U.S. Farmers & Ranchers in ACTION

Transformative Investment in Climate-Smart Agriculture

Unlocking the potential of our soils to help the U.S. achieve a net-zero economy

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Foreword

U.S. Farmers and Ranchers in Action (USFRA) is a national network of farmer and rancher-led organizations and the best minds in food, agriculture, science, and technology. This powerful network of changemakers is co-creating solutions to advance the Decade of Ag Vision: A resilient, restorative, economically viable, and climate-smart agricultural system that produces abundant and nutritious food, natural fiber, and clean energy for a sustainable, vibrant, and prosperous America.

To that end, and building on the findings of USFRA's 2019 briefing paper, The Power of Resiliency in Agriculture's Ecosystem Services, this report examines how innovations in finance and technology can be applied to overcome barriers to adoption of climate-smart agriculture practices to fulfill the mitigation, reduction, and investment potential of the U.S. agriculture sector at scale. USFRA enlisted The Mixing Bowl and The Croatan Institute to analyze the state of agricultural technology and finance today and identify critical investment areas in this sector. The authors relied on peer-reviewed research and direct interviews with producers, value chain stakeholders and the investment community, as well as the depth and breadth of knowledge and experience of the Transformative Investment in Climate-Smart Agriculture Working Group, members listed on page 92 in the Acknowledgments section.

This effort resulted in 1) the inaugural Climate-Smart Soil Technology Landscape and analysis, 2) a first of its kind analysis of the total capital flows into the U.S. agricultural sector, an annual estimate of $972B based on 2018-2020 data, and 3) key action steps to leverage technology and finance innovation to accelerate and scale the adoption of climate-smart agriculture practices.

It is our hope that this report will offer vital insights into the need for targeted, high-impact investments in agriculture and a clear picture of the potential scale of immediate and long-term environmental, societal, and economic returns of investments in climate-smart agriculture.

Executive Summary

U.S. Agriculture is a key enabling sector in the transition to a net zero economy as well as a critical portfolio investment opportunity for those seeking an economic return that also benefits the environment and communities.

By 2025, widespread adoption of climate-smart agriculture practices could reduce U.S. agriculture's contribution to total U.S. GHG emissions by more than half, from 9.9% to 3.8%.[1] These practices—which span nutrient application, manure management, and cultivation and grazing—are "sufficiently mature, both scientifically and in practice, to materially increase carbon storage if widely deployed in the U.S. and globally."[2] By 2035, with increased investments and partnerships across the food and agriculture value chain and the integration of promising frontier technologies, U.S. agriculture has the potential to be a carbon sink, at -4% of total U.S. GHG emissions.

This report focuses on six established practices: 1) no-till/reduced tillage with retained residues, 2) cover crops, 3) crop rotation, 4) compost application 5) managed grazing, and 6) integrated crop and livestock systems—all of which improve soil health, sequester carbon and produce numerous co-benefits such as reduced erosion, increased water infiltration, and economic and environmental resiliency. With technology and financial innovation targeted at specific practice adoption barriers, these benefits will accrue on the farm, throughout rural America and the agriculture value chain, and the nation as a whole.

Climate-Smart Soil Technology Findings

- ***More than 150 companies support digital data collection, analysis and sharing for climate-smart soil agriculture. These digital solutions can accelerate farmer and rancher practice-specific knowledge, aid in business planning, and simplify reporting to value chain, funders or other partners.***
    - ***Key barriers to technology adoption include the lack of standardized data collection methods and soil health metrics, data interoperability and rural broadband connectivity.***

Transformative Finance Findings

- ***Approximately $972 billion flows annually from institutional, retail and government investors across asset classes into the agricultural value chain.***
    - ***Agricultural capital and outside investments can be better aligned to scale adoption of climate-smart practices, and blended capital is a key enabler.***
- ***A range of asset classes, financial mechanisms and enabling infrastructures offer promising avenues to move capital in ways that ultimately help farmers and ranchers scale the adoption of climate-smart practices.***

1 U.S. Environmental Protection Agency. (2019). Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1990-2016, National Academies of Sciences, Engineering, and Medicine. (2019). Negative Emissions Technologies and Reliable Sequestration: A Research Agenda https://doi.org/10.17226/25259

2 Ibid. 1.

The climate-smart agriculture sector is growing, has current deployable technologies and emerging innovations, and capable farmer ingenuity, but needs investment now and throughout the next decade to deliver on the potential of soils to be a key carbon sequestration solution and support resiliency for farmers and ranchers. The report details specific leverage points where stakeholders within the U.S. agriculture value chain and the technology and finance industries can focus innovation, investment, and collaboration to rapidly transition agriculture to the first carbon-negative sector in the economy.

Action steps to leverage technology and finance innovation to accelerate and scale the adoption of climate-smart agriculture in the U.S.

1. **Raise investor awareness of climate-smart agriculture as a key enabling sector in the transitional net zero economy and connect investors to specific agriculture needs and opportunities.**
   - ***While investments in climate-smart agriculture offer positive social, environmental, and financial returns, many climate-specific investment tools (including green bonds) have not identified agriculture as an opportunity.***
   - ***More fund managers would be inclined to invest in agriculture if they had greater familiarity with the potential for climate-smart agriculture practices for carbon mitigation and sequestration and other positive social and environmental outcomes.***
   - ***Identify metrics, frameworks, reporting standards, and criteria that companies can use to promote their ESG credentials as it relates to climate smart agriculture.***
2. **Stimulate catalytic capital to flow into the agriculture sector through mechanisms that reflect the risk and return goals of ESG investors and climate smart agriculture finance innovation.**
   - ***Catalytic capital from foundations, government, and through emerging ecosystem service and carbon markets can help to de-risk transactions and increase the flow of capital.***
   - ***Specifically engage philanthropy through both their grant-making and investment strategies to help grow climate smart agriculture.***
3. **Encourage preferential lending programs, when possible, from existing agriculture lending institutions.**
   - ***Connect the existing agriculture lending market to climate-smart incentive structures that reward producers for indicators of soil-health progress.***
4. **Connect more sources of capital with producer ecosystems ready to transition to climate-smart agriculture to identify mutually beneficial solutions.**
   - ***With a goal of "test and learn," enhance the matchmaking between willing producer ecosystems and willing funders using online platforms and making sure producers are providing funders with digital reporting data to increase their comfort in supporting a producer ecosystem.***
   - ***Help funders gain comfort in providing compensation based on indicators of progress.***
   - ***Create blueprints for sustainability-linked loans that will reduce the time and transaction costs of leveraging this capital to advance climate smart agriculture.***
5. **Promote the further use of digital tools amongst farmers and ranchers to exchange best practice know-how and data (soil health, yield, profitability, etc.).**
   - ***Help to overcome the barriers to adoption of existing climate-smart soil technology tools. This includes ramping up the use of MRV (monitoring & estimation, reporting and verification) and other FMS (farm management systems) that can share information.***

6. **Support the development of tools that collect on-farm data; connect on-farm data to larger databases and platforms to accelerate local and practice-specific knowledge and provide funders with indications of progress to reward farmers and ranchers for climate-smart efforts.**
   - *Develop a national repository of soil carbon reference data.*
   - *Standardize laboratory methods, sensor measurements, and soil data exchange.*
7. **Support emerging revenue enhancement mechanisms for farmers and ranchers.**
   - *Nascent efforts are underway (by actors such as technology start-ups and consumer packaged goods brands) to economically reward producers for implementing climate-smart practices. Private ecosystem services markets are emerging for direct payments to farmers through market-based incentives and vendor direct payments.*
   - *These sources of capital can be blended with other sources to further de-risk the transaction by farmers and ranchers and their value chain partners.*
8. **Demonstrate clear risk/reward profiles of successful climate-smart financial support for today's investors and farmers and ranchers.**
   - *Continue to share success stories of how different financial tools are being applied successfully to specific climate-smart agriculture opportunities to get a broader base of farmers and ranchers and funders aware of and comfortable with the opportunities to transition to climate-smart agriculture at scale.*

Introduction

Agriculture is both uniquely vulnerable to climate change and uniquely positioned to adapt as well as to mitigate and sequester greenhouse gas emissions at scale. Transitioning to a climate smart agricultural system requires critical investments for long-term sustainable food production and broader net zero emissions goals.

Science tells us that the world must reach net zero emissions by 2050, with emissions declining well before 2030 to avoid the most extreme impacts of climate change.[3] This timeline emphasizes the immediate need for significant emission reductions of all sectors, effective mitigation solutions, and increased investments in a net zero economy. U.S agriculture is a low-cost opportunity for all three.

In 2019, the U.S. Farmers & Ranchers Alliance (now U.S. Farmers & Ranchers *in Action)* Ecosystem Services Science Advisory Council published its first briefing paper, The Power of Resiliency in Agriculture's Ecosystem Services. The paper presented the latest science supporting climate-smart practices as a viable and necessary pathway for climate adaptation and mitigation strategies, as well as the challenges and opportunities facing farmers and ranchers in the United States today.

Climate-smart agriculture is a suite of practices that sustainably increase productivity and incomes, enhance resilience and adaptive capacity, and reduce and/or remove greenhouse gas emissions.[4] The "climate-smart" terminology and the specific practices highlighted in this report are common to other sustainable and conservation agriculture initiatives, like regenerative agriculture. The key and common characteristic is that the practices support natural soil processes to build healthy soils.

As stewards of 45% of the nation's two billion acres of land, farmers and ranchers are uniquely able to capitalize on the on-farm and off-farm benefits of climate-smart agricultural practices at a national scale.[5]

See The Power of Resiliency in Agriculture's Ecosystem Services report and specifically pages 7 through 14 for more detail on soil science (health, quality, and products) and soil's relation to carbon sequestration.

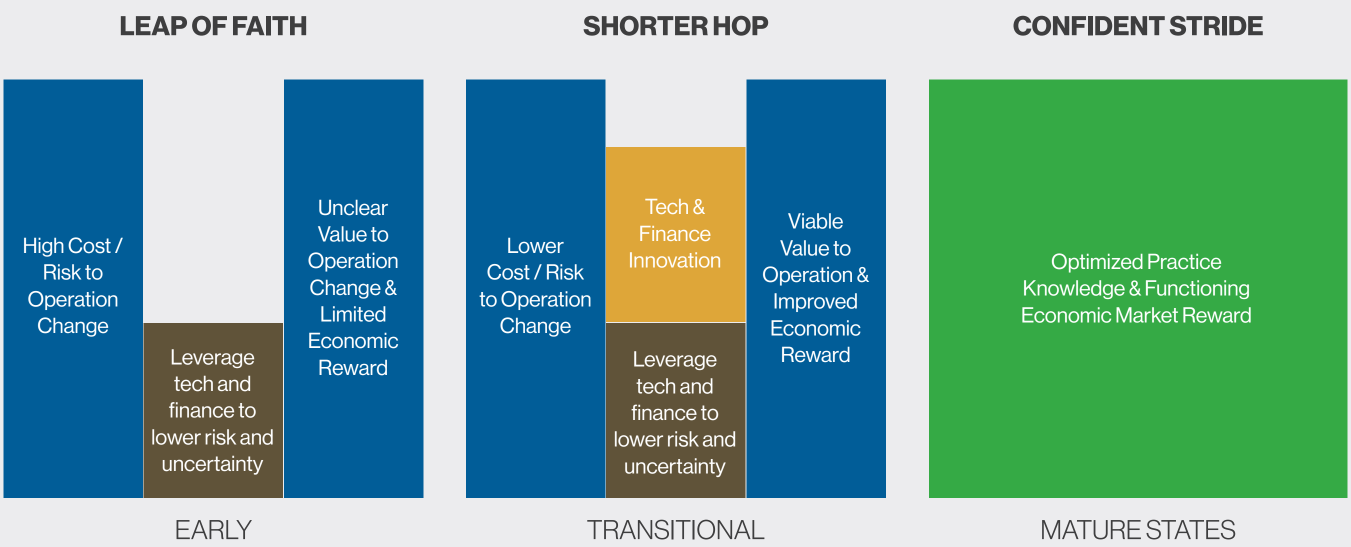
3 IPCC Special Report Global Warming of 1.5 degrees C https://www.ipcc.ch/sr15/
4 Climate-Smart Agriculture and the Sustainable Development Goals http://www.fao.org/3/ca6043en/ca6043en.pdf
5 U.S. Farmers & Ranchers in Action. (2019). The Power of Resiliency in Agriculture's Ecosystem Services https://usfarmersand- ranchers.org/wp-content/uploads/2020/06/USFRA-2019-Report.pdf

Farmers and ranchers have made significant advancements in building soil health, mitigating greenhouse gases, and increasing conservation practices to date, but the scale and pace of the transition required means that stakeholders across the agriculture value chain and beyond have a critical role to play. The transition to a climate-smart agricultural system will require a range of stackable support tools: locale- and practice-specific knowledge, clear revenue opportunities and developed markets, supportive policies and programs, interconnected and interoperable data, and access to technology and capital.

Innovative technology and finance are key enablers to broad adoption of climate-smart soil practices in the U.S. and the focus of this report. To clarify the role of technology and finance to support, fund, and incentivize climate-smart soil practice adoption, this report examines farmer and rancher barriers to practice adoption, the current state of climate-smart soil technology, and the range of financial mechanisms available to farmers and ranchers as well the investment case for including agriculture in the broader portfolio of net zero economy investments. Figure 1 illustrates the collective effort of stakeholders closing the current gap and scale climate-smart soil practices with tech & finance innovation.

Figure 1

Closing the Gap to Scale Climate-Smart Soil Practices with Tech & Finance Innovation



The Challenge for Farmers and Ranchers

The two million farmers and ranchers in the U.S., less than one percent of the population, must balance societal demands for food, fiber and energy with environmental stewardship responsibilities over a vast area, while adapting to and mitigating climate change and maintaining their own livelihoods – an immensely challenging mission.

Agriculture as a sector is particularly vulnerable to climate change due to its reliance on predictable weather patterns for crop and livestock production. Adverse effects of climate change on agricultural productivity in the U.S. are already occurring, and will increasingly continue, with increased average temperatures, changing rainfall patterns, more frequent climate extremes, flooding, and drought, as well as increased pressure from pests, weeds, and disease, and reduced crop and forage production and quality.[6]

Layered onto the normal and substantial risks of farming, challenges such as high input and equipment costs, labor scarcity, rising land prices and farmland loss from encroachment pressures, low commodity prices, and uncertain markets contribute to a chronically challenging economic situation for farmers. In addition, cash-rent land leases, which cover the majority of agricultural acreage in much of the country, combine short-term economic pressures with the longer-term uncertainty of land tenure to non-landowning operators.[7]

These challenges are multifaceted and complex; there is no single cause and no single solution but the need to adapt is clear. Farmers and ranchers have long been innovative and adaptable and as a result,

6 Fourth National Climate Assessment Chapter 10: Agriculture and Rural Communities https://nca2018.globalchange.gov/chapter/10/
7 U.S. Farmland Ownership, Tenure, and Transfer https://www.ers.usda.gov/webdocs/publications/74672/eib-161.pdf?v=0

we have seen decades of increased production per acre of land and with fewer inputs and early adoption of technologies, like GPS for auto-steering of tractors. Despite limited resources and incentives, farmers and ranchers across the country have increasingly adopted climate-smart practices, particularly over the last decade.

Adaptation in the face of climate change is a necessity for the livelihoods of the nation's farmers and the security of the nation's food; it is also an opportunity for bold action and a critical component of the nation's carbon mitigation and sequestration solutions.

The Potential in our Soils

Soil health, also referred to as soil quality, is the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans.[8] Healthy soils are critical for abundant crop production and productive grazing lands, as well as clean air and water and diverse wildlife.[9]

Soils, second only to the ocean, are the largest natural carbon sink on the planet. Storing and cycling nutrients, such as carbon, nitrogen, and phosphorus is one of five essential functions of soil; other essential functions of soil are 1) regulating water, 2) sustaining plant and animal life, including humans, 3) filtering and buffering potential pollutants, and 4) providing physical stability and support, both for plant roots and manmade structures.[9]

One way to measure and monitor soil health is by the level of soil organic matter (SOM) and its component, soil organic carbon (SOC), present in the soil. Soil organic carbon affects the physical, chemical and biological properties of soil and increased levels of SOC improve soil structure and drainage, enhance nutrient levels and water-holding capacity, and support higher levels of microbial life and biodiversity.

Management choices affect the amount of soil organic matter in the soil and as a result, the soil structure, soil depth, and water and nutrient holding capacity[9]; soil managed for agricultural purposes in the U.S. has lost as much as 60% of its original organic carbon content, much of it emitted to the atmosphere.[9] According to the EPA, agriculture contributed 9.9% of U.S. greenhouse gas (GHG) emissions in 2018[10] – primarily from livestock, nutrient application and soil management practices. These numbers include emission loss into the atmosphere into agriculture's overall EPA greenhouse gas inventory numbers, but do not factor in the carbon sequestration of soils. Currently agriculture soils are sequestering one hundred more times carbon than is currently emitted in a given year. Another way of thinking about the current storage potential of soil is, it is like taking 123. 3 billion cars driven per year off the road for the next 150 years.[11] The current soil stocks and the ability to improve them is an essential carbon mitigation pathway and is a great asset in the portfolio of solutions to mitigate carbon emissions.

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8 USDA Natural Resources Conservation Services Soil Health webpage https://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/

9 U.S. Farmers & Ranchers in Action. (2019). The Power of Resiliency in Agriculture's Ecosystem Services https://usfarmersandranchers.org/wp-content/uploads/2020/06/USFRA-2019-Report.pdf

10 Environmental Protection Agency. (2020). Inventory of Greenhouse Gas Emissions and Sinks: 1990-2018 – Agriculture https://www.epa.gov/sites/production/files/2020-02/documents/us-ghg-inventory-2020-chapter-5-agriculture.pdf

11 Second State of the Carbon Cycle Report (SOCCR2): A Sustained Assessment Report https://carbon2018.globalchange.gov/

Every acre of farm and rangeland matters. However, systemic loss of farmland to urban and lower density encroachment are a growing threat to U.S agricultural land. According to American Farmland Trust, the U.S. irreversibly lost 11 million acres of agricultural land -- 2000 acres a day -- between 2001 to 2016.[12] As farmland disappears, the potential for it to hold carbon, provide other ecosystem services and produce food, fiber, and energy is also lost.

Fortunately, the health of soils can be measured, monitored, and, most importantly, restored. Managing for soil health offers a rare win-win opportunity: it's good for farmers and good for the environment. In fact, Dr. Wayne Honeycutt, President and CEO of the Soil Health Institute, explains, "The research has shown that when we increase carbon in the soil just by 1 percent, we can increase the soil's capacity to hold water by anywhere from about 2,500 to 12,000 gallons per acre. That can build resilience to things like drought, so that's how it's good for the farmer. But it's also really good for the environment, because a lot of these same soil-health-promoting practices can help reduce nutrient losses to our waterways, reduce losses to our groundwater, and reduce greenhouse gas emissions."[13]

Many of the practices of climate-smart agriculture are rooted in principles that improve soil health. Scaled adoption of climate-smart practices can restore soil carbon levels, increase biodiversity and soil health across vast acres; reduce erosion and improve water quality; increase farm resilience; and generate cost savings and new revenue opportunities for U.S. farmers and ranchers. A number of these practices are described in the following section.

12 American Farmland Trust. (2020). Farms Under Threat: The State of the States https://farmlandinfo.org/publications/farms-under-threat-the-state-of-the-states/

13 Healthy Soil 101: Why Soil Health Matters and How the Food Sector Can Help https://www.triplepundit.com/story/2018/healthy-soil-101-why-soil-health-matters-and-how-food-sector-can-help/11396

Climate-Smart Agriculture

Soil-Health Practices and Potential Benefits

Climate-smart agriculture is a dynamic approach to farming and ranching with globally applicable principles to sustainably increase production and incomes, build resilience and adapt to climate-change, and reduce and/or remove greenhouse gas emissions.[14]

Climate-smart agriculture encompasses a range of management practices such as nutrient application, manure management, and cultivation and grazing. For the purpose of this report, we examined six climate-smart cultivation and grazing practices that are known to improve soil health: 1) no-till/reduced tillage with retained residues, 2) cover crops, 3) crop rotation[15], 4) compost application 5) managed grazing, and 6) integrated crop and livestock systems.[16]

These practices incorporate the five key principles to improving or maintaining soil health: 1) minimize soil disturbance,[17] 2) maximize plant diversity,[18] 3) maximize presence of living roots,[19] 4) maximize soil cover,[20] and 5) incorporate livestock with crop systems.[21] They are proven in practice, broadly applicable, and ready to implement on the estimated 392 million acres of U.S. cropland and 655 million acres of rangeland and pastureland.[22]

The EPA estimates that broad adoption of climate-smart practices like cover crops, crop rotations, no-till/reduced-tillage, managed grazing, and others offers a "practically achievable" pathway for reducing agriculture sector emissions by nearly 50% over the next 1-5 years.

14 Retrieved from FAO Climate-Smart Agriculture and the Sustainable Development Goals report http://www.fao.org/3/ca6043en/ca6043en.pdf
15 COMET-Planner http://comet-planner.nrel.colostate.edu/COMET-Planner_Report_Final.pdf
16 USDA Natural Resources Conservation Services https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/air/quality/?cid=stelprdb1044982
17 USDA Natural Resources Conservation Services https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/nd/soils/health/?cid=nrcseprd1300910
18 USDA Natural Resources Conservation Services https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/nd/soils/health/?cid=nrcseprd1300918
19 USDA Natural Resources Conservation Services https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/nd/soils/health/?cid=nrcseprd1300919
20 USDA Natural Resources Conservation Services https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/nd/soils/health/?cid=nrcseprd1300631
21 USDA Natural Resources Conservation Services https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/nd/soils/health/?cid=nrcseprd1300922
22 USDA ERS. (2017, December 4). A Primer on Land Use in the United States https://www.ers.usda.gov/amber-waves/2017/december/a-primer-on-land-use-in-the-united-states/

The Nature Conservancy, in its report, rethink Soil A Roadmap to U.S. Soil Health estimates that for each one percent of commodity cropland in the U.S. that adopts key soil health practices, annual economic benefits translate into a mean estimated $226 million of societal value through increased water holding capacity, reduced erosion and nutrient loss to the environment, and reduced GHG emissions, as well as $37 million of on-farm value through greater productivity. In the most optimistic case, it estimates soil health solutions could contribute up to $50 billion in social and environmental impacts annually across the U.S.[23]

From a greenhouse gas mitigation and sequestration perspective, the EPA estimates that broad adoption of climate-smart practices like cover crops, diverse crop rotations, no-till/reduced-tillage, managed grazing, and others offers a "practically achievable" pathway for reducing agriculture sector emissions by nearly 50% over the next 1-5 years (a 46% reduction from a baseline of 8.4% of total U.S. emissions).[24] Crucially, these practices are "sufficiently mature, both scientifically and in practice, to materially increase carbon storage if widely deployed in the U.S. and globally."[25]

The practices examined in this report are in-field practices (as opposed to edge-of-field or off-field practices) and maintain productive use of the land. Other climate-smart practices, such as those requiring land use or significant crop mixture changes (e.g., conversion or afforestation of cropland), non-soil or non-sequestration practices (e.g., manure management), and emerging "frontier practices" are not detailed. While the practices below are examined individually, an integrated set of practices can provide more benefits than a single practice.

Figure 2 outlines these climate-smart practices, key principles, and potential environmental and on-farm benefits. See the appendix for a more detailed description of the practices.

Figure 2

Climate-Smart Practices - Benefits

Practice	Principles	Potential Benefits
No till/reduced till with retained residues	Limited soil disturbance, soil cover	• Reduce sheet, rill and wind erosion • Reduce tillage-induced particulate emissions • Maintain or increase soil quality and organic matter content • Reduce energy use • Increase plant-available moisture • Provide food and escape cover for wildlife

23 The Nature Conservancy. (2016). reThink Soil: A Roadmap for U.S. Soil Health https://www.nature.org/en-us/what-we-do/our-insights/perspectives/rethinking-soil-reinvesting-in-our-foundations/

24 U.S. Environmental Protection Agency. (2017). Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1990-2016. National Academies of Sciences, Engineering, and Medicine. (2017). Negative Emissions Technologies and Reliable Sequestration: A Research Agenda. National Academies of Sciences, Engineering, and Medicine. (2019). Negative Emissions Technologies and Reliable Sequestration: A Research Agenda https://doi.org/10.17226/25259

25 National Academies of Sciences, Engineering, and Medicine. 2019. Negative Emissions Technologies and Reliable Sequestration: A Research Agenda. Chapter 3. page 175 https://doi.org/10.17226/25259

Cover crops	Soil cover, living roots	• Reduce erosion from wind and water • Maintain or increase soil health and organic matter content • Reduce water quality degradation by utilizing excessive soil nutrients • Suppress excessive weed pressures and break pest cycles • Improve soil moisture use efficiency • Minimize soil compaction
Crop rotation	Crop diversity, living roots	• Reduce sheet, rill and wind erosion • Maintain or increase soil health and organic matter content • Reduce water quality degradation due to excess nutrients • Improve soil moisture efficiency • Reduce the concentration of salts and other chemicals from saline seeps • Reduce plant pest pressures • Provide feed and forage for domestic livestock • Provide food and cover habitat for wildlife, including pollinator forage, and nesting
Compost application	Soil/carbon building	• Enhances water-holding capacity, • Provides stable, slow-release nutrients, • Enhances soil carbon sequestration • Increases forage production without harming native plant communities. • Mitigates emissions from other sources • Enhances the land's resilience to extreme weather[26]

26 Retrieved from Marin Carbon Project https://www.marincarbonproject.org/compost

Managed grazing	Soil cover, living roots, crop diversity, limited disturbance	• Improve or maintain desired species composition and vigor of plant communities • Improve or maintain quantity and quality of forage for grazing and browsing animals' health and productivity • Improve or maintain surface and/or subsurface water quality and quantity • Improve or maintain riparian and watershed function • Reduce accelerated soil erosion, and maintain or improve soil condition • Improve or maintain the quantity and quality of food and/or cover available for wildlife • Manage fine fuel loads to achieve desired conditions
Integrated crop and livestock systems	Soil cover, living roots, crop diversity, limited disturbance	• Improve or maintain desired species composition and vigor of plant communities • Improve or maintain quantity and quality of forage for grazing and browsing animals' health and productivity • Improve or maintain surface and/or subsurface water quality and quantity • Improve or maintain riparian and watershed function • Reduce accelerated soil erosion, and maintain or improve soil condition • Improve or maintain the quantity and quality of food and/or cover available for wildlife • Manage fine fuel loads to achieve desired conditions

It's important to note that applicability and implementation specifics and outcomes depend on prior management history and vary across regions, sectors, crops and soil types, to the farm and field level.

Much more combinatorial research is needed to model the expected efficacy of climate-smart soil practices applied to a certain crop production system in a specific geography with its associated microclimate and soil types. All of these practices take time and ongoing adaptation to realize their full potential.

The integration of promising "frontier technologies" unlocks the potential of U.S. agriculture to be a carbon sink, reaching -4% GHG emissions as a sector within the next 5-15 years, even with conservative estimates. Regardless of practice, creative financing solutions and risk-sharing models are critical to stimulate innovation and adoption.[19] The full benefits of carbon removal cascade when partnering across sectors to escalate investment and scale adoption, another critical reason for increased attention and investment in the U.S. agriculture sector.

A separate initiative underway at USFRA will provide a more detailed, quantifiable analysis of the costs and associated impact of various climate-smart practice applications.

Figure 3

U.S. Farmers & Ranchers Need Investment to Reach Full GHG Emissions Net Negative Potential

TODAY | **FUTURE**

2020

Agriculture contributes 9.9% of total U.S. GHG[27]

2025

Widespread adoption of climate-smart ag practices may cut this to 3.8%[28]

- Cover crops
- Diverse crop rotations
- Reduced tillage
- Precision fertilizer management
- Improved grazing systems

2035

With increased investments and partnerships to support frontier technologies, U.S. agriculture could be a carbon sink with -4% in total GHG emissions.[29]

- Advanced crop breeding
- Phenotyping for high carbon root systems
- Biochar amendments

Agriculture & Carbon Sequestration

U.S. farmers and ranchers need help to reach full GHG emissions net negative potential.

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27 EPA (2020). Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1990-2018. Retrieved from https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2018

28 NAS, Engineering and Medicine. (2019). Negative Emissions Technologies and Reliable Sequestration: A Research Agenda. Retrieved from https://www.nap.edu/catalog/25259/negative-emissions-technologies-and-reliable-sequestration-a-research-agenda

29 Ibid.

Figure 4

Drawdown Potential – Agriculture Carbon Removal Estimates

Agricultural ecosystems can play a significant role in carbon dioxide removal and sequestration, through systems that increase the amount of organic carbon stored in living plants, dead plant parts and the soil. U.S. greenhouse gas emissions totaled 6.5 Gt of CO2 Eq. – with agriculture representing a baseline of 9.9 percent. Practically achievable technologies examples include cover crops, no-till, precision animal manure and rotational grazing. Frontier technology examples include biochar amendments, advanced crop breeding or phenotyping for high carbon input root systems. The estimates provided in figure 4 are generally conservative and do not account for food waste emissions reductions and many of the positive contributions from animal agriculture (such as extracting nitrogen, phosphorus and soil amendments through manure fractionation and feed ingredient efficiency gains) towards moving the sector to net-negative carbon emissions. Further, the integration of row crop and livestock agriculture provides enhanced carbon and nitrogen cycling benefits for plants, animals and humans.[30]

30 U.S. Environmental Protection Agency. (2019). Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1990-2016. https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks
National Academies of Sciences, Engineering, and Medicine. (2019) Negative Emissions Technologies and Reliable Sequestration: A Research Agenda Chapter 3 page 89 https://www.ncbi.nlm.nih.gov/books/NBK541442/

Barriers to Farmer and Rancher Adoption of Climate-Smart Soil Practices

The potential of healthy soils in the broader national effort to create a net zero greenhouse gas economy-- if applied broadly-- has been well documented in many other reports; much less effort has been spent to identify the practical implementation barriers that farmers and ranchers face in adopting climate-smart soil practices. In this section we summarize findings from interviews with dozens of farmers and ranchers, some who have adopted the climate-smart practices included in this report and some who have not, to identify and summarize the key barriers they face.

The primary objective of outlining these barriers is to frame the subsequent technological and financial analysis and indicate where technology and finance can or cannot be used to overcome impediments for the farmer and rancher. These barriers can be organized into the following categories: economic factors, personal motivations, practical matters of information and implementation, and external concerns (see figure 5). While the height of these barriers may vary, the barriers themselves are generally common across production systems and practices.

Figure 5

Barriers to Climate-Smart Agriculture Adoption

Economic Factors

Economic model
Funding awareness and access
Contractual terms
Lack of premiums

Personal Motivations

Adaptability
Risk tolerance
Time and effort

Information and Implementation

Locale-specific information
Operator support structure
Technology and equipment
Practice-specific information

External Concerns

Land tenure
Policy and programs

Economic Factors

Economic Model

While the climate-smart practices are generally pragmatic and proven in practice, they do need to be adapted to regional and farm-specific conditions and be shown to be economically sustainable. Farmers need targeted decision support regarding economic outcome and risk, particularly within their operation-specific context. Given the variability farmers and ranchers face in implementing climate-smart practices, generally available economic models may not be sufficient to adequately inform, while local budget examples may not be available. Implementation costs for equipment, seed, labor, compost and containment systems are often front-loaded while the return may take longer to be realized; practice transitions can take several seasons to fine-tune, with added costs throughout.

Economic considerations and the business impact of practice adoption are consistently cited as both critical drivers and critical barriers for producers.

Funding Awareness and Access

Outside funding is critical for most farming and ranching operations. Sources including loans, incentives, cost sharing programs, grants, and tax credits are among the funding resources available to farmers and ranchers. Specific funding sources targeting practice transition are offered from federal, state and local governments, local and regional districts and programs, and conservation organizations. However, producers may not be aware of such sources or how to access them or be subject to access restrictions as a non-landowning operator or be reticent to share the data required by such programs. Additionally, programs may be transient or time restricted, and funding amounts capped or restricted by a limited pool. The Environmental Quality Incentive Program (EQIP) from the USDA National Resource Conservation Service (NRCS) is a notable example. It provides cost-sharing incentives for implementing conservation management practices on agricultural lands nationally but is chronically over-subscribed and had a 45.7% overall acceptance rate in 2019.[31]

31 Congressional Research Service. (Updated August 15, 2018). Agricultural Conservation: A Guide to Programs https://www.everycrsreport.com/files/20190815_R40763_34cb38c8ae95d234ef3c4dff911f36fa7578e160.pdf

Burdensome Contractual Terms

Farmers and ranchers manage a multiplicity of business partner relationships and agreements to produce and market their products, such as: lenders, government agencies, marketing, land access and use, suppliers, insurance, and checkoff and incentive programs. Terms that do not take the extended time horizons of practice change into account, like year-to-year leases and operating loans, also increase producer's risk. Finally, the strict verification requirements of carbon and ecoservices markets may be an added obstruction for those seeking an additional revenue stream from the emerging offset market.

Lack of Premiums for Adoption

Farmers and ranchers generally do not receive price premiums for goods produced using climate-smart practices. In fact, farmers, on average, are currently paid 8 cents per dollar of food sold, with the majority of the dollar going to marketing and other value chain actors.[32] Retaining differentiation through the current supply chain is extremely difficult due to the challenge of segregating and attaching data to climate-smart products as they move through agriculture's complex supply chain and production systems. Some food companies have begun limited pilot programs to encourage and compensate farmers and ranchers for adopting specific practices, but it remains to be seen how long they can subsidize producers or how long it will take to pass along the premium to consumers.

Direct payments to farmers and ranchers for sequestering carbon or other environmental benefits, like improved water retention, are another type of premium. The ecosystem services market is currently being spearheaded by several independent initiatives in lieu of a national carbon market. While these markets hold great promise and have garnered increased interest of late, they are still somewhat nascent.

32 USDA Food Dollar Series https://www.ers.usda.gov/data-products/food-dollar-series.aspx

Information & Implementation

Locale-Specific Information

To borrow from politics, "all farming is local." That statement acknowledges the obvious regional differences across the U.S., but also the farm-to-farm, field, and even sub-field variability farmers and ranchers must operate within, including current production systems, crop selection and diversity, climate, location, resources, presence of livestock, pests, slope, weather, soil type and management history, some of which is not easily adapted to change.

Climate-smart practice adoption requires access to tailored information, technology and support.

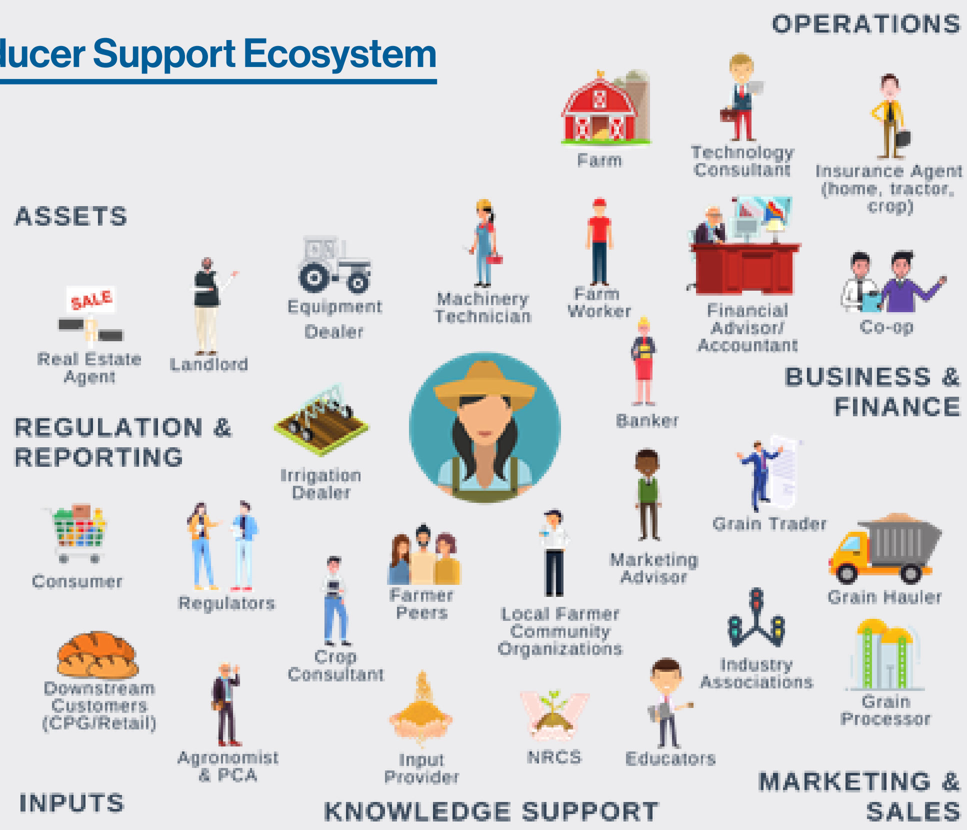
As farmers educate themselves on how to incorporate new methods within their existing systems, they may find an abundance of sources (and possibly conflicting guidance), but limited information on solutions applicable to their specific local context and from sources they trust. That lack of farm-specific planning, decision support and implementation guidance for climate-smart practices can be a significant impediment to adoption.

Alignment of Farmer Support Structure

Farmers and ranchers rely on an ecosystem of support from peers, crop advisors, extension agents, NRCS staff, advocates and local programs, lenders, suppliers and downstream partners (see figure 6). Alignment within this ecosystem can be a key driver of new practice and technology adoption. Local, trustworthy sources are critical, but staffing and funding of local technical staff is an ongoing constraint.

Figure 6

Grain Producer Support Ecosystem



Technology & Equipment

Technology's role as a key support tool to climate-smart practice adoption is discussed in detail later in this document; however, the application of technology faces barriers common to other AgTech solutions, such as a lack of basic digitization, inconsistent and unreliable broadband availability, integration with existing practices and technologies, trust, and adequate tech support. Even for tech-ready producers, there are difficulties getting information into systems efficiently. Granular, accessible and efficient tools for soil sampling, decision making, and monitoring are lacking as are the underlying data standards, methodologies and datasets. Comprehensive planning and management systems depend on the farmer or rancher's digital readiness and these underlying technologies before they can make an impact at scale.

Cost and availability of appropriate farm equipment may also be a barrier. Although there are opportunities to rent equipment and a number of local programs offering shared tools like specialty planters and roller-crimpers, this may not be the case in all areas. Even where offered, availability during peak times can be an issue.

Practice-Specific Information

Each of the climate-smart practices has its own unique challenges and implementation barriers. Although locale is always a factor, it is perhaps most constraining for cover cropping; establishing and terminating covers can be especially problematic in the shorter season and wet spring areas. Also, each practice has specific equipment or other needs, like compost, that the producer may not own or have readily available. Practices also vary in complexity, with cover cropping and integrated livestock operations requiring higher levels of management effort and ongoing adaptation of systems. Lastly, all the practices require some level of measurement or monitoring to be managed effectively and compile data for stringent verification of carbon or other ecosystem services to be monetized.

Personal Motivations

Adaptability

The level of openness to change, or adaptability, can be a barrier to adoption if there remains uncertainty about the potential risks and rewards of climate-smart practices. Farmers and ranchers have likely invested years and significant capital in their current production system, and although they may constantly adapt to changing conditions, larger-scale changes are something different. While there are additional factors farmers may consider -- such as financial necessity, loss of topsoil through erosion, a perceived benefit like reduced fuel usage, or an increased focus on ecological outcomes -- farmers and ranchers follow the general innovation adoption curve of 1) innovators, 2) early adopters, 3) early majority, 4) late majority, and 5) laggards. Innovators and early adopters are typically more open to new ideas and able to deal with the uncertainty of new technologies, while later adopters tend to wait until the majority of their peers have successfully adopted the innovation.

Personal characteristics and influences, such as a farmer's level of adaptability, risk tolerance, and available time and effort, play a key role in their openness to take on new management systems or integrate new technologies.

People may naturally fall along one end of the curve or the other based on past experience, access to resources and knowledge, social norms, economic situation, etc., but all individuals enter into the decision-making process "motivated to reduce uncertainty about the advantages and disadvantages of an innovation".[33] Initial experimentation and success, as well as increased levels of adoption among peers and clear risk/reward outcomes can increase openness to adopt climate-smart practices, expand practice acreage, and layer on additional practices over time.

Risk Tolerance

Farming is fundamentally about managing risks: agronomic, climate, labor, regulatory, environmental, financial, and market. In a sector that is marked by low margins and high debt, extreme weather, societal pressures and market uncertainty, farmers and ranchers, understandably, look to understand the risks in any new practice or management change. Changing practices is an added risk that can translate into the livelihood threats of decreased yields or profitability, or increased debt associated with initial upfront investments. As it often takes a number of years to fully reap the benefits of climate-smart practice adoption, the risk horizon can be a long one. Data-derived insights from verified, field-level data connected to large, aggregated data sets can help reduce the risk of transitioning to new practices and better quantify the potential risk and reward of practice changes.

Time and Effort

Farming and ranching require investments of time and effort to learn and optimize any production system, and farmers and ranchers are already short on time and personnel. Climate-smart agriculture is a more holistic, highly dynamic approach to farming and ranching; climate-smart practices are often complex and require active planning and management with system-level thinking, continuous learning, and local adaptation over time. In addition, they can have increased labor requirements, e.g., cover crop seeding and termination and the regular moving of cattle in managed grazing.

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33 Rogers, E. (2003). Diffusion of Innovations. Fifth edition. Free Press: New York

External Concerns

Land Tenure

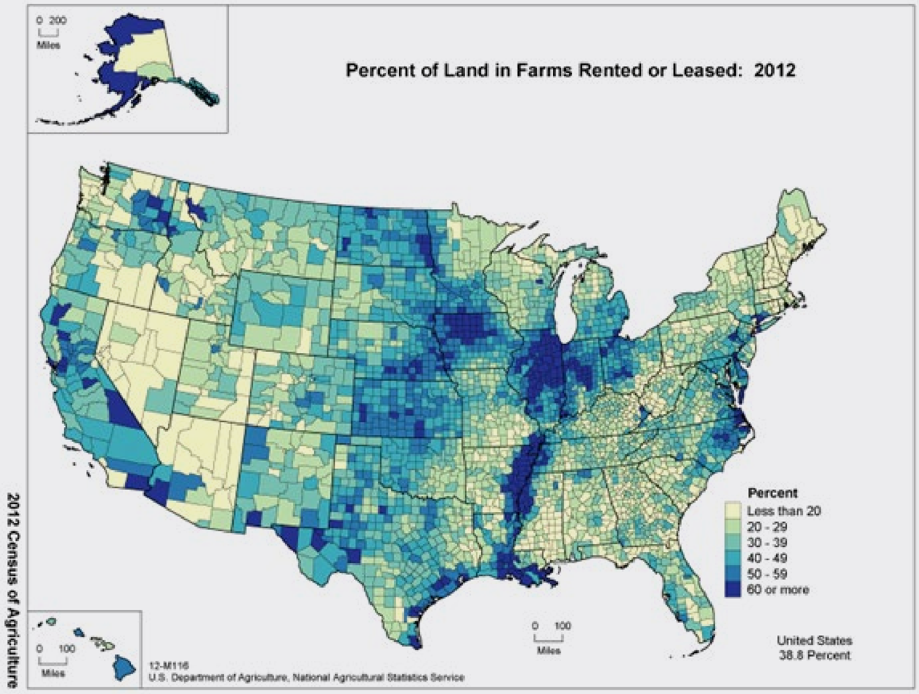
According to the USDA, more than half of cropland and more than a quarter of pastureland is rented or leased. Land tenure, e.g., agricultural land ownership and the relationship between landowner and non-owner operator, affects production and conservation decisions. The core issue is one of time horizon; short-term leases offer a disincentive for the non-owner operator to invest in soil health and soil health practices. There can also be an unclear division of responsibilities and lack of communication, compounded by the fact that farmers often rent parcels from several different landowners. See figure 7 for a USDA Census Ag Atlas Map for percent of land in Farms Rented or Leased.[34]

Like macroeconomic factors that are beyond the producer's immediate control, there are other external concerns and conditions, such short-term land tenure and misalignment of policies and programs, that can affect practice adoption.

Another flavor of the land tenure issue is extended family and multi-generational land ownership, which may require multiple parties to agree on changes. Also related is the ever-increasing inaccessibility of land ownership for new farmers who may be more inclined to pursue climate-smart practices than existing landholders. Recent work by The Nature Conservancy and the American Farmland Trust explores the land tenure barrier in greater depth.

Figure 7

Percent of Land in Farms Rented or Leased: 2012



34 USDA Census of Agriculture 2012 Census Ag Atlas Maps – Operators Percent of Land in Farms Rented or Leased: 2012 https://www.nass.usda.gov/Publications/AgCensus/2012/Online_Resources/Ag_Atlas_Maps/Operators/Tenure/12-M116.php

Alignment with Other Policy and Programs

Although there are policies, programs and regulations intended to support conservation practices, policy can also be a barrier. One recent example was the conflict between cover crop termination windows and federal crop insurance eligibility. Although cover crop practices are now recognized as Good Farming Practice, crop insurance generally may not account for the reduced risk of improved soil health. Likewise, most other policies are lagging in their support for soil health practice adoption. Beyond the government, one anticipated program barrier mentioned earlier is verification policies for carbon and other ecoservices markets. This is discussed in more detail later in this report.

Figure 8 lays out the potential barriers to adoption of each of the six climate-smart practices examined in the previous section.

Figure 8

Barriers to Climate-Smart Practice Adoption

Practice	Principles	Potential Barriers to Adoption
No till / Reduced till with retained residues	Limited soil disturbance, soil cover	• Technology and equipment • Funding awareness and access • Locale-specific information • Land Tenure • Adaptability
Cover crops	Soil cover, living roots	• Technology and equipment • Funding awareness and access • Locale-specific information • Practice-specific information • Risk Tolerance • Time and effort • Land Tenure

Crop rotations	Crop diversity, living roots	• Technology and equipment • Funding awareness and access • Locale-specific information • Practice-specific information • Risk Tolerance • Time and effort
Compost application	Soil/carbon building	• Technology and equipment • Funding awareness and access • Locale-specific information • Practice-specific information • Time and effort
Managed grazing	Soil cover, living roots, crop diversity, limited disturbance	• Locale-specific information • Time and effort • Technology and equipment • Funding awareness and access • Practice-specific information • Adaptability • Land tenure
Integrated crop and livestock systems	Soil cover, living roots, crop diversity, limited disturbance	• Locale-specific information • Time and effort • Technology and equipment • Funding awareness and access • Practice-specific information • Adaptability • Land tenure • Policy and programs

There are numerous organizations and programs focused on reducing barriers to adoption, particularly with regard to supporting science, education, and policy.

Not all of the barriers can be overcome with technology and finance solutions, but attention and innovation in these areas can accelerate adoption of soil health practices to help realize the multiplicity of benefits discussed above.

State of Agricultural Technology for Soil

The digitization of agriculture may be the single biggest opportunity to meet farmers' challenges and scale climate-smart soil practice adoption. Many of the economic, psychological, implementation, and external barriers to transitioning to climate-smart practices can be mitigated by more targeted, trusted, and easily collected information and metrics.

This section of the report explores how the application of technologies can help reduce uncertainty in transitioning to climate-smart soil practices. Over time, digital tools that measure and verify the efficacy of different practices will encourage familiarity and trust, reducing the uncertainty associated with a new or modified management practice. With emerging datasets and advances in informatics, exponential learning curves become possible -- learning curves that reduce the barriers to scaling practices and inform the models of those financing climate-smart farming and ranching practices. Moreover, the learning curves gained through digital agriculture adoption can provide policymakers and investors with data insights on the efficacy and potential benefits of climate-smart practices.

The scope of this analysis is technologies with a soil-health focus, but we begin by recognizing the important role of general technologies in the day-to-day success of farmers and ranchers. These technologies, like social media and online communication/collaboration technology platforms, are not included in the Climate-Smart Soil Tech Landscape, but are vital tools for information-sharing, trust and network-building, and time and effort-saving.

There are robust and informative producer discussion threads in private Facebook Groups; quick best-practice sharing in WhatsApp; information sharing through YouTube, webinars, and podcasts; streamlined on-farm communications via Slack; and collaborative exchanges using Google Docs and many other consumer and lightweight business productivity applications. Important lessons can be learned from the simplicity of these collaborative sharing platforms by how easily they fit into people's day-to-day lives and serve as links to trusted sources of information.

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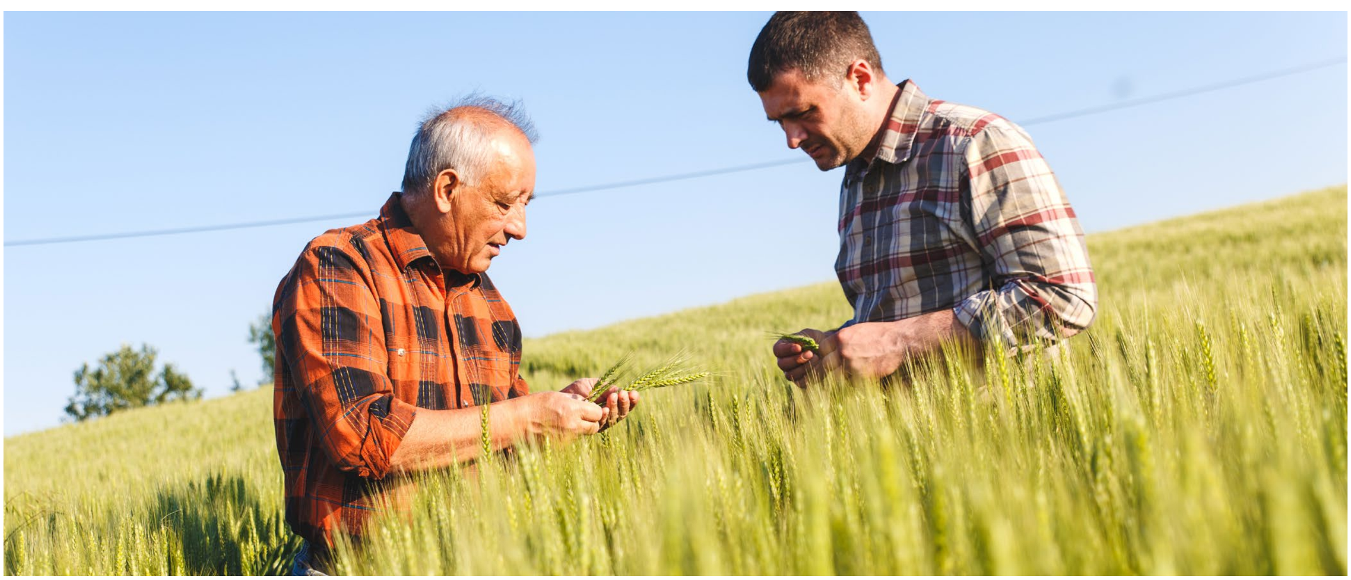
Likewise, it is important to remain grounded in the idea that most agricultural technology adoption is likely to be incremental. Technology can simplify and enable data collection and sharing, accelerate locale-specific decision support knowledge, and enable new revenue models to accelerate adoption of climate-smart practices, but there are also inherent barriers to scaled adoption of any agricultural technologies. Too often the basic barriers to digital agriculture are overlooked — like a preference for pen and paper systems or inadequate internet bandwidth. Below are three common barriers in agriculture technology adoption that limit the scale of climate-smart soil technologies on the market today and are critical to consider prior to an analysis of the Climate-Smart Soil Technology Landscape, starting on page 21.

Barrier #1: Basic Digitalization

Barriers to Climate-Smart Soil Tech adoption generally follow barriers of general AgTech adoption yet are made more difficult by the fragmentation and complexity of metrics and measurements. The fact remains that adoption of decision support technologies remains relatively low. On this point, it is important to distinguish between precision agriculture technologies (variable rate applicators, yield mapping, autosteer, etc.) which log crop protection or fertility applications and Farm Management Software (FMS) solutions (discussed in more detail below) that aggregate activity information, including precision ag data, and provide a dashboard for farmers or ranchers to manage their day-to-day operations. In a 2018 Alpha Brown study of 1,490 American farmers, only 16.5% currently used Farm Management Software, while 69% relied on pen, paper, and non-digital tools. In contrast, 50-75% of growers utilize precision agriculture technologies in commodity row cropping.[35]

16.5% of farmers are currently using a Farm Management Software solution while 69% of farmers rely on pen, paper, and non-digital tools.



35 Alpha Brown Farm Management Software (FMS) Market Potential Repor, January 2018 https://www.alphabrown.com/product-page/farm-management-software-fms-market-potential

When it comes to digitalization, much of the research points to limited awareness, difficulty getting information into systems, and lack of trust (data security and data use) as key barriers. In order to scale up adoption of practices and technologies, farmers and their support networks need to be able to see the business case and ROI. In this, the support network can play an important role in overcoming the first steps in digitalization by introducing appropriate technologies and discussing benefits and risks (as service providers look for new ways to add value to their relationships). Data collection and analysis are an essential part of making the business case and measuring the ROI.

At the core of these basic digitization issues is the fundamental challenge of broadband access. Many others are working on this topic and thus is not something we delve into in this report. For a general overview of on farmer perspectives on data collection and sharing see figure 9[36].

Figure 9

Farmer Perspectives on Data Collection and Sharing

Low Software Usage & Digitization
62% did not use farm-level data software in 2019; 46% store and manage their data primarily on paper records

Transparency is not a Right
49% said they do not believe their customer(s) has a right to know how they manage their farm

Low Satisfaction Rates
70% of those who did use data software in 2019 are not having all of their needs met by the software

Unequal Profit Distributions
Farmers identify unequal financial gain from data sharing, where downstream organizations profit from farm-level data sharing at higher levels than farmers

Minimal Advocacy by Trusted Advisers
71% said their primary agronomic advisor or retailer has not recommended that they increase their data collection

Trust Issues are Widespread and Nuanced
More than half said they do not trust the federal government or private companies with their data

Barrier #2: Standardization and Interoperability

A major obstacle is the absence of agreed upon standards to facilitate data interoperability across the farm and ranch management ecosystem. Common data field structures and language frameworks enable standardized information capture, communication, and analysis to be shared between different computers and software applications. Structural interoperability defines the data's syntax or format. Semantic interoperability acts as a translation engine, bridging terminology gaps.

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36 Farmer Perspectives on Data: Trust in Food a Farm Journal Initiative & The Sustainability Consortium
https://www.trustinfood.com/wp-content/uploads/2020/05/Farmer-Data-Perspectives-Research_final.pdf

A lack of standardized data makes it challenging for technology developers to establish terminology and protocols that can align with others' systems. This can make it difficult for a farmer or rancher to integrate operational data into business systems, or to share data with regulators, certifiers, or supply chain partners. Siloed data also inhibits the ability to scale data sharing across operations to inform predictive models and agricultural research. In fact, "scale" may not come in the form of one dominant platform, but in the form of multiple platforms that enable interconnected data sharing. This concept of "systems of systems" will enable the flow of more data and knowledge, faster analysis and insights, and is likely to lead to more solutions capable of accommodating the wide variety of ranches and farms across regions and crops.

Related to interoperability is appropriate data-sharing and usage. Digital approaches, particularly those that automatically capture data, may also require enhanced safety, privacy, security, and fraud protocols that are beyond the reach of individual proponents to provide.

Barrier #3: Adequate Technology Support

Drawing on experiences of other industries, like telecommunications, that experienced early fragmentation among operating systems, standards, data transmission protocols, and hardware/software interoperability, it becomes increasingly apparent that AgTech implementation and support service models are needed to ease the pain of adoption.

The consumer electronics chain Best Buy in the United States is well-known for its Geek Squad, a squad of service trucks that make house calls to install and service gear, regardless of brand. In farming and ranching, this service aspect could manifest as a network of regional tech support professionals that connect and service different technologies in a portfolio of on-farm or in-field solutions. This would allow farmers to spend less time calibrating, programming, or troubleshooting, while increasing the likelihood the device is operating effectively because it was properly installed and calibrated. This service delivery model could take several forms, depending on the region or commodity, but a few plausible ideas include local tech managed services companies, progressive dealers or retailers, independent value-added resellers, or entrepreneurial young people with a basic understanding of agriculture who are technologically literate. Ensuring that these new business models can truly meet farmers' needs, such as not having to wait for equipment to be serviced, will be essential to their success.

Overcoming the three agriculture technology adoption barriers above will go a long way in easing the journey to a more holistic view of farming and ranching operations.

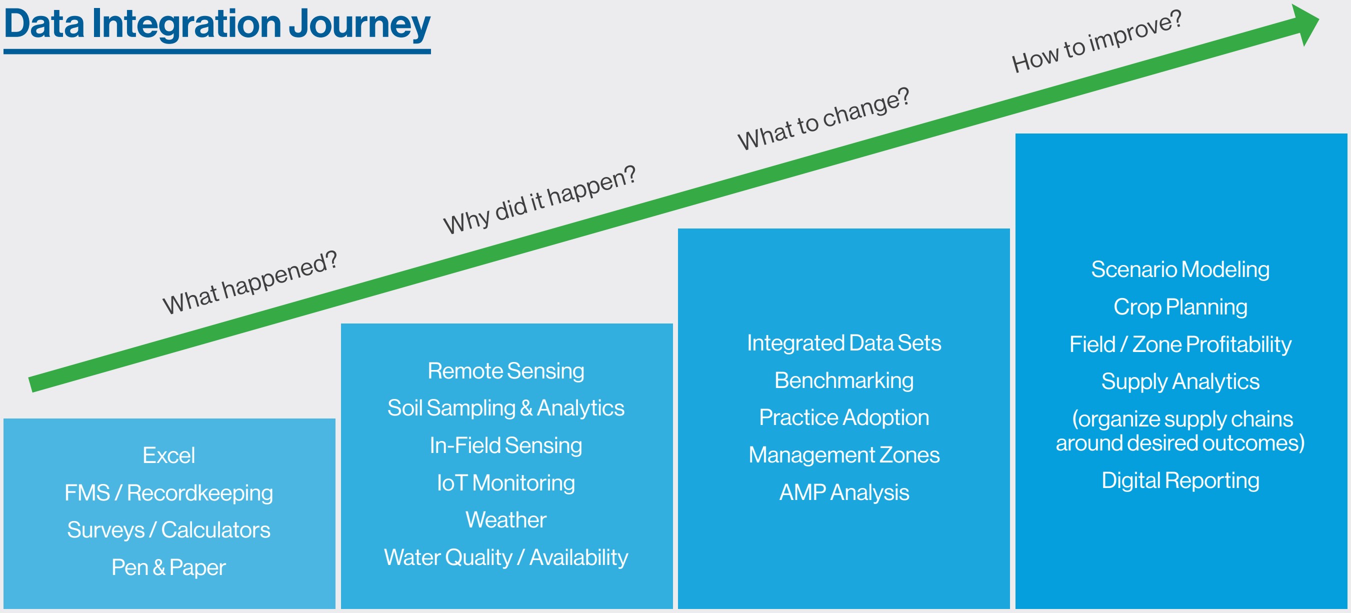
Data Collection, Measurement, Reporting, Verification (MRV) & Integration

Data collection is the foundational first step in evaluating the business case for any new agricultural practice, particularly given the tools now available to farmers and ranchers. Simplified data collection and sharing, locale-specific decision support, and new revenue models can be scaled through barrier-breaking technology innovation, the underpinnings of which are digital Measurement & Estimation, Reporting, and Verification (MRV).

Data collection must be done with consistent recordkeeping, calibration, configuration, storage, and organization to create clean, useful datasets that feed MRV systems to avoid the adage: garbage in, garbage out. Below is an illustration of a farmer or rancher's data integration journey with key questions they may ask along the way, as well as examples of the types of technologies appropriate with each step on that journey. The initial integration of technology supported data collection may begin slowly, as the transition from pen and paper and general AgTech adoption barriers are often the most complex hurdles to overcome; as farmers move along the data integration journey (see figure 10), layered datasets become easier to access, minimize time and effort required, and unlock insights not previously possible.

Figure 10

Data Integration Journey



The integration of data collection and sharing into digital agriculture's Measurement & Estimation, Reporting, and Verification (MRV) frameworks can be grouped into three broad categories:

1. **Solutions to automate shared access and enhancement of datasets: (national soil reference data, scientific models, GIS datasets, etc.).**
   - ***This includes solutions targeting the use of third-party data in lieu of direct measurement 'in-field' to automate aspects of MRV.***
   - ***Bioregional sensor networks with large sets of data points that act as training and validation datasets also fall into this category.***

2. **Solutions that capture data directly from the source: (farm/field/activity-specific, direct capture via sensors, IoT monitoring, hardware, etc.).**
   - ***This includes direct capture of data in-field through technology in place of manual effort, typically using IoT and cloud-based technologies to automate data collection and transmission via geolocated precision agriculture data.***
   - ***Farm Management Software (FMS) solutions that enable digital recordkeeping of activities, soil amendments, prescriptions, and yield, among other agronomic data points also fall into this category.***

3. **Solutions that capture data remotely: (activity-specific, remote capture).**
   - ***These are primarily remote sensing technologies, satellite (with LIDAR or RADAR) or even drone-capture and can be used to track spatial and temporal changes in land use, biomass, and other relevant surface measurements (there are even some subsurface technologies in development).***

The value of collected data increases as soil, yield, inputs, weather, aerial imagery, costs, and other datasets are integrated into a geospatial view that provides farmers, ranchers, and their support organizations with a multidimensional view of their baselines, soil health indicator changes, management zones, and benchmarks.

This holistic view, comprised of integrated land or field-specific data and public models and datasets, empowers decision-makers to make informed management decisions on a daily, weekly, seasonal or even multi-year basis, such as scenario modeling and crop/herd planning. The ability to model different operational or economic impacts based on different conservation decisions is central to understanding the risks and benefits of practice adoption.

The ability to model different operational or economic impacts based on different conservation decisions is central to understanding the risks and benefits of practice adoption.

A combination of direct measurements (at the field/farm scale) and modeling (at larger spatial scales) can significantly aid in defining the efficacy of different practices in enhancing soil health. When layered with a Farm Management Software (FMS) solution to provide activity and temporal context, a practical decision framework for farmers and ranchers looking to implement climate-smart soil practices is possible.

Navigating the 2020 Climate-Smart Soil Technology Landscape

More than 150 different solutions were assessed to construct the Climate-Smart Soil Technology Landscape (see figure 11 and in the Appendix). The focus of this analysis is soil-related Measurement & Estimation, Reporting, and Verification (MRV) software platforms that can provide farmers with data-driven insights to support their management decisions or connect with other platforms, like marketplaces, to realize new revenue streams.

For the past five years The Mixing Bowl team has tracked the development and adoption of agriculture technology and published a series of AgTech Landscapes. The same methodology used to develop those broader landscapes has been applied to this analysis of climate-smart soil technologies. The approach and subsequent insights into the technology landscape of climate-smart soil practices are predicated in four key principles:

1. **Connect lessons learned from the adoption of precision agriculture over the last 5-10 years with recommendations and success factors specific to Climate-Smart Soil Tech.**

2. **Make a compelling business case for adoption of both climate-smart soil practices and the enabling technologies for Measurement & Estimation, Reporting, and Verification (MRV).**

3. **Evaluate technology product and market readiness for commercial adoption at scale.**

4. **Recognize the value of data in supporting new, market-based business models that can benefit farmers and ranchers through:**
    - *Risk management tools for insurance and financial institutions (financial incentives)*
    - *Ecosystem services markets (new revenue streams)*
    - *Potential for climate-smart premiums through supply chain or long-term contracts (contract premiums)*

There are a variety of noteworthy soil-related databases, frameworks and calculators that were not included in this analysis and several additional key considerations to note about the scope of this analysis when navigating the landscape:

- **Soil Health Focus:** *The scope of this landscape should be viewed through a lens of soil health. That said, it is recognized that an ecosystem approach should embody a landscape of tools and technologies capable of estimating, measuring, and managing indicators beyond soil health to include, biodiversity, atmospheric emissions/respiration, water quality and use, as well as land use.*
- **Protocols and Standards:** *Although scientific measurement is foundational to the credibility and adoption of soil health practices, this analysis is not an evaluation of the particular models or measurement approaches. Rather, this analysis looks at the potential for technologies to be a catalyst in scaling up practice adoption by enabling data-driven MRV that ultimately leads to transparent risk/reward outcomes.*
- **Scaling Up Adoption:** *The challenge with scale comes from the inherent complexity of biological and environmental systems. While algorithm design is by its nature well-suited to scale, other solutions like sensors can become prohibitive at scale. This unique opportunity to design for scale at the outset which will require a balance between scientific precision and technological cost.*
- **Scope of Information:** *A market analysis uncovered many information sources accessible to farmers, ranchers, crop advisors, researchers, and companies in support of practice recommendations, best practices, and decision making. The volume of information available, often lacking in standardization, may be currently viewed as a barrier to adoption. Efficiency and trusted sources of information are a critical part of the solution. Within the landscape, the reader will note categories for Databases and Resources, Ecosystem Enablers, and Calculators, Models, and Reporting Tools which are intended to represent a selection of recognized sources, not an exhaustive list.*
- **"Glo-cal" (Global/Local) Landscape:** *It is important to look globally and include best-of-breed hardware, software, and applications that may help scale MRV approaches. However, there are other categories, featuring representative organizations, such as Information Sharing, and Calculators, Models, and Reporting Frameworks and Farm Management Software Interfaces that are primarily North American with their more regional, production system nuances and thus potentially more relevant to the USFRA audience at this time.*
- **The Need for Digital Connectivity:** *It is essential to underscore the importance of rural digital connectivity to make any of these technologies practical for producers. Developers of all AgTech solutions need to recognize and design for current limited bandwidth in rural agricultural areas.*

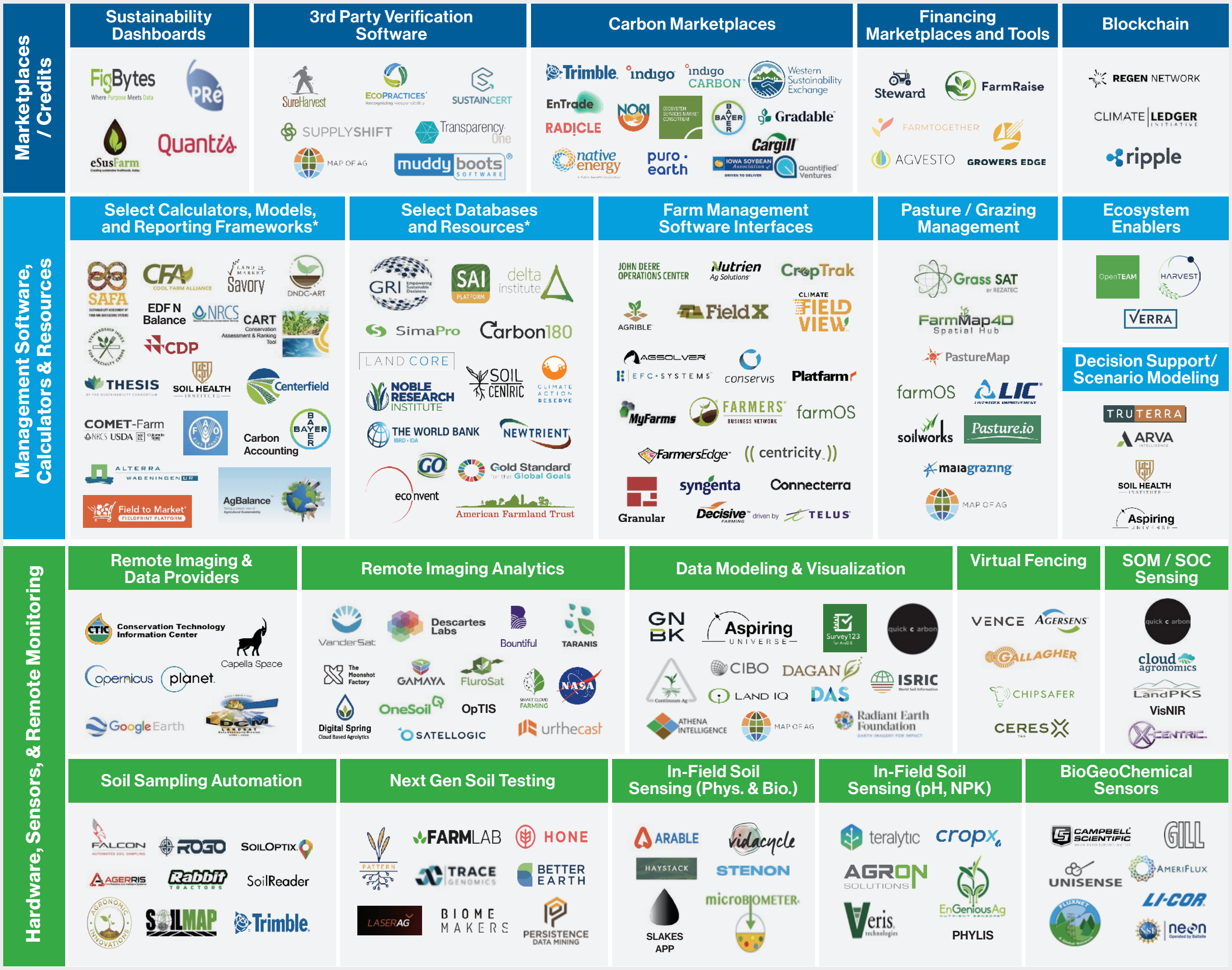
The landscape is generally oriented around market-based models, MRV activities, and data collection technologies that can aid in planning, adoption, and business modeling, and three layers of solutions (from bottom to top in graphic):

1. **Hardware, Sensors, and Remote Monitoring.**
2. **Management Software, Calculators/Assessments, Databases and Resources.**
3. **Marketplaces and Credits.**

Figure 11

Climate-Smart Soil Tech Landscape 2020

Full size version of the landscape is available in the Appendix.



Climate-Smart Soil Tech Landscape Analysis

Hardware, Sensors, and Remote Monitoring

To date, soil sensing, sampling, and testing for soil organic carbon (SOC) has been largely the domain of soil labs and researchers. Do-it-yourself and in-field SOC testing technologies have not reached commercialization scale. Of course, if farmers and ranchers had access to on-site, accessibly priced, and accurate hardware soil sensors, it would address a huge barrier to informing practice decisions.

A noteworthy finding from the research interviews for this report is that there is frequent confusion among technologists, farmers and ranchers, and researchers about which soil health measurements and functionalities are most critical in a soil health sensor. Farmers and ranchers are interested in time-and cost-effective solutions to aid in decision-making, while the science and research community has different, often more expensive and labor intensive, priorities. The Soil Health Institute's "North American Project to Evaluate Soil Health Measurement" is a promising initiative that may help clarify these issues by identifying key soil health measurements and providing technology innovators with clear targets to develop market appropriate solutions.

On the other hand, remote sensing is advancing dramatically and holds compelling, near-term possibilities. Remote sensing is done by relating UAV, airplane, or satellite data directly to soil properties by inferring changes in SOC from vegetation changes, or by using remote imagery as a covariate in digital soil mapping of SOC. Analysis of land-use change, net primary productivity, and SOC stocks are helpful in identifying hotspots of carbon sequestration potential. Finally, the potential to use satellite imagery as covariates in digital soil mapping, where the relation between soil properties and satellite information is used to predict SOC maps at various depths using point observations and satellite imagery, is being driven by some of the large remote imaging and data providers indicated on the landscape. Significant advancements on this front are expected in the next few years.

Although not yet at commercial scale (or marketable cost), new spectral methods for measuring SOC concentration and stocks are becoming available for direct measurements in-field and in the lab, as well as for measurement of patterns at larger scales across landscapes and regions. At this stage, scalability could be accelerated by partnerships and collaborations with large equipment manufacturers and input incumbents who have the resources and technical know-how to accelerate the manufacturing and distribution of innovative technologies. These players have a strong interest in scaling nutrient management measurement technologies and have dedicated R&D to deploying faster, increasingly automated soil sampling and analysis techniques.

Scalability could be accelerated by partnerships and collaborations with large equipment manufacturers and input incumbents who have the resources and technical know-how to accelerate the manufacturing and distribution of innovative technologies.

While the technology landscape for on-farm SOC/SOM testing is still relatively nascent, the adoption of macro- and micro-nutrient sensors and automated field testing has seen some encouraging startup activity in recent years (notable companies indicated in **In-Field Soil Sensing**). One category that may be unfamiliar to readers is **BioGeoChemical Sensors**. While not a one-to-one correlation with measurable SOC sequestration in the soil, technologies like eddy covariance provide information on net ecosystem exchange, or the net exchange of carbon between the land and the atmosphere, and can approximate carbon accumulation in vegetation and soils (but not yet distinguish from which source). New sensors are starting to become available, as well as computer models that estimate the exchange of gases from the soil to the atmosphere and take into account seasonal variability over many years and across large areas.

Management Software, Calculators/Assessments, and Databases and Resources

Many information sources available to producers, crop advisors, researchers and companies in support of climate-smart practice recommendations, best practices, and decision making were uncovered. The **Ecosystem Enablers, Databases and Resources**, and **Calculators, Models, and Reporting Tools** categories are intended to represent well-recognized sources but is not an exhaustive list, particularly at the regional, local and practice-specific level. The value of these categories of tools at the current maturation level of climate-smart soil agriculture cannot be understated, particularly with the overall scarcity of operation-specific information available to producers in Farm Management Software (FMS) solutions.

The lack of on-farm digital recordkeeping and FMS usage is a significant gating factor in linking changes of soil organic carbon (SOC) to specific drivers (such as management practices or climate change) and specific impacts (like yield). FMS can track and analyze an operation's land-use change and land management changes between sampling periods. In cases where records of land use and management have been available, the effects of management changes can be more readily assessed, thereby providing better verification of modeling approaches to quantifying SOC stock changes. One challenge associated with repeat soil sampling in the same site is that corresponding recordkeeping of land management practices must be captured as well (e.g., grazing, irrigation, and fertility).

The importance of FMS that tracks agronomic activity and conservation practices is well summarized by the Chief Science Officer of The Climate Corporation, Brian Lutz: "More than directly measuring, managing for improved soil health requires understanding how soil properties affect crop productivity. Despite digging and tilling and working land -- despite how well farmers know their soil -- it's difficult to relate key observable soil properties to soil health."

He goes on to observe that, "Every seed sowed by a farmer is like a sensor, dependent on the soil it must survive in, and serves as an indicator if anything is amiss. Digital ag is providing the opportunity to measure and monitor the productivity of these plant 'sensors' at spatial scales not possible before. Yield maps have, in effect, become a new window into their soils that have historically been unavailable."[37]

On a practical level, row crop farmers trying to decide whether to implement climate-smart soil practices, like cover cropping, crop rotations and integrated livestock, may find it difficult to do so without an understanding of the potential advantages or disadvantages. The key to reducing the uncertainty associated with climate-smart soil practices is looking at the productivity data over time. The ability to layer datasets with geospatial visualization can create powerful decision support tools.

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With readily available technology, standardized yield maps can be stacked to produce a single map that represents productivity over time, and a machine learning algorithm can be used to segment the map into zones with similar values (see figure 12).[38] For example, if a zone consistently underperforms over time, it may make sense to consider different conservation strategies, or alternative management practices (AMPs). AMP examples can include alternatives like leasing land for wind or solar energy production, or planting seed mixes that support biodiversity, capturing carbon from the atmosphere and protecting water quality. In this example, the zones that rank lowest become AMP zone candidates. This type of data-driven scenario modeling can be key to overcoming practice adoption barriers.

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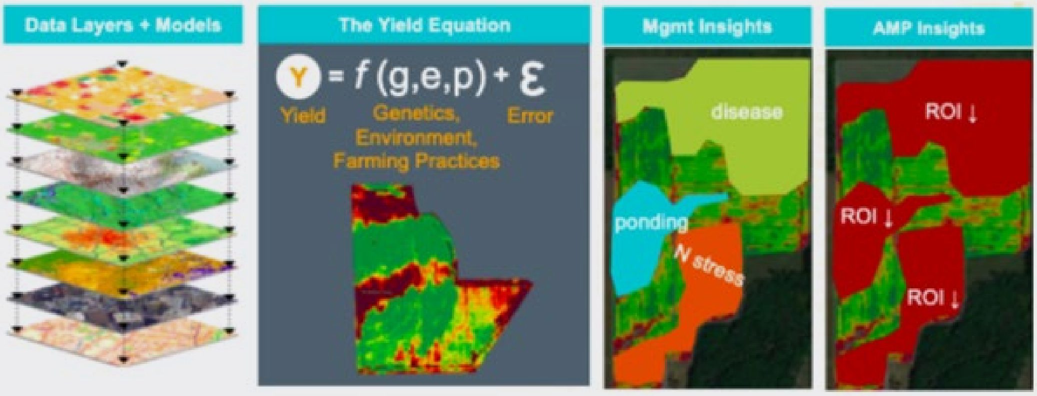
37 Soil: THe Food for Our Food https://climate.com/tech-at-climate-corp/soil-the-food-for-our-food

38 Alternative Management in Practice: How Digital Ag Enables Conservation Decisions, The Climate Corporation, Patricia Carroll, Senior Data Scientist, Sustainability

Figure 12

Layered Data, Models and Maps Enable Management Insights



Another benefit of FMS is that many operational SOC models rely heavily on estimation of carbon inputs in residues and organic amendments (manure, compost, etc.) as well as information on the nutrient content of these inputs, which is easily captured (typically via integrations with machinery) and exported into and out of FMS platforms.

Accelerating Data Insights Through Artificial Intelligence and Machine Learning

Advancements and affordability of computing power and data analytics, vision recognition systems, and associated technologies have given rise to the usability of Artificial Intelligence and Machine Learning (AI/ML). AI/ML will play a crucial role in overcoming barriers to climate-smart soil agriculture. Most notably, it enables us to overcome the arduous and costly process of field-level data collection with its powerful remote sensing capabilities. Additional benefits of AI/ML will be realized with better sample analysis and predictive models over time.

To be clear, further development of climate-smart soil AI/ML is necessary. The foundational data collection must be built upon clean, contextualized, and connected data. The lack of interoperable data is a barrier to unlocking the potential of AI/ML, as well as a general challenge for all AgTech adoption. Today, there is still a reliance on ground-truthed field data that can feed machine learning and artificial intelligence models. With more and more data to refine these computational models, their estimative and predictive accuracy will improve.

The need for estimation is arguably most important when it comes to measuring the spatial distribution of carbon in soils. It remains a challenge to correlate remotely sensed data with what is actually in the soil due to the large (and impractical) number of samples required, and because remotely sensed data does not measure soil carbon directly. When it is possible to combine 'layers' with actual soil test results, then it becomes possible to start to gain an understanding of soil carbon variation across the landscape (at least at a local level).

Since it would be prohibitively expensive to set up benchmark sites covering all possible combinations of land use, climate, soil type and management practice, models of SOC change are required to interpolate and infer change across all combinations and project changes into the future, across landscapes and under novel combinations. To establish confidence in the accuracy and reliability of models to simulate SOC change, researchers maintain that samples from across the full range of parameter space (e.g., multiple soils types, climate zones, land-use types and soil management options) need to be tested.

Laboratory costs associated with testing and data collection could also be reduced by using AI/ML, to the extent that larger libraries can be sub-selected to build local (spectral or geographical) prediction models using AI/ML. After a library is built, the measurements can be fast and inexpensive, and can assess all of the available soil properties at the same time. These spectral libraries can also be used to calibrate field spectrometers that will enable producers to gain faster access to operational recommendations.

Relatedly, one critical factor for climate-smart soil agriculture is the need for national repositories for calibrated and validated data of soil carbon. The research suggests that, thus far, no agreement on calibration or criteria for data acquisition has emerged. National repositories of quality soil carbon data would provide AI/ML models key data to leverage for analysis. AI/ML can be used for data verification, for example, to check that records comply with a specific protocol before entry into a registry. AI/ML can also be used to cross-check soil carbon data with other data to validate that what the record states is indeed true.

Marketplaces and Credits

A key barrier to the adoption of climate-smart agriculture is the lack of clear economic rewards for farmers and ranchers who implement these practices. Technology innovators are creating new solutions to connect farmers with those willing to compensate producers for soil-health outcomes or indicators through new business models. To date, the primary focus of compensation models for climate-smart agriculture has been related to carbon sequestration, in the form of carbon credits. The introduction of new business models for market-based approaches means that the distinction must be made between improving overall soil health and the rigorous verification required to engage with carbon markets (discussed in more detail below). Meeting both goals requires accurate measurements or models of soil carbon outcomes of agricultural practices and accurate accounting for the cost of practice implementation. Today, the specific protocols required to achieve broad soil health and carbon market goals differ. Broadly speaking, the companies and initiatives identified in this category are playing a role in overcoming some of this friction, yet broader adoption is constrained by lack of consensus on measurement and estimation protocols and soil-health metrics.

Carbon Marketplaces are built upon the concept that market-based incentives and free-market principles can be used to incentivize carbon sequestration, among other beneficial environmental outcomes. The vision of these marketplaces is to give farmers access to technical assistance and additional revenue streams while enhancing the resilience of their operations; provide corporate credit buyers with an additional route to meet their sustainability goals; and benefit the public with cleaner air and water and climate change mitigation.

Other innovative **Financing Marketplaces and Tools** are emerging to reduce barriers to financing for operators, especially when it comes to transitioning to climate-smart practices. Others are helping operators leverage technology to enhance reporting and data sharing for financial institutions (banks and insurers). Financial mechanisms and enabling infrastructure, such as emerging revenue markets, are discussed in great detail in the Transformative Finance section of this report, starting on page 37.

The emergence of distributed, data transfer, and registry frameworks (like **Blockchain**) may hold the key to integrating more transparency and sustainability across food production systems. An automated data ingestion system, like blockchain, can incorporate carbon stock inventories; calculate and publish through open data standards; and provide a registry for mitigation actions as well as a national carbon asset registry and a climate finance registry. Blockchain can simplify data sharing among diverse registries within the soil health ecosystem but it is not a suitable repository for storing large amounts of attribute information. Furthermore, it should be noted that governance mechanisms for data security and sharing are essential to establishing the “rules of the data sharing road.” The work of Regen Network, The Climate Ledger, and others in pioneering these frameworks is notable, particularly because they appear to be focused on open, transparent protocols which can be foundational in this ecosystem development.

The funding and development of these data systems should be relatively agnostic to the scientific protocols and models and viewed as the data superhighways designed for transmission of data or smart contracts. It would be up to the users to determine what models, protocols, and testing are appropriate for their objectives. Any new system faces challenges of set-up and transaction costs (and of determining who bears these costs along the value chain). Digital approaches may initially impose higher transaction costs, particularly for first adopters, underscoring the need to help fund digital transformation initiatives and build capacity, awareness, and resources.

Sustainability dashboards provide brands and CPGs with ways to measure progress on climate-smart agriculture or other operational goals through data analysis in a digestible user interface. Within the **Sustainability Dashboard** category, much of the independent software company activity comes from Europe and encompasses a broad range of metrics and KPIs, beyond soil health. The proliferation of proprietary dashboards and internal sustainability reporting occurs largely within brands and CPGs, yet according to The Sustainability Consortium’s Impact report, only 8% of suppliers surveyed 2016-2019 could trace crop supply back to the farm of origin. As 3rd party verification software developers continue to expand services on traceability they will play an increasing role in identifying areas for integration of standards and architecting for data interoperability. Often these companies can play a role in integrating standards and architecting for data interoperability beyond the capabilities of a proprietary system. Several examples of this include SureHarvest’s work with the Almond Board of California and California Sustainable Winegrowing Alliance, and SupplyShift’s work with The Sustainability Consortium and the Stewardship Index for Specialty Crops.

Climate-Smart Soil Technology Adoption Barriers & Recommendations

Technologies must have an appropriate product/market fit to see scaled adoption of solutions. Correlating specific technology barriers to the technology categories on the landscape provides a better understanding of gaps in product/market readiness (see table below). If technology is too nascent, it will likely not meet the farmer or rancher's cost/performance expectation. In fact, many cases exist where solution providers have not properly managed the producer's expectation and a setback to the adoption of that technology occurred. While the barriers represented below in figure 13 are not an exhaustive technical list, they should provide readers with a guide to evaluate a technology's efficacy for a particular operation or identify areas where solution providers should focus to improve the usability of their technology.

Figure 13

Summary of Key Barriers to Scale Technology Adoption

Technology	Landscape Categories	Potential Barriers to Scale Adoption
Data Collection: Field/Land Ground- Truthing	Soil Sampling Automation Next Gen Soil Testing In-Field Soil Sensing SOM/SOC Sensing BioGeoChemical Sensors	• Connectivity / data transmission • Agreement on what to measure and how to measure • Device calibration • Data reliability and security • Affordability of technology and capacity to deploy it at scale (moving from R&D to commercialization) • Obtaining funder or standards buy-in to apply the technology
Data Collection: FMS	Calculators, Models, & Reporting FMS Interfaces Decision Support / Scenario Modeling Data Modeling & Visualization	• Data standardization / interoperability • Agreement on what to measure and how to measure • Data reliability and security • UI/UX • Integrating and cleaning data • Translation tables
Data Collection: Remote Sensing	Remote Imaging Data Provider Remote Imaging Analytics	• Affordability and usability (if outside of an FMS system) • Varying degrees of resolution accuracy • Cloud cover / weather interruptions • Generally, lack of soil-specific indicators (good for land use, biomass, etc.) • Amount of data cannot move scalably between tech platforms

Grazing Management	Virtual Fencing Grazing Management	• Affordability of technology and capacity to apply it at scale (especially virtual fencing) • Virtual fencing hardware still nascent • Data standardization / interoperability • Product / market fit (perceived value)
Verification & Reporting	Blockchain Sustainability Dashboards 3rd Party Verification Software	• Deviating from established verification timelines and processes • Capacity and resource of verifiers • Perceived threat to verifier's business model • Standard processes to flexibly adapt, assess and approve • Allowing for plural approaches • Data privacy concerns
Ecosystem Services Marketplaces	Carbon Marketplaces Financing Marketplaces & Tools	• Agreement on what to measure and how to measure • Standards • Reliability / double counting • Data models to account for risk/reward of climate-smart soil practices • Trusted issuance to recognized registry system • Translation tables • Set up and transaction costs • Data availability / quality to feed AI/ML

Lessons Learned from Precision Agriculture Adoption

For those looking to invest in or build climate-smart technology solutions, there are lessons to be learned from precision agriculture technology adoption in the U.S. over the last decade. Just as precision agriculture technologies like GPS, auto-steer and variable rate application technologies saw incremental improved performance, cost reduction, and eventual broad adoption in the U.S. commodity row crop sector, an even faster adoption curve is anticipated for modern digital agriculture that automates the collection and sharing of information in a networked fashion, particularly as it applies to climate-smart soil practices.

Scaling Up Innovation

An important takeaway from the analysis is to look more at how promising startups with innovative solutions for MRV and marketplaces can be scaled through partnerships and collaborations. It is also important to distinguish between the formation of more working groups or research projects and broader commercialization of proven technologies to drive market adoption.

As indicated by the 150+ soil health solution providers on the landscape, few have established the functionality, market validation, or scientific credibility to breakthrough into larger market adoption. To be clear, the models, technologies, or R&D are mostly anchored in credible science, but the adoption challenge has been in scaling up through manufacturing and sales and marketing, which is typically a function of funding and know-how.

A key learning from the precision ag marketplace is that a startup's capacity to scale-up can be accelerated by leveraging corporate partners for success. Large corporates can bring access, talent, finance, leadership and in some instances, infrastructure, to the table which are typically the missing ingredients in driving incremental innovation to wider market adoption. In the case of climate-smart soil technology, this ecosystem crucially includes the public sector, researchers, scientists, NGOs and nonprofits with whom the essential practice know-how and science is developed and shared.

Incremental Innovation and Adoption

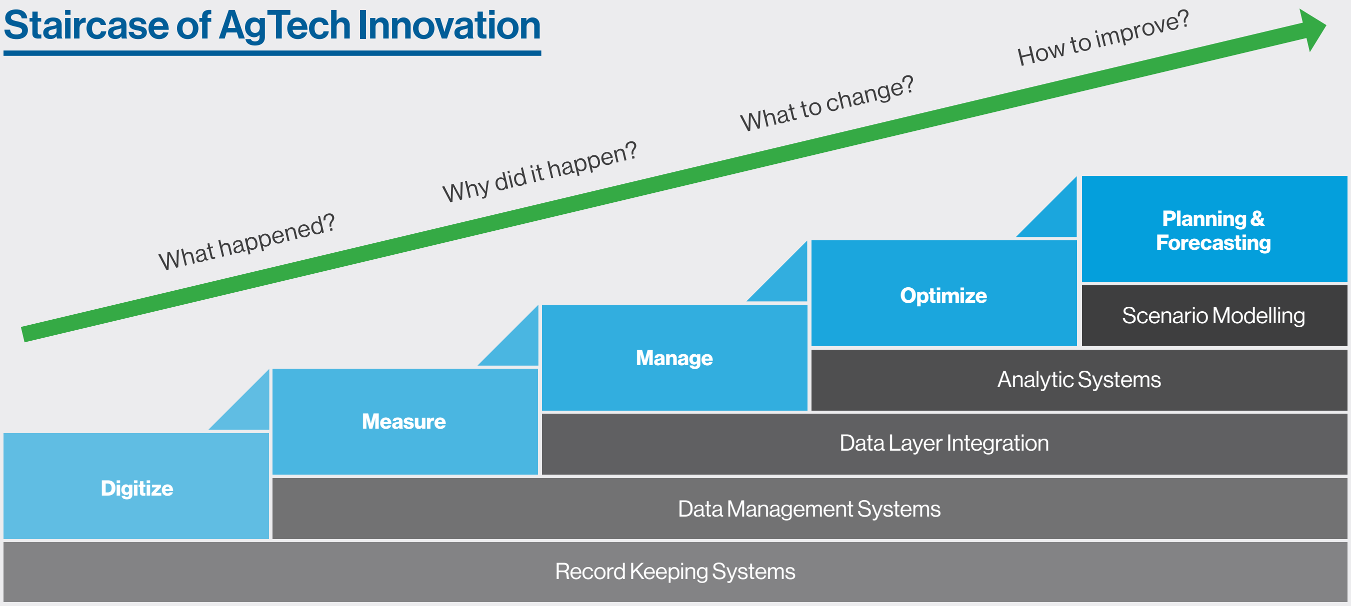
In looking at implementing technology to support the adoption of climate-smart soil practices, it is instructive to anchor any analysis in the broader adoption of AgTech over the past five years. In doing so, insight can be gleaned relative to the business cases, motivations, and barriers to adoption such that solutions are designed for usability, scale, and ROI, in addition to sustainability and environmental resilience.

GPS, auto-steer, and variable rate applications were key enabling technologies for precision agriculture in its infancy. They laid the foundation for the introduction of yield maps that tied agronomics to outcomes, unlocking unprecedented precision. From that point, new solutions that layered data insights from climate and aerial imagery were integrated with FMS platforms. Today, these innovations are giving rise to digital agriculture used not only for recordkeeping, work order management, and inventory, but also for planning, scenario modeling, and forecasting through interconnected layers of data.

In this sense, the incremental improvement of precision agriculture can be seen as a staircase with more capable IT systems corresponding to each step on the staircase (see figure 14).

Figure 14

Staircase of AgTech Innovation



The initial business case for adoption of GPS and autosteer may not have been immediately clear, but farmers could observe the benefits with fewer passes on the field and more efficient applications or harvesting. In a similar way, the initial business case for testing soils periodically for nutrient management and soil structure may be simply to improve efficiency or reduce input costs. Over time, as farmers integrate a testing and monitoring protocol with digital records, it then becomes easier to evaluate experiments with new practices and compare them to baselines in order to determine what practices may make sense to implement.

Over time, as farmers integrate a testing and monitoring protocol with digital records, it then becomes easier to evaluate experiments with new practices and compare to baselines in order to determine what practices may make sense to implement.

Once established, the ability to layer site-specific data over time with remote imagery, external models like COMET-Farm, and FMS enables data-driven management decisions about practices and financial incentives. For example, today, combining precision agriculture and FMS data enables farmers and ranchers to track their true cost of production and then make the appropriate management decisions about their crops in order to maximize cash flow, profitability, or other desired outcomes.

In a similar way, improving climate-smart soil technology adoption is about seeing the incremental value and insights from integrated data. Each step of the journey reinforces the value of the tools and technologies and the accumulation both builds the individual's confidence and strengthens the business case through the supply chain with verifiable data (see figure 15).

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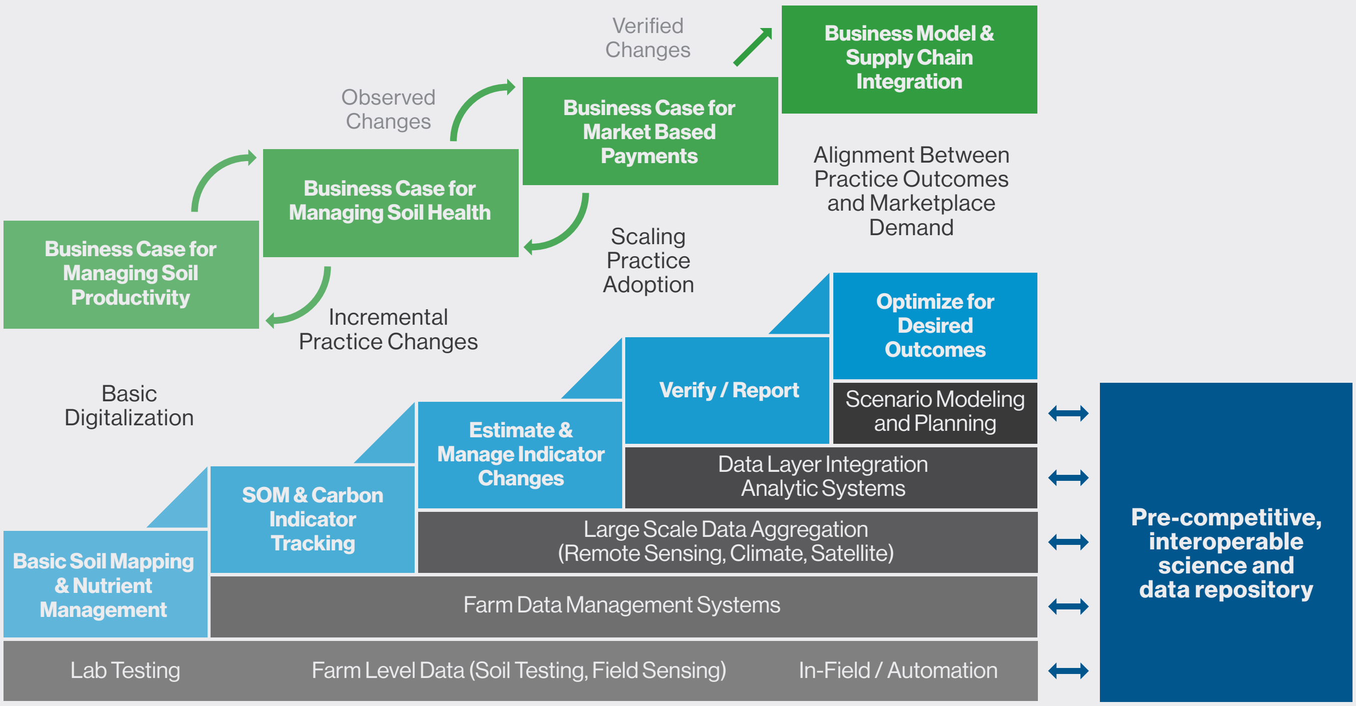
Figure 15

Scaling Climate-Smart Soil Tech Adoption



In this way, the mechanical concept of a flywheel (now often referenced in technology) can be borrowed to describe a source of feedback, stabilization, and momentum. Instead of trusting instincts and prior assumptions, the idea is to harness the power of a flywheel to verify hypotheses in simulation and in the real world. Doing so exponentially expands the array of choices and reduces the cost of experimentation. In applying this concept to climate-smart soil practices and enabling technology, farmers and ranchers can reduce the uncertainty of practice adoption and better quantify the potential rewards (see figure 16).

Figure 16

The Digital Ag Flywheel for Scaling Climate-Smart Practices

Most significant business decisions involve some level of uncertainty and risk, but data insights allow decision makers to understand and quantify risks and uncertainties. While it is not possible to fully de-risk environmental and biological systems, it is possible to monitor what happened, use data to understand why it happened, and combine plot-level data with scientific models and AI/ML to estimate what may happen in the future. Technology will not solve all of the adoption barriers in isolation, but it can:

- ***Aid in the credibility of new economic models with verified data.***
- ***Minimize barriers to sharing locale and practice-specific information (as well as influence peers) via social media, YouTube, and other communication technologies.***
- ***Reduce information sharing friction across the operator support structure with FMS and other digital agriculture platforms.***
- ***Minimize time and effort required by automating data collection and analysis.***
- ***Shift perceived risk and reduce uncertainty with observable, verifiable feedback data.***

Investment Recommendations to Scale Climate-Smart Practices with Digital Agriculture

1. **Invest in Market-Based Solutions Measuring Soil Health Indicators versus Outcomes**
   Recognize the first steps in connecting practice adoption to market-based outcomes may not be absolute measurement but rather estimated indicators of soil health. Herein the concept of estimation (vs. measurement) is important because it recognizes that the market still lacks the technology and standards to measure soil carbon "accurately" at scale, in a cost-effective manner. As a first step, we may be well served to consider market-based payment mechanisms that arise from risk pricing and premiums (much like other financial markets), where risk is a function of uncertainty and something that can be analyzed. From an economics standpoint, it is well understood that markets are normally fairly efficient at quantifying uncertainty. In this context, "indicators" can be used to understand the sources of uncertainty and how to value and measure them. Indicators in the world of climate-smart soil would likely be the attainment of ecosystem service goals other than actual carbon sequestration, like water infiltration rates, that indicate progress in restoring soil health.

   As a first step, we may be well served to consider market-based payment mechanisms that arise from risk pricing and premiums (much like other financial markets), where risk is a function of uncertainty and something that can be analyzed.

   Furthermore, allowing for degrees of data sharing and indicator estimation may also be key to establishing more robust markets. The higher the level of data or estimation confidence, the more demand the credit should create versus a credit that has a lower degree of indicator data. In other words, data with a more stringent protocol will command higher values.

2. **Invest in a National Repository of Soil Carbon Reference Data**
   Current quantification methods that adequately represent variation in soil carbon or soil health require physical collection of samples at time and geographic scales that can be expensive, time-consuming, and infeasible at scale. Good work is being done with remote sensing tools and models but they are not yet accurate enough to represent the variation and changes in soil health and SOC. There is currently no comprehensive effort or system to quantify soil carbon reliably, granularly, and cost-effectively across the U.S. While there are encouraging collaborations across the private and public sectors to build this critical soil carbon reference infrastructure.

3. **Fund the Development of Leadership Beyond Data Standards**
   Leadership is necessary to coalesce around the standardization of reference laboratory methods, spectral measurements, and soil data exchange. This level of consensus is a heavy lift, but if standardization and calibration transfer challenges can be solved, combining spectral libraries can provide a vast data resource for not only local but also regional and global soil analyses.

4. **Invest in the Accelerated Adoption of Practice, Indicator, and FMS Translation Tables**
   As digital agriculture data standards are still emerging, funding and development of open translation tables that interoperate with leading models and are accessible to any FMS solution provider is critical. With a translation layer, farmers and ranchers can seamlessly connect practice data and models for measurement and estimation, reporting and verification (MRV).

5. **Invest in Solutions to Leverage Enterprise Know-How and Speed Collaboration at Scale**
   Commercialization and funding of commercially available, low-cost soil sensing devices is critical. Beyond in-field sensing devices, collaboration between AgTech companies, established equipment manufacturers, retailers and input companies, and non-profits / NGOs should be explored to scale viable solutions via partnerships.

Additional Recommendations

The additional recommendations are beyond the primary investment recommendations above for climate-smart soil technologies, but noteworthy enough they should not be overlooked.

1. **Promote Online Locale & Practice-Specific Information Sharing for Greater Confidence**
   Farmers, ranchers, and others in their ecosystem need to feel confident that climate-smart soil practices will work for them. Hearing the experiences of other farmers and experts can build confidence and help develop trust networks. Farmers and ranchers are self-organizing online to supplement numerous organizations with formal programming. Many others (like extension services) should be doing more. COVID appears to be accelerating the use of online digital technologies for this purpose, in lieu of on-site farm/ranch visits. Leveraging these general-purpose communication technologies more should be easy as most are already integrated into the day-to-day lives of farmers and their support ecosystem.

2. **Decrease Barriers to Calibrated Producer Digital Soil Health Testing**
   With only 25% of producers testing soil (mostly for fertility, and only a subset of those testing for soil organic matter or soil organic carbon (SOM/ SOC)), cheaper, easier, and more automated testing needs to be made available.[39] If SOM/SOC testing is cost-prohibitive, even simple measurements like water infiltration and soil aggregate stability can be used as interim proxies. In-field, do-it-yourself SOC sensor testing has been close to market readiness for a few years and could use industry support to get a workable product/market fit that enables farmers to test soil on-farm.

   Industry, academia, NGOs and government can support farmer and rancher soil testing by providing standard protocols or regimes to avoid the "garbage in, garbage out" problem of data collection.

3. **Integrate Digital Soil Health Test Data into Digital Farm Management Solutions**
   The necessary first step on a farmer's digital agriculture data integration journey is data capture; the very next is inputting that data into a digital farm management and decision support solution that connects soil data with production data or other interoperable databases. On this front, the entire agricultural community is awaiting the Soil Health Institute's farm management solution set to be released and made available for free.

   Industry, academia, NGOs and government can assist by developing standards or calibrating translation tables between hardware sensors, for instance, or lab-testing protocols or aerial imaging, semantic interoperability and application protocol interfaces to accelerate greater data analysis. With larger dataset to analyze, AI/ML models can be rapidly refined to provide farmers, ranchers, crop advisors and others with locale and practice-specific recommendations to support the climate-smart soil flywheel.

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39 Are Australian and United States Farmers Using Soil Information for Soil Health Management? https://www.mdpi.com/2071-1050/8/4/304/html

4. **Improve Usability**

   The usability of AgTech has improved dramatically over the past two years. In addition to useful functionality, companies learned that careful attention to the user interface and user experience (UI/ UX) was critical in driving adoption. In the conducted interviews and research, it can be noted that the UI/UX for the models and assessments appears to be a secondary consideration in the current state of climate-smart soil technology.

Transformative Finance

Many studies have shown that the adoption of climate-smart agriculture practices is more profitable for farmers in the long term.[40,41,42,43] These shifts in practices also come with additional benefits for farmers and ranchers, including decreased agronomic risks and access to new markets.

The benefits that accrue from climate-smart farming and ranching have both public and private benefits, with each benefit having different mechanisms that can be used to help fully account for the value being produced. Sources of return or non-return seeking capital can be found in emerging ecosystem service and carbon markets, from government sources, and through private market transactions.

While many farmers and ranchers have adopted these types of agricultural systems and practices, many more operations and acres could be transformed to helping mitigate climate change while also increasing their profitability and resiliency. That said, a typical transition to climate-smart agriculture practices may require various front-loaded implementation costs (equipment, seed, labor, compost and containment systems, etc.) with a return-on-investment that is realized across a variable timeframe, sometimes several years. Further, practice transitions can take several seasons to fine-tune, with added costs throughout.

Critically, as the need increases for farmers and ranchers to have to access appropriate forms and sources of capital to navigate climate-smart practice transitions, an increasing amount of capital is also seeking sustainability and positive environmental outcomes from investments.

The November 2020 release of the biennial Trends Report from the US SIF Foundation identified $17.1 trillion of assets in the U.S. being managed using sustainable investing strategies.[40] Since the last assessment in 2018, there has been a 42% increase in assets using these strategies and assets using these criteria now account for one in three dollars of U.S. assets under professional management.[41]

40 Regenerative agriculture: merging farming and natural resource conservation profitably https://peerj.com/articles/4428/
41 Quantifying Economic and Environmental Benefits of Soil Health https://farmland.org/project/quantifying-economic-and-environmental-benefits-of-soil-health/
42 Farm finance and conservation: How stewardship generates value for farmers, lenders, insurers and landowners https://www.edf.org/ecosystems/how-farm-conservation-can-generate-financial-value
43 The Economics of Cover Crops and No-till http://www.daturesearch.com/wp-content/uploads/Case-Studies-Overview-v3.pdf
44 Report on US Sustainable and Impact Investing Trends (2020) US SIF Foundation https://www.ussif.org/store_category.asp?id=4
45 Ibid. 35.

With this framing in place, there are many avenues for increased investment in climate-smart agriculture. There are smaller pools of catalytic capital, such as philanthropic grants, government programs and payments, and emerging ecosystem services, but it is the existing bedrock finance – hundreds of billions of dollars – that is the focus of this report.

We detail the rationale and mechanisms available to move capital from across financial value chains into climate-smart agriculture value chains in ways that would create positive impacts or to meet certain environmental, social, and governance (ESG) criteria. The existing flows of capital need to be re-oriented toward climate-smart farming and ranching, and new capital needs to be brought in for those seeking to create positive impact or address ESG issues, particularly as it relates to broader national investments in a net zero economy.

Existing flows of agricultural capital need to be re-oriented toward climate-smart farming and ranching, and new capital needs to be brought in for those seeking to create positive impact or address ESG issues, particularly as it relates to broader national investments in a net zero economy.

Across these transactions there are significant opportunities for value creation, whether that be on the farm, within the value chain, and for the investor. We have an opportunity to use these examples to create new markets, offer additional compensation for farmers and ranchers, and adapt existing capital flows in agriculture toward rewarding climate-smart soil outcomes, ultimately leading to outsized societal, biological, and financial returns.

This section is divided into two parts. First, the distribution of capital from financial value chains into agricultural value chains is presented in detail. Second, the report identifies examples of financial mechanisms that are already working, or could be increasingly leveraged, to capitalize the transition to a more climate-smart agriculture.

Capital Flows to Agriculture

Mapping Capital Flows

Mapping the agricultural capital flows in the U.S. helps contextualize the current agri-financial landscape and presents opportunities to explore several new and innovative financial mechanisms in the next segment of this research. The financial capital flow map details the flows of capital between key entities, or nodes, in the agri-financial system: asset owners, asset classes, intermediaries, and agricultural value chains. The full set of linkages between these nodes is graphically represented on the following page. This visualization is in the format of a Sankey diagram (see figure 17), in which the width of the linkage is proportional to the size of the economic relevance. Here, the nodes represent asset holders, asset classes, and financial entities.

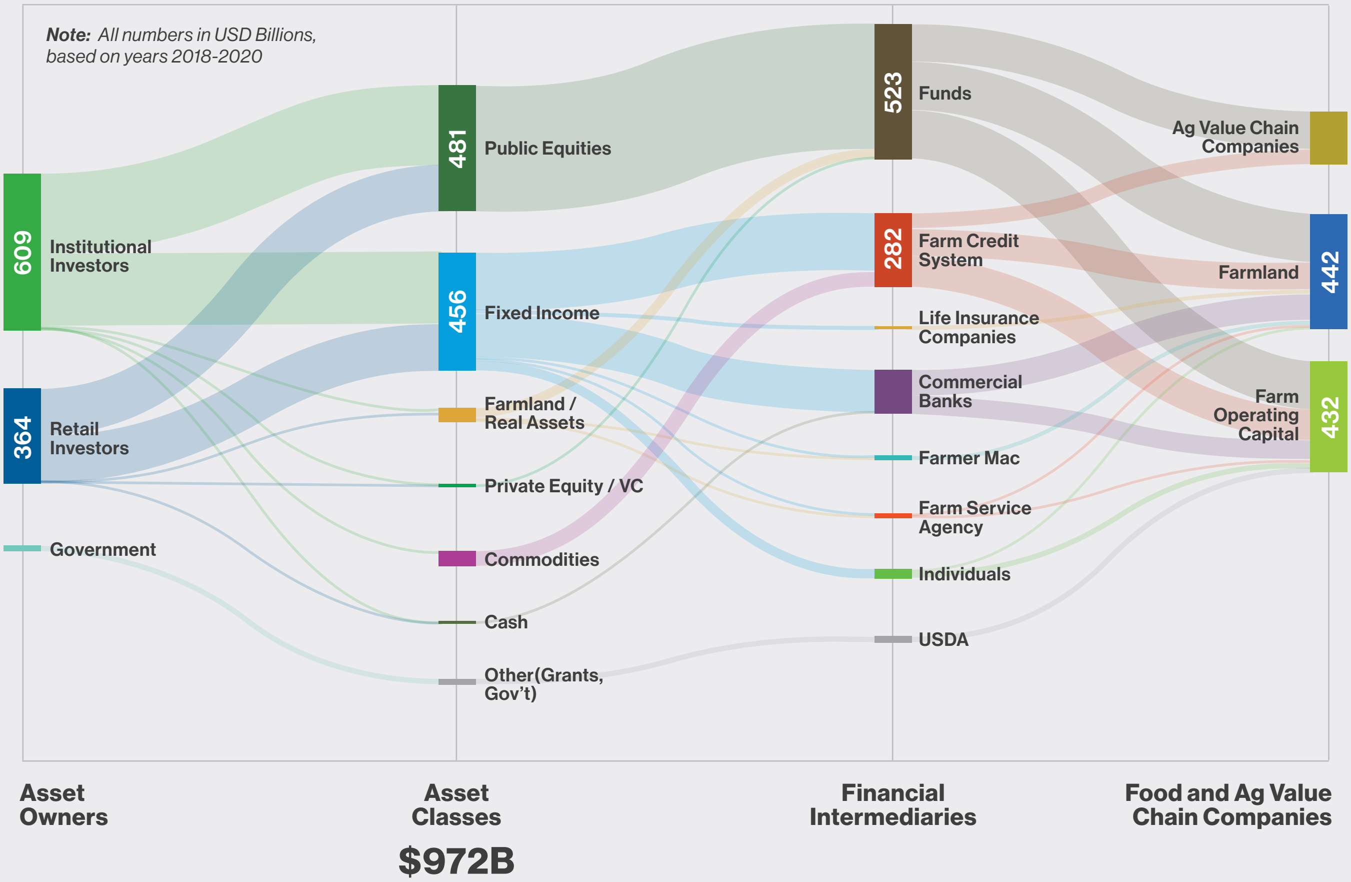
The scale of this landscape is in the billions; the number visible in some of the larger nodes represents the total assets under management (AUM) in USD billions. The research identified a total of approximately $972 billion flowing from institutional, retail and government investors across asset classes throughout the agricultural value chain.

Tracking flows from these investors involved curating research and data from a number of sources to piece together the totality of U.S.-based investments and their flows through the system. While the data collected is not comprehensive, it is an informed estimate based on existing and available research. Previous Soil Wealth research looked at investment across top asset classes, ranging from public equities to fixed income to cash investments, for channeling capital into agriculture. Building on this knowledge of the regenerative landscape, it is important to understand the trends within the industry at large beyond sustainable and regenerative agriculture, as well as catalogue the intermediaries that are delivering and deploying capital to target entities through various financial mechanisms.

To identify the capital flows from asset holders, through asset classes, intermediaries, and into the agricultural value chain, data was relied on and research from several well-established sources was utilized. Valoral Advisors research on the global food and agriculture sector provided the foundation for understanding trends in the North American landscape. Global AgInvesting provided context and data on the scale of investment across asset classes. Tracing capital flow through intermediaries and into which of the three main target entities (Farmland, Farm Operating Capital, and Agricultural Value Chain Companies) involved analyzing data from a number of different sources, including USDA Economic Research Service (ERS) for fixed income investments, as well as AgFunder and Crunchbase for private equity.

Figure 17

Annual Agricultural Capital Flows in the United States



Findings

The visualization of this system of capital flows confirms some previous hypotheses of how funds currently move through food and agriculture – for example, the established nature of fixed income financing in this space – but it also highlights opportunities around existing structures that might be leveraged to specifically target climate-smart systems on farms.

A summary of these findings starts with an analysis of the distribution of capital between asset holders. Total investment in agriculture totals $972B, with institutional investors – professional investors who are trading or investing at a scale large enough to qualify for preferential treatment and lower fees – making up the majority. Calculated estimates place institutional investment total at just over $600 billion, approximately two-thirds of all investment.

Retail or non-institutional investors are usually individuals who are investing on their own through brokerage firms or personal accounts, comprising about $360 billion. Lastly, the U.S. government as an institutional investor plays a special role in this space, as these funds are distributed primarily through the U.S. Department of Agriculture as grants, technical assistance, and educational programs. Though not as large as a stand-alone asset holder, the government through the USDA is extremely influential in terms of setting federal agricultural policies and priorities that drive broader market trends.

Total investment in agriculture totals $972 billion, with institutional investors making up the majority, approximately two-thirds, of all investment. Across asset classes, the majority of funds flow through fixed income and public equity instruments.

Across asset classes, the majority of funds flow through fixed income and public equity instruments. Public equity represents the largest proportion of the entire agricultural value chain, totaling $481 billion and is mostly concentrated in food products and value chain companies, though they are also flowing to farmland and operating capital investments. Fixed income follows close behind at $456 billion, representing most traditional lending including commercial bank loans and agricultural loans through the Farm Credit System and other banks. In terms of directly reaching farmers and those value chain actors working closely with farmers, public equity and fixed income appear to be the greatest opportunities to promote or develop financial mechanisms targeting climate-smart agriculture.

In terms of directly reaching farmers and those value chain actors working closely with farmers, public equity and fixed income appear to be the greatest opportunities to promote or develop financial mechanisms targeting climate-smart agriculture.

Beyond fixed income and public equity, investments in farmland and real assets total approximately $52 billion. Three-quarters of that reach the value chain through private and public funds, with the rest ($13.5 billion) flowing through the USDA Farm Service Agency and Farmer Mac, the main secondary market for agricultural credit. Commodities represent $62 billion of the market, almost exclusively invested through the Farm Credit System. Finally, though private equity is relatively small in scale at just over $3 billion, this emerging asset class may allow for more flexibility in terms of taking on additional risk associated with financing climate-smart agriculture. Cash, also valued at approximately $3 billion, primarily flows through commercial banks reaching farmland and farm operating capital, remaining an important source of liquidity for the value chain.

Stacking Capital Investment and Farm-level Revenue Streams

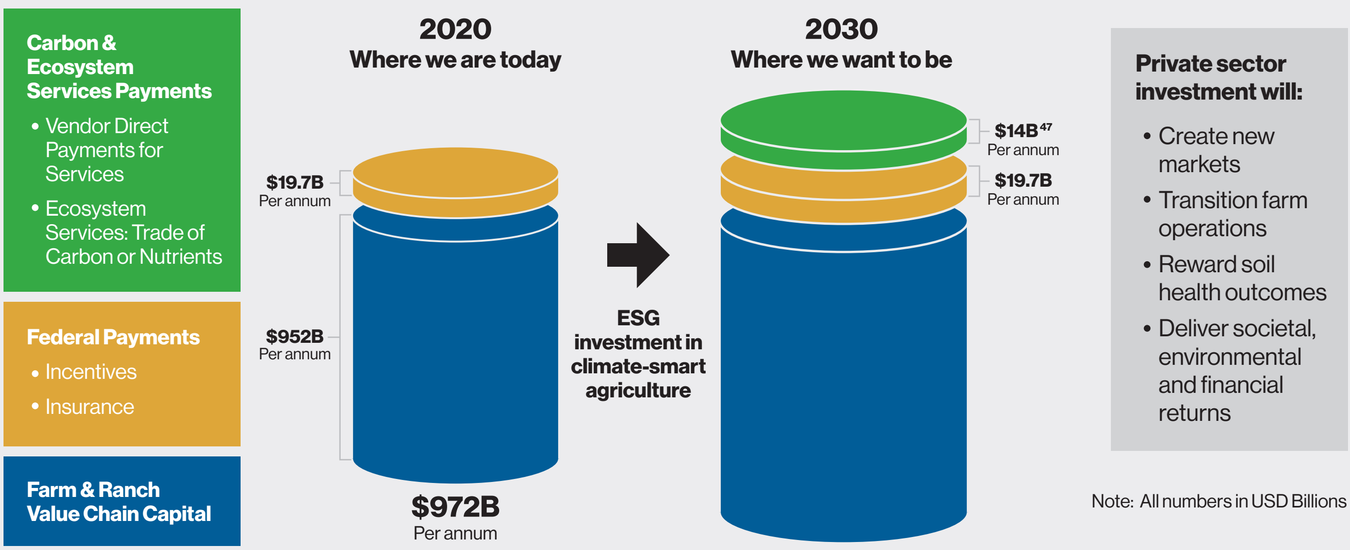
An emerging pool of capital in the agri-financial landscape is new revenue streams for farmers and ranchers that are coming online in the form of payments for environmental outcomes, such as greenhouse gas mitigation, carbon capture in soil, or the retention of nutrients on a farm. More traditional revenue streams include programs and payments from the government, which is expected to be 36% of farm income in 2020[46].

Figure 18 visualizes the three main pools of capital that can be stacked to facilitate the transition to a more climate-smart agriculture as well as examples of organizations working in this space.

Figure 18

The Path to Scaling Up Climate-Smart Agriculture

Scaled adoption of climate-smart practices by farmers and ranchers requires **the realignment of existing flows of capital toward climate-smart outcomes** as well as **new sources and forms of capital**.



As depicted, most of the capital flowing into agriculture does so through private financial markets and through several asset classes and financial mechanisms. Scaled adoption of climate-smart practices will not only take the alignment of existing flows of capital toward climate-smart outcomes, but also the ability to draw in new sources and forms of capital. There are other sectoral transitions that are ongoing, such as in the energy sector, where many lessons can be learned, especially around how to attract appropriate investment at scale. The Financial Mechanisms & Enabling Infrastructure section of this report details a variety of pathways that this capital might flow, as well as the importance of collaborative and blended approaches to capital deployment that will de-risk these transitions in the coming decades.

46 Retrieved from Successful Farming 6/10/2020 https://www.agriculture.com/news/business/huge-federal-payments-will-make-up-36-of-farm-income-this-year

47 Economic Assessment for Ecosystem Service Market Credits from Agricultural Working Lands https://ecosystemservicesmarket.org/wp-content/uploads/2019/09/Informa-IHS-Markit-ESM-Study-Sep-19.pdf

Financial Mechanisms & Enabling Infrastructure

Capital flows in circular and interconnected ways where it helps build value in people, grow enterprises, and nourish communities. This analysis assesses the near-term opportunities across financial mechanisms and the necessary enabling infrastructure needed to facilitate the movement of capital toward climate-smart practices. In this context, we define a financial mechanism as one that facilitates the movement of capital, with the expectation of financial returns.

Enabling infrastructure are elements that help to facilitate the flow of capital, often supporting data, information, models, metrics, and protocols. In many cases these tools help to transparently convey the differentiated risk profiles, the positive social and environmental outcomes, and the increased resilience of these systems in the face of change. The most mature and actionable mechanisms are presented below, including examples and action steps that could be taken to implement the mechanism at scale. From working capital loans for cover crop seeds to initial public offerings, the transaction size varies greatly in the mechanisms presented. Here, we define deal sizes of up to one million dollars being "small," from one to ten million dollars as "medium," and larger than ten million dollars as "large."

Farmers and ranchers, as well as those in the financial sector, are professional risk managers. The financial mechanisms outlined in this report may be recently developed or adapted from other sectors, which introduces some level of risk to the partners involved. As the use of these mechanisms become more widespread, it is imperative that catalytic capital be used to help de-risk these transactions and facilitate the flow of additional capital to support the expansion of climate-smart agriculture. Supporting the development, testing, growth, and expansion of these mechanisms will benefit from technical assistance, grants, low-cost loans, and other forms of impact-oriented capital.

The six asset classes, financial mechanisms, and examples are compiled below in figure 19 and are examined in detail in the pages that follow.

Figure 19

Six Asset Classes, Financial Mechanisms, and Target Entities

Page	Asset Class	Mechanism	Target Entity
60	Cash & Equivalents	Thematic Certificates of Deposits (CDs) & Money Market Funds Targeted Institutional and Bank Lending Climate Risk Assessment at Banks & Lending Institutions Voluntary Standards and Certifications	Farm Operating Capital Value Chain Companies Farmland
64	Fixed Income: Public Bonds	Land-Secured Assessment Financing Climate Bonds/ Green bonds Blended Capital Facilities Credit Enhancements for Climate Bonds	Farm Operating Capital Value Chain Companies Farmland
68	Fixed Income: Private Debt	On-Bill Financing Environmental Impact Bonds (EIBs) Sustainability-Linked Loan Facilities Tailored Lending Programs CDFI Loan Funds Loan Guarantees	Farm Operating Capital Value Chain Companies Farmland
74	Public Equity	Initial Public Offering Exchange Traded Funds (ETFs) & Mutual Funds	A variety of assets that could include value-chain entities with a relationship to climate- smart agriculture
77	Private Equity & Venture Capital	Bridge Capital Funds Small Business Investment Company / Rural Business Investment Company Community Dev Venture Capital (CDVC) Venture Capital Fund Corporate Venture Capital Funds	Farmland Farm Operating Capital Agriculture Value Chain Companies
81	Farmland & Real Assets	Opportunity Zone Funds Real Estate Investment Trust (REIT)	Farmland Farm operating capital Agriculture Value Chain Companies
83	Additional Enabling Infrastructure	Credit Risk and Other Frameworks	• Technology and equipment • Funding awareness and access • Locale-specific information

Cash & Equivalents

Mechanisms

Thematic Certificates of Deposits (CDs) and Money Market Funds

Overview: CDs and Money Market Funds are savings instruments offered by banks and credit unions that provide interest rate premiums in exchange for a customer (investor) to leave funds untouched in an account or fund for a predetermined period of time. Benefits of these mechanisms include offering investors a fixed, safe, interest rate that is usually higher than what is offered by checking and savings accounts, which is considered less risky and less volatile than the stock market. Banking and lending institutions can create food- and farming-thematic CDs that explicitly support climate-smart practices and target agricultural businesses along the value chain.

Example: Self Help Credit Union's Green Term Certificate invests in sustainable businesses, including solar farms, sustainable food, and land trusts.

- **Average deal size:** ***Small – Medium***
- **Originating entity:** ***Commercial banks***
- **Target entity:** ***Farm Operating Capital, Value-Chain Companies***

Action steps for implementation:

- **Engage with banks and credit unions around developing dedicated depository products explicitly linked to investing in climate-smart agriculture**
- **Structure a money-market fund that ladders a diverse series of CDs and money-market deposits at a wide variety of mission-aligned banks, which include partial or full exposure to short-term instruments that support climate-smart investment.**
- **Identify target investors for thematic CDs and/or money market funds (i.e., private individuals, local or regional institutions)**

Targeted Institutional and Bank Lending

Overview: Banks and lending institutions, particularly agricultural lenders, are critical sources of farm financing. Nearly half of the approximately $200 billion of agricultural loans originating at U.S. commercial banks are held by agricultural banks. Stakeholders in climate-smart agriculture can collaborate with banking institutions, credit unions, and Community Development Financial Institutions (CDFIs) to develop targeted loans and metrics for farming enterprises with soil health practices. Furthermore, loans that strategically target young and beginning farmers can both serve as much-needed capital for emerging farming enterprises while also providing incentives for beginning farmers to integrate soil health practices from the start.

Examples: The Carrot Project, an organization that facilitates access to financing and business support for small farm and food businesses, developed a partnership with community bank, Salisbury Bank & Trust Company, to offer the Greater Berkshire Agricultural Fund. The Fund offers loans to local and regional farmers and value chain businesses for up to $75,000, as well as technical assistance. The loans can be used to help farmers and business owners finance capital investments (including farmland investments) and meet operating costs.

Farm Credit East's Farm Start targeted lending program serves those in New England and New York State. Yankee Farm Credit also offers the Farm Start program in Vermont and eastern New York. The Farm Start program offers working capital investments of up to $75,000 to agricultural ventures who are generally not yet eligible for conventional lending programs. Targeting beginning farm ventures ensures that climate-smart practices are integrated from the planning stage and likely to continue as the farm develops.

- **Investment needed:** ***Small – Medium.***
- **Originating entity:** ***Commercial banks, Farm Credit System.***
- **Target entity:** ***Farm Operating Capital, Value-Chain Companies, Farmland.***

Action steps for implementation:

- **Identify local and/or community banks or lending institutions for collaboration**
- **Assess current loan programs to determine the feasibility of adapting existing opportunities to incorporate specific climate-smart criteria**
- **Determine climate-smart metrics for qualifying farms and value chain businesses**
- **Build relationships and conduct outreach with local farming or agricultural groups and chambers of commerce, climate-smart farmers and business audiences**

Enabling Infrastructure

Climate Risk Assessment at Banks & Lending Institutions

Overview: Banks and other lending institutions regularly stress-test their portfolios against a number of drivers that may affect the ability of borrowers to meet their obligations. To date, rarely has climate change been included as a risk factor in these scenarios but doing so could help banks better evaluate their portfolios against these emerging risk categories. The integration of climate stress-testing into banking and loan fund risk management would help to plan for and assess the effects of climate change and provide additional rationale to expand the pool of credit for farmers seeking to invest in climate-smart farming practices and technologies.

Example: In 2017 nine international banks conducted modeling exercises using a tool developed as part of a framework designed by the Natural Capital Financial Alliance and GIZ to measure the impact of severe droughts on farms' ability to repay loans. This modeling showed that severe droughts could cause significant losses to banks.

Action steps for implementation:

- **Collect high quality, granular data from local and regional farms and institutions to improve the specificity of the modeling for place-based assessments**
- **Expand piloting of climate stress testing to U.S. commercial and agricultural banks, including local banks and credit unions**
- **Financial institutions develop or adopt frameworks, such as those developed by Partnership for Carbon Accounting Financials, to assess the exposure of their assets to climate stressors. Additional analysis can be performed to assess the primary, secondary and macroeconomic impacts of climate change on agriculture and food sectors and opportunities to mitigate those risks.**
- **Back initiatives that support greater transparency and financial disclosure for banking and lending institutions around their climate and energy investments**

Voluntary Standards and Certifications

Overview: Industry-wide standards and certifications lend credibility and foster trust between customers and producers at varying levels of the agricultural value chain. These standards hold businesses, financial institutions, and organizations up and down the agricultural value chain accountable for using practices aligned with climate-smart agriculture and making farms more resilient to current and impending climate impacts.

Furthermore, ascribing to certain voluntary affiliations may lead a bank's lending to be more supportive of climate-smart agriculture-related businesses. These affiliations may also be required to secure Green Bonds or Climate Bonds. Certifications from second- or third-party groups also give lenders additional confidence that their investment is following a tested framework for making a positive impact, as well as generating returns.

Examples: There are many certification schemes and standards that may be beneficial for use by investors and enterprises in the climate-smart agriculture space.

- *Certified B Corporations (B Corp) are businesses that are legally required to balance purpose and profit, measure their social and environmental impacts, and consider the impact of their decisions on workers, customers, suppliers, community, and the environment. Farming and ranching companies that have pursued and maintained B-Corp certification include Stonyfield Organic, Danone North America, and Cabot Creamery Co-operative.*
- *The Global Alliance for Banking on Values (GABV) is an independent network of banks using finance to deliver sustainable economic, social and environmental development. With 63 financial institutions and over $210 billion in assets globally, the Network provides resources and technical assistance for progressive, values-based, and sustainability-oriented banks.*
- *Leading Harvest is a sustainability nonprofit organization that provides assurance programs comprised of standards, audit procedures, training and education, and reporting and claim offerings. The Leading Harvest Farmland Management Standard is designed to optimize sustainable farmland management through a comprehensive assurance program, addressing 13 principles including soil health and conservation, protection of water resources, and employees and farm labor. Users of the standard can achieve certification through independent third-party auditing.*
- *The Partnership for Carbon Accounting Financials (PCAF) released the first global standard to measure and report financed emissions in September 2020. The Global GHG Accounting and Reporting Standard for the Financial Industry) is a framework for a standardized and clear way of measuring and reporting GHG emissions tied to lending and investment portfolios.*
- *The UN Principles for Responsible Investment (PRI) is an independent proponent of responsible investment, encouraging investors to use responsible investment to enhance returns and better manage risks. Signatories to the PRI are committing to the six Principles, which include incorporating environmental, social, and governance (ESG) issues into investment analysis and decision-making processes and reporting activities and progress towards implementation.*

Action steps for implementation:

- **Identify which existing standards and certification schemes are most relevant to climate-smart agriculture and USFRA organizations**
- **Collaborate with existing certification schemes to explicitly integrate or target climate-smart agricultural practices and outcomes**
- **Determine how climate-smart criteria would be met and verified**
- **Explore creating new climate-smart agricultural certification that specifically targets the desired practices and outcomes and requires third-party verification of criteria**
- **Ensure standards work on-farm and farmers are included in the design**

Fixed Income – Public Bonds

Mechanisms

Land-Secured Assessment Financing

Overview: Land-secured financing is often applied through special taxing districts, which are independent governmental units that exist with varying degrees of administrative and fiscal independence from local governments. The laws governing this model generally vary state by state but many overlap in terms of their structure and purpose, which could make it a replicable model in different parts of the U.S. Land-secured, property-assessed financing mechanisms based in special tax districts have long been used to finance infrastructure improvements and other public-purpose projects such as roads, lighting, water, sewage and utility lines. This model could be adapted and used to target climate-smart agriculture interventions in rural areas or farming communities, allowing property owners within the district to implement improvements without large up-front cash payments. In turn, the repayment obligation may be transferred with property ownership if the buyer agrees to assume responsibility.

Examples: Land-secured assessment financing has recently been used to invest in sustainability improvements through the Property Assessed Clean Energy (PACE) program. PACE allows private and commercial property owners to finance the up-front costs of energy improvements on their property and then pay back the amortized costs over time through a special assessment that is attached to the property (i.e. through the tax bill), rather than the individual.

Croatan Institute was awarded an NRCS Conservation Innovation Grant to research and pilot the model of special purpose tax districts termed Regenerative Organic Agricultural Districts (ROADs), focused on a place-based approach to financing regenerative agriculture in five regions. The model includes exploring the feasibility of developing a land-secured, property assessed financing mechanism known as a Soil Wealth Improvement Mechanism (SWIM), which would be deployed to unlock new sources of private capital to finance the accelerated development of regenerative systems.

- **Scale of investment needed:** ***Large.***
- **Originating entity:** ***Government, Institutional Investors, Fixed Income.***
- **Target entity:** ***Farm Operating Capital.***

Action steps for implementation:

- **Catalogue landscape of existing districts and determine whether existing districts could be enhanced with climate-smart agricultural features; explore collaborations and partnerships with existing tax districts and governing bodies**
- **Explore the feasibility of public vs. private special purpose-tax districts based on interest of value chain participants, policy environment, and private investors**
- **Assess financial risks and returns, as well as the social and environmental impacts, associated with investing in climate-smart agriculture in target geographies**
- **Develop place-based metrics for the climate-smart agricultural practices and outcomes appropriate for districts**
- **Identify financing mechanisms best suited for channeling private investment capital into districts**

Climate / Green Bonds

Overview: Climate Bonds and Green Bonds are debt securities issued by financial, corporate or public entities where the proceeds are used to finance "green" or sustainable projects and assets. Climate Bonds are a type of Green Bond that encompasses projects and assets that are focused on transitioning to a low-carbon and climate resilient economy.

As of January 2020, Agriculture has been integrated as a criterion in the Climate Bonds Standards and Certification Scheme. This means that Climate Bonds can be better tracked and targeted to financing climate-smart agricultural practices and expenditures, such as acquiring farmland, planting and management costs, training and research and performance monitoring. In order to qualify as a Climate Bond under the agricultural criteria, the targeted assets need to meet both climate mitigation (net reduction in greenhouse gas emission or increase in carbon sequestration) and resilience requirements (increasing resilience to risks such as temperature- and water-related climate patterns).

Examples: While the Agriculture criteria in the Climate Bonds Standards and Certificate Scheme is nascent, finalized in January 2020, there are many examples within the green bond market that have addressed climate-smart agricultural goals. The green bond market has a total valuation in $861 billion in outstanding bonds to date. In 2019, total green bond issuance rose to $257 billion, representing a 51% increase from 2018. The vast majority of these issuances have been in sectors outside of agriculture, but the investor demand for these types of products is clear. There are many opportunities for companies to raise capital that would hasten the transition to a more climate-smart agriculture from both within the company and across supply chains.

Brazil has emerged as a leader in Green Bond issuance, with five out of its nine certified green bonds having an agriculture or forestry component to them. Paper and pulp company Suzano Papel e Celulose, for example, issued a $500 million Green Bond in 2016 to finance sustainable forest development and conservation efforts on its 1.2 million hectares. The investing firm Sustainable Investment Management Ltd (SIM), in partnership with the UK government and UN Environment Programme, launched the first financial facility to offer green bonds for sustainable soy production in Brazil, which is expected to provide $1 billion through 2023 to fund the sustainable production of more than 180 million tons of soy and corn.

- **Scale of investment needed: *Medium – Large.***
- **Originating entity: *Institutional Investors, Fixed Income, Funds.***
- **Target entity: *Farm Operating Capital, Value-Chain Companies.***

Action steps for implementation:

- **Determine scale of investor appetite for targeted agricultural Climate Bonds to structure offerings and investments appropriately**
- **Collaborate with Climate Bond Standard Board to further refine climate-smart agricultural practices or outcomes in agricultural criteria**
- **Identify the scale and category of agricultural businesses that would benefit from bond financing; target outreach to these enterprises**
- **Identify how investments would be used, what criteria would need to be met in order to qualify (i.e., climate-smart standards, reporting or certification) and how meeting criteria would be demonstrated (i.e., self-reporting, third-party verification)**

Blended Capital Facilities

Overview: Blended finance is an approach to development finance that strategically employs finance and philanthropic funds to mobilize private capital flows to emerging markets. Blended finance or capital facilities could be developed to support the participation of any number of finance sources with different risk and return expectations focused on incentivizing building soil health and supporting climate-smart agriculture in the U.S. These facilities can aggregate and facilitate investment from multiple finance sources, while also integrating an educational and/or technical assistance component to provide guidance and resources to farmers and projects they fund.

Example: The Agri3 Fund Technical Assistance Facility bridges the gap between the needs of farmers and the limitations of banks by providing de-risking financial instruments and technical assistance.

Instruments include risk mitigation and tenor extension. Technical assistance includes training programs, research and feasibility studies, and Environmental and Social Framework support.

- **Scale of investment needed: *Medium – Large.***
- **Originating entity: *Commercial Banks, Farm Service Agency, Individuals.***
- **Target entity: *Farm Operating Capital, Value-Chain Companies, Farmland.***

Action steps for implementation:

- **Identify and catalogue specific investment risks that are holding back investment in climate-smart agriculture.**
- **Explore partnerships or collaborations with CDFIs, philanthropic funders, and private impact investors to integrate blended finance to target climate-smart agricultural operations.**
- **Develop tools to attract private capital to such a facility, such as partial- or full-risk underwriting, guaranteed payments contingent on performance and/or payment in exchange for upfront investment, or offering technical assistance.**

Enabling Infrastructure

Credit Enhancements for Climate Bonds

Overview: Banks, private lenders, philanthropies, and other funders could provide enhancements to strengthen the credit ratings of Climate Bonds, specifically those targeting climate-smart agriculture. Credit enhancements, such as partial or full guarantees, subordinated debt, insurance, and A/B loans, are strategies for reducing risk exposure for investors, which allows lenders to offer bonds with better loan repayment terms or lower interest. With Climate Bonds, some investors may be hesitant to invest in this vehicle because climate-smart agriculture and other sustainability projects are viewed as high risk for defaulting or a low rate of return. By getting banks and other lenders to guarantee or assure a portion of the repayment of the bond, thereby enhancing the security of a Climate Bond's principal and interest rate, bonds can improve their risk rating and become more attractive for investors.

Examples: Credit enhancements are well-established in traditional infrastructure and are expanding in green infrastructure and energy financing schemes. In 2018, Singapore energy company Sindicatum Renewables issued three green bonds totaling approximately $60 million, enhanced by a full credit guarantee from GuarantCo. The Republic of Seychelles issued the world's first "Blue Bond" of $15 million in 2018, which was enhanced through a concessional loan, to finance sustainable marine and fisheries projects. The Inter-American Development Bank offered credit-enhanced loans, first-loss guarantees, and insured loans to finance a high upfront cost project to develop the geothermal energy sector in Mexico.

Action steps for implementation:

- **Identify pools of capital via banks, lenders, philanthropy or private investors willing to provide additional collateral or offer guarantees to make climate-smart bonds with agricultural features more attractive to investors**

Fixed Income – Private Debt

Mechanisms

On-Bill Financing

Overview: On-bill financing is well-established in the U.S., particularly with energy utilities, to enable customers to invest in energy efficiency. This model allows a utility to incur the cost of a clean/renewable energy upgrade or energy efficiency improvements, which are then repaid on the utility bill, with the upfront capital being provided by a third-party. For financing climate-smart agriculture, public and private lenders (such as utilities, seed companies, and other suppliers) should incorporate the development of agricultural value chains into financing frameworks. Third parties could provide credit enhancements and public bond guarantees to facilitate transactions and attract lender participation.

This mechanism is especially attractive to those farmers and value chain businesses for whom access to conventional loans may be difficult, and particularly for investments or upgrades in soil health management practices which may be difficult to demonstrate near-term returns to lenders.

- **Scale of investment needed:** ***Medium – Large.***
- **Originating entity:** ***Institutional & Retail Investors, Government, Fixed Income.***
- **Target entity:** ***Farm Operating Capital, Value-Chain Companies.***

Action steps for implementation:

- **Explore partnerships with existing utilities or other agencies that are already offering an on-bill financing program, and assess feasibility of including or integrating climate-smart agriculture into the target funding projects (i.e., rural energy utility already financing energy efficiency improvements)**
- **Identify terms and conditions for recruiting lenders and investors to purchase or fund on-bill financing, and explore mechanisms such as credit enhancement or risk underwriting to incentivize such investments**
- **Determine cost-effectiveness metrics for assessing impact and ROI**

Environmental Impact Bonds (EIBs)

Overview: EIBs are investment vehicles that can help provide up-front capital from private investors for implementing climate-smart farming practices. When soil health or other on-farm conservation improvements have been achieved and assessed by evaluators, investors are then repaid by the farmer or partner payors.

EIBs are well-suited for public-private partnerships. For example, private utilities benefit from water and energy efficiency due to improved soil quality, and governments and public agencies benefit from improved run-off management and drought and flooding mitigation. As federal and state public funds become increasingly scarce for investment in resiliency, including soil health, EIBs help direct private funds to these efforts by sharing the costs (and benefits) to each shareholder, thereby reducing risk. If the project achieves its goals or performs better than expected, then the issuer pays an outcome payment to the investors; if it underperforms, the issuer pays a pre-determined risk-sharing payment.

Example: Blue Forest Conservation, supported by philanthropies as well as the World Resource Institute, developed the Forest Resilience Bond (FRB) to deploy private capital to forest restoration projects, delivering benefits to private and public stakeholders such as the U.S. Forest Service and private water-dependent companies. The FRB then contracts with beneficiaries to share the costs while providing modest returns to investors.

Chesapeake Bay Foundation's partnership with impact investment advisory firm Quantified Ventures provides support to regional municipalities to develop EIBs for stormwater management projects.

These Stormwater Management EIBs allow municipalities to sell EIBs to private investors to finance these and other green infrastructure needs. Current projects include the city of Baltimore, MD constructing bioretention facilities for wetland restoration, and the city of Hampton, VA's investments in flood management projects.

- **Scale of investment needed*: Medium – Large.***
- **Originating entity: *Commercial banks, Farm Credit System, Government.***
- **Target entity: *Farm Operating Capital, Value-Chain Companies.***

Action steps for implementation:

- **Partner with municipalities, tax districts or other bond-issuing authorities that would benefit from climate-smart agricultural investment**
- **Identify large-scale agricultural practices or projects that would benefit from bond issuance capital but may be considered risky or not yet proven at scale**
- **Determine revenue stream or allocated budget for repayment of loans**
- **Develop social and environmental metrics aligned with climate-smart agriculture for measuring performance and outcome of bonds**

Sustainability-Linked Loan Facilities

Overview: Sustainability-linked loan facilities offer loans to individuals or companies that commit to specific, pre-determined improved sustainability outcomes. Those outcomes are assessed by an independent auditor to determine whether metrics and goals have been met, usually on an annual basis. If the sustainability goals have been met, then the borrower enjoys a reduced interest rate.

Examples: There are many recent examples of sustainability-linked loans targeting sustainable agriculture and food systems. Cofco International's $2.3 billion sustainability-linked loan facility offers three financing timelines, including a one-year loan, in which the facility's interest rate is tied to the company's sustainability performance. The sustainability targets include increasing traceability of agricultural commodities with a focus on soy in Brazil, assessed by an independent inspect annually. Tereos Sugar and Energy Brazil took out a $105 million sustainability-linked loan that measures performance indicators such as annual reduction in GHG emissions and annual reduction in water consumption per ton of cane. Louis Dreyfus Company took out a sustainability-linked loan that ties the interest rate on a $750 million loan in North America to its performance on sustainability criteria. Hong Kong's DBS Group signed a 10-year, SGD 27 million sustainability-linked loan with Chew's Agriculture, a leading egg producer in Singapore. Chew's Agriculture will get lower interest rates if it meets humane animal care standards. Lastly, French agricultural cooperative Agrial took out a €900 million sustainability-linked loan, which will measure a number of social and environmental indicators, including worker safety, reduced energy use, and increased sales of non-chemical farm inputs.

- **Scale of investment needed:** ***Large.***
- **Originating entity:** ***Commercial banks, Farm Credit System, USDA.***
- **Target entity:** ***Farm Operating Capital, Value-Chain Companies, Farmland.***

Action steps for implementation:

- **Develop partnership with banks, investment firms, or other lending institutions interested in climate and/or sustainability goals**
- **Determine specific social and environmental targets for a climate-smart agriculture linked loan facility (i.e., reduced tillage, greenhouse gas reductions, cover cropping)**
- **Identify borrowers of scale that would benefit from a CSA-linked loan (i.e., privately held and/or publicly traded companies, large NGOs, land trusts)**
- **Develop assessment metrics and timeline for project performance review**
- **Engage third-party or external reviewers for verification of climate-smart benchmarks and outcomes**

Tailored Lending Programs

Overview: Tailored Lending Programs can be designed to meet specific needs of farmers transitioning toward climate-smart practices, while providing accredited investors with access to tailored fixed income investment networks.

Examples: Austin Foodshed Investors' (AFI) Bridge Loan Fund is a tailored loan program that was created to support farmer and rancher access to the NRCS Environmental Quality Incentives Program (EQIP) program by lessening the burden of the EQIP reimbursement process. The Bridge Loans cover the cost of EQIP projects upfront so that farmers do not have to struggle with cash flow concerns until the project is completed. Upon completion, NRCS reimburses AFI directly. AFI also offers additional tailored lending programs, targeting new farmer land access, livestock purchasing, soil enhancement, and equipment capital. California Farm Link also offers this type of financing.

New Hampshire Community Loan Fund (NHCLF) offers loans, capital and technical assistance to traditionally underserved people in the state' economy. NHCLF's Local Food Fund offers flexible capital to grow food and farm businesses along the value chain. To date, the fund has loaned $14m and provided over 12,000 hours of technical assistance to local food businesses.

- **Scale of investment needed:** ***Small – Medium.***
- **Originating entity:** ***Commercial banks, Funds, Farm Credit System.***
- **Target entity:** ***Farm Operating Capital, Value-Chain Companies, Farmland.***

Action steps for implementation:

- **Identify community of investors that are located in or invested in the outcomes of particular areas (local, regional or state-wide) or around particular outcomes of the food and agricultural system (i.e., improved soil health, water pollution and run-off management, increased biodiversity)**
- **Engage with investors to develop new or enhance existing tailored lending programs that target climate-smart agriculture in their areas**
- **Develop soil health metrics for reporting project progress and measuring outcomes**

CDFI Loan Funds

Overview: Community Development Financial Institutions (CDFIs) are private financial institutions that are dedicated to responsible, affordable lending, offering targeted support to disadvantaged peoples and sectors in achieving economic success. By developing their own loan programs, CDFIs can help investors interested in financing climate-smart agriculture gain more targeted private debt exposure.

Examples: Maine's Coastal Enterprise Inc (CEI)'s Sustainable Agriculture and Food System Program offers loans and investments to farms and agricultural value-chain businesses, ranging from short- and long-term financing from $10,000 or less to greater than $500,000. In the past 5 years it has provided more than $10 million in loans to 87 businesses. Similarly, CEI's Sustainable Fisheries program provides technical assistance, conducts research, and offers financing to fisheries, aquaculture and marine trades.

California FarmLink invests in farmers through offering loans, education and access to land across the state. They offer several types of loans with interest rates and repayment terms for farmers, many geared to those adopting climate-smart practices, including equipment loans, general operating loans, conservation loans, and resource efficiency loans.

Nebraska's Rural Investment Corporation (affiliated with the Center for Rural Affairs) serves rural communities in the Heartland region and has a selection of loan products specifically designed to assist farmers.

- **Scale of investment needed:** ***Small – Medium.***
- **Originating entity:** ***Commercial banks, Funds, Farm Credit System.***
- **Target entity:** ***Farm Operating Capital, Value-Chain Companies, Farmland.***

Action steps for implementation:

- **Partner with CDFIs serving rural or agricultural communities to develop targeted loan fund that supports climate-smart practices**
- **Identify philanthropic funds or private capital stakeholders for place-based, high-impact, fixed rate of return on investments into climate-smart agriculture**
- **Determine loan types, terms and interest rates appropriate for spurring growth of the scale and speed of uptake of climate-smart agricultural activity. Microenterprise, small business, and community service organization loans may be offered to target a variety of enterprises along the farming value chain.**
- **Develop technical or business assistance program in order to support grantees in guaranteeing success with implementing or developing climate-smart practices**

Enabling Infrastructure

Loan Guarantees

Overview: Loan guarantees are contractual obligations where one party agrees to be liable for all or a portion of the debt of another party if it is not repaid. The guarantor can be the government, an organization (like a company or philanthropic foundation), or an individual. This loan guarantee is a credit enhancement that allows a lender to offer a loan with more favorable terms to the farmer for investing in or adopting climate-smart practices. Guarantees can also be used to mitigate risk and provide multiple access points for investors with different financial and impact objectives.

Examples: The USDA Farm Service Agency has a loan-guarantee program with $150 million set aside for conservation projects, which went unutilized in both FY2017 and FY2018.

PVGrows Investment Fund, a lending vehicle managed by the Franklin County Community Development Corporation in the Pioneer Valley of Massachusetts, has a risk capital pool funded by foundations that serves as a loan-loss reserve for its community loan fund financing regional food systems.

The Small Business Administration (SBA)'s 7(a) Loans, the Community Development Corporation (CDC)/504 loan guarantee programs, and the SBA's Microloan program provide funds to specially designated non-profit intermediary lenders, which then issue loans to eligible borrowers, and small businesses with small, short-term loans — up to $50,000 — for working capital or to buy inventory, supplies, machinery and equipment.

- **Scale of investment needed:** ***Small – Medium.***
- **Originating entity:** ***Government, Asset-owning organizations (philanthropies, corporations, or other value chain intermediaries), or Individuals.***
- **Target entity:** ***Farm operating capital, Value-Chain Companies.***

Action steps for implementation:

- **Banks, government, or private philanthropic actors can provide guarantees to enhance public and private loans to climate-smart enterprises along the value-chain**
- **Within private or blended capital stacks, loan guarantee and loan-loss reserve pools could be invested more aggressively to de-risk loans for climate-smart agriculture and food system businesses**

Public Equity

Environmental, Social, and Governance Investing

According to the US SIF 2020 Trends report, of the $54.1 trillion of US assets under professional management, 33% ($17.1 trillion) are managed under sustainable investing strategies. Farms, farm businesses and investment vehicles that practice or serve the climate smart agriculture sector will be better positioned to access these pools of capital that are increasingly interested in environmental outcomes, such as climate mitigation and adaptation.

Mechanisms

Initial Public Offering

Overview: IPOs are a mechanism for private companies to raise capital by offering shares of their company to the public. Companies providing services for the transition to climate-smart agriculture could use this mechanism to help accelerate their growth. Emerging exchanges, such as the Long Term Stock Exchange, may be appropriate given the long-term value creation with climate-smart agricultural systems.

Example: Vital Farms, a pasture-raised egg company, filed for an IPO in July 2020. Agricultural systems that are perennial and pasture-based usually deliver a multitude of climate-smart benefits; expanding these types of companies can engage additional producers and a larger land-base.

- **Scale of investment needed:** ***Medium – Large.***
- **Originating entity:** ***Public investors.***
- **Target entity:** ***Value-Chain Companies.***

Action steps for implementation:

- **There is a relatively standard process for going through an initial public offering, although there are likely some modifications for climate-smart agricultural businesses. For example, issues related to valuation, risk, and pricing could be altered based on the material benefits that climate-smart agriculture provides**
- **Document the social and environmental outcomes from climate-smart agriculture and the supply chain for demonstrating the material value of the company**
- **Further research into climate-smart agricultural market dynamics. The increasing consumer knowledge about climate-smart agriculture could lead to increased demand for the resulting stock or the company's products or services**

Exchange Traded Funds (ETFs) and Mutual Funds

Overview: While sustainable, responsible and impact investing trends continue to grow, as do the number of agricultural value chain companies connected to climate-smart agriculture, there has yet to be many branded investment products (ETFs & Mutual Funds) at the intersection of these themes, which could potentially make it easier for investors to invest in these companies. ETF and Mutual Fund instruments are slightly different, but they both represent bundles of securities that are often thematically bundled. As companies and investors continue to build out the climate-smart investing universe, there are many opportunities to create innovative financial products that simultaneously meet the needs of investors while flowing capital to transition to climate-smart agriculture.

Example: Several themes ETFs have come to market in the past few years with an emphasis on food and agriculture. Examples include the NextGen Food & Sustainability ETF which follows the BlueStar Food and Agriculture Sustainability Index and the recently shuttered Organics ETF. In Australia, many AgTech companies have listed on the Australian Securities Exchange (ASX), which has welcomed many growing companies from across the world. Krane Fund Advisors launched the KFA Global Carbon ETF, which tracks the IHS Markit Global Carbon Index and could have eventual connections with agricultural carbon markets.

- **Scale of investment needed:** ***Medium – Large.***
- **Originating entity:** ***Financial services & asset management firms.***
- **Target entity:** ***A variety of assets that could include value-chain entities with a relationship to climate-smart agriculture.***

Action steps for implementation:

- **As the number of available securities related to climate-smart agriculture grows, thematic instruments can be constructed that allow investors to more easily invest in climate-smart agricultural businesses and services**
- **Education for fund managers and other financial value chain stakeholders is needed to highlight the benefits of climate-smart agriculture and the pent-up investor demand**
- **Encourage agriculture to be broadly considered as part of carbon-oriented funds**

Private Equity & Venture Capital

Mechanisms

"Bridge" Capital Funds

Overview: Bridge capital offers a short-term financing option for companies with sustainable and saleable growth projections. This can be a helpful financing mechanism for companies transitioning from early to growth stage in the business life cycle, or for companies that have large upfront costs, such as processing and packing facilities, that need investment to scale. It is used when current financing runs out and there is a gap between when long term financing can be secured.

Example: Traction Capital launched a hybrid private equity and venture capital fund to invest in or acquire early-stage and lower, middle market companies that are stuck in the "capital gap". On the venture side, Traction seeks minority deals with $250k - $5m in revenue; on the private equity side, Traction seeks majority deals with $500k - $1.5m in EBITDA or $5m - $20m in revenue.

- **Average Deal Size:** ***Small – Medium.***
- **Originating entity:** ***Private equity and venture capital firms raise capital for bridge capital funds from retail and institutional investors.***
- **Target entity:** ***Value-Chain Companies, Farm Operating Capital.***

Action steps for implementation:

A bridge capital fund could target climate-smart agriculture value chain businesses that have market viability, strong leadership, scalability, and sustainable growth potential.

Small Business Investment Company / Rural Business Investment Company

Overview: A Small Business Investment Company (SBIC) is licensed by the Small Business Administration (SBA) and uses privately raised capital to make investments in small businesses. The SBA can also provide guaranteed leverage, up to three times the private capital raised. This mechanism allows a private equity firm to easily secure funding from large institutions, like banks, without onerous paperwork that could prohibit investment. This SBA program currently supports funds that invest in clean tech, education, and economic development in low to moderate income areas.

Similar to a SBIC, a Rural Business Investment Company (RBIC), is an equity investment organization licensed by USDA Rural Development to help meet the equity capital investment needs in rural communities. This new mechanism allows Farm Credit System entities to invest in equity funds, who can then deploy those assets across rural America. The current designation is not tied to climate-smart practices.

Example: In 2012, SJF Ventures organized one of its venture funds as the first Impact Investment SBIC in order to tap SBA support for investing in economically disadvantaged areas and targeted sectors like education and clean energy.

In 2019, M&T Bank announced a $5 million private equity investment with Blue Highway Growth Capital, a registered RBIC, to support small rural businesses in the Northeast and Mid-Atlantic, including businesses in the service sector, specialty manufacturing, transportation and logistics, business and technology services, healthcare and medical products, and agriculture.

The Open Prairie Rural Opportunity Fund is another licensed RBIC that has received investment from Farm Credit Institutions including Compeer Financial and CoBank commercial and community banks, family offices, and high net worth investors. The private equity fund offers debt and equity capital to growth and later-stage companies across the agribusiness value chain, such as businesses focusing on crop protection, ingredients, processing, storage, data management and logistics.

- **Average Deal Size:** ***Large.***
- **Originating entity:** ***Institutional investors, banks, and money managers invest in funds managed by venture capital firms; government can invest in debt capital.***
- **Target entity:** ***Farmland, Farm Operating Capital, Value-Chain Companies.***

Action steps for implementation:

Climate-smart agriculture could become a targeted sector for SBICs and RBICs, so that private equity fund managers can organize as SBICs in order to raise capital from large institutions and borrow low-cost, government-backed capital to invest in small businesses that are within climate-smart agricultural value chains.

Community Development Venture Capital (CDVC)

Overview: Community Development Venture Capital (CDVC) funds make equity investments in businesses for the purpose of supporting economic development in underinvested or overlooked communities because of their size, geographic location, or industry focus.

Example: CEI Ventures, based in Maine, provides equity venture capital to businesses in underserved rural New England communities, including a limited number of "natural and organic" food companies. Portfolio companies enter into a Social Agreement with CEI.

- **Average Deal Size:** ***Small.***
- **Originating entity:** ***Foundations, banks, financial institutions, government, NGOs, and retail investors.***
- **Target entity:** ***Value-Chain Companies.***

Action steps for implementation:

A CDVC fund could provide more intentional exposure to a diversified portfolio of companies along the climate-smart agriculture value chain, providing both positive social impact and environmental benefits.

Venture Capital Fund

Overview: Venture capital funds make equity investments in start-up and small businesses with strong growth potential. Often these investments have high risk factors but have the potential for above-average returns.

Example: Almanac Investments is a $30 million venture capital fund focused on climate-smart agriculture by investing in CPG, retail, and technology companies.

- **Average Deal Size:** ***Small – Medium.***
- **Originating entity:** ***Accredited retail investors, financial institutions.***
- **Target entity:** ***Farm operating capital, Value-Chain Companies.***

Action steps for implementation:

Accredited retail investors and institutional investors provide equity investment capital to early-stage ventures within the climate-smart agriculture value chain.

Corporate Venture Capital Funds

Overview: Many larger corporates have stood up corporate venture capital funds in order to seek out, support, and scale aligned businesses in the agriculture sector. These quasi-research and development funds can be used to align innovative ideas and products, resourceful entrepreneurs, and durable business models with existing supply chains, brands, and sources of capital. While the types of transactions can vary, portfolio companies are often given access to corporate resources and advisors while the business models, market strategy, and growth are closely observed.

Example: Patagonia created a $20 million corporate venture fund called Tin Shed Ventures to invest in early stage companies that are addressing environmental problems, including those related to agriculture.

General Mills launched 301 INC, a business development and venture unit to work with innovative and growing brands that align with General Mill's core business. It has invested in companies including Beyond Meat, Rhythm Superfoods, and Kite Hill.

- **Average Deal Size:** ***Large.***
- **Originating entity:** ***Corporations.***
- **Target entity:** ***Farm operating capital, Value-Chain Companies.***

Action steps for implementation:

Large corporations along the food and agriculture value chain can develop venture capital arms to invest in climate-smart agricultural enterprises that align with the company's core strengths and values.

Farmland & Real Assets

Mechanisms

Opportunity Zone Funds

Overview: Recently introduced as a new mechanism, accredited investors earn tax-favorable, risk-adjusted returns in non-correlated assets. These funds could achieve tax-advantaged capital appreciation in production agricultural projects in disadvantaged regions in the US. These funds need to have ninety percent of assets invested in opportunity zones and are organized for the purpose of investing in Qualified Opportunity Zone (QOZ) property.

Example: Harvest Returns' Sustainable Agriculture Opportunity Fund is currently open for soft investment commitments. The fund's investment objective is to achieve tax-advantaged capital appreciation in production agricultural projects that are economically, socially, and environmentally sustainable.

- **Average Deal Size:** ***Small.***
- **Originating entity:** ***Accredited retail investors.***
- **Target entity:** ***Farmland, Farm operating capital, Value-Chain Companies.***

Action steps for implementation:

- **As part of a rural resiliency strategy, Opportunity Zones could be used to entice investors to invest in businesses along the climate-smart agriculture value chain in targeted regions**
- **New investment strategies would need to identify the investable opportunities and geographies (and potential investors) that could advance climate-smart agriculture, given the limitations and structures of the Opportunity Zone structure**

Real Estate Investment Trust (REIT)

Overview: These investment structures invest in income producing real estate, such as farmland. In this structure, farmers gain access to land and pay a base rent plus variable rent in subsequent years based on revenue. Investors also receive dividends based on variable rent payments and share in the risk/ return with the farmers.

Example: Iroquois Valley Farmland REIT offers investors director ownership in a diversified portfolio of organic farmland, which in turn, supports independent farmers with long-term access to land. Iroquois Valley addresses one of the biggest barriers to organic farming by offering innovative leases and mortgages to transitioning organic and organic farmers.

Farmland LP targets farmland poised for long-term appreciation with a strong demand for locally grown, organic food, robust existing farming communities, and favorable long-term climate projections. They convert conventional farmland to organic using a pasture and crop rotation, managing the land for optimal climate metrics, food production, and financial returns.

- **Average Deal Size:** ***Small – Medium.***
- **Originating entity:** ***Retail investors, including accredited and non-accredited investors; family offices; foundations.***
- **Target entity:** ***Farmland.***

Action steps for implementation:

- **Farmland Investment REITs can offer access to land and support farmers' transition to climate-smart agricultural practices. This financing provides patient capital for the transition period and offers land security for the farmer**
- **New REITs could be owned by or invested in supply chain partners to assist their supply chains in transitioning toward a more climate-smart agriculture. These corporate strategies would need to be assessed individually by each interested corporate firm**

Additional Enabling Infrastructure (Cross Asset Class)

Over the last decade, many frameworks, tools, initiatives, and structures have emerged to add transparency and accountability to public companies that not only reflect and capture their internal operations, but also their supply chains.

As these mechanisms mature, they can provide a rationale for investors to shift their decision-making toward investments that advance a more climate-smart agriculture. This list is not exhaustive.

Insurance

Insurance is one of the primary mechanisms farmers and ranchers use to manage risk within their operations. Current insurance products and policies have been slow to incorporate the differentiated risk profile of soils managed for climate-smart outcomes. Initiatives such as the AGree Economic and Environmental Risk Coalition are advancing changes in crop insurance through USDA's 508(h) process that would create new insurance products that incorporate the risk of several climate-smart practices. While insurance for farmers and ranchers is critical, other de-risking and risk sharing instruments need to be considered in other parts of the agricultural value chain and within financial transactions as well.

Blended Finance and Catalytic Capital

Other mechanisms that are commonly used to de-risk transactions include blended finance, which uses capital from multiple sources to facilitate the movement of capital to break down barriers to investment, and catalytic capital, which is "capital that accepts disproportionate risk or concessionary returns to generate positive impact and enable third-party investment that otherwise would not be possible". Catalytic capital can be used on its own or with other sources of capital within an investment or other financial mechanism. The use of these structures and capital further help to de-risk transactions and facilitate the flow of capital to various parts of the climate-smart agriculture value chain.

Credit Risk

In their report, Stranded Assets in Agriculture: Protecting Value from Environmental-Related Risks, the Stranded Assets program at the University of Oxford's Smith School of Enterprise and the Environment conducted a high-level assessment of the materiality of environmental-related risks that can strand assets throughout the agriculture supply chain.

Standards and Disclosures

- The Task Force on Climate-related Financial Disclosures (TCFD) and the World Business Council on Sustainable Development (WBCSD) have developed guidance specific for companies in the food, agriculture and forestry space around the adoption of TCFD's standards. The joint report outlines practical steps to further enhance climate-related financial disclosure, including integrated risk management, scenario analysis and decision-making, financial focus, and taking a value chain perspective.

- Sustainability Accounting Standards Board (SASB) has developed industry standards to help businesses identify, manage, and communicate financially-material sustainability information to their investors. SASB has identified materiality concerns with GHG emissions in the Food and Agriculture industry.

- The Environmental Impact Reporting in Agriculture (EIRA) initiative laid the foundation for dynamic, globally-relevant benchmarking of environmental impacts in agriculture, convening an international consortium of investors, companies, scientists, and technical partners to initiate design of an EIRA prototype that can be applied in multiple regions. As the EIRA tool is developed, it will provide environmental metrics to a wide array of companies and financial institutions operating in the agricultural sector, working to connect demand and supply for environmental impact information in agriculture, including stimulating greater investment in primary research and monitoring.

Frameworks

- The Natural Capital Finance Alliance, with a Secretariat led by UNEP Finance Initiative and Global Canopy, has provided a comprehensive framework that captures agriculture's impacts and dependencies on natural capital, including those which have not been fully evaluated by lenders in the past, leading to sub-optimal allocation of capital in current credit risk assessment processes.

- True Cost Accounting (TCA) is an economic framework for capturing all of the upstream and downstream costs and benefits associated with business practices, including their long-term impacts on natural resources and communities. The Economics of Ecosystems and Biodiversity (TEEB), an initiative hosted by the United Nations Environment Program and coordinated by the TEEB Office in Geneva, Switzerland, has a program, TEEB for Agriculture and Food that is focused on true cost accounting through a holistic evaluation of agriculture and food systems along their value chains including their most significant externalities. The program has proposed a TCA systems-based evaluation framework, described in their 2018 synthesis report, Measuring What Matters in Agriculture and Food Systems, for better understanding and managing the impacts and externalities of agriculture and food value chains. (more TCA resources catalogued here)

- Ceres has an initiative called Feeding Ourselves Thirsty, which links water risk management as a business imperative for food businesses. Since 2015, Ceres has published three benchmarking reports, and track the progress of 40 major companies in the agricultural product, beverage, meat, and packaged food industries.

Emerging Revenue Markets

In addition to the variety of financial mechanisms available or in development that could assist in the transition to a more climate-smart agriculture, there are several emerging revenue markets that are being developed to provide financial incentives to farmers to adopt climate-smart agricultural practices.

Generally, these markets rely on the creation of a quantified and verifiable credit that equates to a given environmental indicator; these credits are then sold to a buyer, either directly or through a market mechanism. The creation and transfer of these credits help to change practices through the use of a financial incentive *and* also provide individuals and businesses with an opportunity to purchase these credits to offset portions of their environmental footprints, making these emerging revenue markets a critical component of the broader efforts to fund the transition to a net zero economy.

The Ecosystem Services Market Consortium (ESMC) seeks to create a national marketplace designed to sell carbon and water quality and quantity credits in the agriculture sector operating by 2022. In their 2019 study, they identified a potential $13.9 billion market demand for U.S. ecosystem credits from agriculture, which is divided into $5.2B for carbon credits and the remaining $8.7B for nitrogen and phosphorus reduction credits[48]. There has been a growth in approaches trying to track, verify, and compensate these services through markets. ESMC is a collaboration of members from across the entire agricultural supply chain and value chain with the goal to scale the program in a way that can meet the needs of farmers and ranchers, as well as those of corporations, NGOs, consumers and society.

Other carbon marketplace schemes in development include startup Indigo Ag, backed by a range of companies including recent investor FedEx, which is planning to pay farmers based on how much carbon they have stored in their soil. Software company Nori is building an open-source market infrastructure to allow for carbon removal projects to measure and monetize their activity based on blockchain technology to manage the transactions. Regen Network is building a platform for farmers and ranchers to monetize their ecosystem services. Their platform will collect and organize data, produce transparency, and assure accountability by applying blockchain technology to track and verify the production of long-term ecosystem services, and remote sensing to verify carbon levels in the soil.

California has created a carbon marketplace through its carbon cap and trade program, and carbon credits, or offsets, are issued by two registries in the U.S. which design and operate voluntary and compliance GHG reporting programs. One of these, Climate Action Reserve has developed protocols to measure ecosystem services carbon credits, such as the Soil Enrichment Protocol, currently under development. Through the California Climate Investments initiative, the proceeds from California's Cap-and-Trade program help fund the California Healthy Soils Program, which provides financial assistance for the implementation of conservation management that improves soil health, sequesters carbon and reduces greenhouse gas emissions.

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48 For the analysis behind the total potential ecosystem services in the U.S., see the 2018 Informa – IHS Markit study, Economic Assessment for Ecosystem Service Market Credits from Agricultural Working Lands, commissioned by ESMC.

There are also new corporate initiatives in providing financial incentives for ecosystem services that have been introduced in 2020, including the Soil and Water Outcomes Fund is a new collaborative partnership between the Iowa Soybean Association, Quantified Ventures and Cargill, a market-based program to accelerate soil health and water conservation by providing financial incentives to farmers for implementing best agricultural practices that yield environmental improvements on their farms. The pilot program is focused on Iowa, with the intention of expanding to more states, and will compensate farmers for new practices put in place. Bayer has just launched a new program in July 2020 that will reward farmers in Brazil and the U.S. for generating carbon credits by adopting climate-smart practices, helping meet the company goal of reducing field GHG emissions by 30% in 2030. Also in this space is the Bayer Carbon Initiative which will begin with around 1,200 row crop farmers in the first season and plans to scale up and eventually expand to other countries.

In addition to private sector activity around carbon and other ecosystem service payments, there has been bi-partisan U.S. legislation introduced in June 2020 to encourage sustainable, climate-friendly farming and forestry practices, and allow participation in private greenhouse gas credit markets. Under the Growing Climate Solutions Act of 2020, farmers and growers would get credits for finding ways on their land to reduce their carbon emissions, which would be verified independently, and then they would be assigned credits to sell on the market.

Finally, there are models outside the US that have applicability for adaptation stateside to leverage the payments from the sale of the ecosystem service credits for other types of financial arrangements. Community Markets for Conservation (COMACO) is a social enterprise founded in 2003 to reduce illegal wildlife poaching by addressing the root cause of rural poverty. COMACO works closely with rural communities across Zambia's Luangwa Valley to promote sustainable agricultural practices with enhanced market access in a way that incentivizes forest and wildlife conservation, promotes household income and food security, and increases climate resilience for small-scale farmers. COMACO's model combines agricultural extension services with the management of a full-scale commercial value chain that provides a powerful impact to its now 170,000 small-scale farmers that it organizes in its network of cooperatives with 2-3 times increase in production yields and over 300% increase in household incomes. In 2015, COMACO partnered with the World Bank to expand into a carbon credits business segment; a share of the revenue from these credits is redistributed to the cooperatives, creating an even stronger incentive.

COMACO has been able to leverage the World Bank carbon payment as collateral with a lending institution in order to gain favorable debt arrangement to grow its operating fund, which is essentially a revolving fund for payments to the farmers early in the growing season in exchange for commitment to certain regenerative and wildlife-protection practices, before they've delivered the actual crops which are then sold to replenish the fund. This operating-fund-carbon-collateral transaction enables COMACO's operation in Eastern Zambia to operate at a steady state with its large number of small farmers. COMACO is looking to expand its model to other geographies. This structure could be assessed for applicability to advance climate-smart agriculture in the U.S. as carbon and other ecosystem services markets mature.

The variety of approaches that quantify and value the variety of ecosystem services that farmers and ranchers produce are an important set of innovations that help to fully value the contributions of agriculture. These additional revenue sources are important to develop, test, and scale, as there is a high degree of complementarity with other more traditional revenue sources for farmers and ranchers. As these approaches continue to mature, there will be many opportunities to integrate them into other financial and market innovations across the climate-smart agriculture sector.

Recommendations to Scale Climate-Smart Practices with Finance Innovation

A range of financial mechanisms and enabling infrastructure were examined that can be harnessed to incentivize, fund, and scale adoption of climate-smart agriculture. The agricultural capital flows analysis identified three key areas where current agricultural capital and outside investments can be better aligned to scale adoption of climate-smart practices in the United States.

1. **There is nearly $1 trillion in private capital flowing in the U.S. agriculture sector today. How can more agricultural capital be steered toward climate-smart soil outcomes?**
2. **There is a much greater pool of untapped capital outside the agriculture capital flow system looking for investment opportunities like those offered in agriculture. How can outside capital be attracted to scale up climate-smart agriculture?**
3. **There are a variety of financial mechanisms in use today with different risk/reward/impact profiles of varying sizes. How can the financial system more effectively match the right financial tools with the right climate-smart opportunities?**

To that end, we offer the following recommendations:

1. **Educate those deploying capital on the proven practices and outcomes of climate-smart agriculture**
   This report is but an initial attempt to educate financial institutions and others on the need and opportunity for funding to improve soil health and sequester carbon. Many financial institutions, even those working within agriculture, are not fully aware of or have not updated credit lending policies to account for the solid science demonstrating increased profitability and decreased risk of the USDA-backed climate-smart practices in this report. Specific outreach should be targeted to lenders, credit risk analysts, underwriters, and those engaged in both the delivery of existing insurance products and the development of new insurance products and policies.

2. **Raise awareness of new financial innovations amongst those in agri-finance.**
   To meet the likely offerings of new entrants, those partaking in agriculture financial activities today would be wise to familiarize themselves with many of the financial innovations outlined in this report, including those happening at a smaller scale today in food and agriculture and outside the industry in forestry, clean energy and other sectors. It is only a matter of time until these financial innovations and innovators already active in other markets find their way into US agriculture. Foundations could further the net zero economy by investing in the climate smart agriculture sector.

3. **Align the producer's ecosystem and value chain partners to finance transition.**
   At the beginning of this report we emphasized that farmers and ranchers should not and cannot shoulder the burden of transitioning to climate-smart practices on their own. Landowners, input providers, equipment providers, bankers, insurers, offtake partners, downstream supply chain partners and the end consumers of their goods should examine what they all can do to remove barriers and ease the transition of producers to climate smart agriculture.

4. **Leverage information technology to identify and follow opportunities to financially support farmers and ranchers.**
   In the earlier section of this report on scaling climate-smart practices with digital agriculture we discussed the importance of monitoring, estimation, reporting and verification (MRV) systems to provide information to those providing financial assistance to farmers and ranchers. Additionally, we identified the role technology can play in marketplaces for carbon and other ecosystem services, and financial service innovation.

5. **Blend capital to scale collective impact on targeted opportunities.**
   Efforts should be made to align blended sources of capital to help overcome barriers to scale the transition to climate-smart agriculture. Facilitating the layering of different financial instruments by different players with different risk/reward profiles-- from family offices and foundations, to private equity and venture capital, to both traditional and conservation-minded financial institutions-- enables more risk averse and more progressive capital to close gaps and pave the way for less risk averse, standard market return-oriented institutions and tools.

6. **Test new financial mechanisms that activate financial and agricultural value chains.**
   While sustainability linked loans have been used in other sectors and in other regions, there is an opportunity to use these financial mechanisms to flow capital in ways that enables the transition to a more climate smart agriculture. USFRA and its partners can advance these mechanisms by pulling together investors, agriculture value chain companies, agricultural retailers, banks and farmers and ranchers to demonstrate how capital can be used as a tool to support climate smart agriculture.

Conclusion

Increased investment in climate-smart practices and partnerships can enable U.S. agriculture to become the first carbon-negative sector in the economy. A range of technological and financial innovations are poised to fuel the adoption of climate-smart practices at scale, at the same time a growing number of investors seek to decrease their risk exposure and increase their impact.

The next ten years will require significant emissions reductions, mitigation strategies and transformative capital in all sectors to meet the monumental challenges of climate change. Active investment in the agriculture sector is needed to increase adoption of climate-smart practices that rebuild soil health to promote sustainable food production, the economic and environmental resilience of American farms and ranches, and the carbon mitigation and drawdown needs of the nation -- and the planet. Climate-smart agriculture investments provide financial, community and environmental returns over both short-term and long-term horizons and deliver long-term positive impact.

The science is clear and the essential technological and financial elements to implement climate-smart practices at scale are present; they just need to be woven together.

According to the climate-smart soil technology landscape analysis, many new companies have brought technologies to market, but adoption rates remain low. Climate-smart soil technology faces similar barriers to general agriculture technology adoption, such as limited broadband connectivity and data interoperability. Additionally, practical technology for collecting, evaluating and tracking soil health is still nascent; so too are Measurement and Estimation, Reporting and Verification (MRV) platform adoption and privacy protocols to connect farm-level data to other data sets and analytical tools.

There are a myriad of opportunities for investors to fund innovations that enable farmers and ranchers to scale up climate-smart practices. Venture investment, for instance, in the sector is growing but too often funds are deployed into technologies not aligned with the critical needs of farmers and ranchers. Tools need to enable farmers and ranchers to increasingly do more with less, optimize inputs, restore soil carbon and soil health, and provide information that helps them run profitable, agile and resilient businesses.

We have identified a number of financial vehicles to fund the transition to climate-smart soil agriculture, leveraging the approximately $972 billion flowing from institutional, retail and government investors into the agricultural value chain. The vehicles connect the existing lending market to indicators of progress and outcomes related to climate-smart practices, and directly support farmers, ranchers and close value chain actors through two key asset classes: fixed income and public equity instruments. Ecosystem services markets and federal and state government policy have a role to play in these transitions but given the magnitude of private capital moving in this space, the grand challenge will be to align those flows of capital with climate-smart outcomes. Even a relatively small percentage shift in this massive market would have a large impact.

There is also an opportunity to increase total investment in agriculture with the growing pool of environmental, social and governance (ESG) capital looking for impacts related to sustainability, socially responsible, or mission-aligned investment opportunities. Cumulatively, these investors can make a big impact by investing in agriculture that enables and targets climate-smart practice adoption and soil health outcomes.

Enabling farmers and ranchers to meet the challenges of the next decade will require innovative thinking, technologies and financial mechanisms, but with increased collaboration and focus in this space, it can be done. More directly, for the sake of rural America, the nation's food security, and the necessary responses in the face of climate change, it must be done.

Action steps to leverage technology and finance innovation to accelerate and scale the adoption of climate-smart agriculture in the U.S.

1. **Raise investor awareness of climate-smart agriculture as a key enabling sector in the transitional net zero economy and connect investors to specific agriculture needs and opportunities**
   a. While investments in climate-smart agriculture offer positive social, environmental, and financial returns, many climate-specific investment tools (including green bonds) have not identified agriculture as an opportunity.
   b. More fund managers would be inclined to invest in agriculture if they had greater familiarity with the potential for climate-smart agriculture practices for carbon mitigation and sequestration and other positive social and environmental outcomes.
   c. Identify metrics, frameworks, reporting standards, and criteria that companies can use to promote their ESG credentials as it relates to climate smart agriculture.
2. **Stimulate catalytic capital to flow into the agriculture sector through mechanisms that reflect the risk and return goals of ESG investors and climate smart agriculture finance innovation**
   a. Catalytic capital from foundations, government, and through emerging ecosystem service and carbon markets can help to de-risk transactions and increase the flow of capital.
   b. Specifically engage philanthropy through both their grant-making and investment strategies to help grow climate smart agriculture.

3. **Encourage preferential lending programs, when possible, from existing agriculture lending institutions**
    a. Connect the existing agriculture lending market to climate-smart incentive structures that reward producers for indicators of soil-health progress.
4. **Connect more sources of capital with producer ecosystems ready to transition to climate-smart agriculture to identify mutually beneficial solutions**
    a. With a goal of "test and learn," enhance the matchmaking between willing producer ecosystems and willing funders using online platforms and making sure producers are providing funders with digital reporting data to increase their comfort in supporting a producer ecosystem.
    b. Help funders gain comfort in providing compensation based on indicators of progress.
    c. Create blueprints for sustainability-linked loans that will reduce the time and transaction costs of leveraging this capital to advance climate smart agriculture.
5. **Promote the further use of digital tools amongst farmers and ranchers to exchange best practice know-how and data (soil health, yield, profitability, etc.)**
    a. Help to overcome the barriers to adoption of existing climate-smart soil technology tools. This includes ramping up the use of MRV (monitoring & estimation, reporting and verification) and other FMS (farm management systems) that can share information.
6. **Support the development of tools that collect on-farm data; connect on-farm data to larger databases and platforms to accelerate local and practice-specific knowledge and provide funders with indications of progress to reward farmers and ranchers for climate-smart efforts**
    a. Develop a national repository of soil carbon reference data.
    b. Standardize laboratory methods, sensor measurements, and soil data exchange.
7. **Support emerging revenue enhancement mechanisms for farmers and ranchers**
    a. Nascent efforts are underway (by actors such as technology start-ups and consumer packaged goods brands) to economically reward producers for implementing climate-smart practices. Private ecosystem services markets are emerging for direct payments to farmers through market-based incentives and vendor direct payments.
    b. These sources of capital can be blended with other sources to further de-risk the transaction by farmers and ranchers and their value chain partners
8. **Demonstrate clear risk/reward profiles of successful climate-smart financial support for today's investors and farmers and ranchers**
    a. Continue to share success stories of how different financial tools are being applied successfully to specific climate-smart agriculture opportunities to get a broader base of farmers and ranchers and funders aware of and comfortable with the opportunities to transition to climate-smart agriculture at scale.

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Appendix

Climate-Smart Soil Practices

No-Till/Reduced Tillage with Retained Residues

Tillage has historically served a variety of functions for the farmer including preparing the seedbed, killing weeds, and incorporating nutrients and residues. However, sustained tillage can also destroy soil structure and lead to erosion, compaction, poor water infiltration and holding capacity, reduced microbial activity, and the loss of carbon and increased greenhouse gas emissions. The established practices of reduced (strip till) and eliminated tillage (no-till) and keeping the soil covered with retained crop residues can improve soil structure and address the aforementioned tillage-related problems. No-till, and, specifically, continuous (permanent) no-till, maximizes the positive soil health impacts and sequestration of carbon. Reducing or eliminating tillage also directly reduces fuel, labor and equipment costs as well as dust and air pollution associated with additional passes across the field under conventional tillage practices.

It is important to note that the functions provided by tillage do have to be managed in other ways, e.g., by using different equipment, such as no-till seed drills and planters, for seeding in unprepared soil. Driven by its potential to reduce erosion, reduced tillage has seen its most significant adoption by commodity row crop producers in the Midwest. According to the USDA, "Almost 50% of corn, soybean, wheat, and cotton acreage was in no-till or strip-till at some time over a 4-year period (including the survey [year] and 3 previous years), but only about 20% of these acres were in no-till or strip-till all 4 years." Reducing tillage is probably the most accessible and widely adopted of the climate-smart soil practices and is a logical first step for many producers looking to begin improving their soil health and related resources.[49]

Cover Crops

Cover crops, as the name implies, are typically grown to protect the soil, as well as reduce erosion, add or retain nutrients, and address other resource concerns. Their range of uses is impressive. They can be cut for hay or grazed or terminated in place to provide residues and organic matter. They can also replace fallow periods between main crops, be planted concurrently with them, or supplement existing pasture forages. There are a multitude of crop species grown as covers and often mixes of multiple species are grown together. In addition to the benefits mentioned above, they can also be used to suppress weeds, break up compacted soil, improve water management, and disrupt pest cycles. Cover crops can be implemented widely, although consideration must be given to locale, associated cash crops, and grazing activity. They can be tricky to establish and terminate and may be easier to adopt in some areas due to timing constraints relative to the main crop. Cover crops can be seeded in a number of ways (planted/drilled, broadcast, and aerially), at different times relative to or during cash crop growth cycles, and terminated via herbicide application, tillage, harvest, and in-place cutting, for example, with a roller-crimper. Costs include seed, seeding and termination labor, fuel, equipment, and herbicides, if applied.

49 USDA Tillage Intensity and Conservation Cropping in the United States https://www.ers.usda.gov/webdocs/publications/90201/eib-197.pdf

Cover crops offer returns through reduced inputs, potential yield improvements, and lower feed costs for livestock as well as directly addressing erosion and soil health concerns.

Though adoption is up 50% over the last five years, cover crops are used on less than four percent of U.S. cropland, according to the latest USDA census. Low adoption is in part due to unfamiliarity, implementation complexities, and upfront costs combined with sometimes hard-to-quantify benefits or delayed returns, particularly if the cover crops are not used for grazing. However, cover crops remain a logical companion to or next step after reduced tillage practices have been adopted.

Crop Rotation

Crop rotation, growing a series of different crops in succession in the same field, is a way to balance demands on a particular plot of land by adding biodiversity to continuous monocultures or limited planting systems. Benefits of diverse crop rotations include improved soil fertility, improved or maintained yields, decreased erosion, and reduced pest and disease pressure by breaking up their cycles and resistance. Crop rotation progressions might be limited to a couple of cash crops, like the simple corn- soy system, or may include several crops, including cover crops, with additional diversity generally equating to increased benefits. Crop rotations can help spread farmer workload across different planting and harvest dates, and add operational diversity by spreading risk across different crops. Obviously managing multiple crops and their impacts on each other adds complexity and requires additional management, while new or modified equipment may be required to seed, cultivate and harvest added crops. As with cover crops, locale, timing and residue management must be considered as well as adapted rotations to changing conditions.

Compost Application

Application of compost and manure to pasture and rangeland improves soil properties and forage production and reduces the need for chemical nutrient inputs. It can also help address the waste management problem associated with livestock production systems. Compost and manure application are the most universally applicable of the climate-smart practices discussed here, and manure application can be a common practice in areas with concentrated livestock production and a surplus of animal waste. The application of compost, a decomposed mixture of carbon and nitrogen sources, is less common due to its availability and cost as a manufactured product. However, compost, as opposed to raw manure, is a lower-odor and more stable product that reduces GHG emissions and can retain more soil carbon. Modeling based on results from pilots on California pasture and rangeland shows significant sequestration potential that extends over long time periods from single applications of compost. These amendments are applied by broadcasting on the surface or injecting below ground and require the equipment, fuel, and labor to do so. Transportation of materials from source to application site can be a logistics and cost issue, as can regular testing of manure for its nutrient profile. Application timing and rates are also subject to restrictions for water and air quality and food safety reasons.

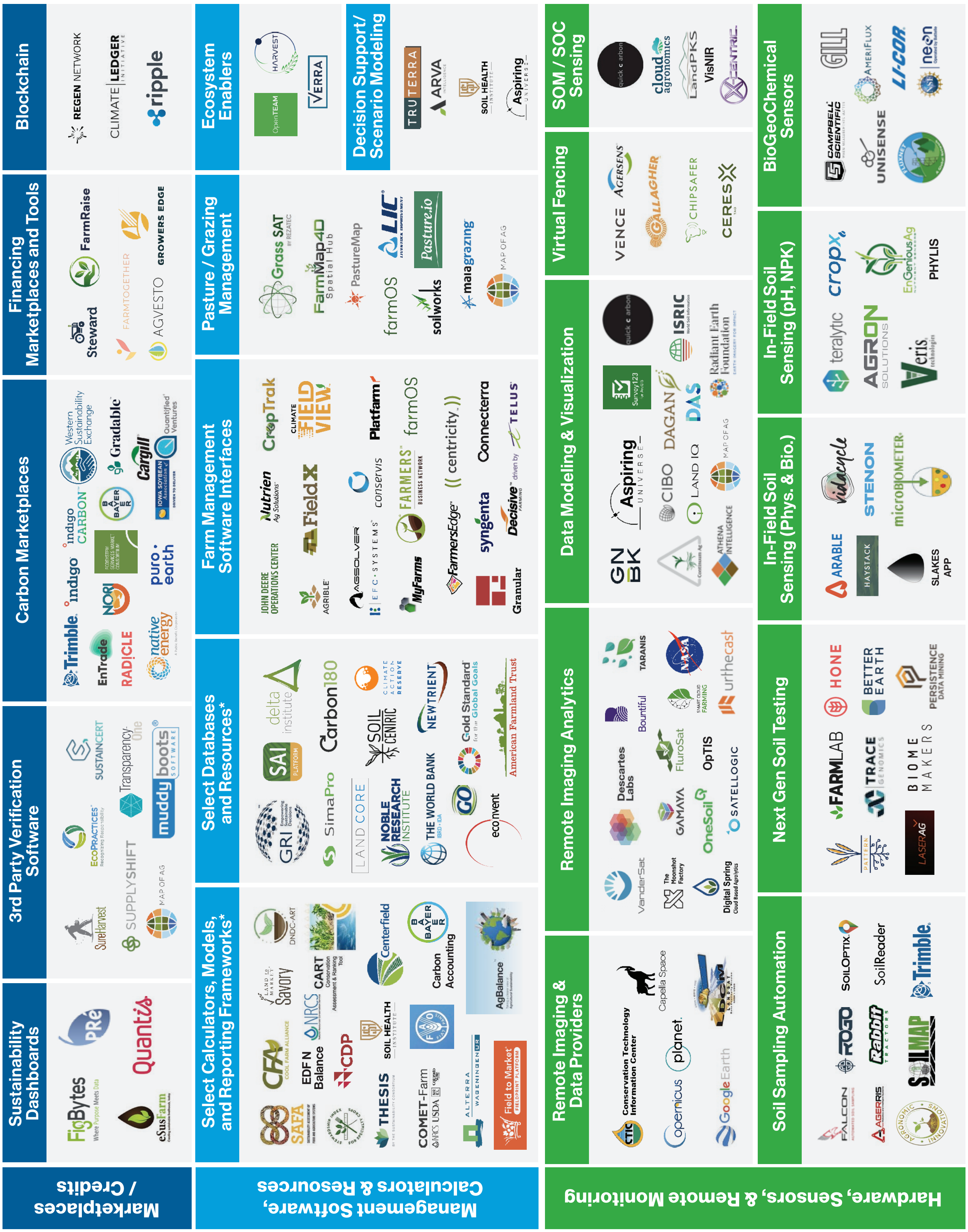
Managed Grazing

Managed or rotational grazing, as opposed to conventional continuous grazing practice, adjusts how long livestock graze a specific area and how long the land is rested before livestock are reintroduced. This practice is effective with a variety of livestock, although at scale in the U.S. this means primarily beef and dairy cattle. The benefits of managed grazing are improved soil health and other resource concerns such as forage quantity, quality, diversity and longevity, and an increased awareness of resource capacity. In the more intensive and adaptive management systems, inspired by the behavior of original migrating herds, animal concentration over short time periods is used as a tool to improve and level forage utilization and optimize productivity. As with the crop practices, locale-specific characteristics are important factors, especially water availability and forage density, as is optimizing the stocking density and rest period for forage regrowth. From an implementation perspective, there is the additional management complexity of actively managing and integrating forage and livestock production systems and creating and adapting paddock and grazing plans. Additional time and labor is needed to move stock, and livestock containment, i.e., fencing, and water must be provided and possibly moved or provided along with the animals. There may also be the issue of access to enough contiguous land to make sufficient rotations feasible.

Integrated Crop and Livestock Systems

To a limited extent, the advantages of integrating livestock and crop production can be achieved by the incorporation of animal manures as a nutrient source or soil health builder (see Compost Application above). An even more promising application of the practice to deliver significant soil-health outcomes is the temporary integration of livestock via grazing of specific crop rotations or residues. This integration can involve different forages and livestock, although like Managed Grazing discussed earlier, primarily beef and dairy cattle at scale in the U.S. Integrated crop-livestock systems can reduce the need for outside feed sources and improve soil health and fertility, though this is dependent upon weather conditions and nutritional requirements. They can also improve the economics of cover crops and residue management by utilizing these resources in an additional way while offering farmers a means to increase farm diversification and income potential. Like with managed grazing, there is the additional complexity of managing multiple production systems, forage selection and management, containment and water availability, and in some locales, the availability of livestock and overall feasibility of tending to their well-being.

Climate-Smart Soil Technology Landscape



Summary Table of Financial Mechanisms

Type	Mechanism	Average Deal Size / Investment Needed	Originating Entity	Target Entity	Examples
Cash & Equivalents	Thematic Certificates of Deposits (CDs) & Money Market Funds	Small – Medium	Commercial banks	Farm Operating Capital, ValueChain Companies	Self Help Credit Union's Green Term Certificate invests in sustainable businesses, including solar farms, sustainable food, & land trusts.
Cash & Equivalents	Targeted Institutional & Bank Lending	Small - Medium	Commercial banks, Farm Credit System	Farm Operating Capital, ValueChain Companies, Farmland	The Carrot Project in a partnership with community bank Salisbury Bank & Trust Company offered the Greater Berkshire Agricultural Fund.
Fixed Income – Public Bond	Land-Secured Assessment Financing	Large	Government, Institutional Investors, Fixed Income	Farm Operating Capital	Land-secured assessment financing has recently been used to invest in sustainability improvements through the Property Assessed Clean Energy (PACE) program.
Fixed Income – Public Bond	Climate Bonds	Medium - Large	Institutional Investors, Fixed Income, Funds	Farm Operating Capital, ValueChain Companies	As of January 2020, Agriculture has been integrated as a criterion in the Climate Bonds Standards and Certification Scheme.
Fixed Income – Public Bond	Blended Capital Facilities	Medium – Large	Commercial Banks, Farm Service Agency, Individuals	Farm Operating Capital, ValueChain Companies, Farmland	The Agri3 Fund Technical Assistance Facility bridges the gap between the needs of farmers and the limitations of banks by providing de-risking financial instruments and technical assistance.
Fixed Income – Private Debt	On-Bill Financing	Medium – Large	Institutional & Retail Investors, Government, Fixed Income	Farm Operating Capital, ValueChain Companies	On-bill financing is well-established in the U.S., particularly with energy utilities, to enable customers to invest in energy efficiency.

Fixed Income – Private Debt	Environmental Impact Bonds (EIBs)	Medium – Large	Commercial banks, Farm Credit System, Government	Farm Operating Capital, Ag ValueChain Companies	Blue Forest Conservation, supported by philanthropies as well as the World Resource Institute, developed the Forest Resilience Bond (FRB) to deploy private capital to forest restoration projects, delivering benefits to private and public stakeholders.
Fixed Income – Private Debt	Sustainability-Linked Loan Facilities	Large	Commercial banks, Farm Credit System, USDA	Farm Operating Capital, Value Chain Companies, Farmland	Cofco International's $2.3 billion sustainability-linked loan facility Tereos Sugar and Energy Brazil took out a $105 mil sustainability-linked loan Louis Dreyfus Company took out a $750 million sustainability-linked loan French agricultural cooperative Agrial took out a €900 million sustainability-linked loan
Fixed Income – Private Debt	Tailored Lending Programs	Small – Medium	Commercial banks, Funds, Farm Credit System	Farm Operating Capital, ValueChain Companies, Farmland	Austin Foodshed Investors' (AFI) Bridge Loan Fund and California Farm Link both offer tailored loan programs that support farmer and rancher access to the NRCS Environmental Quality Incentives Program (EQIP).
Fixed Income – Private Debt	CDFI Loan Funds	Small – Medium	Commercial banks, Funds, Farm Credit System	Farm Operating Capital, ValueChain Companies, Farmland	Maine's Coastal Enterprise Inc (CEI)'s Sustainable Agriculture and Food System Program offers loans and investments to farms and agricultural value-chain businesses. Nebraska's Rural Investment Corporation has a selection of loan products specifically designed to assist farmers.

Public Equity	Initial Public Offering	Medium – Large	Public investors	Ag value chain companies	Vital Farms, a pasture-raised egg company, filed for an IPO in July 2020.
Public Equity	Exchange Traded Funds (ETFs) and Mutual Funds	Medium – Large	Financial services & asset management firms	A variety of assets that could include value-chain entities with a relationship to climate-smart agriculture	The NextGen Food & Sustainability ETF which follows the BlueStar Food and Agriculture Sustainability Index. In Australia, many AgTech companies have listed on the Australian Securities Exchange (ASX). Krane Fund Advisors launched the KFA Global Carbon ETF, which tracks the IHS Markit Global Carbon Index and could have eventual connections with agricultural carbon markets.
Private Equity Venture Capital	"Bridge" Capital Funds	Small Medium	Private equity and venture capital firms raise capital for bridge capital funds from retail and institutional investors	Ag value chain companies	Traction Capital launched a hybrid private equity and venture capital fund to invest in or acquire early-stage and lower, middle market companies that are stuck in the "capital gap".
Private Equity Venture Capital	Small Business Investment Company / Rural Business Investment Company	Large	Institutional investors, banks, and money managers invest in funds managed by venture capital firms; government can invest in debt capital	Farmland, Farm Operating Capital, Ag Value Chain Companies	M&T Bank announced a $5 million private equity investment with Blue Highway Growth Capital, a registered RBIC, to support small rural businesses in the Northeast and Mid-Atlantic. The Open Prairie Rural Opportunity Fund is licensed RBIC that has received investment from Farm Credit Institutions including Compeer Financial and CoBank commercial and community banks, family offices, and high net worth investors.

Private Equity Venture Capital	Community Development Venture Capital (CDVC)	Small	Foundations, banks, financial institutions, government, NGOs, and retail investors	Ag value chain companies	CEI Ventures provides equity venture capital to businesses in underserved rural New England communities, including a limited number of "natural and organic" food companies.
Private Equity Venture Capital	Venture Capital Fund	Small -- Medium	Accredited retail investors, financial institutions	Farm operating capital, agriculture value chain companies	Almanac Investments is a $30 million venture capital fund focused on climate-smart agriculture by investing in CPG, retail, and technology companies.
Private Equity Venture Capital	Corporate Venture Capital Funds	Large	Corporations	Farm operating capital and agriculture value chain companies	Patagonia created a $20 million corporate venture fund called Tin Shed Ventures to invest in early stage companies that are addressing environmental problems, including those related to agriculture. General Mills launched 301 INC, a business development and venture unit to work with innovative and growing brands that align with General Mill's core business.
Farmland and Real Assets	Opportunity Zone Funds	Small	Accredited retail investors	Farmland, farm operating capital, agriculture value chain companies	Harvest Returns' Sustainable Agriculture Opportunity Fund is currently open for soft investment commitments. The fund's investment objective is to achieve tax-advantaged capital appreciation in production agricultural projects that are economically, socially, and environmentally sustainable.

Farmland and Real Assets	Real Estate Investment Trust (REIT)	Small - Medium	Retail investors, including accredited and non-accredited investors; family offices; foundations	Farmland	Iroquois Valley Farmland REIT offers investors director ownership in a diversified portfolio of organic farmland, which in turn, supports independent farmers with long-term access to land. This addresses one of the biggest barriers to organic farming by offering innovative leases and mortgages to transitioning organic and organic farmers. Farmland LP targets farmland poised for long-term appreciation with a strong demand for locally grown, organic food, robust existing farming communities, and favorable long-term climate projections. They convert conventional farmland to organic.

Summary Table of Enabling Infrastructure

Category	Description	Overview	Examples
Cash & Equivalents	Climate Risk Assessment at Banks & Lending Institutions	Integrate climate stress-testing into banking and loan fund risk management, in order to adequately plan for and assess the effects of climate change and expand the pool of credit for farmers seeking to invest in climate-smart farming practices and technologies	In 2017 nine international banks conducted modeling exercises using a tool developed as part of a framework designed by the Natural Capital Financial Alliance and GIZ to measure the impact of severe droughts on farms' ability to repay loans. This modeling showed that severe droughts could cause significant losses to banks.
Cash & Equivalents	Voluntary Standards and Certifications	Industry-wide standards and certifications lend credibility and foster trust between customers and producers, they hold businesses, financial institutions, and organizations accountable for using agreed practices. These affiliations may also be required for securing Green Bonds or Climate Bonds.	• Global Alliance for Banking on Values • Partnership for Carbon Accounting Financials • Benefit Corporation (B Corp) • UN Principles for Responsible Investment • Leading Harvest • Climate Bonds Standard and Certification
Fixed Income – Public Bond	Credit Enhancements for Climate Bonds	Banks, private lenders, philanthropies, and other funders could provide enhancements to strengthen the credit ratings of Climate Bonds, specifically those targeting climate-smart agriculture. Credit enhancements, such as partial or full guarantees, subordinated debt, insurance, and A/B loans, are strategies for reducing risk exposure for investors, which helps bonds offer better loan repayment terms or a lower interest rate on the bond.	Singapore energy company Sindicatum Renewables issued three green bonds totaling approximately $60 mil, enhanced by a full credit guarantee from GuarantGo. The Republic of Seychelles issued the world's first "Blue Bond" of $15 mil in 2018, which was enhanced through a concessional loan, to finance sustainable marine and fisheries projects.

Fixed Income – Private Debt	Loan Guarantees	Loan guarantees are contractual obligations where one party agrees to be liable for all or a portion of the debt of another party if it is not repaid. The guarantor can be the government, an organization (like a company or philanthropic foundation), or an individual. Guarantees can also be used to mitigate risk and provide multiple access points for investors with different financial and impact objectives.	The USDA Farm Service Agency has a loan-guarantee program with $150 mil set aside for conservation projects, which went unutilized in both FY2017 and FY2018. PVGrows Investment Fund, a lending vehicle managed by the Franklin County Community Development Corporation in the Pioneer Valley of Massachusetts, has a risk capital pool funded by foundations that serves as a loan loss reserve for its community loan fund financing regional food systems. The Small Business Administration (SBA)'s 7(a) Loans, the Community Development Corporation (CDC)/504 loan guarantee programs, or the SBA's Microloan program, provide funds to specially designated non-profit intermediary lenders, which then issue loans to eligible borrowers, and small businesses with small, short-term loans — up to $50,000 — for working capital or to buy inventory, supplies, machinery and equipment.