match geographic and operational variation in the difficulty or cost of practices and offer additional support to measure and verify soil outcomes over time. Potential market mechanisms could include procurement incentives, payment for ecosystem services, tax credits, offset mechanisms, or direct payments for carbon storage. New incentives should be paired with required impact assessment of soil health and carbon outcomes.

Section Four

Conclusion

Many groups have a vested interest in a transition to more sustainable and resilient agriculture industry:

- Farmers and ranchers looking to make management decisions in the face of climate change;
- Businesses that have made climate commitments and want to de-risk their supply chains;
- Startups developing new and innovative technologies;
- Rural communities in need of economic opportunity;
- Local and state governments with climate commitments.

Tactical investments from the federal government today can unlock additional funding and spur action for decades to come.

Coordinated efforts to clearly define accessible soil health metrics and soil carbon measurement protocols can go a long way toward building confidence in soil carbon storage across all stakeholder groups. As scientists improve modeling approaches and develop new tools for soil carbon quantification, these tools can help policymakers develop incentive structures that rely on trusted and accurate measurement of soil carbon. And as measurement tools improve, they will be more accessible to producers, who have a vested interest in tracking their data and controlling transactions around soil health and carbon.

Long-term soil carbon storage poses a huge economic and climate opportunity, but it is only achievable with durable changes to our agricultural production system, spurred by federal support. When designing policy to address the barriers laid out in this report, there are a few key considerations to weigh:

System of Change

We advocate for policies that help marshall a system of change rather than addressing a single stress point. While we often provide single policy recommendations to address single barriers, we envision enacting a suite of durable policies that work in concert, as many of our recommendations reinforce others.

Feedback

As policies are crafted, we recommend a strong connection and iteration with on-the-ground stakeholders to assess their impact and success. Producers should be engaged at every step and in every aspect of the work. Even the greatest advancements in soil science and the best policies will not make a meaningful difference if producers are not at the forefront.

Timescale

We need patience. Soil changes and carbon gains can be slow and small enough from one year to the next to be undetectable. That means incentive structures should take into account the speed of carbon accrual and support farmers through the initial five or more years it takes for soil carbon to accumulate at measurable rates. There is also an opportunity to consider and reward other positive outcomes for water, soil nutrients, soil erosion, and crop yields.

Durability

Carbon storage is likely to peak near the beginning of management change and slow over time.[59] Policies should be structured to not only increase soil carbon storage but also maintain that storage over time, ensuring it is not lost back into the atmosphere.[60]

Agricultural soil carbon storage is ready for prime time today. Significant local and state action has demonstrated the promise of these practices: Healthy soils practices can improve farmers' and ranchers' bottom lines, increase their resilience to climate impacts, and help fight climate change. The management practices that build healthy, carbon-rich soils are not new, not reliant on the invention of a specific new technology, and can be implemented on millions of acres across the United States today. We just need the will and support of the federal government to realize this potential.

59. Conant, R.T., Paustian, P. & Elliott, E.T. (2001). Grassland management and conversion: Effect on soil carbon. Ecological Applications 11(2), 343-355.

60. Bossio, D.A., Cook-Patton, S.C., Ellis, P.W., et al. (2020). The role of soil carbon in natural climate solutions. Nature Sustainability https://doi.org/10.1038/s41893-020-0491-z

Section Five

Appendices

APPENDIX 1

Leading with Soil partner organizations in Montana, Colorado, and New Mexico

PARTNER ORGANIZATION	MISSION	CONTRIBUTIONS
One Montana	One Montana is a nonpartisan nonprofit organization dedicated to ensuring a positive future for both rural and urban communities in Montana.	One Montana developed and led producer workshops and worked to expand the network of producers using soil health practices in the state.
Soil and Water Conservation Districts of Montana (SWCDMT)	SWCDMT is a nonprofit sister organization to the Montana Association of Conservation Districts. SWCDMT supplements the resources of Conservation Districts across Montana with additional funding, technical support, knowledge sharing, and other resources.	SWCDMT supported the coalition of partners in Montana, conducted outreach to producers, and worked with conservation districts to plan and implement workshops.
Western Landowners Alliance (WLA) One Montana	WLA is a nonprofit organization that advances policies and practices that sustain working lands, connected landscapes, and native species. WLA provides a collective voice, a peer network, and a shared knowledge base for landowners striving to keep the land whole and healthy.	WLA shared soil health objectives from ongoing efforts promoting regenerative grazing across Western states, conducted outreach to landowners in Montana, Colorado, and New Mexico, and coordinated the Winnett Rangeland Monitoring Group in Montana.
Western Sustainability Exchange (WSE) One Montana	WSE is a nonprofit organization with a mission to conserve the Northern Rockies. The organization brings together farmers and ranchers to design and implement innovative and sustainable production strategies, develop value-added markets, educate consumers about the long-term benefits of sustainable purchasing, and increase access to sustainably produced local foods in the region.	WSE connected with a network of early adopters to support peer-to-peer education. WSE expanded the pilot carbon ranching project with Native Energy in Montana and worked with the Soil Interns of Montana program to collect baseline soil carbon data. WSE also supported community soil health workshops throughout Montana..

APPENDIX 1 *(Continued)*

Leading with Soil partner organizations in Montana, Colorado, and New Mexico

PARTNER ORGANIZATION	MISSION	CONTRIBUTIONS
World Wildlife Fund (WWF)	The Montana chapter works across the Northern Great Plains and focuses on sustainable ranching, supporting programs that improve outcomes for both ranching families and grasslands.	WWF helped organize and host several oil health convenings in Montana and participated in soil health workshops.
Northern Plains Resource Council (NPRC)	NPRC is a grassroots conservation and family agriculture group that organizes Montanans to protect water quality, family farms and ranches, and their unique quality of life.	NPRC helped form and organize several soil health convenings in Montana, conducted demonstration workshops for growers, and organized partners to develop policy recommendations.
National Center for Appropriate Technology (NCAT)	NCAT contributes to the development of appropriate and sustainable technologies to help improve the lives of low-income families with hands-on training and field demonstrations.	NCAT helped organize and host soil health convenings in Montana, organized and hosted a soil health workshop for growers, and worked with partners to develop policy recommendations.
Montana State University (MSU)	MSU is the state land-grant university, with extensive institutional expertise in land management and soil science, and extension services that reach the entire state to provide technical assistance in agriculture and natural resource management. Dr. Tony Hartshorn is an MSU professor of soil science whose projects include working with Montana producers and quantifying soil carbon.	University faculty and students collected and analyzed baseline soil samples from participating farms and ranches across Montana to track soil health and carbon outcomes. Participated in technical workshops and training.
Mad Agriculture	Mad Agriculture's mission is to reimagine and restore our relationship with Earth through good agriculture.	Mad Ag led the development of partner and producer networks in Colorado, initiated field trials, prepared and conducted a workshop series for producers, and developed training materials for "train the trainer" efforts in Colorado.

APPENDIX 1 *(Continued)*

Leading with Soil partner organizations in Montana, Colorado, and New Mexico

PARTNER ORGANIZATION	MISSION	CONTRIBUTIONS
Quivira Coalition	Quivira Coalition is a nonprofit organization that builds soil, biodiversity, and resilience on western working landscapes. Quivira's goal is to foster ecological, economic, and social health through education, innovation, and collaboration. Addressing the impacts of climate change is foundational to its mission and work in rangelands and forests.	Quivira Coalition led the partner and producer networks in New Mexico, organized soil health workshops, developed a training series for producers, initiated field trials, and worked with academic partners throughout New Mexico to develop multistate and transboundary collaborative efforts to address open soil carbon science questions and technical assistance gaps.
People, Food, and Land Foundation	The People, Food, and Land Foundation is an umbrella nonprofit organization committed to meaningful food systems change.	Calla Rose Ostrander, working as part of the People, Food, and Land Foundation, provided guidance for the development of the partner and producer networks across the Rocky Mountain states, advised field trials and workshops, and developed policy recommendations.
Bird Conservancy of the Rockies	This regional nonprofit's mission is to conserve birds and their habitats through an integrated approach of science, education, and land stewardship. It works with a network of producers, including ranchers who are interested in building resilient operations through soil health practices, in Montana and throughout the Rocky Mountain states.	The Bird Conservancy of the Rockies helped plan and conduct a soil health workshop.

APPENDIX 2

Discretionary spending programs and recent funding levels

US FEDERAL AGENCY	PROGRAMS	PREVIOUS FUNDING LEVELS	RECOMMENDATIONS
U.S. Department of Agriculture	Economic Research Service	FY20 $84,757,000[61]	FY21 $87,757,000
	NRCS Soil Survey Program	FY20 $74,987,000[62]	FY21 $79,987,000
	NRCS Conservation Technical Assistance	FY20 $735,760,000 [63]	FY21 $749,760,000
	NIFA Agriculture and Food Research Initiative[64]	FY20 $425,000,000	FY21 $444,000,000
	NIFA Sustainable Agriculture Research and Education	FY20 $37,000,000	FY21 $39,000,000
U.S. Department of Energy	Terrestrial Ecosystem Science	FY20 $38,200,000[65]	FY21 $45,000,000
National Science Foundation	Directorate for Biological Sciences	FY19 $783,690,000[66]	FY21 $788,690,000

61. H.R. 1865. *Further Consolidated Appropriations Act, 2020, Agriculture, Rural Development, Food and Drug Administration, and Related Agencies Appropriations Act, 2020.* (2020).

62. Ibid.

63. Ibid.

64. While not included in the policy recommendations, the Agriculture and Food Research Initiative is also relevant to developing and scaling soil carbon storage on U.S. agricultural lands.

65. H.R. 1865. *Further Consolidated Appropriations Act, 2020, Agriculture, Rural Development, Food and Drug Administration, and Related Agencies Appropriations Act, 2020.* (2020).

66. National Science Foundation. (n.d.). NSF & Congress. Retrieved from https://www.nsf.gov/about/congress/116/highlights/cu19_0222.jsp

APPENDIX 3

Mandatory spending programs and recent funding levels

US FEDERAL AGENCY	PROGRAMS	AUTHORIZED FUNDING LEVELS	RECOMMENDATIONS[67]
U.S. Department of Agriculture	CIG On-Farm Conservation Innovation Trials (including Soil Health Demonstration Trials)	FY19 - FY23 $25,000,000[68]	FY21$50,000,000 FY22 $50,000,000 FY23 $100,000,000 FY24 $100,000,000
	NRCS EQIP	FY20 $1.75 billion[69] FY21 $1.8 billion FY22 $1.85 billion FY23 $2.025 billion	FY21$1.8 billion FY22 $1.85 billion FY23 $2.025 billion FY24 $3 billion
	NRCS CSP	FY20 $725,000,000[70] FY21 $750,000,000 FY22 $800,000,000 FY23 $1 billion	FY21 $942,500,000 FY22 $1.23 billion FY23 $1.6 billion FY24 $2.08 billion

67. Before significant increases in funding for core Farm Bill programs are made, the federal government should tweak these programs to account for geographic differences and build out the technical assistance capacity of the NRCS.

68. Stubbs, M. (2019). *Agricultural Conservation: A Guide to Programs*. Congressional Research Service. 18.

69. Stubbs, M. (2019). *Agricultural Conservation: A Guide to Programs*. Congressional Research Service. 16.

70. Stubbs, M. (2019). *Agricultural Conservation: A Guide to Programs*. Congressional Research Service. 12.

APPENDIX 4

Cultural inertia and practice change

Though regenerative agriculture is becoming more accepted and commonplace, cultural inertia of existing or conventional agricultural practices is still strong. Agricultural producers tend to be members of an older demographic, and some are uncomfortable with accessing new markets, accessing public capital through conservation or loan/insurance programs, or deploying new technologies. In addition, many producers must take on debt to implement new practices and acquire new equipment. For others, there is apprehension to work with or use government services, often due to the bureaucracy of securing funds (i.e., NRCS EQIP). Management decisions can be slow and strongly shaped by broader social, economic, and political dynamics.[71] These factors have tended to prevent many agriculture producers from changing their operations.[72]

Agricultural producers are also unlikely to change without a community of change (i.e., seeing is believing).[73] Early adopters are rare, and are often perceived as radical and sometimes face ridicule for shifting to new production practices or products. Moreover, many producers are not comfortable with emerging language or movements (e.g., carbon and climate). Producers often look to and learn from neighbors, which can mean new practices are slow to spread. These kinds of barriers are difficult to address with policy change, but are critical to consider as we look to ensure that changes in agricultural practices endure. It is also important to support early adopters and facilitate peer-to-peer learning and mentorship that can help new and innovative practices take hold.

Part of addressing cultural inertia barriers is elevating local champions.[32] Community organizations have been instrumental in elevating and supporting local soil health champions[74] by organizing and hosting field days and workshops that help connect producers who are interested in soil health and creating a community of practice that is rooted in local agricultural realities. As that community grows, producers often get engaged with other activities, including discussions about finance and policy innovation. Local events and workshops provide a variety of opportunities for producers to engage with technical assistance providers and scientists, helping de-risk and monitor the transition to soil health practices. Demonstration projects provide the "seeing is believing" pieces, helping farmers gain comfort with new practices and de-risking their implementation operationally and economically. The ethos of legacy and stewardship can help align soil management goals with climate mitigation objectives, focusing on conservationist "identity" and resilience rather than climate outcomes per se.[75]

71. Wilmer, H., Augustine, D.J., Derner, J.D., Fernández-Giménez, M.E., Briske, D.D., Roche, L.M., Tate, K.W. & Miller, K.E. (2018). Diverse Management Strategies Produce Similar Ecological Outcomes on Ranches in Western Great Plains: Social-Ecological Assessment. *Rangeland Ecology & Management* 71(5), 626-636.
72. Prokopy, L.S., Floress, K., Arbuckle, J.G., Church, S.P., Eanes, F.R., Gao, Y., Gramig, B.M., Ranjan, P. & Singh, A.S. (2019). Adoption of agricultural conservation practices in the United States: Evidence from 35 years of quantitative literature. *Journal of Soil and Water Conservation* 74(5), 520-534.
73. Gosnell, H., Gill, N. & Voyer, M. (2019). Transformational adaptation on the farm: Processes of change and persistence in transitions to "climate-smart" regenerative agriculture. *Global Environmental Change* 59, 101965.
74. Wilmer, H., Porensky, L.M., Fernández-Giménez, M.E., Derner, J.D., Augustine, D.H., Ritten, J.P. & Peck, D.P. Community-Engaged Research Builds a Nature-Culture of Hope on North American Great Plains Rangelands. *Social Sciences* 8(1), 1-26.
75. Roesch-McNally, G.E., Arbuckle, J.G. & Tyndall, J.C. (2018). Soil as Social-Ecological Feedback: Examining the "Ethic" of Soil Stewardship among Corn Belt Farmers. *Rural Sociology* 83(1), 145-173.

APPENDIX 4 *(Continued)*

Cultural inertia and practice change

Scaling soil carbon storage in agricultural systems will require education, science, and policy, but it will also require behavioral and cultural change and a fundamental shift in how we approach agriculture.[76] To ensure that changes are real and sustained over time, we must engage producers at every step and in every aspect of the work. Even the greatest advancements in soil science and the best policies will not make a meaningful difference if producers are not at the forefront. There are so many benefits of soil health beyond soil carbon storage, and shifting agricultural practices toward building soil health truly is a win-win for farmers and our climate.

76. Roesch-McNally, G.E., Arbuckle, J.G. & Tyndall, J.C. (2018). Barriers to implementing climate resilient agricultural strategies: The case of crop diversification in the U.S. Corn Belt. *Global Environmental Change* 48, 206-215.

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